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Email:
contact@a-paea.org
contact.apaea@gmail.com

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Intricacies of Competition, Profitability & Stability in Dual Banking Economies. Does Presence of Islamic Banks Change the Dynamics?

Wajahat Azmi*, Mohsin Ali*, Shaista Arshad**, Syed Aun R. Rizvi***

**INCEIF, Kuala Lumpur, Malaysia*
***Nottingham University Business School, University of Nottingham Malaysia Campus, Semenyih, Malaysia*
****Suleman Dawood School of Business, Lahore University of Management Sciences (LUMS), Lahore, Pakis*tan. *Email: aun.raza@lums.edu.pk*

Abstract

This paper adds to the debate on the impact of competition and on bank stability and profitability. The novelty lies in analyzing the impact of studying the nexus of stability and competition, and performance and competition in dual banking We aim to examine whether (1) Islamic banks contribute towards overall banking stability, (2) conventional banks benefit from Islamic banks in a dual banking system and (3) whether the relationship between competition and stability is heterogeneous across banks in a dual banking system. Our results show that in general, Islamic banks increases the stability of commercial banking sector and are inherently more stable themselves but with similar profitability. Furthermore, there is a homogenous effect of competition on stability and profitability across bank types. To add robustness to our results, multiple proxies are used for competition, stability and profitability. A further analysis is conducted on split sample based on size as measured by total assets.

Keywords: Competition, Boone index, Stability, Islamic banks, Dual banking economies

JEL Classification: D40, G21, Z12

1. Introduction

This paper adds a novel dimension of dual banking systems to the intensely debated topic of whether competition is good for banking stability and profitability. Researchers remain divided on its impact; where one group are of the opinion that competition has a positive effect on stability, known as the competition-stability view (Leroy and Lucotte, 2016; Fiordelisi and Mare, 2014; Schaeck and Cihák, 2014 and Pawlowska, 2015). The second group argue based on competition-fragility, as increasing competition leads to greater risk taking and instabilities prompting banking problems (Keeley, 1990; Jiménez et al., 2013; Weill, 2013; Allen and Gale, 2000 and Hellmann et al. 2000).

The expansion of Islamic banks over the last two decades has further complicated the debate on bank competition and stability in three major ways. (1) Islamic banks have reported strong growths globally with 34% of the market share in GCC countries and 13% in ASEAN countries. With the incessant growth of Islamic banking, the shifting degrees of market power may bear serious implications for competition and banking stability. (2) In its risk sharing and interest free nature, Islamic bank's charter prohibits the inclusion of several toxic assets, raising the question of whether the impact of competition would have the same effect. (3) Theoretically, Islamic banks are deemed more stable and resilient, particularly during crisis periods (Farooq and Zaheer, 2015), opening avenues for healthier economic stability overall. It can be argued whether diversification between Islamic and conventional banks would benefit the industry.

Structurally, the presence of Islamic banks in a dual banking system provides a parallel market for both banks while sharing the same clientele base. Islamic banks provide a channel for diversification between banks, albeit in a limited capacity. Choi and Kotrozo (2006), Valverde and Fernandez (2007) found that diversification enhances banks revenue and helps increase market share, leading to more competitiveness in the industry. Chiorazza's et al. (2008) analysis for Italy post shift towards non-interest revenues found a positive relation between income diversification and risk-adjusted returns. Theoretically, we can apply the same argument to the interest free nature of Islamic banks, where Molyneux and Yip (2013) examined the effects of diversification of Islamic banks and found interest-free income to have a positive influence on banks risk-adjusted performance.

Against this backdrop, the objectives of this study are to analyze whether: (1) Islamic banks contribute towards overall banking stability, (2) conventional banks benefit from Islamic banks in a dual banking system and (3) the relationship between competition and stability is heterogeneous across banks in a dual banking system.

To address our objectives we first delve into measurement of competition, stability and profitability. Once, we obtain the measures our stability and profitability equations are tested by employing system GMM methodology. The measurement of our three parameters is divided into three phases. First, to measure competition, three measures are used: the Boone index as proposed by Boone (2008), H-statistics and the Herfindahl–Hirschman Index. Second, to analyze bank stability, we use two alternative measures, Z-score and loan loss provisions to equity (LLP/E) ratios is used. Third, return on asset and return on equity are used as measures of profitability.

Our analysis revealed four new results. First, Islamic banks appear more stable across both stability proxies, which are in line with Beck et al. (2013), who argued these findings based on the argument that Islamic banks are better capitalized. Second, our findings suggest that the

presence of Islamic banks brings banking stability. This is in line with Cihak and Hesse (2007). Third, Islamic banks outperformed in terms of profitability and stability during the crisis as compare to conventional banks. This can be owing to Islamic banks restrictions in investing in toxic assets considered as one of the main reasons for the collapse. Fourth, while diversification brought stability for both types of banks, it was more effective in the case of Islamic banks. The results are in line with our expectations as most of the risk management/hedging tools are not compatible with the Islamic law and the only way to diversify the risk is to venture into non-intermediation activities.

The current study extends existing literature with three major contributions. First, our findings lend support to the competition-stability view led by Boyd and De Nicolo (2005) that competition is associated with more stability. However, in our analysis competition is also associated with lower profitability. Second, the results are consistent across both type of banks suggesting that the impact of competition is homogeneous and not contingent on the bank types. This lends credibility to existing views on competition and banking stability. Third, the results indicate that the presence of Islamic banks increases the stability of conventional banks. Indicating that conventional banks engaging in Islamic finance might have benefited from diversifying their portfolio and thus limiting their exposure to risky assets. Moreover, our results showed Islamic banks to be more stable as compared to their conventional peers but with similar profitability. This adds to the emerging literature on the support of Islamic banking and finance.

To reaffirm the results obtained, the empirical evidence is subjected to multiple robustness tests. Firstly, we use three different proxies for stability, namely Boone index, H-Statistics and the Herfindahl–Hirschman Index. The results are consistent across all the three measures of competition. Secondly, we use two different proxies of stability (Z-score, the ratio of loan loss provision to equity and profitability (return on assets and the return on equity). Our results generally conformed despite different measures. Lastly, we split the sample based on size, measured by total assets. In general, the results are in line with the full ample.
Following the introduction in Section 1, section 2 and 3 explore the data and methodological construct of our study respectively. Section 4 discusses the empirical results and section 5 provides the conclusion.

2. Data

To achieve our proposed objectives, our sample dataset consists of 398 banks, out of which 106 are Islamic and 292 are conventional. Data is obtained from Bankscope for a period of 9 years from 2005-2014. Selecting countries with dual banking systems, after adjusting for data availability and consistency issues, leaves us with 15 countries, namely: Bahrain, Bangladesh, Brunei, Indonesia, Jordan, Kuwait, Lebanon, Malaysia, Pakistan, Qatar, Saudi Arabia, Tunisia, Turkey, UAE and Yemen.

In order to measure bank performance, both traditional and frontier measures are employed. In additional to traditional measures, Table 1 provides the descriptive statistics of the Z-score, Boone Index, HH Index and H-statistics. Overall, the mean of Z-score is 26.63 with the standard deviation of 28.830. Comparison of Z-scores of Islamic and conventional suggests that mean Z- scores of Islamic banks are slightly better than conventional banks. Similarly, the ratio of cost to income suggests that the Islamic banks are more cost efficient. Both banking systems appear to be capitalized equally. In terms of profitability, Islamic banks fare better than conventional banks as suggested by their ROA and ROE. Competition measures suggest

that Islamic banks are more competitive owing to Islamic banks having a different client base and there is competition within Islamic banks to attract this pool.

3. Methodology

The methodology used in this study delves into two aspects primarily, firstly the estimation of the measurements of the competition, stability and profitability and secondly the econometric modelling for addressing the research questions.

A. Measurement of Competition

In this paper, the main approach to estimate competition is based on the Boone index (2008). In addition, for robustness tests we rely on Herfindahl–Hirschman Index (HH Index) and H-Statistics. The reason for relying on Boone index as the main variable is its apparent advantages over the traditional measures, such as H-statistics, Lerner Index, concentration ratio. In comparison to H-statistic, Boone index does not impose long-run equilibrium restriction. It captures the capability of efficient banks to reallocate profits, based on their cost advantage, from the inefficient ones in the market as highlighted by Schaeck & Cihak (2014). Claessens and Laeven (2004) had argued that concentration ratio and Herfindahl-Hirschman (HH) index do not fully capture the competition in banking industry. Even other proxies such as the Panzar and Rosse (1987) H-Statistic and the Lerner index have been criticized for not being able to fully capture competition.

The intuition underlying the Boone index has its roots in the efficiency hypothesis, which argues that performance correlates with efficiency (Demsetz, 1973). Precisely, this hypothesis maintains that banks with lower cost to income ratio, that is, banks with cost advantages can gain superior performance and grow at the cost of their less efficient counterparts. Relaxed entry restrictions establish this effect further.

This indicator, also termed as profit elasticity, is an estimation of percentage loss from an increased marginal cost of 1 percent. Hence, the intuition is that increase in competition, either due to products becoming close substitutes or relaxed entry restrictions, will lead to superior performance of efficient banks as compare to the performance of less efficient banks.

$$\pi_{it} = \alpha + \beta lnMC_{it} + e_{it} \qquad (1)$$

In above equation, π_{it} is the profit of the bank i at time t and β is the Boone index or profit elasticity. *MC* is the marginal cost. As marginal cost is unobservable, we follow Schaeck and Cihak (2012, 2014) to approximate it using average cost[1]. Since competition enhances this negative relationship, the greater the bank competition, the more negative Boone index will be. Although there are criticisms raised on the traditional measures, in the interest of robustness, we also used Herfindahl–Hirschman Index (HH Index) and H-Statistics to measure competition. We estimate HH Index by squaring the market share of each bank and then summing the squares:

$$HH\ Index = \sum_{n=1}^{j}(Market\ share_n)^2 \qquad (2)$$

For the estimation of Panzar and Rosse (1987) method of H-Statistics, we rely on following reduced form equation for each country:

[1] Another way of estimating marginal cost is to calculate a translog cost function (Leuvensteijin et al., 2011).

$$ln(TR_{it}) = \alpha + \beta_1 \ln(w_{L,it}) + \beta_2 \ln(w_{F,it}) + \beta_3 \ln(w_{FC,it}) + \beta_4 \ln(Y_{1,it}) + \beta_5 \ln(Y_{2,it}) \quad (3)$$

In the above equation, our dependent variable TR_{it} is total revenue measure as the ratio of total interest and non-interest revenue to total assets of bank *i* at time *t*. Three input prices, $w_{L,it}$, $w_{F,it}$ and $w_{FC,it}$ are cost of labor (ratio of personnel expenses to total assets), cost of funds (ratio of interest expenses to total deposit) and cost of fixes assets (ratio of other operating and administrative expenses) respectively. Following Gelos and Roldos (2004) and Claessens and Laeven (2004) and Cihak and Hesse (2010), we also include certain bank level control variables. In above equation, $Y_{1,it}$ and $Y_{2,it}$ represent the ratio of equity to total assets and net loans to total assets, respectively.

B. Measurement of Stability

For measuring stability, we use the Z-score as suggested and used in banking literature (See: Lepetit et al., 2008; Laeven and Levine, 2009; Cihak and Hesse, 2007, 2010). For robustness purpose we use the alternative Loan loss provision to equity of bank.

Z-score is estimated as follows:

$$Z - score = \frac{ROA + \frac{E}{TA}}{\sigma ROA} \quad (4)$$

where ROA is the return on assets, E/TA is the equity to total assets ratio, and σROA is the standard deviation of return on assets. Z-score reflects the probability of banks becoming insolvent. Therefore, higher the Z-score lower the probability of banks becoming insolvent.

After obtaining the estimates of competition and stability measures, we run the following specification to test our stability:

$$Stability_{i,j,t} = f(Stability_{i,j,t-1}\, Competition_{j,t}, GDP\ per\ capita_{j,t}, Islamic\ banking\ share_{jt}, Z_{i,j,t}, Islamic_{i,j} \quad (5)$$

We use two proxies for our stability measure. In the above equation, $Stability_{i,j,t}$ refers to the Z-score and the ratio of Loan loss provision to equity of bank *i* at time *t* in a country. $Competition_{i,j}$ refers to our estimated HH Index, H-Statistics and Boone index. Islamic banking share refers to the share of Islamic banks in terms of assets in the banking industry. *Z* refers to the control variables such as cost to income ratio, total assets, diversification index, $Islamic_{i,j}$ is a dummy variable that takes the value of 1 in case bank *i* is an Islamic bank[2].

C. Measurement of Profitability

In order to explore the objective of profitability we use two alternative measures namely ROA and ROE. The control variables in the above two equations are the same. A dummy variable is used for crisis period interacting with the Islamic bank dummy to investigate the impact of crisis on stability and performance of Islamic banks.

$$Profitability_{i,j,t} = f(Profitability_{i,j,t-1}, Competition_{j,t}, GDP\ per\ capita_{j,t}, Islamic\ banking\ share_{jt}, Z_{i,j,t}, Islamic_{i,j}) \quad (6)$$

[2] For set of control variables, we refer to Angkinand and Wihlborg (2010), Jeon et al. (2011) and Lee and Hsieh (2013, 2014).

Table 2 summarizes the alternative proxies that this study utilizes to undertake a robust analysis.

D. Econometric Method

To estimate the above two equations, we use dynamic panel data approach, following the works of Lee and Hsieh (2014), Fu et al., (2014) and Jimenez et al., (2013). We employ panel GMM methodology for the following reasons. (1) It controls for endogeniety concerns when there is a reverse causality from stability to competition and other independent variables[3]. (2) There is a possibility that some of the unobserved bank characteristics are correlated with our dependent variables[4]. (3) Using panel GMM is more suited to handle minor series with large cross-sections, as is our case where the dataset spans for 10 years.

To decide between first-difference and system GMM, we rely on the coefficient of lagged dependent variable and the random walk properties of the variables[5]. Moreover, system GMM is advisable in case of unbalanced panel as the first-difference GMM further magnifies this gap (Roodman, 2009). Based on the autoregressive parameter, we prefer system GMM as the necessary condition for using system GMM is high persistence in series[6].

4. Empirical Results

The empirical results are presented in Table 3 and 4. Table 3 presents the results for the Stability and competition nexus (See Eq 5 above) while Table 4 presents the GMM estimations for the profitability and competition nexus (See Eq 6 above).

As discussed earlier, we have used two alternative measures for bank stability, namely Z-Score and Loan Loss Provisions to equity. In Table 3, Panel A presents the findings with Z -score as measure of Stability while Panel B uses Loan loss provision to equity (LLP/E) as stability measure. While the (1), (2) and (3) in each panel represents the three alternative measures of competition; H-Statistics, HH Index, and Boone Index respectively.

A. Stability and Competition

The following discussion first delves into the stability and competition nexus and then follows it with the profitability competition while trying to explain the interlinkages of the results.

The Table 3-Panel A results where stability is measured by Z-scores the results suggest a difference between Islamic banks and conventional banks since the Islamic banking dummy is significant and positive.

[Insert Table 3 around here]

It suggests that the Islamic banks are more stable as compare to conventional banks. This may be owing to the prohibitive law in Islamic banking, which prohibits the investment in derivative and exotic instruments like Credit Default Swaps and other derivative instruments, which had major contribution to the recent financial meltdown of 2007. The findings are further reaffirmed when we use the alternative stability measure of Loan loss provision to equity.

3 See Lee and Hsieh (2014).

4 For instance, Jimenez et al., (2013) note that NPL ratios (dependent variable) in their case may be correlated with the unobserved bank characteristics such as the risk appetite of bank managers and/or shareholders.

5 System is superior to first-difference GMM in presence of random walk variables and the autoregressive coefficient that is close to unity (Roodman, 2009 and Sarafidis et al., 2009).

6 For instance, Roodman (2009) suggests that the autoregressive parameter of 0.8 and above is a good indication of high persistence and in that case system GMM produce superior results than the first-differenced GMM.

The control variables used primarily concur to expectations and earlier literature in terms of their relationship signs. Cost to income ratio and loan to asset ratio has a significant negative relationship as expected in all the models. Further, one of our focal variable, diversification index suggest that the diversification has positive and significant effect on the stability. The findings are similar for the interaction of Islamic dummy and diversification index. These findings suggest that income source diversity brings stability to the banking system. It can be further be cautiously deduced that a diversifying away from traditional lending activities to other areas such as trading and fee based income would make the overall system more stable.
Specific to Islamic banks the interaction term is significantly positive, which suggest that diversification brings more benefit to Islamic banks. This conclusion can be explained by the nature of Islamic banking activities, which are restricted by Shariah law in indulging in derivatives for hedging purposes. This exposes the balance sheet of Islamic banks to multiple risks, which can only be minimized through diversification to non-intermediation income. These results hold with the alternative measure of stability (Loan loss provision to equity).
Recently Ibrahim and Rizvi (2017) has argued on the banks size matters for Islamic banks performance. Our findings related to the size (measured by assets) provides evidence for a negative relationship between size and stability and competition of the banks. The earlier works of Cihak and Hesse (2007) can explain the findings, who had suggested towards increasing riskiness of asset nature of banks as size grows.

An extension to the earlier findings is nested in the impact of Islamic Banking share in the banking industry. With both proxys of stability (Z-score and Loan loss provision to equity), the impact of Islamic bank share is positive and significant and suggesting that the presence of Islamic banks adds to the banking stability in the dual system. It should be noted that the results point to the average effect based on the presence of Islamic and the conventional banks[7]. Furthermore, our results also suggest that increase in Islamic banks adds to the stability of conventional banks.

B. Profitability and Competition

In terms of using different proxies for profitability, the results suggest that profitability (ROA and ROE) of Islamic banks is higher than the conventional banks only in the model where Boone index (Table 4 – Panel B (3)) is used. Our finding remains inconclusive towards suggesting a higher profitability of Islamic banks as compared to their conventional counterparts in contrast to poular literature which suggests that Islamic banks are more profitable as compare to conventional banks (See: Samad, 1999; Samad & Hassan, 1999; Iqbal, 2001; Hassoune, 2002). However, our results reaffirm the findings of Turk-Ariss (2010) whose analysis suggested that the Islamic banking operations do not necessarily bring more rewards as compare to their conventional peers.

[Insert Table 4 around here]

In terms of the impact of diversification on profitability our results suggest it to be insignificant for both Islamic and conventional banks. Similar insignificant results are seen for the interaction term between Islamic banks dummy and diversification coefficient. Earlier the study had highlighted that a higher presence of Islamic banks adds to the stability of the system. But in terms of impact of performance there is no significant relationship suggesting that presence of Islamic banks in a dual system does not contribute towards increasing profitability of the banks.

[7] See, Cihak and Hesse (2007).

While our finding suggest that higher competition is associated with higher stability (Table 3) but it results in lower profitability (Table 4). These results are conform to the competition-stability paradigm. Similarly, the results are consistent with the profitability measures as the competition tends to decrease the profit whereas higher concentration is associated with more profitability. We can cautiously infer that our results suggest that venturing into a market with low competition or high concentration could be rewarding for the banks. In case of Islamic banks, competition measures have different impact on stability (Table 3) and profitability (Table 4). However, the difference is negligible suggesting there are same incentives for Islamic banks to enter in the market where the concentration is high or competition is low. Taking a cue from literature earlier cited about crisis and banking, we investigate the impact of crisis on our sample, and results suggest that crisis had a negative impact on stability and the profitability of conventional banks. However, the Islamic banks dummy points towards Islamic banks tended to perform better as compared to their conventional counterparts.

C. Split Sample Robustness Check

To further check for reliability of our findings, we split the sample based on bank size. The results are presented in Table 5 and 6 for large banks and in Table 7 and 8 for small banks. We classify small and large banks following the work of Cihak and Hesse (2010) who suggest that banks with assets more than USD 1 billion are categorized as large banks.

[Insert Table 5 and 6 around here]

The findings of competition measure in the split sample generally conform to our earlier results. The Islamic banking dummy is significant and positive in case of small banks in terms of both stability and profitability (Table 7 and the Table8) while in large banks case (Table 5 and the Table 6), it is insignificant for both stability profitability. This leads us to conclude that smaller Islamic banks are more stable and more profitable in comparison to smaller conventional banks. However, in case of large banks, both the conventional and Islamic banks are similar in terms of stability and the profitability.

[Insert Table 7 and 8 around here]

On the other hand, the diversification results provide interesting insights as diversification is significant only for the smaller banks (Table 7) whereas it is insignificant for the case of large banks (Table 5). The insignificance of the Islamic bank dummy for large banks may suggest that once the Islamic banks become bigger, it does not benefit from the diversification. Overall, our results suggest that the diversification is only favorable to small banks, be it Islamic or conventional. While the impact of diversification on the profitability (Table 6 and the Table 8) remained similar to the earlier findings suggesting diversifying into non-intermediation activities does not have any effect on banks.

The impact of Islamic Banking share on their counterparts for the split sample confirms our earlier results, suggesting that the increase in Islamic banking share on average, irrespective of the whether the bank is big or small, adds to the overall stability of conventional banks. While higher presence of Islamic banks does not affect the profitability of the other banks in the

system. Also, the higher presence of Islamic banks does not influence the profitability of the conventional banks[8].

5. Conclusion

The importance of finance for growth has led the researchers to explore the determinants of sound banking system. One such strand of the literature explores the impact of competition on banking stability and profitability. We provide robust results on this as we have utilized three different proxies of competition and two proxies for stability and profitability measures. Our results summarizes as follows. First, the presence of Islamic banks increases the stability of conventional banks. Second, Islamic banks are more stable as compare to their conventional peers but with similar profitability. This finding is in sharp contradiction with the theoretical standing of Islamic banks being more profitable. This may be due to the significant divergence of Islamic banks from the theory as it is supposed to operate on the risk sharing arrangement. Third, competition has similar effects on stability and profitability on both the banks. Fourth, Islamic banks did better in terms of profitability during the crisis as compare to conventional banks. It also suggests that the Islamic banks were more stable during the crisis period.

Our results have several policy implications for countries aspiring to open avenues for Islamic banking in their countries. Our findings legitimize the economic value of Islamic banks whereby, it adds to the overall banking stability. Moreover, the presence of Islamic bank can attract customers based on religious needs without compromising on the stability of the banking industry.

[8] The sample was also split based on the mean deposit and the results are consistent with those reported in Table 5 to 7. For brevity, the results are not reported (available on request).

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Table 1: Descriptive Statistics of Sample Banks

This table provides descriptive statistics for all banks in our sample. Panel A provides statistics on all 398 banks, while Panel B shows only Islamic banks and Panel C provides information on conventional banks. Z-score, Boone Index, HH Index, H-statistic, Diversification Index are calculated by the authors. Remainder are obtained from Bank scope.

Panel A: Full Sample					
Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Z-score*	3321	26.635	28.831	-12.735	512.708
Cost-income	3582	0.509	0.569	0.110	9.500
Loan/Total Asset	3214	0.457	0.257	0.188	1.091
Equity/Total Asset	3582	0.142	0.169	-0.959	1.506
ROA	3215	0.011	0.049	-1.303	0.383
ROE	3214	0.113	0.390	-9.461	9.419
Boone Index*	3582	-0.135	9.661	-3.851	2.383
Total deposit	3582	5430.200	11062.670	2301.800	96161.200
Loan loss provision/Equity (LLP/E)	3213	0.053	0.342	-9.031	8.782
Loan loss provisions	3582	39.727	108.841	-183.942	1533.640
Loans	3582	3643.863	8209.263	2162.700	85360.400
HH Index*	3582	1201.321	656.148	517.608	5172.245
H-Statistic*	3582	0.191	0.197	-0.077	0.631
Diversification index*	3197	-0.298	15.330	-308.013	516.824
Panel B: Islamic banks					
Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Z-score*	890	28.294	27.817	-5.380	492.926
Cost-income	954	0.472	0.423	0.110	8.415
Loan/Total Asset	853	0.487	0.275	0.214.6	1.091
Equity/Total Asset	954	0.142	0.185	-0.959	0.999
ROA	853	0.012	0.048	-0.697	0.322
ROE	853	0.145	0.477	-2.599	9.419
Boone Index*	954	-0.142	5.688	-3.851	2.383
Total deposit	954	3498.312	7500.473	2301.800	59767.500
Loan loss provision/Equity (LLP/E)	853	0.059	0.368	-9.031	3.474
Loan loss provisions	954	28.394	77.174	-48.995	876.332
Loans	954	2424.205	5421.046	2162.700	51809.600
HH Index*	954	1362.302	724.768	517.608	5172.245
H-Statistic*	954	0.220	0.178	-0.077	0.631
Diversification index*	847	-0.212	9.366	-111.790	157.500
Panel C: Conventional banks					
Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Z-score*	2431	25.835	28.379	-12.735	512.708
Cost-income	2628	0.523	0.613	0.417	9.500
Loan/Total Asset	2361	0.446	0.249	0.188	0.927
Equity/Total Asset	2628	0.141	0.163	-0.920	1.506
ROA	2362	0.010	0.049	-1.303	0.383
ROE	2361	0.101	0.353	-9.461	4.741
Boone Index*	2628	-0.132	0.651	-3.851	2.383
Total deposit	2628	6131.502	12023.740	2301.800	96161.200
Loan loss provision/Equity (LLP/E)	2360	0.051	0.332	-4.729	8.782
Loan loss provisions	2628	43.841	118.001	-183.942	1533.640
Loans	2628	4086.616	8970.406	2162.700	85360.400
HH Index*	2628	1142.883	619.266	517.608	5172.245
H-Statistic*	2628	0.180	0.202	-0.077	0.631
Diversification index*	2350	-0.330	16.975	-308.013	516.824

Table 2: Summary of Alternative Proxies Used

This table summarizes the different proxies that are used as robustness measures for the three critical variables under discussion in this research.

Variable	**Proxies Used**		
Competition	Boone Index	H-Statistics	HH Index
Stability	Z-Score	Loan Loss Provision to Equity	
Profitability	ROA	ROE	

Table 3: System GMM - Stability and Competition

This table presents the GMM estimations for the Stability and competition nexus for the Equation 5 as presented below.

$$Stability_{i,j,t} = f(Stability_{i,j,t-1} Competition_{j,t}, GDP\ per\ capita_{j,t}, Islamic\ banking\ share_{jt}, Z_{i,j,t}, Islamic_{i,j}$$

Panel A presents the findings with Z -score as measure of Stability while Panel B uses Loan loss provision to equity (LLP/E) as stability measure. While the (1), (2) and (3) in each panel represents the three alternative measures of competition; H-Statistics, HH Index, and Boone Index respectively. The superscripts ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively

	Panel A: Z Score			**Panel B: LLP/E**		
	1	**2**	**3**	**1**	**2**	**3**
	H-	**HH Index**	**Boone**	**H-**	**HH Index**	**Boone**
Z Score(-1)	0.892 (0.000)***	0.813 (0.000)**	0.914 (0.000)***			
LLP/E(-1)				0.792 (0.002)***	0.924 (0.002)**	0.890 (0.000)***
Cost to Income Ratio	-1.044 (0.011)**	-1.083 (0.008)**	-1.032 (0.012)**	0.016 (0.008)***	0.015 (0.071)**	0.001 (0.013)**
Loan to Total Asset	-3.493 (0.002)***	-3.416 (0.002)**	-3.499 (0.001)***	0.037 (0.000)***	0.035 (0.000)**	0.037 (0.000)***
Size	-0.003 (0.038)**	0.024 -0.481	-0.003 -0.421	0.006 (0.027)**	0.004 (0.019)**	0.091 (0.100)*
Diversification Index	0.027 (0.042)**	0.084 (0.038)**	0.076 (0.012)**	-0.034 (0.001)***	-0.004 (0.000)**	-0. 0308 (0.028)**
Diversification Index*Islamic	0.002 (0.071)*	0.002 (0.097)*	0.002 (0.083)*	-0.004 (0.097)*	-0.002 (0.012)**	-0.001 -0.675
Islamic Banking (IB) Share	2.850 (0.000)***	2.640 (0.000)**	2.060 (0.000)***	-0.021 (0.000)***	-0.025 (0.000)**	-0.030 (0.000)***
IB Share*CB Dummy	-1.080 -0.101	1.930 (0.10)*	0.082 (0.008)***	-0.091 (0.083)*	-0.322 (0.091)*	-0.002 -0.173
Islamic	1.300 (0.073)*	1.510 (0.084)*	1.310 (0.012)**	-0.029 -0.127	-0.026 -0.713	-0.033 (0.014)**
GDP per capita	0.008 (0.000)***	0.003 (0.000)**	0.003 (0.000)***	-0.002 (0.000)***	-0.019 (0.000)**	-0.002 (0.000)***
Competition	1.080 (0.096)*	-0.002 (0.065)*	1.170 (0.019)**	-0.005 (0.028)**	0.007 (0.013)**	-0.011 (0.025)**
Competition*Islamic	0.637 -0.957	-0.001 (0.051)*	1.790 (0.062)**	-0.017 -0.661	0.024 (0.067)*	-0.013 (0.084)*
Islamic*Crisis	2.460 (0.017)**	2.590 (0.013)**	2.350 (0.024)**	-0.074 (0.004)**	-0.074 -0.606	-0.073 (0.042)**
Crisis	-0.292 (0.098)*	-0.355 -0.121	-0.397 (0.074)*	0.022 -0.580	0.022 (0.049)**	0.022 (0.091)*
Constant	24.840 (0.000)***	21.890 (0.000)**	24.770 (0.000)***	0.023 (0.000)***	0.036 (0.000)**	0.025 (0.000)***
Sargan p-values	0.560	0.420	0.570	0.680	0.610	0.710
AR(1)-p values	0.089	0.092	0.047	0.082	0.071	0.162
AR(2)-p values	0.415	0.588	0.018	0.125	0.089	0.263

Table 4: System GMM - Performance and Competition

This table presents the GMM estimations for the profitability and competition nexus for the Equation 6 as presented below.

$$Profitability_{i,j,t} = f\left(Profitability_{i,j,t-1}, Competition_{j,t}, GDP\ per\ capita_{j,t}, Islamic\ banking\ share_{jt}, Z_{i,j,t}, Islamic_{i,j}\right)$$

Panel A presents the findings with ROA as measure of Profitability while Panel B uses ROE as profitability measure. While the (1), (2) and (3) in each panel represents the three alternative measures of competition; H-Statistics, HH Index, and Boone Index respectively. The superscripts ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively

	Panel A: ROA			**Panel B: ROE**		
	1	**2**	**3**	**1**	**2**	**3**
	H-	**HH Index**	**Boone**	**H-**	**HH Index**	**Boone**
ROA (-1)	0.714	0.890	0.793			
	(0.001)***	(0.001)**	(0.000)***			
ROE (-1)				0.915	0.836	0.880
				(0.012)**	(0.019)**	(0.009)***
Cost to Income Ratio	-0.020	-0.020	-0.103	-0.106	-0.146	-0.019
	(0.000)**	(0.000)**	(0.000)**	(0.000)**	(0.000)**	(0.000)**
Loan to Total Asset	0.002	0.002	-0.003	0.011	0.008	0.002
	-0.473	-0.479	-0.981	-0.713	-0.612	-0.981
Size	0.016	0.083	0.024	0.042	0.011	0.007
	-0.326	-0.173	-0.541	-0.457	-0.166	(0.054)*
Diversification Index	0.061	0.043	0.015	0.004	-0.077	0.328
	-0.984	-0.936	(0.004)***	-0.922	-0.806	(0.028)**
Diversification Index*Islamic	0.009	0.002	0.001	0.008	0.009	0.008
	-0.823	-0.213	-0.667	-0.997	-0.101	-0.098
Islamic Banking (IB) Share	0.006	-0.001	0.069	-0.098	0.043	0.062
	-0.436	-0.825	-0.197	-0.122	-0.162	(0.000)***
IB Share*CB Dummy	0.008	0.761	0.109	0.834	0.002	0.119
	-0.561	-0.163	-0.101	-0.782	-0.639	(0.083)*
Islamic	0.001	-0.007	0.036	0.036	0.077	0.042
	-0.671	-0.141	(0.083)*	-0.194	-0.287	(0.014)**
GDP per capita	0.004	0.136	0.938	0.007	-0.030	0.009
	(0.036)**	(0.001)**	-0.679	(0.078)*	-0.458	(0.000)***
Competition	0.015	0.888	-0.033	-0.027	0.209	-0.012
	-0.215	(0.082)*	(0.013)**	(0.097)*	(0.065)*	(0.025)**
Competition*Islamic	0.004	0.081	0.042	-0.002	0.059	-0.016
	-0.544	-0.563	-0.484	-0.189	-0.937	(0.084)*
Islamic*Crisis	0.006	0.007	0.072	0.065	-0.002	0.006
	-0.172	(0.013)**	(0.149)**	(0.007)***	-0.112	(0.042)**
Crisis	-0.011	-0.010	0.179	-0.010	0.105	0.002
	-0.644	(0.011)**	-0.684	(0.087)*	-0.919	-0.561
Constant	0.016	0.022	0.179	0.176	0.139	0.021
	(0.000)***	(0.000)**	(0.000)***	(0.000)***	(0.000)**	(0.000)***
Sargan p-values	0.610	0.530	0.670	0.670	0.590	0.710
AR(1)-p values	0.091	0.031	0.011	0.124	0.078	0.044
AR(2)-p values	0.669	0.512	0.812	0.018	0.293	0.005

Table 5: Robustness Tests for Large Banks on Stability and Performance

This table presents the GMM estimations for the Stability and competition nexus for the large banks per Equation 5 as presented below. Large Banks are defined by Cihak and Hesse (2010) who suggests that banks with assets more than USD 1 billion are categorized as large banks.

$$Stability_{i,j,t} = f(Stability_{i,j,t-1} Competition_{j,t}, GDP\ per\ capita_{j,t}, Islamic\ banking\ share_{jt}, Z_{i,j,t}, Islamic_{i,j}$$

Panel A presents the findings with Z -score as measure of Stability while Panel B uses Loan loss provision to equity (LLP/E) as stability measure. While the (1), (2) and (3) in each panel represents the three alternative measures of competition; H-Statistics, HH Index, and Boone Index respectively. The superscripts ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively

	Panel A: Z Score			**Panel B: LLP/E**		
	1	**2**	**3**	**1**	**2**	**3**
	H-	**HH Index**	**Boone**	**H-**	**HH Index**	**Boone**
Z Score(-1)	0.9163 (0.000)***	0.8205 (0.000)**	0.8931 (0.000)***			
LLP/E(-1)				0.6973 (0.001)***	0.9129 (0.000)**	0.7301 (0.001)***
Cost to Income Ratio	-1.97 (0.031)**	-1.08 (0.000)**	-1.91 (0.021)**	0.0119 (0.006)***	0.0003 (0.041)**	0.0012 (0.019)**
Loan to Total Asset	-2.98 (0.000)***	-2.68 (0.000)**	-2.33 (0.003)***	0.0047 (0.009)***	0.1320 (0.001)**	0.3201 (0.000)***
Size	-0.0183 (0.049)**	-0.0331 (0.210)	-0.0125 (0.021)**	0.0033 (0.049)**	0.0031 (0.073)*	0.0186 (0.093)*
Diversification Index	0.0331 (0.162)	0.0118 (0.291)	0.0341 (0.122)	-0.0113 (0.090)*	-0.0331 (0.221)	-0.1391 (0.454)
Diversification Index*Islamic	0.1191 (0.431)	0.0104 (0.327)	0.1342 (0.113)	-0.1108 (0.269)	-0.1103 (0.335)	-0.0110 (0.075)*
Islamic Banking (IB) Share	1.01 (0.000)***	1.21 (0.000)**	1.19 (0.000)***	-0.3101 (0.000)***	-0.0031 (0.000)**	-0.0001 (0.000)***
IB Share*CB Dummy	1.89 (0.099)*	1.93 (0.444)	1.46 (0.322)	-0.0013 (0.161)	-0.0003 (0.216)	-0.0031 (0.139)
Islamic	0.0701 (0.034)**	0.885 (0.010)**	0.0712 (0.231)	-0.0001 (0.004)***	-0.0118 (0.011**)	-0.0019 (0.100)*
GDP per capita	0.0018 (0.000)***	0.0137 (0.000)**	0.1013 (0.000)***	-0.0211 (0.000)***	-0.0113 (0.000)**	-0.0001 (0.000)***
Competition	1.083 (0.000)***	-0.0022 (0.000)**	1.1735 (0.000)***	-0.0054 (0.000)***	0.0000 (0.000)**	-0.0105 (0.000)***
Competition*Islamic	0.8395 (0.957)	-0.0001 (0.011)**	0.9976 (0.213)	0.1167 (0.553)	0.0117 (0.287)	-0.0134 (0.057)*
Islamic*Crisis	1.01 (0.063)*	1.91 (0.048)**	2.33 (0.077)*	-0.1901 (0.001)***	-0.0081 (0.031)**	-0.0701 (0.019)**
Crisis	-0.3378 (0.067)*	-0.672 (0.061)*	-0.8821 (0.000)***	0.3312 (0.057)*	0.0011 -0.169	0.0211 (0.000)***
Constant	18.31 (0.000)***	17.63 (0.000)**	17.91 (0.000)***	0.0001 (0.000)***	0.0053 (0.000)**	0.0021 (0.000)***
Sargan p-values	0.72	0.44	0.39	0.21	0.83	0.67
AR(1)-p values	0.061	0.006	0.672	0.011	0.007	0.015
AR(2)-p values	0.221	0.664	0.117	0.115	0.201	0.113

Table 6: Robustness Tests for Large Banks on Performance and Competition

This table presents the GMM estimations for the profitability and competition nexus for the large banks per Equation 6 as presented below. Large Banks are defined by Cihak and Hesse (2010) who suggests that banks with assets more than USD 1 billion are categorized as large banks

$$Profitability_{i,j,t} = f\left(Profitability_{i,j,t-1}, Competition_{j,t}, GDP\ per\ capita_{j,t}, Islamic\ banking\ share_{jt}, Z_{i,j,t}, Islamic_{i,j}\right)$$

Panel A presents the findings with ROA as measure of Profitability while Panel B uses ROE as profitability measure. While the (1), (2) and (3) in each panel represents the three alternative measures of competition; H-Statistics, HH Index, and Boone Index respectively. The superscripts ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively

	Panel A: ROA			**Panel B: ROE**		
	1	**2**	**1**	**2**	**1**	**2**
	H-Statistics	**HH Index**	**Boone Index**	**H-Statistics**	**HH Index**	**Boone Index**
ROA (-1)	0.8130	0.893	0.6845			
	(0.000)***	(0.001)***	(0.000)***			
ROE (-1)				0.7981	0.8028	0.8919
				(0.001)***	(0.041)**	(0.000)***
Cost to Income Ratio	-0.0648	-0.0283	-0.1839	-0.0186	-0.1039	-0.0836
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Loan to Total Asset	0.0011	0.0037	-0.01691	0.0083	0.0013	0.0197
	(0.567)	(0.201)	(0.891)	(0.992)	(0.062)*	(0.121)
Size	0.0483	0.0156	0.0381	0.0954	0.0671	0.0611
	(0.013)**	(0.221)	(0.661)	(0.883)	(0.913)	(0.610)
Diversification Index	0.0196	0.0114	0.0097	0.0014	-0.0140	0.0031
	(0.114)	(0.226)	(0.123)	(0.622)	(0.971)	(0.331)**
Diversification Index*Islamic	0.0153	0.0185	0.0192	0.0108	0.0911	0.0081
	(0.113)	(0.030)**	(0.992)	(0.301)	(0.883)	(0.114)
Islamic Banking (IB) Share	0.0116	0.0195	0.1101	-0.1861	-0.0139	0.0011
	(0.991)	(0.777)	(0.118)	(0.081)*	(0.010)*	(0.166)
IB Share*CB Dummy	0.0188	0.0631	0.1605	0.0013	0.0004	0.0181
	(0.310)	(0.231)	(0.221)	(0.133)	(0.313)	(0.529)
Islamic	0.0108	0.1331	0.0921	0.0031	0.2333	0.0231
	(0.081)*	(0.710)	(0.192)	(0.183)	(0.032)**	(0.101)
GDP per capita	0.0138	0.0130	-0.0140	0.0109	-0.0108	0.0116
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Competition	0.1806	0.1886	-0.0340	-0.0265	0.0000	-0.0124
	(0.025)**	(0.002)***	(0.313)	(0.068)*	(0.065)*	(0.025)**
Competition*Islamic	0.0031	0.0082	0.0039	-0.0011	0.0067	-0.0066
	(0.333)	(0.547)	(0.344)	(0.220)	(0.661)	(0.111)
Islamic*Crisis	0.0051	0.0067	0.0036	0.0029	-0.0039	0.0061
	(0.001)***	(0.061)*	(0.149)	(0.000)***	(0.002)***	(0.221)
Crisis	-0.0188	-0.0197	0.0186	-0.0210	0.0191	0.0199
	(0.133)	(0.001)***	(0.777)	(0.001)*	(0.000)***	(0.961)
Constant	0.0263	0.0148	0.0781	0.0013	0.1119	0.0193
	(0.001)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Sargan p-values	0.69	0.63	0.54	0.71	0.53	0.59
AR(1)-p values	0.023	0.043	0.056	0.073	0.012	0.019
AR(2)-p values	0.091	0.433	0.231	0.013	0.163	0.119

Table 7: Robustness Tests for Small Banks on Stability and Competition

This table presents the GMM estimations for the Stability and competition nexus for the small banks per Equation 5 as presented below. Small Banks are defined by Cihak and Hesse (2010) who suggests that banks with assets less than USD 1 billion are categorized as small banks.

$$Stability_{i,j,t} = f(Stability_{i,j,t-1} Competition_{j,t}, GDP\ per\ capita_{j,t}, Islamic\ banking\ share_{jt}, Z_{i,j,t}, Islamic_{i,j}$$

Panel A presents the findings with Z -score as measure of Stability while Panel B uses Loan loss provision to equity (LLP/E) as stability measure. While the (1), (2) and (3) in each panel represents the three alternative measures of competition; H-Statistics, HH Index, and Boone Index respectively.

The superscripts ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively

	Panel A: Z Score			**Panel B: LLP/E**		
	1	**2**	**3**	**1**	**2**	**3**
	H-	**HH Index**	**Boone**	**H-**	**HH Index**	**Boone**
Z Score(-1)	0.8813 (0.000)***	0.8601 (0.000)**	0.8188 (0.000)***			
LLP/E(-1)				0.7931 (0.002)***	0.7831 (0.000)**	8834 (0.008)***
Cost to Income Ratio	-2.81 (0.067)*	-1.67 (0.000)**	-2.93 (0.019)**	0.0135 (0.000)***	0.0188 (0.068)*"	0.0338 (0.069)*
Loan to Total Asset	-1.23 (0.000)***	-2.98 (0.000)**	-1.67 (0.008)***	0.0335 (0.007)***	0.1181 (0.006)**	0.6701 (0.001)***
Size	-0.0013 (0.089)*"	-0.3351 (0.008)**	-0.1311 (0.042)**	0.0185 (0.026)**	0.0191 (0.011)*	0.1151 (0.61)
Diversification Index	0.4813 (0.034)**	0.3351 (0.023)**	0.1167 (0.012)**	-0.0017 (0.188)	-0.9145 (0.081)*	-0.6783 (0.031)**
Diversification Index*Islamic	0.3391 (0.022)**	0.1192 (0.013)**	0.1671 (0.000)***	-0.1341 (0.071)*	-0.1151 (0.023)**	-0.0113 (0.045)**
Islamic Banking (IB) Share	1.38 (0.000)***	2.81 (0.000)**	1.67 (0.000)***	-0.1192 (0.000)***	-0.0134 (0.000)**	-0.0889 (0.000)***
IB Share*CB Dummy	2.93 (0.011)**	1.88 (0.041)**	1.93 (0.067)*	-0.0135 (0.001)***	-0.0003 (0.016)**	-0.3931 (0.367)
Islamic	0.2871 (0.135)	0.1105 (0.009)**	0.2351 (0.001)***	-0.0016 (0.921)	-0.0142 (0.311)	-0.0001 (0.023)**
GDP per capita	0.3351 (0.000)***	0.1183 (0.000)**	0.7144 (0.000)***	-0.6721 (0.000)***	-0.3321 (0.000)**	-0.1581 (0.000)***
Competition	0.1341 (0.000)***	-0.2241 (0.000)**	0.0351 (0.000)***	-0.6721 (0.000)***	0.3012 (0.000)**	-0.0012 (0.000)***
Competition*Islamic	0.9987 (0.781)	-0.0312 (0.001)**	0.9071 (0.671)	0.1067 (0.053)*	0.1351 (0.221)	-0.1101 (0.301)
Islamic*Crisis	0.8013 (0.041)**	0.0016 (0.049)**	0.0039 (0.089)*	-0.1191 (0.067)*	-0.0167 (0.042)**	-0.0835 (0.089)*
Crisis	-0.3015 (0.092)*	-0.0061 (0.000)**	-0.0013 (0.000)***	0.6120 (0.029)**	0.0351 (0.000)**	0.2319 (0.301)
Constant	21.45 (0.000)***	22.56 (0.000)**	19.89 (0.000)***	0.0083 (0.000)***	0.0367 (0.000)**	0.0011 (0.000)***
Sargan p-values	0.69	0.61	0.47	0.56	0.88	0.77
AR(1)-p values	0.043	0.001	0.391	0.001	0.067	0.035
AR(2)-p values	0.115	0.43	0.32	0.223	0.101	0.116

Table 8: Robustness Tests for Small Banks on Performance and Competition

This table presents the GMM estimations for the profitability and competition nexus for the small banks per Equation 6 as presented below. Small Banks are defined by Cihak and Hesse (2010) who suggests that banks with assets less than USD 1 billion are categorized as small banks

$$Profitability_{i,j,t} = f\left(Profitability_{i,j,t-1}, Competition_{j,t}, GDP\ per\ capita_{j,t}, Islamic\ banking\ share_{jt}, Z_{i,j,t}, Islamic_{i,j}\right)$$

Panel A presents the findings with ROA as measure of Profitability while Panel B uses ROE as profitability measure. While the (1), (2) and (3) in each panel represents the three alternative measures of competition; H-Statistics, HH Index, and Boone Index respectively. The superscripts ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively

	Panel A: ROA			**Panel B: ROE**		
	1	**2**	**3**	**1**	**2**	**3**
	H-	**HH Index**	**Boone**	**H-**	**HH Index**	**Boone**
ROA (-1)	0.7312 (0.000)***	0.7791 (0.001)**	0.7813 (0.000)***			
ROE (-1)				0.7351 (0.000)***	0.8102 (0.000)**	0.8311 (0.000)***
Cost to Income Ratio	-0.0015 (0.000)***	-0.0119 (0.000)**	-0.0631 (0.000)***	-0.1102 (0.000)***	-0.1119 (0.000)**	-0.0036 (0.000)***
Loan to Total Asset	0.1351 (0.081)*	0.0017 (0.667)	0.1183 (0.993)	0.0124 (0.410)	0.0016 (0.430)	0.0018 (0.201)
Size	0.0083 (0.513)	0.0081 (0.551)	0.1130 (0.067)*	0.1034 (0.081)*	0.1167 (0.318)	0.6711 (0.550)
Diversification Index	0.0115 (0.191)	0.0667 (0.182)	0.1861 (0.623)	0.1191 (0.329)	0.0008 (0.173)	0.0161 (0.061)*
Diversification Index*Islamic	0.1101 (0.166)	0.1193 (0.533)	0.9351 (0.331)	0.0001 (0.812)	0.8881 (0.331)	0.3301 (0.211)
Islamic Banking (IB) Share	0.1106 (0.831)	0.1135 (0.067)*	0.1510 (0.331)	0.3351 (0.145)	0.8801 (0.110)	0.1131 (0.066)*
IB Share*CB Dummy	0.0011 (0.0431)**	0.3191 (0.001)**	0.1117 (0.008)***	0.3310 (0.133)	0.0014 (0.013)**	0.0110 (0.029)**
Islamic	0.1135 (0.531)	0.0018 (0.040)**	0.0013 (0.223)	0.0019 (0.086)**	0.1024 (0.567)	0.1109 (0.331)
GDP per capita	0.0011 (0.000)***	0.1103 (0.000)**	0.0115 (0.000)***	0.1104 (0.000)***	0.0011 (0.000)**	0.1193 (0.000)***
Competition	0.0831 (0.000)***	0.0023 (0.001)**	-0.0133 (0.010)*	-0.0341 (0.128)	0.0529 (0.005)**	-0.0113 (0.147)
Competition*Islamic	0.2034 (0.063)*	0.1183 (0.671)	0.5610 (0.391)	-0.1351 (0.020)**	0.0031 (0.993)	0.3351 (0.945)
Islamic*Crisis	0.3382 (0.000)***	0.1192 (0.113)	0.0067 (0.167)	0.0192 (0.004)***	0.8617 (0.671)	0.1342 (0.021)**
Crisis	-0.3351 (0.431)	-0.0014 (0.000)**	-0.0016 (0.332)	-0.3351 (0.020)**	-0.5581 (0.035)**	0.0199 (0.693)
Constant	0.2013 (0.000)***	0.1401 (0.000)**	0.7381 (0.004)***	0.9821 (0.006)***	0.1330 (0.000)**	0.1193 (0.000)***
Sargan p-values	0.88	0.71	0.79	0.81	0.66	0.63
AR(1)-p values	0.011	0.035	0.067	0.063	0.001	0.034
AR(2)-p values	0.113	0.261	0.118	0.311	0.818	0.228

Modelling Market Integration in the Middle East and Africa through the Law of One Price

Vinh Q.T. Dang*, Yu (Alan) Yang**

**Nanjing University of Finance and Economics. Email: dang.vinh@outlook.com*
***University of Wisconsin – Madison*

Abstract

We model market integration in the Middle East and Africa by analyzing price dispersion and testing the law of one price (LOP) on highly-comparable *actual* local retail prices of 115 goods and services across 23 countries in the region over the period of 1990-2016. Second-generation panel estimators are applied to four price benchmarks: Regional average, South Africa, China, and US prices. Cross-regional price dispersion diminishes considerably over time up to 2008, particularly for non-tradables around China price. The test of LOP indicates the percentage of convergent prices is highest in China price benchmark, followed by US, South Africa, and regional average benchmarks. Direct estimation of the convergence speed confirms this order. Overall, the results show evidence of increasing market integration in Middle East and Africa but it appears to be driven by global forces and, especially, the rise of China as a new economic power.

Keywords: Middle East and Africa; economic integration; law of one price; convergence; price dispersion; China

JEL Classification: E31; F31; F36

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1. Introduction

The world economy in the last half century has made tremendous progress in economic integration, with European Union (particularly, its Economic and Monetary Union) and, more recently, Asia as being the prime examples. The Middle East and Africa, despite abundance of natural resources, however, is the least integrated region in the world. Although the region accounts for around 6 percent and 4 percent of the world's population and GDP, respectively, its share of non-oil world trade is less than 2 percent (World Bank, 2013). Recently, some oil-rich regional states, such as Saudi Arabia and Qatar, have made efforts to diversify their economy away from sole reliance on exports of natural resources. A notable attempt at regional integration is the move toward Tripartite Free Trade Area, which consists of 26 member countries of the East African Community (EAC), the Common Market for Eastern and Southern Africa (COMESA), and the Southern African Development Community (SADC).

Such initiative to forge closer cooperation and integration is important in itself, particularly for this region, as it helps promote trade in other goods and services, raising economic competitiveness of the member states and the whole region. The expanded scope of commercial activities can reduce reliance on natural resources and absorb labor surplus, thereby lowering income inequality in the region. Besides more sustainable economic growth and equitable income distribution, greater economic cooperation and integration play a crucial role in preventing political instability within each state as well as conflict among the member states.[1] Lastly, regional economic integration is also important, given slowdown in the growth of world trade since the 2008 global crisis and recent disengagements from international relations such as the UK's exit from the European Union and the USA's withdrawal from Trans-Pacific Partnership (TPP).

Motivated by these developments, we examine economic integration in the Middle East and Africa through the law of one price (LOP) in this paper. The LOP states that prices of the same product sold in different markets, after conversion to the same currency, should be the same due to market participants' taking advantage of arbitrage opportunities. Investigation of whether the LOP holds is useful in assessing how integrated markets in this region currently are. Moreover, the LOP is the building block for the purchasing power parity (PPP); these two parities feature prominently in open-economy macroeconomics. Testing the PPP is one of the most active research areas in international finance (Taylor and Taylor, 2004; Rogoff, 1996; Froot and Rogoff, 1995; Frenkel, 1978). Hence, our results also bear important implications for future co-ordination of financial and monetary policies in the region, particularly if the member countries aspire to a monetary union.

Our study contains the following innovations. First, we model economic integration through the lens of the law of one price (LOP). Although there have been numerous empirical studies on the PPP, research on the LOP is scant because of the lack of comparable retail prices. The use of individual prices reveals more insights and therefore is more suitable in studying market integration than price indices that are usually not comparable across countries because of different weights and compositions of the goods and services used in those indices. In this paper, we use a data set that contains highly comparable *actual* retail prices of 115 tightly-defined goods and services in cities across 23 countries in the Middle East and Africa over the period of 1990-2016. The data set used in our paper is the most comprehensive survey of retail prices for this region.

[1] After all, the creation of European Economic Community, effected by Treaty of Rome in 1957, was predicated on a simple idea that trading partners are less likely to go to war with each other.

Second, although there is a large body of empirical literature on economic integration in Europe and, to a lesser extent, Asia, research on Middle East and Africa has been very limited. This explains our choice of this region as we wish to contribute to this limited collection of research. We also have a brief look at the European Union to check the robustness of our results. Our third contribution is to examine whether integration in the Middle East and Africa is a result of regional endeavor or simply part of a global trend. To this end, we test relative influence of large economies on the process of integration in the region: South Africa, USA, and China; the presence of the two largest economies in the world represents global factors. This analysis has important implication on how to promote economic integration in light of recent disengagements of a few major economies from international relations.

Fourth, we examine market integration in the region from two different, but complementary, perspectives: price dispersion and convergence to the law of one price. The results from different analyses within each approach and between these approaches are consistent with each other; they collectively shape our interpretation. Fifth, we employ Pesaran (2006) common correlated effects (CCE) estimator and Pesaran (2007) panel unit-root test, which are not only suitable to our inquiry but also reflect recent advances from panel data econometrics. For example, since incorrect assumption of cross-section independence in the data can lead to severe size distortion in the test statistic and therefore wrong conclusion about the degree of market integration, we formally test if cross-section correlation exists in our data and then employ a panel unit root test that explicitly accounts for this important data feature.

2. Data and Sample Selection

Our analysis is applied to City Data, a survey conducted by the Economist Intelligence Unit (EIU).[2] Each year, the EIU collects local retail prices of around 160 tightly-defined individual goods and services such as "white sugar, 1kg", "Aspirin, 100 tablets", "man's hair cut", "taxi: initial meter charge", and "visit to dentist (one X-ray and one filling)" from comparable retail outlets and service providers in more than 140 cities worldwide. The purpose of CityData is to provide a consistent basis for calculating and comparing the cost of living in major cities around the world; it can be used by multi-national corporations in determining compensation levels of their employees working in different cities in the world. We use this data set because the goods and services are highly comparable across cities as the LOP proposition dictates. Exchange rate between the local currency and the US dollar is also collected in the same survey; it is used to convert all local-currency prices into US-dollar prices before further transformation and analysis.

[Insert Table 1 around here]

In some countries, prices are surveyed in more than one city and the starting year of price collection as well as coverage of goods and services can be different across cities. In these cases, we select the city in which data collection starts the earliest and covers the largest number of items; the city

[2] See http://eiu.com/ for more information.

selection is shown in Table 1.[3] Our sample contains annual observations covering 1990-2016 for Bahrain, Côte d'Ivoire (Abidjan), Egypt (Cairo), Iran (Tehran), Israel (Tel Aviv), Jordan (Amman), Kenya (Nairobi), Morocco (Casablanca), Nigeria (Lagos), Saudia Arabia (Riyadh), Senegal (Dakar), South Africa (Johannesburg), Tunisia (Tunis), United Arab Emirates (Abu Dhabi), Zimbabwe (Harare), 1991-2016 for Cameroon (Douala), Kuwait, 2000-2016 for Oman (Muscat), Qatar (Doha), Zambia (Lusaka), and 2001-2016 for Algeria (Algiers) and Syria (Damascus). Within this region, we consider cross-city average price as a benchmark. Prices from Johannesburg of South Africa, the largest economy in the region, are considered as another local price benchmark.

As we wish to examine the potential global effect on regional integration, we also use price data from the USA and China. For USA, we select prices sampled in Cleveland because its median income is closest to the national media income. For China, prices sampled in Beijing are selected as Beijing's data coverage is the best among 8 sampled cities. Not all items surveyed by the EIU are available in all of these countries because some products, such as alcohol and certain types of meat, are not sold in several countries in the Middle East and Africa due to religion and culture. In addition, there are missing observations for some items, especially in early years. Therefore, we have to balance between the number of items, the number of cities, and the number of time-series observations in the sample selection. To select the sample for the main analysis, we consider a criterion that favors long time-series dimension in anticipation of unit-root tests. By this criterion, 6 cities with fewer than 20 years of data coverage are dropped from the sample. We then follow Rogers' (2007) two-third rule in that a commodity or service item is selected if its price is available for at least 12 out of 17 cities. The final sample consists of 115 items: 82 tradeables (goods) and 33 non-tradeables (services); the price of each item is available for at least 20 consecutive years. The items are listed in the appendix. To consider possible effect of the global crisis, we also drop the observations after 2008 and repeat the analysis to the 1990-2008 sample.

To check the robustness of the results, we use an alternative selection criterion that is less stringent on the time-series dimension so as to include more goods and services for more cities. An item is included if its price is available for at least 14 consecutive years for at least 16 out of 23 cities. This criterion yields a sample of 135 items: 95 tradeables and 40 non-tradeables; they are also listed in the appendix. The results from this sample, presented in the robustness check section, are similar. In CityData survey, prices of many goods are sampled from different outlets, for example "supermarket" and "mid-priced store". For most service items, however, an average price is provided. We choose the supermarket or chain-store prices, which are more comparable across countries (Rogers, 2007), when their data series meet the above criteria; if not, we take prices from mid-price store. Table A1 in the appendix lists the items that are included or dropped (marked by "*X*") in the samples according to the above selection criteria. In the table, items are grouped into different categories such as food and non-alcoholic beverages, personal care, and transport. To facilitate exposition of the results, we follow Rogers (2007) and put the items into two groups: tradeables and non-tradeables (marked by "*N*").

As for data reliability, Crucini and Shitani (2008) suggest that the EIU price data collected in US cities match up closely with US Bureau of Labor Statistics disaggregated price data; the two surveys have similar sampling intensities for most categories of goods and services. Rogers (2007)

[3] For example, CityData contain prices sampled from 8 cities (Beijing, Dalian, Guangzhou, Qingdao, Shanghai, Shenzhen, Suzhou, Tianjin) in China; Beijing is selected because its data coverage is the best.

shows that there is positive and large correlation between EIU price changes and the annual official CPI inflation for all European countries. The EIU data have been used in other studies such as Bergin and Glick (2007), Parsley and Wei (2002), and Hufbauer et al. (2002).

3. Empirical methods

3.1 Price dispersion

In the first approach, we calculate and plot the degree of price dispersion across cities in the Middle East and Africa over the period of 1990-2016. The time path and pattern of the price dispersion can convey useful information. For example, if there is greater market integration over time, price dispersion is expected to diminish accordingly. In the sample period, whether and how significant economic shocks affect price dispersion can also be seen. Moreover, we can compare the pattern of price dispersion in this region with that in other countries or regions. Following Rogers (2007), we first calculate "de-meaned" price $\%_{ikt}$ as

$$\%_{ikt} = g^*_{ikt} / \bar{g}^*_{it}, \quad (1)$$

where g^*_{ikt} denotes the US-dollar price of item *i* in city *k* in year *t*; and $\bar{g}^*_{it}$ denotes a benchmark price of item *i* in year *t*.[4] To examine integration in the Middle East and Africa, we use cross-city average price as a benchmark $\bar{g}^*_{it}$. In addition, to gauge relative integration of other regional economies to South Africa, China and US, we also take Johannesburg, Beijing, and Cleveland prices, respectively, as alternative benchmark $\bar{g}^*_{it}$.[5] We then apply identical empirical methods to the same data sample in the four price benchmarks (region-average, South Africa, China, and the US). Differences in the results among the price benchmarks would provide some insights into which country is the leading center of economic gravity for the region and whether regional economic integration has been born out of local initiatives or has simply been a by-product of globalization.

For better exposition and interpretation of the results, we present the results for groups of items instead of each item. There are three groups (g): tradeables, nontradeables, and all items (that is, *i* in Equation 1 belongs to one of these three groups). To this end, we calculate equal-weighted price index, $P(g)_{kt}$, which is a simple average of the de-meaned prices $\%_{ikt}$ for each group g.[6] All indexes are normalized to make the cross-city mean equal to 1 in each year for each index.[7]

Next, we obtain the standard deviation of price indices $P(g)_{kt}$ across cities in each year *t* from 1990 to 2016 for *group g*:

[4] All local-currency prices are converted to US-dollar prices using the exchange rates collected in the same CityData survey.

[5] This is similar to Parsley and Wei (1996), in which New Orleans is defined as the benchmark city in testing price convergence among 48 US states.

[6] Rogers (2007) also calculates a "CPI-weighted" price index and reports that the results are similar to those obtained from equal-weighted price index.

[7] Since price index is involved in this part of the empirical analysis, our study covers purchasing power parity concept as well. Our results therefore can hold at price-index level in addition to individual-price level although the latter is the main focus of this paper. We thank an anonymous referee for pointing out this implication.

$$\sigma(g)_t = \{[K\sum_k (P(g)_{kt})^2 - (\sum_k (P(g)_{kt}))^2]/[K(K-1)]\}^{1/2} \quad (2)$$

where the summations are taken over cities *k*, and *K* is the number of cities in the sample. We also calculate price dispersion across cities at the item level. For *each individual item i* for each year *t* from 1990 to 2016:

$$\sigma(i)_t = \{[K\sum_k (P_{ikt})^2 - (\sum_k (P_{ikt})^2]/[K(K-1)]\}^{1/2} \quad (3)$$

then an average of $\sigma(i)_t$ is taken for the groups of tradeables, non-tradeables, and all items.

3.2 Convergence to the law of one price

Since there are some unavoidable transaction costs such as shipping costs, the LOP is not expected to hold absolutely in practice even in a single-currency market like the US or euro zone where most, if not all, of the remaining trade barriers have been removed. Hence, in the second approach, we follow the literature and consider convergence to the law of once price as evidence of market integration (Fan and Wei, 2006; Allington et al., 2005; Golberg and Verboven; 2004; Cecchetti et al., 2002; Engel and Rogers 1996; Parsley and Wei, 1996). To test price convergence, we examine whether relative prices $p_{ikt} = \ln(g^*_{ikt} / \bar{g}^*_{it})$ are mean-reverting over time. Rejection of unit-root hypothesis in these relative prices is taken as evidence supporting the law of one price.

Univariate unit root tests, such as augmented Dickey-Fuller (ADF) test, suffer from lower power, particularly for short data series, and result in high non-rejection rate of the null hypothesis of unit root. To utilize full information in the data set, thereby improving the power of the test, we resort to panel unit-root test for the price of each item of goods and services in our sample. Early commonly-used tests such as Levin, Lin, and Chu (LLC) (2002) and Im, Pesaran, and Shin (IPS) (2003), also referred to as first-generation tests, assume data are cross-sectionally independent (Westerlund and Breitung, 2013; Breitung and Pesaran, 2008).

Many countries in the Middle East and Africa, besides geographical proximity, share similar history of colonialism, languages, religion, and ethnicity. These countries are also likely exposed to similar external economic and political shocks; or shocks in one country can be propagated quickly to others as in the case of the global crisis. Hence, the assumption of cross-section independence may not be valid in our data sample. Empirical and simulation studies have shown that the first-generation panel unit-root tests exhibit severe size distortion if cross-section dependence exists in the data (O'Connell, 1998; Wu and Wu, 2001, Banerjee et al., 2004 and 2005; Breitung and Das, 2005; Gengenback et al., 2010).

As erroneous assumption of cross-section independence can lead to very different conclusion about the degree of market integration in the Middle East and Africa and therefore incorrect policy implications, we formally test if this feature is present in our data sample with Pesaran (2004) cross-section dependence (CD) test. It is based on an average of pairwise correlation coefficients of OLS residuals from individual (city *k*) ADF regressions in the panel for each price item *i*:

$$\Delta p_{kt} = \rho_k p_{kt-1} + \alpha_k D_{kt} + \sum_\tau \gamma_{k\tau} \Delta p_{kt-\tau} + \varepsilon_{kt} \ , \quad (4)$$

where $D_{k,t}$ represents a vector of deterministic variables. Pesaran (2004) CD test statistic is calculated as:

$$CD = \sqrt{\frac{2T}{K(K-1)}}\left(\sum_{k=1}^{K-1}\sum_{j=k+1}^{K}\hat{\pi}_{kj}\right), \quad (5)$$

where $\hat{\pi}_{kj} = \sum_{t=1}^{T}\hat{\varepsilon}_{kt}\hat{\varepsilon}_{jt} \Big/ \left(\sum_{t=1}^{T}\hat{\varepsilon}_{kt}^2\right)^{1/2}\left(\sum_{t=1}^{T}\hat{\varepsilon}_{jt}^2\right)^{1/2}$. Under the null hypothesis of no cross-section dependence, $CD \sim N(0,1)$.[8]

Pesaran (2007) proposes a panel unit-root test that accounts for cross-section dependence. He suggests augmenting the ADF regressions in IPS (2003) with lagged cross-section mean and its first difference mean to capture cross-section dependence that arises in a single factor model:

$$\Delta p_{kt} = \rho_k p_{kt-1} + c_k \bar{p}_{t-1} + \sum_{\tau}\delta_{k\tau}\Delta\bar{p}_{t-\tau} + \sum_{\tau}\gamma_{k\tau}\Delta p_{kt-\tau} + \alpha_k D_{kt} + \varepsilon_{kt} \quad (6)$$

The *t*-statistics on coefficient ρ_k (called CADF) are averaged to obtain the CIPS statistic, which is used in our paper to test if the relative prices contain a unit root:

$$CIPS = \frac{1}{K}\sum_{k=1}^{K} CADF_k \quad (7)$$

From equation (6), another complementary method of examining the extent of market integration is to directly estimate the price convergence parameter ρ_k. For this purpose, we will employ Pesaran (2006) common correlated effects (CCE) estimator, which also accounts for cross-section dependence. When there is convergence in the relative price, the estimate of ρ_k is expected to be negative and statistically significant. In addition, as the magnitude of ρ_k indicates convergence speed, comparing these point estimates and the corresponding half-life measures among South Africa-, China- and US-price benchmarks can demonstrate the influence of these economies in the Middle East and Africa.

4. Results

4.1 *Price dispersion*

We first look the time path of price dispersion across countries in the region. Figure 1 shows the price standard deviation for the groups of tradeables, non-tradeables, and all items from corresponding region-average (a), South Africa (b), China (c), and US (d) prices over the period of 1990-2016. Except South Africa price benchmark, price dispersion in the other three benchmarks diminishes over the sample period. Most notably, variation of regional prices around China price for the group of non-tradeables registers the biggest decline. There appears to be some disruption of price convergence over the crisis of 2008. The largest effect is seen in the South Africa price benchmark, where price dispersion for both tradeables and non-tradeables rises after 2008 back to 1990 level.[9]

[8] Pesaran CD test is valid under a variety of models, including stationary and unit root dynamic heterogenous panels or panels containing multiple structural breaks. It also has satisfactory performance for small data panels such as those with cross-section and time series dimensions $N = 5$ and $T = 10$ or 20.

[9] The sudden drop in the price dispersion for the group of non-tradeables in the US price benchmark is caused by two service items from Senegal: (i) "annual premium for car insurance" and (ii) "car hire, weekly rate". Excluding these two items from the sample does not materially change any conclusion we make later. In fact, excluding them reduces the magnitude of the drop in price dispersion in US price benchmark, thereby reinforcing the ranking of China price as the most influential among the four price benchmarks.

[Insert Figure 1 around here]

In Table 2, we formally test if the change in price dispersion is statistically significant, we present *F*-statistic, calculated as the ratio of variances estimated over these two time intervals: 1990/2016 and 1990/2008. Note that 2008 is selected as an alternative end-of-sample year to exclude potential effect of the global crisis on the magnitude of price dispersion. Values of the *F* statistic less than 1 indicate increasing price dispersion whereas values greater than 1 indicate decreasing dispersion over these time intervals. Consistent with the striking decline in the price dispersion for the group of non-tradeables in China-price benchmark shown in Figure 1(c), the *F*-statistic is the largest (11.816) and statistically significant at 1% level. The *F* test also confirms that there is no significant decrease in price dispersion over the full sample period for both tradeables and non-tradeables in the South-Africa price benchmark.

[Insert Table 2 around here]

Overall there appears some evidence of price convergence, in terms of reduction in price dispersion, particularly around the benchmark prices from the two largest economies in the world. This pattern suggests influence of outside force on regional integration and is consistent with the emergence of China as the largest trading partners of and a major source of FDI to many countries in the region in the last two decades. We will take a closer look at individual items in the next empirical approach, as opposed to group of items considered so far.

[Insert Figure 2 around here]

As a robustness check, we calculate standard deviations of prices across cities for each *individual item i*, and then take the average of their values in the groups of tradeables, non-tradeables, and all items. The results are shown in Figure 2. The magnitude of price dispersion is higher, as expected, because dispersion is calculated for individual items. The patterns obtained for South Africa, China, and US price benchmarks are similar to those in Figure 1. A notable difference is that there is no significant change in price dispersion for non-tradeables over the full sample period in the region-average price benchmark (2a).

4.2 *Convergence to the law of one price*

We now turn to examining convergence to the law of one price (LOP) via panel unit root test. First, we perform Pesaran (2004) cross-section dependence test to see if there is correlation in prices across cities. Table 3 presents the percentages of goods (or tradeables, T) and services (non-tradeables, NT) for which the null hypothesis of no cross-section correlation is rejected. The values are very high, and close to 100% in many cases in different price benchmarks, samples, and significance levels ($\alpha = 0.10$ and $\alpha = 0.05$). There is strong evidence of cross-section dependence in the data; hence, it warrants the use of second-generation panel tests to account for such feature.

[Insert Table 3 around here]

Results of Pesaran (2007) panel unit root test with zero lag are shown in Table 4. The values indicate the percentage of items for which the null hypothesis of unit root is rejected, hence

providing evidence of convergence to the benchmark price, at two levels of statistical significance, $\alpha = 0.10$ and $\alpha = 0.05$. In the (1990-2016) sample, for 82 tradeables (T), at $\alpha = 0.10$, the percentage of convergent prices is 52%, 56%, 63%, and 56% for region-average, South Africa, China, and US price benchmarks, respectively. The corresponding percentages of convergent prices of 35 non-tradeable items (NT) are much smaller at 27%, 39%, 45%, and 36%. That higher percentages of convergent prices are obtained for goods than for services is consistent with arbitrage mechanism. The values for the group of all items are some average of the above two sets of values. At $\alpha = 0.05$, these percentages fall but the order of magnitude among the four price benchmarks is maintained.

[Insert Table 4 around here]

To consider the potential effect of the global crisis, we repeat the unit root test to the shortened sample of 1990-2008. The percentage of convergent prices for tradeables is lower across price benchmarks; the values are still higher in China and US (56% at $\alpha = 0.05$) than the other two benchmarks. This could be a result of lower power of the unit-root test from a shorter sample period or the effect of global crisis. The percentage of convergent prices for non-tradeables, however, rises in this sample, particularly for China (52% at $\alpha = 0.05$). This is consistent with what Figure 1 shows: the 2008 crisis causes much bigger disruption to the price convergence for services than for goods, which is sensible because it is much harder to carry out price arbitrage across countries for services.

[Insert Table 5 around here]

Overall, there is evidence of convergence to the law of one price in the Middle East and Africa. The percentage of regional prices converging to China price is higher than that to US and South Africa prices. The percentages of convergent items are lowest in the region-average price benchmark. Pesaran (2006) CCE estimation of the price convergence parameter ρ_k in equation (6) provides another way to examine integration. The results are presented in Table 5. The values shown in the "ρ_k" columns in this table are averages of the estimates of the convergence parameter for individual items in the groups of tradeables (T) and non-tradeables (NT). These average estimates are negative and statistically significant across benchmarks and samples, hence providing evidence of convergence in prices. The convergence speeds are always higher for tradeables than non-tradeables, as expected. In addition, these estimates and the corresponding half-life measures (in years) of convergence show that the speed of convergence from the highest to lowest follows this order: China, US, South Africa, and region-average price benchmarks. Overall, the results from Pesaran (2006) CCE estimation are consistent with results from Pesaran (2007) unit-root test and analysis of price dispersion.

4.3 *Robustness checks*

The above results indicate that regional prices in the Middle East and Africa gravitate more toward China prices than the US and the other two benchmark prices. The robustness checks in this subsection seeks to confirm this finding. To simplify the exposition, we show the results from the analyses in this sub-section for the group of all items.

We first check if different lag lengths used in the unit-root test qualitatively change the above conclusion. We perform Pesaran (2007) test with 1 lag and 2 lags and present the results in columns

(1)-(4) of Table 6. Although higher lag orders reduce the test power, resulting in lower percentages of items for which the unit root test is rejected (compared to those in Table 4), the percentage of prices in Middle East and Africa converging to China price remains the highest across samples, lags, and significance levels, and far above that in other price benchmarks.

In the second robustness check, we perform IPS (2003) test, a frequently-used first-generation panel unit-root test. This serves two purposes: (i) to show that not accounting for cross-section correlation in the data can give rise to size distortion and (ii) to see if the above ranking of influence still holds with a different panel unit-root test. In columns (5)-(8), the percentages of items for which the unit root hypothesis is rejected under IPS (2003) test are far larger than those obtained under Pesaran (2007), confirming the issue of size distortion well documented in many recent studies (O'Connell, 1998; Wu and Wu, 2001, Banerjee et al., 2004 and 2005; Breitung and Das, 2005; Gengenback et al., 2010). Even in the presence of size distortion, the percentages of convergent prices remains the highest in China price benchmark than in other price benchmarks.

[Insert Table 6 around here]

For the third robustness check, we analyze the alternative "wider and shorter" data panel discussed in the sample selection section. This sample contains 135 items (95 tradeables and 40 non-tradeables); an item is included if its price is available for at least 14 consecutive years for at least 16 cities. The results of Pesaran (2007) test are shown in columns (9)-(12) of Table 6. Note that we do not consider shortened sample period of 1990-2008 here because dropping 9 time-series observations from this sample would render the unit-root test inexecutable. Again, the results confirm the order established by previous analyses: the percentage of convergent prices is highest in China benchmarks, followed by US, South Africa, and region-average price benchmarks.

[Insert Table 7 around here]

In the fourth and final robustness check, we apply Pesaran (2007) test to prices sampled from members of the European Union (EU), the most integrated economic region in the world. This exercise helps check the soundness of our methodology. The EU sample contains 119 items (84 tradeables and 35 non-tradeables). Because data coverage is better for EU members, an item is selected if its price is available for at least 20 consecutive years for at least 19 out of 23 cities.[10] There are three benchmarks: EU-average, China, and US prices. The results in Table 7 show that the percentages of convergent prices for tradeables and non-tradeables are much higher in EU than in the Middle East and Africa. This indicates that the unit-root test of the LOP employed in our analysis is capable of measuring economic integration. Moreover, the percentages of EU prices converging to China prices is the lowest. In fact, one can argue that it is the deep economic linkage in EU that gives rise to such large percentages of convergent prices in China and US price benchmarks.

[10] We increase the required number of the cities in the selection criterion to obtain similar number of goods and services for EU sample (119 items) as the Middle East and Africa sample (115 items)

5. Concluding remarks

Based on panel unit-root test, slightly more than half of the goods and services in the Middle Eastern and African cities converge to the law of one price in the China, US, and South Africa price benchmarks; the proportion is lower for region-average price benchmark. Taking the values obtained at 0 lag and $\alpha = 0.10$ as the upper bound, they are decidedly lower than those found in some studies on European cities and USA states one or two decades ago. For example, Parsley and Wei (1996) find that prices of 80% of commodities and 50% of services exhibit convergence across 48 US cities based on quarterly data from mid 1970s to early 1990s. Crucini and Shintani (2008), using annual data from 1990 to 2005, show that the proportion of convergent prices is more than 90% for OECD countries.

Lower trade barriers, including absence of currency risk, across US states and/or similar economic development landscape in OECD and particularly European countries certainly contribute to greater degree of market integration. The gap in the extent of integration between these regions and the Middle East and Africa, however, is probably smaller than what the above numbers suggest. First, data samples in Parsley and Wei (1996) and Crucini and Shintani (2008) contain many more cross-section units (US states and countries) than our sample does, resulting in higher power of the test in rejecting the unit-root hypothesis. Second, they employ first-generation unit root tests that do not explicitly account for cross-section dependence, and therefore their results may be overestimated due to size distortion.

Overall, there is evidence of increasing market integration in the Middle East and Africa. This, however, appears to be driven not by local or regional initiatives, but rather by global forces, particularly by the emergence of China as a new economic power and the largest trading partner of several economies in the region. This has important implication not only for the Middle East and Africa, but also for the global economy. As the USA may become less engaged in international economic relations, other large economies, including those in emerging markets such as China and India can step up to promote further cooperation and integration. Economies can pursue policy initiatives that are specific to their region, such as Tripartite Free Trade Area for the Middle East and Africa, and at the same time reach out through bilateral or multi-lateral trade agreements with outside economies.

Our results suggest both potentials and challenges for the prospect of integration in the Middle East and Africa. On the bright side, there have been few significant initiatives for economic cooperation in the region, leaving much room for improvement. In addition, as large emerging markets such as China and India tend to trade more, their rise in the world stage can maintain the momentum of globalization, pulling their trading partners in the Middle East and Africa into a more diversified global trading orbit. Yet, there are also challenges. The analysis of price dispersion shows that the crisis of 2008 caused considerable disruption to the process of integration in the region. Volatile exchange rate movements in the aftermath of the crisis partly account for that. But many countries around the world have resorted to protectionism as well, erecting several trade impediments since the crisis. In a longer term, slowdown in China's economic growth, which means lower demand for natural resources from the Middle East and Africa, and, more importantly, its pivot from dependence on goods export to reliance on domestic consumption and services will have significant impact on price convergence of many goods and services given China's weight in the world trade.

In this paper, we utilize a comprehensive survey data set of actual local prices for 115 goods and services to model market integration in the Middle East and Africa, a region that has not been studied well for this particular topic. We employ recent advances in panel data econometrics to account for cross-section dependence in the data. Our study also contributes to the literature on real exchange rate.[11] The real exchange rate is normally defined at a more aggregate price level such as consumer price index. But suppose we move to individual commodity- or service-level, then each pair of local city price and the corresponding benchmark price, as expressed in equation (1), can define a "real exchange rate" that is specific to that commodity or service. This way, our test of convergence to the law of one price via the panel unit root test would be equivalent to testing whether the "real exchange rates" in the panel are stationary.

The Middle East and Africa is an important economic region, with great potential beyond rich endowment of natural resources. A lot more research is needed to identify policies and initiatives that are conducive to further economic cooperation within the region as well as to deeper and more diversified linkage with the rest of the world. Our study is a step in that direction.

[11] We thank an anonymous referee for pointing this out.

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Figure 1. Price dispersion (*groups of items*)

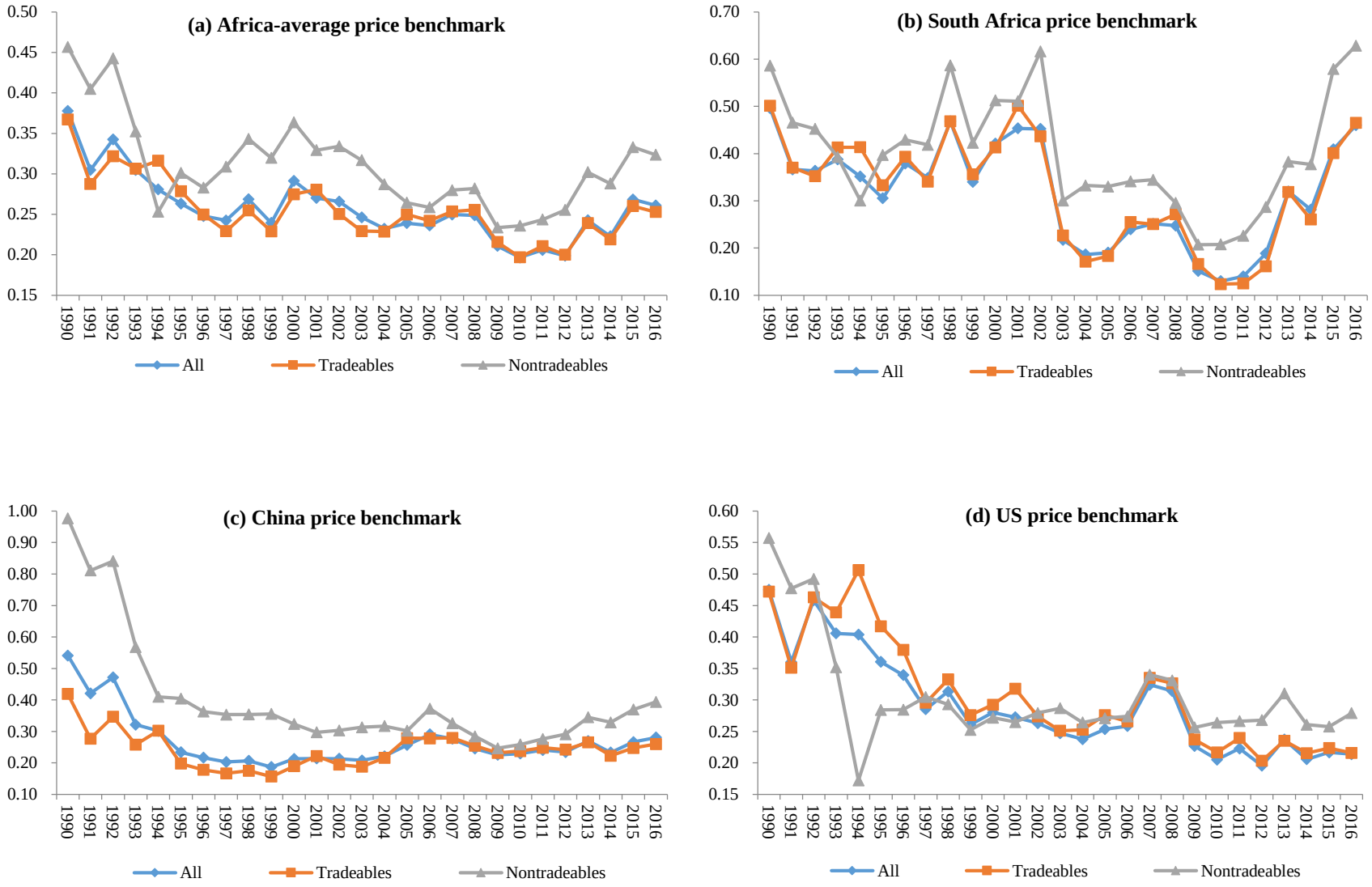


Figure 2. Price dispersion (*individual items*)

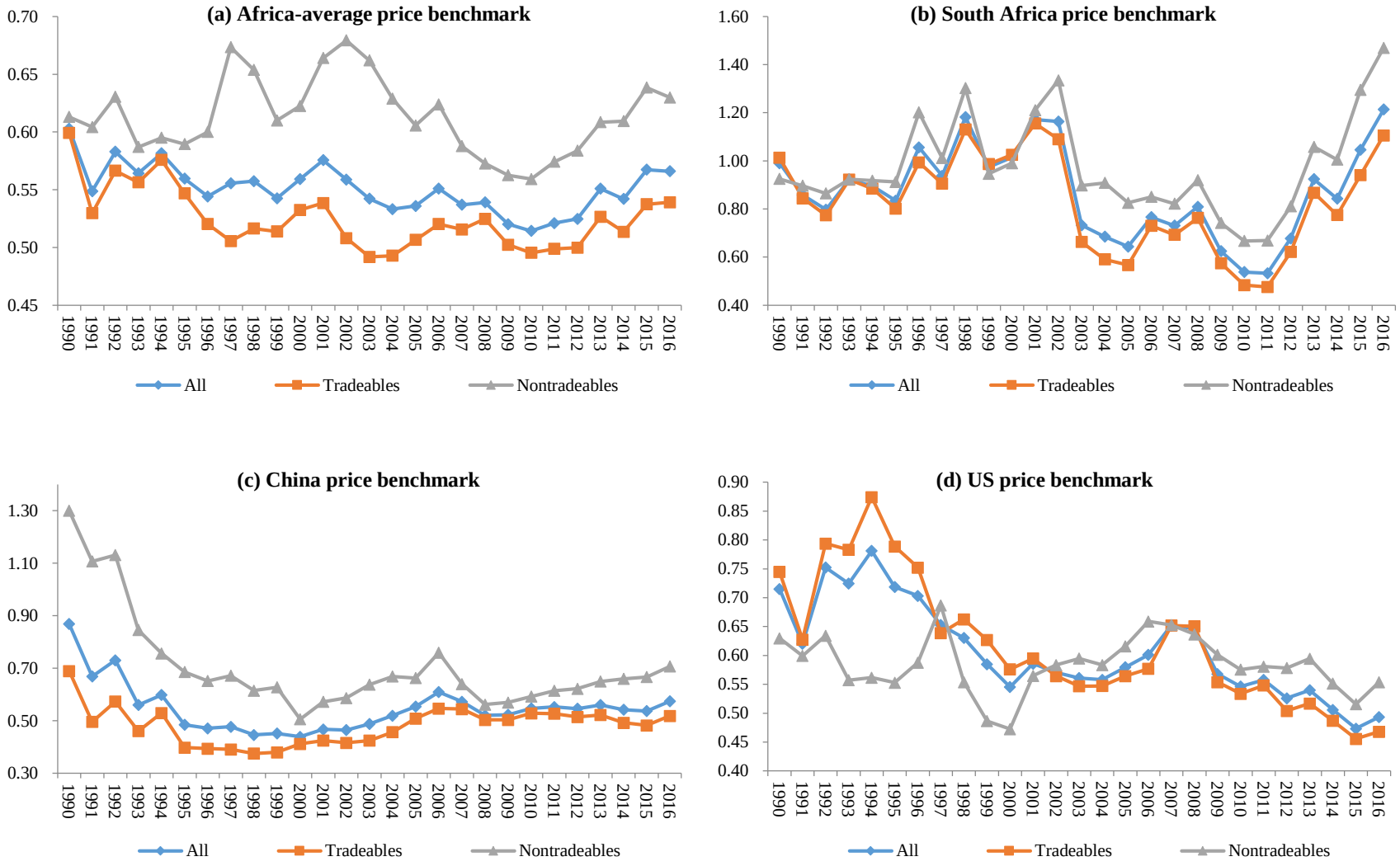


Table 1: Country (city) and data coverage

Country (city)	Coverage period
Algeria (Algiers)	2001-2016
Bahrain (Bahrain)	1990-2016
Cameroon (Douala)	1991-2016
Côte d'Ivoire (Abidjan)	1990-2016
Egypt (Cairo)	1990-2016
Iran (Tehran)	1990-2016
Israel (Tel Aviv)	1990-2016
Jordan (Amman)	1990-2016
Kenya (Nairobi)	1990-2016
Kuwait (Kuwait City)	1991-2016
Libya (Tripoli)	1990-2016
Morocco (Casablanca)	1990-2016
Nigeria (Lagos)	1990-2016
Oman (Muscat)	2000-2016
Qatar (Doha)	2000-2016
Saudi Arabia:	
Al Khobar	1990-2016
Jeddah	1990-2016
Riyadh √	1990-2016
Senegal (Dakar)	1990-2016
South Africa:	
Johannesburg √	1990-2016
Pretoria	2000-2016
Syria (Damascus)	2001-2016
Tunisia (Tunis)	1990-2016
United Arab Emirates:	
Abu Dhabi √	1990-2016

Dubai	1990-2016
Zambia (Lusaka)	2000-2016
Zimbabwe (Harare)	1990-2016
China (Beijing)	1990-2016
United States of America (Cleveland)	1990-2016

Notes: When prices are collected from two or more cities in the same country, we select the city for which data coverage is the best. The selected city is indicated by a check mark (√). CityData contains prices for 8 cities (Beijing, Dalian, Guangzhou, Qingdao, Shanghai, Shenzhen, Suzhou, Tianjin) in China; Beijing is selected because its data coverage is the best. Cleveland is selected for US price benchmark because its median income is closest to the national median income.

Table 2: Ratio of price variances (*F*-statistic)

	Tradeables (T)				Non-tradeables (NT)			
	Region	S. Africa	China	US	Region	S. Africa	China	US
1990/2008	2.064[b]	2.329[b]	2.717[b]	2.089[b]	2.625[b]	2.581[b]	11.816[c]	2.830[c]
1990/2016	2.109[b]	1.537	2.606[b]	4.785[c]	1.994[b]	0.777	6.150[c]	3.987[c]

Note: [a], [b], and [c] indicate statistical significance at, respectively, 10%, 5% and 1% levels.

Table 3: Pesaran (2004) panel cross-section dependence test: percentage of items for which the null hypothesis of no cross-section correlation is rejected

	Region		**S. Africa**		**China**		**US**	
	T	NT	T	NT	T	NT	T	NT
(1990-2016)								
α = 0.10	71%	61%	100%	100%	99%	100%	100%	100%
α = 0.05	59%	58%	100%	100%	99%	100%	100%	100%
(1990-2008)								
α = 0.10	50%	58%	100%	100%	100%	100%	100%	97%
α = 0.05	35%	36%	100%	100%	100%	100%	100%	97%

Note: The sample contains the same 115 items (82 tradeables and 33 non-tradeables) across different benchmarks; an item is included in the sample if its price is available for at least 20 consecutive years for at least 12 cities.

Table 4: Pesaran (2007) test with 0 lag: percentage of items for which the null hypothesis of unit root is rejected

	Tradeables				Non-tradeables				All Items			
	[Region	S. Africa	China	US]	[Region	S. Africa	China	US]	[Region	S. Africa	China	US]
(1990-2016)												
α = 0.10	52%	56%	63%	56%	27%	39%	45%	36%	45%	51%	58%	50%
α = 0.05	44%	46%	51%	49%	15%	33%	39%	36%	36%	43%	48%	45%
(1990-2008)												
α = 0.10	40%	51%	56%	56%	36%	45%	52%	39%	39%	50%	54%	51%
α = 0.05	32%	44%	46%	46%	27%	30%	42%	36%	30%	40%	45%	43%

Note: The sample contains the same 115 items (82 tradeables and 33 non-tradeables) across different benchmarks; an item is included in the sample if its price is available for at least 20 consecutive years for at least 12 cities.

Table 5: Pesaran (2006) CCE estimates of convergence coefficient ρ_k in equation (7)

	Region-average		S. Africa benchmark		China benchmark		US benchmark	
	ρ_k	Half-life (years)	ρ_k	Half-life (years)	ρ_k	Half-life (years)	ρ_k	Half-life (years)
(1990-2016)								
T	-0.384[c]	1.526	-0.394[c]	1.520	-0.432[c]	1.349	-0.416[c]	1.420
NT	-0.308[c]	2.054	-0.320[c]	2.016	-0.358[c]	1.676	-0.346[c]	1.811
All items	-0.362[c]	1.678	-0.373[c]	1.662	-0.411[c]	1.443	-0.396[c]	1.532
(1990-2008)								
T	-0.500[c]	1.095	-0.526[a]	1.039	-0.568[b]	0.921	-0.546[c]	0.977
NT	-0.446[c]	1.255	-0.444[c]	1.297	-0.469[c]	1.220	-0.465[c]	1.178
All items	-0.484[c]	1.141	-0.503[a]	1.113	-0.539[b]	1.007	-0.524[c]	1.034

Note: The values shown in the "ρ_k" columns in this table are averages of the estimates of the convergence parameter for the individual items in each group and benchmark. The sample contains the same 115 items (82 tradeables and 33 non-tradeables) across different benchmarks; an item is included in the sample if its price is available for at least 20 consecutive years for at least 12 cities.

Table 6: Robustness checks (I) – (III)

	(I) Different lag length				(II) Different test: IPS (2003)				(III) Different sample selection			
	[Region	S. Africa	China	US]	[Region	S. Africa	China	US]	[Region	S. Africa	China	US]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: 1 lag												
(1990-2016)												
$\alpha = 0.10$	22%	30%	38%	29%	45%	45%	47%	44%	36%	39%	49%	42%
$\alpha = 0.05$	15%	21%	30%	20%	37%	30%	35%	34%	29%	32%	41%	33%
(1990-2008)												
$\alpha = 0.10$	17%	26%	33%	24%	48%	48%	53%	48%	.	.	.	.
$\alpha = 0.05$	10%	18%	27%	17%	40%	38%	41%	41%	.	.	.	.
Panel B: 2 lags												
(1990-2016)												
$\alpha = 0.10$	4%	11%	23%	17%	40%	36%	37%	35%	12%	16%	24%	21%
$\alpha = 0.05$	3%	7%	16%	13%	29%	30%	26%	26%	7%	9%	19%	13%
(1990-2008)												
$\alpha = 0.10$	10%	11%	19%	12%	42%	41%	44%	36%	.	.	.	.
$\alpha = 0.05$	6%	9%	11%	9%	30%	28%	31%	26%	.	.	.	.

Notes: In the robustness checks (I) and (II), the sample contains the same 115 items (82 tradeables and 33 non-tradeables) across different benchmarks just as in Tables 3-5; an item is included in the sample if its price is available for at least 20 consecutive years for at least 12 cities. The sample in robustness check (III) contains 135 items (95 tradeables and 40 non-tradeables); an item is included in this sample if its price is available for at least 14 consecutive years for at least 16 cities. In the robustness check (III), we do not consider shortened sample period of 1990-2008 because the loss of 9 time-series observations renders Pesaran (2007) unit-root test inexecutable. Pesaran (2007) unit-root test in robustness check (I) and (III) accounts for cross-section dependence whereas IPS(2003) test in robustness check (II) does not.

Table 7: Robustness check (IV): European Union (EU) sample; percentage of items for which the null hypothesis of unit root in Pesaran (2007) test is rejected

	Tradeables			Non-tradeables			All items		
	EU	China	US	EU	China	US	EU	China	US
α = 0.10	94%	91%	92%	60%	59%	70%	83%	81%	85%
α = 0.05	92%	87%	88%	57%	54%	58%	81%	77%	79%

Note: The sample period is 1990-2016. An item is included if its price is available for at least 21 consecutive years for at least 19 out of 23 cities. This sample contains 119 items (84 tradeables and 35 non-tradeables); the items are the same across the three price benchmarks.

Appendix

Table A1: List of items

	Tradeables	Main sample	Alternative sample (Robustness check)
Food & Non-Alcoholic Beverages			
White bread, 1 kg (supermarket)			
Butter, 500 g (supermarket)			
Margarine, 500g (supermarket)			
White rice, 1 kg (supermarket)			
Spaghetti (1 kg) (supermarket)			
Flour, white (1 kg) (supermarket)			
Sugar, white (1 kg) (supermarket)			
Cheese, imported (500 g) (supermarket)			
Cornflakes (375 g) (supermarket)			
Yoghurt, natural (150 g) (supermarket)			
Milk, pasteurised (1 l) (supermarket)			
Olive oil (1 l) (supermarket)		X	
Olive oil (1 l) (mid-priced store)			X
Peanut or corn oil (1 l) (supermarket)			
Potatoes (2 kg) (supermarket)			
Onions (1 kg) (supermarket)		X	
Onions (1 kg) (mid-priced store)			X
Mushrooms (1 kg) (supermarket)		X	
Tomatoes (1 kg) (supermarket)			
Carrots (1 kg) (supermarket)			
Oranges (1 kg) (supermarket)			
Apples (1 kg) (supermarket)			
Lemons (1 kg) (supermarket)			
Bananas (1 kg) (supermarket)			
Lettuce (one) (supermarket)			
Eggs (12) (supermarket)			
Peas, canned (250 g) (supermarket)		X	
Tomatoes, canned (250 g) (supermarket)		X	
Tomatoes, canned (250 g) (mid-priced store)			X
Peaches, canned (500 g) (supermarket)		X	
Peaches, canned (500 g) (mid-priced store)			X
Sliced pineapples, canned (500 g) (supermarket)		X	
Sliced pineapples, canned (500 g) (mid-priced store)			X
Beef: filet mignon (1 kg) (mid-priced store)			
Beef: steak, entrecote (1 kg) (supermarket)			
Beef: stewing, shoulder (1 kg) (supermarket)			
Beef: roast (1 kg) (mid-priced store)		X	
Beef: ground or minced (1 kg) (supermarket)			

Lamb: Stewing (1 kg) (supermarket)		X	
Chicken: frozen (1 kg) (mid-priced store)		X	
Chicken: fresh (1 kg) (supermarket)		X	
Frozen fish fingers (1 kg) (mid-priced store)		X	
Fresh fish (1 kg) (mid-priced store)		X	
Instant coffee (125 g) (supermarket)			
Ground coffee (500 g) (supermarket)		X	
Tea bags (25 bags) (supermarket)			
Drinking chocolate (500 g) (supermarket)			
Coca-Cola (1 l) (supermarket)			
Tonic water (200 ml) (supermarket)			
Mineral water (1 l) (supermarket)			
Orange juice (1 l) (supermarket)			
Alcoholic Beverages & Tobacco			
Wine, common table (750 ml) (supermarket)			
Wine, superior quality (750 ml) (supermarket)		X	
Beer, local brand (1 l) (supermarket)			
Beer, top quality (330 ml) (supermarket)			
Scotch whisky, six years old (700 ml) (supermarket)			
Gin, Gilbey's or equivalent (700 ml) (supermarket)		X	
Gin, Gilbey's or equivalent (700 ml) (mid-priced store)			X
Cigarettes, Marlboro (pack of 20) (mid-priced store)			
Cigarettes, local brand (pack of 20) (mid-priced store)		X	
Personal Care			
Soap (100 g) (supermarket)			
Laundry detergent (3 l) (supermarket)			
Toilet tissue (two rolls) (supermarket)			
Dishwashing liquid (750 ml) (supermarket)			
Insect-killer spray (330 g) (supermarket)			
Aspirins (100 tablets) (supermarket)		X	
Razor blades (five pieces) (supermarket)			
Toothpaste with fluoride (120 g) (supermarket)			
Facial tissues (box of 100) (supermarket)			
Hand lotion (125 ml) (supermarket)			
Shampoo & conditioner in one (400 ml) (supermarket)			
Lipstick (deluxe type) (chain store)			
Man's haircut (tips included) (average)	N		
Woman's cut & blow dry (tips included) (average)	N		
Furnishing & Household Equipment			
Light bulbs (two, 60 watts) (supermarket)			
Batteries (two, size D/LR20) (supermarket)			
Frying pan (Teflon or good equivalent) (mid-priced store)			
Electric toaster (for two slices) (supermarket)			
Hourly rate for domestic cleaning help (average)	N		
Maid's monthly wages (full time) (average)	N		
Babysitter's rate per hour (average)	N		
Recreation & Culture			

Compact disc album (average)		
Television, colour (66 cm) (average)		
Personal computer (64 MB) (average)		X
Kodak colour film (36 exposures) (average)		
Cost of developing 36 colour pictures (average)	N	
International foreign daily newspaper (average)		
Daily local newspaper (average)	N	
International weekly news magazine (Time) (average)		
Paperback novel (at bookstore) (average)		
Four best seats at cinema (average)	N	X
Green fees on a public golf course (average)	N	
Hire of tennis court for one hour (average)	N	
Cost of six tennis balls eg Dunlop, Wilson (average)		
Entrance fee to a public swimming pool (average)	N	
One good seat at cinema (average)	N	X
Clothing & Footwear		
Laundry (one shirt) (standard high-street outlet)	N	
Dry cleaning, man's suit (standard high-street outlet)	N	
Dry cleaning, woman's dress (standard high-street outlet)	N	
Dry cleaning, trousers (standard high-street outlet)	N	
Men's business suit, two piece, medium weight (chain store)		
Men's business shirt, white (chain store)		
Men's shoes, business wear (chain store)		
Socks, wool mixture (chain store)		
'Women's dress, ready to wear, daytime (chain store)		
Women's shoes, town (chain store)		
Women's tights, panty hose (chain store)		
Child's jeans (chain store)		
Child's shoes, dresswear (chain store)		
Child's shoes, sportswear (chain store)		
Girl's dress (chain store)		
Boy's dress trousers (chain store)		
Housing, Water & Electricity		
Furnished residential apartment: 1 bedroom (moderate)	N	
Furnished residential apartment: 2 bedrooms (moderate)	N	
Unfurnished residential apartment: 2 bedrooms (moderate)	N	
Unfurnished residential apartment: 3 bedrooms (moderate)	N	X
Telephone line, monthly rental (average)	N	X
Electricity, monthly bill for family of four (average)	N	
Transport		
Low priced car (900-1299 cc) (low)		
Compact car (1300-1799 cc) (low)		
Family car (1800-2499 cc) (low)		
Deluxe car (2500 cc upwards) (low)		
Cost of a tune up (but no major repairs) (low)	N	
Annual premium for car insurance (low)	N	
Regular unleaded petrol (1 l) (average)		

Taxi: airport to city centre (average)	N	
Hire car, weekly rate for lowest price classification (average)	N	X
Hire car, weekly rate for moderate price classification (average)	N	X
Restaurants & Hotels		
Three-course dinner at top restaurant for four people (average)	N	
Business trip, typical daily cost	N	X
Hilton-type hotel, single room, one night including breakfast (average)	N	
Moderate hotel, single room, one night including breakfast (average)	N	
One drink at bar of first class hotel (average)	N	
Two-course meal for two people (average)	N	
Simple meal for one person (average)	N	
Fast food snack: hamburger, fries and drink (average)	N	
Education		
American/English school: annual tuition, ages 5-12 (average)	N	
American/English school: annual tuition, ages 13-17 (average)	N	
American/English school: kindergarten annual fees (average)	N	
Medicare		
Routine checkup at family doctor (average)	N	
Visit to dentist (one X-ray and one filling) (average)	N	

Notes: N=Non-tradeable. X=not included in the sample

Oil Palm, Land Use Change and Community Livelihoods in Indonesia: A Policy Simulation Analysis

Dennis Mark Onuigbo [a *], Bonar Marulitua Sinaga[b], Harianto[c]

[*a] *Agricultural Economics Study Program, Department of Resources and Environment Economics, Bogor Agricultural University, Dramaga – Bogor 16680, Indonesia. Email: simple14all@gmail.com*
[b] *Department of Resources and Environment Economics, Bogor Agricultural University, Dramaga – Bogor 16680, Indonesia*
[c] *Department of Agribusiness, Bogor Agricultural University, Indonesiam*

Abstract

Oil palm production has huge economic benefit. However, the business as usual approach of increasing oil palm production has both environmental and social cost. We suggest that the environmental cost can be seen through land use change and community vulnerability, whereas, the social cost can be seen through livelihood changes. This study explored the determinants of oil palm production and trade, land use change and community livelihoods; and proffered evidence based policy alternatives that will ensure sustainability. To achieve this, the econometric approach was used and the livelihood assets were defined based on review of several livelihood frameworks. Historical data for 25 years (1990 – 2014) was analyzed using the simultaneous equations model estimated with the two-stage least squares (2SLS) method of estimation. The results showed that the policy instruments of increasing export tax, secondary school enrolment ratio and workers wage played a major role in increasing community livelihoods and reducing land use change. However, this policy has a tradeoff effect as it resulted in a net national economic loss of Rp. 15.8 billion which may require sacrifice or compensation for sustainability or for Pareto optimality to be attained.

Keywords: Oil palm production; trade; land use change; livelihoods; sustainability policy.

1. Introduction

Oil palm production has contributed to government revenue as the third largest export earner after coal and petroleum with over $17.6 billion worth of crude palm oil exported in 2012. The oil palm industries have employed over 3.7million people and have alleviated them from poverty [1]. The numerous economic benefits of crude palm oil (CPO) production in Indonesia motivate governments to make policies that targets increased production. The business as usual approach to increasing CPO production is basically through forest, grassland or agricultural land conversion. This increases the oil palm harvested area. This processes and practice has both social and environmental cost. The social cost can be approached with livelihoods changes in the community and the environmental cost through the concept of land use change.

Livelihood encompasses the ability of people to access the basic assets required for daily human activities. Several livelihood frameworks identified five livelihood assets which include: (1) Natural capital, (2) Human capital, (3) Social capital, (4) Physical capital and (5) financial capital ([2]; CARE in [3]; [4]). These assets enable the community to overcome risk or reduce vulnerability to changes, threats or shocks. Thus, a change in the optimum level of the assets affects the livelihoods of the community. Changes in livelihoods are associated with land use change (LUC). LUC can have both positive and negative effect on livelihoods and can be defined by its cause. In agreement with several studies ([5]; [6]; [7]; [8]), LUC can be seen in the conversion of rainforest, other agricultural lands, soil biomass/ peatlands into oil palm plantation. It can result in increased economic benefit but with a tradeoff effect on environment and community livelihoods. Climate change, flood, forest fire, water/air pollution and access to basic livelihood assets are major environmental and livelihood concerns. Indonesia, the total oil palm planted area increased at an annual average of 346,030ha, while the total forest area decreased at an annual rate of 685,000ha. The increase in total planted area was accompanied with an annual average increase in CPO production of about 1,985,710 million tons.

From the foregoing, it is pertinent to ensure that oil palm production and policies do not harm the environment or reduce the livelihood of oil palm communities. So, we shall discuss at this stage what determines oil palm production, domestic market, livelihoods in Indonesia and suggest policies with better sustainability outcome. The major limitation of this work was limited access to data; and at such, some were extrapolated. Because livelihood assets were variables with mostly qualitative nature, derivation was necessary. However, this work will provide an opportunity for empirical determination of land use change and livelihood changes due to oil palm production. It will combine theories to test for endogenous behaviors and most importantly create a room for further research or questions.

2. Determination of Livelihoods Assets

The different livelihood frameworks enabled the determination of the different livelihood assets, the vulnerability context and land use change as endogenous. The determination is necessary for the modeling as there are no direct data or standard measurement for the different livelihoods assets available to the researcher. The derivation here were based on the sustainable livelihoods frameworks discussed in [2], [3], and [4].

2.1 Community Access to Natural Capital

The community access to natural capital (CAN) is the ability of the community to benefit from the natural resources such as land, water, soils, forest. When these resources are degraded, the benefit for the communities diminishes. Mining, manufacturing and construction activities can degrade the natural resource base of the community but they have almost immediate return or economic benefit for the community. However, land degraded due to oil palm production may

not quickly transform to economic benefit for the community. From the foregoing, the community access to natural capital will include the total land area not degraded by oil palm production. It was given as thus:

$$CAN = (TAP - DLAP)/TAP * 100 \quad (1)$$

Where:

CAN = Community Access to Natural Capital (% of prov. land area un-degraded by oil palm prod.)
TAP = Total land area (provinces) (1000 Ha)
DLAP = Oil palm degraded land area (provinces) (1000 Ha)

2.2 Community Access to Physical Capital

The community access to physical capital (CAP) is the ability of the community to utilize assets that provide secure shelter, health care, education, energy, transportation, tools, equipment and services provided through bank, grocery stores and related outlets. In the communities, the access to electricity and households with roof main material provides the most importance access to physical capital and thus the community access to physical capital was measured as the weighted average of the percentage of households with roof main material and access to electricity. It was given as thus:

$$CAP = (0.4*HHR + 0.6*HHAE) \quad (2)$$

Where:

CAP = Community access to physical capital (% of household with main roof and access to electricity)
HHR = Households by Roof Main Material (Non Sugar Palm Fiber/Other %)
HHAE = Household Access to Electricity (% of total household)

2.3 Community Access to Financial Capital

Community access to financial capital (CAF) is the ability of the community to earn income from farm or off farm employment, trade activities, personal remittance or from bank credit. The closest measure for this capital is the total own source revenue as data for remittance and access to credit may not capture the poorer community members. Their access to credit can be limited as most members are non-bankable since they may not have the basic requirements for credit. Thus, the community access to financial capital can be measured by the per capita own source revenue. It was given by:

$$CAF = (TOSR/POPP) \quad (3)$$

Where:

CAF = Community access to Financial Capital (Rp.1000 /person)
TOSR = Total own source revenue oil palm prov. (Million Rp.)
POPP = Population of people in 1000 persons (Average population of oil palm prov.)

2.4 Community Access to Social Capital

Community access to social capital (CAS) is the ability of the households to make valuable connections or network with other members of the community. This network either formal or informal has the potential for economic benefit. However, the ability of households to make such valuable connections depends on their status in the community. Poorer households find it difficult to gain the required trust or meet basic fee required for meaningful cooperation especially if it involves economic benefit. Households that live above the national poverty line have better chances to make valuable connections that yield economic benefits. Thus a

community's access to social capital can be seen in the number of people that live above the poverty line. This was given as:

$$CAS = ((POPP-NPPL)/POPP)*100 \quad (4)$$

Where:

CAS = Community Access to Social Capital (% of population above poverty line)
POPP = Population of people (1000persons oil palm prov.)
NPPL = Number of people that live below the poverty line (1000 persons)

2.5 Community Access to Human Capital

Community access to human capital is the ability of the community to possess the necessary skills, knowledge, strength of mind and body that enable them to work for economic benefit. This could be approached in several ways including approximating it for the population of labour force within ages 15 – 64years with a certain education level. However, the population of labour force at any education level may include people that are not economically active. Thus, the community access to human capital is better approached with the labour force participation rate which shows the percentage of labour force that are economically active. According to the worldbank, these are the persons that supply labour for the production of goods and services within a given period. This can be given by:

$$CAH = LFPR \quad (5)$$

Where:

CAH = Community access to human capital (labour force participation rate %)
LFPR = Labor force participation rate for ages 15-64 (%)

3. Determination of Community Vulnerability

Community vulnerability/risk is the tendency of the community to experience disaster whether natural or man-made. Disaster can be in form of disease outbreaks, famine, flood, landslides, forest fire and earthquake. However, disaster like famine or disease can be more easily controlled compared to environmental issues such as land slide, erosion, forest fire and earthquake. Thus, the community vulnerability can be approached with the frequency of occurrence of these environmental issues in the oil palm communities. This was given by:

$$CVR = D \quad (6)$$

Where:

CVR = Community vulnerability (frequency of environmental disaster)
D = Frequency of disasters in form of landslide, forest fire, flood, long dryness, tornado

The community capability and their access to the livelihood assets is influenced by policies. Policies can decrease or increase land use change which influence the community vulnerability.

4. Determination of Land Use Change

Land Use Change (LUC) can be likened to any form of land conversion resulting from human activities. These human activities include land conversion for agricultural or industrial production. It was defined as human induced activities that results in greenhouse gas emission [9]. In this work, land use change was determined as a percentage of the total greenhouse gas emission. It was given as thus:

$$LUC = (TLE/TGHG)*100 \quad (7)$$

Where:

LUC = Land Use Change (% of land use emissions (CO_2))
TLE = Total land use emissions (gigagrams (CO_2))
TGHG = Total Indonesia greenhouse gas emission (gigagrams (CO_2))

To arrive at the models, the identified variables will be estimated and the econometric criteria tested and validated. In the process of estimation and validation, irrelevant variables are removed and the model re- specified to yield a robust model. Effort has been made to ensure relevant variables are included through literature review and personal experience.

5. Economic Welfare

In a nation without government intervention in trade, the activities of producers and consumers results to a market equilibrium. The market equilibrium represents the point of allocative efficiency and this is the point where the economic surplus is maximized because consumers and producers both get the highest benefit for the price they pay and accept. Thus, the economic surplus measures the economic welfare for producers and consumers in a given nation. However, since market equilibrium may not easily occur, government plays a role to maintain a balance between consumer and producer surplus using tax or tariff. With tax or tariff, government gets revenue from trade and could either make a transfer to cover for losses in consumer surplus through special transfer programs like rice for the poor (*RASKIN*) or higher education expenditure in Indonesia or involve in market operation to ensure better prices for producers as it's the case of the Logistics Bureau (*Bulog*) in Indonesia. With government involvement in trade through tax or tariff, the net national surplus becomes the linear summation of the producer surplus, the consumer surplus and government revenue. With tax however, there will be a loss in total surplus known as the deadweight loss.

Let:

D = Demand curve
S = Supply curve
P_{wtp} = Maximum price consumers are willing to pay (Rp/tonne)
Pp = Price paid by consumers (Rp/tonne)
Pe = Market equilibrium or efficient price (Rp/tonne)
Pr = Price received by producers (Rp/tonne)
P_{wta} = Minimum price producers are willing to accept (Rp/tonne)
Qe = Equilibrium or efficient quantity (tonnes)
Qt = Quantity with tax (tonnes)
e0 = Market equilibrium

The economic surplus can be illustrated as in Figure 1:

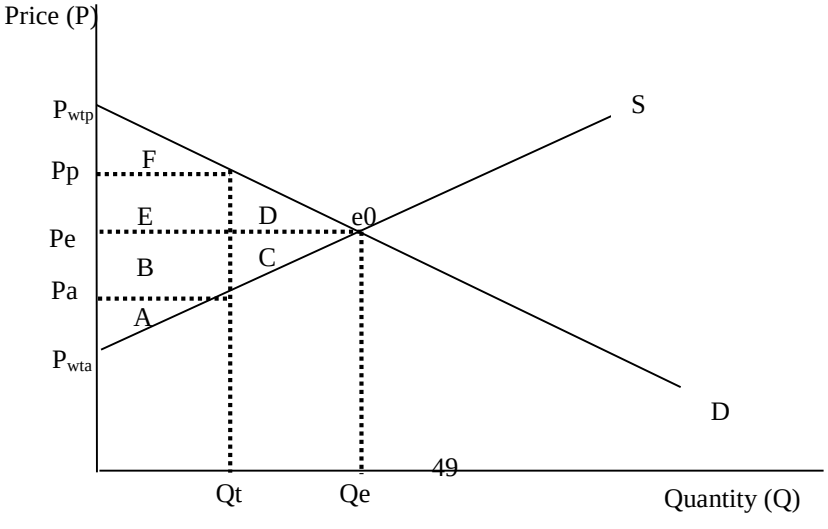


Figure 1 Consumer and Producer Surplus

The producer surplus indicates the welfare gain by sellers from selling at a price (Pr) higher than the minimum they are willing to accept (P_{wta}). On the other hand, consumer surplus measures the gain a consumer gets from buying at a price (Pp) lower than he would be willing to pay (P_{wtp}). It can be calculated as shown in table 1. Note that A to F in figure 1 can be calculated with the area of the triangle which is ½ (Base x Height) or Base x Height for rectangle. It can also be measured by the integration of the demand and supply function as:

$$PS = \int_{Pr}^{Pe} Qs\,(P)dp \quad (8)$$

and

$$CS = \int_{Pe}^{Pp} Qd\,(P)dp \quad (9)$$

Where:

PS = Value of producer surplus (Rp)
CS = Value of consumer surplus (Rp)
Qs = Quantity supplied (tonnes)
Qd = Quantity demanded (tonnes)

In this study we have applied the above concepts to measure the economic surplus of CPO producers and consumers and the government revenue due from export tax. This will help us to suggest the maximum (compensating variation) or minimum (equivalent variation) compensation for making or not making a policy change. The concept of compensating variation means the maximize compensation that should be paid for a change, whereas, equivalent variation is the minimum compensation that one is willing to pay for a change not to occur. As first used by [10], the compensating variation (CV) considers that a price increase for a consumer who has a given level income will reduce the economic welfare of that consumer. Therefore, the CV reflects the extra money which should be given to a consumer to compensate for the price increase or a policy change.

6. Research Methodology

6.1 Data

Since oil palm is produced in selected provinces in Indonesia, this study have used data from the seven major oil palm producing provinces to minimise overgeneralization for the community livelihood assets. These were obtained from statistics Indonesia (BPS), World bank subnational data (INDODAPOER). Data on community vulnerability were obtained from the Indonesian national disaster management authority (BNPB). Data was also accessed from FAO and USDA through Indexmundi. The data collected was annual and ranged from 1990 – 2014 (25 years). The selected oil palm communities (provinces) included Riau, Jambi, North and South Sumatra, Central, East and West Kalimantan. These provinces are recognized as top oil palm producing provinces in Indonesia.

6.2 Method

The simultaneous equations model was used to establish the relationship between endogenous and exogenous variables while the Two Stage Least Square (2SLS) method of estimation was used since the model was over-identified using the order condition [11]. This method curtails errors of misspecification or other stochastic bias. The modeling went through stages of model

specification, model identification, model estimation, model evaluation and validation. The model comprised of 24 equations of which 19 are behavioral and 4 are identity equations. Policy simulation was used to suggest policy alternatives with better sustainability outcome.

7. Model Specification

The model specification was drawn from theories, studies and the author's experience. Among others, the production function, demand and supply elasticities, understanding of international trade and standard livelihoods frameworks have offered a lot to strengthen this work. Most of these theories and various related studies have been discussed in [12]. The endogenous relationship was summarized in figure 2.

[Insert Figures 2 around here]

The model specification was based on economic theories and standard livelihood frameworks. The model comprised of 24 equations of which 19 are behavioral and 5 are identity equations. Generally, the model comprise of six blocks which include; (1) Oil palm production block, (2) Oil palm domestic market block, (3) International Trade block (4) Environment/emissions block, (5) Community livelihoods block and (6) Community Vulnerability block. From figure 2, the arrow head shows the direction of influence flowing from the non-arrow head to the arrow head. For instance, the diagram showed that Oil Palm Harvested Area (OHA) influenced Land Use Change (LUC) and LUC influenced the community vulnerability/risk (CVR) and so on.

8. Results of Model Validation

In this study the RMSPE and U-theil Coefficient noted earlier were used for the model validation. The results of model validation have been shown in table 2.

[Insert Table 2 around here]

From the results of OLCL model validation in table 2, it was observed that from the 24 equations (both structural and Identity), only four (4) equations (16% of total equations) have a RMSPE above 30. CPOM and CPOR equations performed badly. This was due to the high disparity or fluctuation in the annual data of CPOM and CPOR resulting in a wide gap between the regression line and the actual data. Meanwhile, only one (CPOM) equation (4% of total equations) has a U-theil coefficient above 0.3. With the noted cases of high RMSPE and U-theil, this validation result indicates that the predictive ability of the OLCL model is appropriate for its intended use.

9. Results of Policy Simulation

From a historic overview of the oil palm policies mostly from 1993 *Perkebunan Inti Rakyat* (PIR Trans) to date, the major policy instruments included the use of export tax, directed sales of 80% of CPO production from government owned plantations to domestic market and the expansion of oil palm harvested area.

The variable or windfall tax system was used. This tax system was based on the CPO international price. Below an international CPO price of 700 $/MT, the export tax is zero (0%), above 700 $/MT the tax increase by 1.5% for every 50$ increase and 2.5% for every 50$ increase above 950$/MT. However, above 1,250 $/MT it remains at a ceiling of 25%. From the period simulated (2009-2014), the export tax has averaged at about 9% each year and in some months when the international CPO price is low, the export tax is zero and its impact

high on government revenue such that the Jokowi government in 2015 intend to place a US $50 levy and tax rate from $3-200 per ton for international prices in excess of US $750.

Another very important policy instrument was the use of land concession for oil palm production. From the policy review, land allocation for oil palm plantation purposes have continuously increased. And the Indonesian government has recently mentioned on a future target of 6 million hectare expansion [13]. This will be roughly a 75% increase from the 2014 harvested area. This and other instruments have been simulated to find a more sustainable policy. From over 50 policy scenarios tried, we selected to discuss four (5). Three (4) single and one (1) combined policy scenarios. The aim was to determine the scenario that ensure sustainable oil palm production, reduce land use change, improve community livelihoods and reduce vulnerability.

The policy scenarios (S) presented here included:
S1: Increase CPO Export Tax by 5%
S2: increase oil palm harvested area by 15%
S3: increase net enrolment ratio to secondary school by 5%
S4: increase wage by 10%
S5: combination of s1, s3, and s4

The results of the policy simulation has been shown in table 3.

9.1 Effect of increase in CPO variable export tax by 5%

The simulation of increasing the variable export tax by 5% basically led to a decrease in export quantity and CPO international market price. The behavior and values for the endogenous variables are shown in table 3. From table 3, an increase in variable tax stimulated a 0.33% and 0.30% increase in CPO international market price and CPO export price respectively. This resulted to a 0.04% (about 333,728 tonnes) increase in CPO domestic supply (CPOS) valued at about which led to 0.02% drop in the real domestic price of CPO and a 0.04% increase in the community access to physical capital. The increase in community access to physical capital was due to increase in export tax which could stimulate higher government spending on basic infrastructural development such as improving access to electricity which will increase the peoples access to financial capital by 0.20% and a subsequent increase in social networks though reduction in poverty by about 0.009%. From this policy of increasing export tax by 5%, some undesirable outcome included a 0.39% and 0.06% decrease in China and India CPO import respectively. This led to a 0.005% drop in Indonesian CPO export. This policy however is not desired because it has very little or no effect on land use change, community livelihood assets and community vulnerability.

9.2 Effect of increasing Oil palm harvested area by 15% on Oil palm production, market, trade, land use change, community livelihoods and community vulnerability

As this was the business as usual approach of increasing oil palm production, we simulated a 15% increase in oil palm harvested area even though the target was about a 75% (6million Ha) increase from 2014 harvested area (Basri & Patunru. 2006 in Cervantes-Godoy *et al*. 2010). The results of the can be seen in table 3.

[Insert Table 3 around here]

From table 3, a 15.00% increase in oil palm harvested area in the period simulated (2009-2014) will increase oil palm production by 28.24% which will lead to an increase in CPO domestic supply and CPO export by 55.29% and 15.21% respectively. This will reduce real domestic price of CPO, CPO export price and CPO international market price by 16.67%, 6.5% and 4.89% respectively. The fall in CPO price will lead to a 0.11% increase in CPO domestic demand, 0.88% and 5.30% increase in India and China CPO import respectively. The noted changes will be accompanied by a 14.23% increase in the community access to financial capital, a 0.61% and 0.66% increase in community access to physical and social capital respectively. Even though this policy increased production and community access to financial capital, It is not a desirable choice if concern for environment and overall community livelihoods was considered serious. It is not a sustainable choice because of the huge trade off on the community access natural capital, reducing it by about 34.30%. This also increased land use change and community vulnerability/risk by 11.35% and 1.1% respectively.

9.3 Effect of increasing net secondary school enrollment ratio by 5%

With the thought that education will raise the quality of the human capital, we simulated the effect of increasing the net secondary school enrolment ratio by 5% and the results have been shown in table 3. From table 3, it was observed that a 5% increase in the net secondary school enrolment ratio will increase the human capital by 0.28%, this will increase CPO production by 0.28% due to better efficiency of labour. The resulting increase in production will lead to a 0.55% and 0.15% increase in CPO domestic supply and Indonesian CPO export respectively. The increase in domestic supply and export will result in a 0.17% and 0.05% drop in CPO real domestic price and CPO international market price respectively. This will be followed by a 0.05% and 0.01% increase in China and India CPO imports respectively. Note that, the ability of Indonesia to influence the CPO international market price indicates that Indonesia is a big country meaning that Indonesia has a large share in the CPO international market. This single policy of increasing the net secondary school enrolment ratio by 5% is not a sustainable option as it increased land use change by 0.12% and had no impact on community vulnerability/risk. It also resulted in a 0.34% decrease in the natural capital due to the increase in CPO production which resulted from a 0.18% increase in oil palm harvested area.

9.4 Effect of increasing plantation sector wage by 10%

The wage received or paid can serve as an important source of income for the plantation worker and as an additional cost for the oil palm plantation. We simulated the increase in wage by 10% and the results have been shown in table 3. From table 3, a 10% increase in wage will increase the community access to human capital by 0.26%. This increase can be due to an increase in the incentive to work which raise the number of people willing and ready to work from the community and from outside the oil palm communities. However, this increase in wage resulted in a higher cost of production, and reduced oil palm harvested area by 0.33% which led to an increased access to natural capital by 0.64% and a 0.52% drop in total oil palm production. Nevertheless, the decrease in production will result to a 1.03% and 0.28% decrease in CPO domestic supply and Indonesian CPO export respectively. The decrease in Indonesian CPO domestic supply and export will result to a 0.31% and 0.09% increase in CPO domestic price and International price respectively. This policy was appropriate for reducing land use change and community vulnerability by 0.12% and 0.02%. However, it was not the most desirable because it reduced the community access to physical, financial and social capital by 0.005%, 0.11%, and 0.005%. This is a double tragedy since it reduced oil palm production without a full positive impact on all the livelihood assets.

9.5 Effect of policy combination of increasing CPO variable export tax by 5% (S1), increasing secondary school net enrolment ratio by 5% (S3) and increasing plantation sector wage by 10% (S4)

At several trials, we attempted to harness the combined potential of the single policy scenarios. Here, we simulated the combined (S5) effect of increasing CPO variable tax by 5% (S1), increasing secondary school net enrolment ratio by 5% (S3) and increasing plantation sector wage by 10% (S4). The results are shown in table 3. From table 3, S5 combination had a more desirable effect. A trade off effect existed in the production block, environment/ emissions block and community livelihoods block. This policy decreased total oil palm production by 0.24% all things been equal but with a consequent reduction in land use change and community vulnerability by 0.06% and 0.02% respectively. This also led to an improvement in all the community livelihood assets which are necessary for their daily living and survival. The improvement in human and natural capital was more with a 0.54% and 0.30% increase, whereas, physical, financial and social capital increased by 0.03%, 0.09% and 0.004% respectively.

10. Results of economic surplus

The effect of the different policy scenarios were tested on the economic welfare of CPO producers and consumers, and on government revenue from tax. This will enable the estimation of the net national surplus due to the policy changes. The results of economic surplus for year 2009 -2014 were given in table 4.

[Insert Table 4 around here]

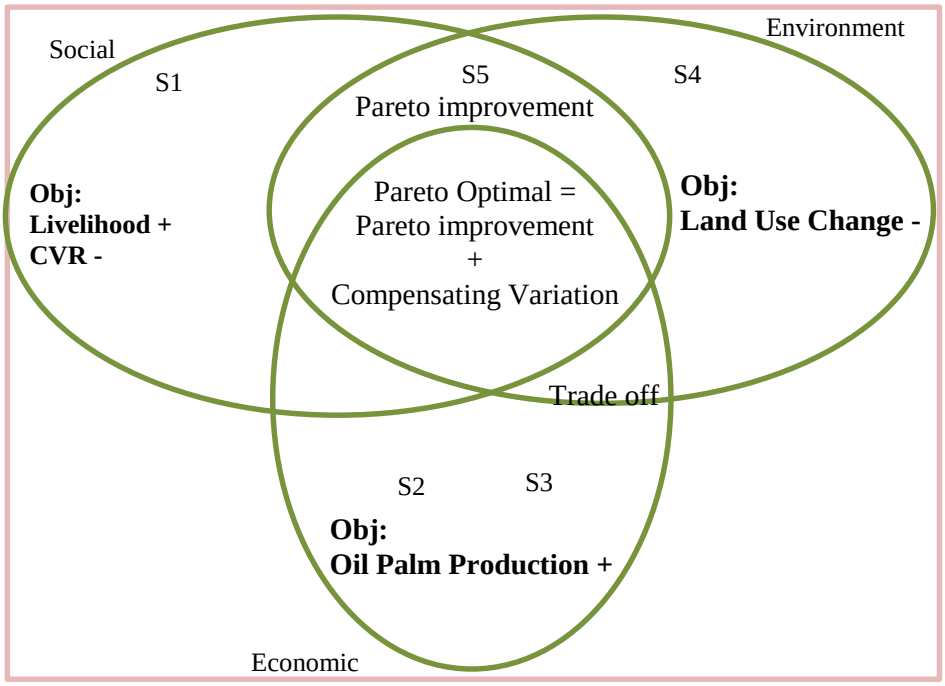
From the results of simulating economic surplus in table 4, the business as usual approach to oil palm production (increasing oil palm harvested area by 15%) will result in a gain in net national surplus of about Rp. 160.5 billion over 6years (2009-2014). Increasing the variable export tax by 5% resulted in a net national loss of about Rp. 174 million over a period of 6years. This is due to a higher percentage decrease in CPO export with a relatively little increase in tax. Thus, resulting in a loss in government revenue from tax; a Rp. 49400 gain in producer surplus and an Rp. 12880 gain in consumer surplus due to higher international market price for the producer and lower domestic price for the consumer. This phenomenon indicates that the oil palm producers are loss averse which represent the rational behavior of producers generally.

An increase in the secondary school net enrolment ratio by 5% was positive to the net national surplus with a gain of about Rp. 3.1 billion. This was because an increase in the secondary school net enrolment increased the human capital, oil palm production and Indonesian CPO export. An increase in the workers wage by 10% was negative to the net national surplus with a loss of about Rp. 2.97 billion. This was because an increase in workers wage decreased Indonesian CPO production and export which decreased producers surplus and raised the real domestic price of CPO. As expected, the S5 combination was negative to net national surplus, reducing it by Rp. 15.8 billion. This helped to emphasize the tradeoff effect between economic and environmental/ social concerns.

11. Conclusion

From the study shows a tradeoff effect between oil palm production and land use change with the business as usual approach of increasing oil palm harvested area. S1 – S5 are different policy scenarios tried. The figure 3 illustrates the in a box.

A lot more scenarios can be tried until the point of pareto optimal. However, with over 60 scenarios tried so far, no policy could ensure an improvement in one or two without making at least one worse off. S5 did better for land use change, livelihood assets and vulnerability but with economic loss due to a slight reduction in oil palm production. The compensating variation (CV) used by [9] can be explored to service the net national loss in table 4. Generally, as expected, a 15% increase in oil palm harvested land increased oil palm production by 28.24%. The increased production led to a 14.23%, 0.61%, 0.66% increase in the community access to financial, physical, and social capital respectively. It also led to a gain in net national surplus of about Rp. 160.5 billion with a consequent 11.35% increase in land use change which resulted in a 1.1% increase in community vulnerability.



Description:

S1-S5	= Selected policy scenarios (Table 14)
Obj:	= Objective
Livelihood +	= Objective to increase community livelihood assets (CAN, CAP, CAF, CAS, CAH)
CVR -	= Objective to decrease community vulnerability (CVR)
Land use change -	= Objective to decrease land use change
- Or +	= Decrease or increase

Figure 2 OLCL Sustainability Box

This could be attributed to the resultant 34.30% decrease in the community access to natural capital. Contrary to expectation, a 5% in increase in the net secondary enrolment ratio increased human, physical, financial and social capital by 0.28%, 0.005%, 0.11% and 0.005% respectively but had no effect on community vulnerability. It instead, resulted in a 0.34%

decrease in natural capital and a 0.11% increase in land use change. More so, a 5% increase in export tax was against expectation as it decreased the net national surplus by Rp. 174 million.

This indicates a loss aversive behavior of producers who will react by reducing a larger quantity exported relative to a small increase in export tax. This was positive to both consumer and producer surplus as they gained from lower domestic price and higher international prices respectively. In the same vein, an increase in workers wage did not improve all livelihoods assets as expected but was appropriate for reducing land use change and vulnerability. Increasing wage by 10% was good in increasing human and natural capital by 0.25% and 0.64% respectively but reduced the community access to physical, financial and social capital by 0.009%, 0.20% and 0.01% respectively.

12. Policy Recommendation

Through policy simulation aimed at solving the objective for sustainable oil palm production, reduction in land use change and improvement in community livelihoods, we recommend a policy combination of increasing the variable export tax by 5%, increase secondary school enrolment by 5% and increasing plantation worker wage by 10% within a six year period as options for sustainability. These policy instruments will not yield the desired outcome if used as a single instrument. They are better when combined. The rationale for the combination was that an increase in export tax, will increase domestic supply and decrease domestic CPO price which kept production relatively stable or low, whereas, an increase in secondary school enrolment will increase the quality and quantity of human capital whose ability and knowledge will help to increase oil palm production in a more sustainable way as they may serve as labour for the plantations or be advocates for good environmental and social practices. On the other hand, an increase in wage will raise the cost of production, and limit the need to expand harvested area and thus reduce land use change. The purpose for combining the instruments is to make up for their individual undesirable impact. Furthermore, the economic surplus calculation indicates a national economic loss due to an improvement in environmental and social concerns, but an economic gain due to the business as usual production. The economic loss can be a national sacrifice since environmental and social cost are more expensive; or requires compensation by nations or groups with environmental and social concerns. The compensation will make up for the economic loss due a slight reduction in production and an improvement in community livelihoods accompanied with a decrease in land use change and community vulnerability.

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Figure 3 Oil Palm Policy, Land Use Change and Community Livelihood (OLCL) Model.

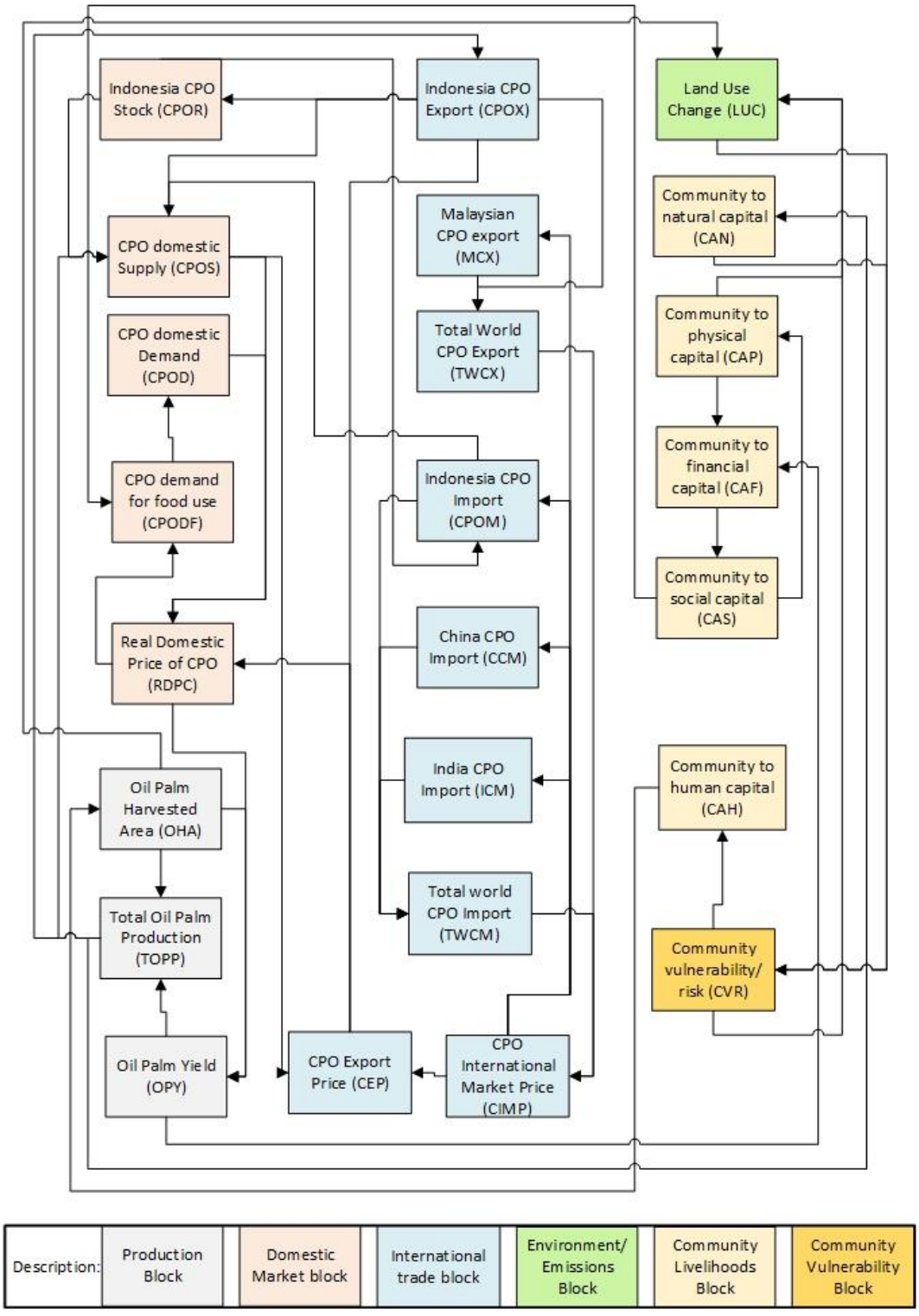

Table 1 Economic Welfare With Tax and Without Tax

	Without tax	With tax	Change
Consumer surplus	D+E+F	F	-(D+E)
Producer surplus	A+B+C	A	-(B+C)
Government revenue	None	B+E	+(B+E)
Net National surplus	A+B+C+D+E+F	A+B+E+F	-(C+D)

Table 2 Results of Model Validation

VARIABLE	RMSPE	U-THEIL	LABEL
OHA	0.47	0.00	Oil palm harvested area (1000 Ha)
OPY	7.18	0.04	Oil palm yield (MT/Ha)
TOPP	7.29	0.03	Indonesia total CPO production (1000MT)
CPOR	493.20	0.18	Indonesia CPO stock (1000MT)
CPOS	38.18	0.15	Indonesia CPO supply (1000MT)
CPOD	4.32	0.02	Indonesia CPO domestic demand (1000MT)
CPODF	6.21	0.03	CPO demand for food use (1000MT)
RDPC	10.38	0.05	Real domestic price of CPO (Rp/Kg)
CPOX	4.57	0.02	Indonesia CPO export (1000MT)
MCX	2.64	0.01	Malaysia CPO export (1000MT)
TWCX	2.49	0.01	Total World CPO Export (1000 MT)
CPOM	799.60	0.35	Indonesia CPO import (1000MT)
CCM	7.70	0.04	China CPO Import in (1000 MT)
ICM	4.96	0.02	India CPO Import (1000 MT)
TWCM	2.49	0.01	Total World CPO Import (1000 MT)
CIMP	5.72	0.03	CPO international market price (USD/MT)
CEP	16.99	0.09	CPO Export Price (USD/tonne)
LUC	9.35	0.05	Land Use Change (% of land use emission (CO_2))
CAN	82.70	0.19	Community Access to Natural Capital (% of prov. land area un-degraded by oil palm prod.)
CAP	2.19	0.01	Community access to physical capital (% of household with main roof and access to electricity)
CAF	20.90	0.09	Community Access to Financial Capital (Rp.1000 per capita)
CAS	2.47	0.01	Community Access to Social Capital (% of pop. above poverty line)
CAH	0.44	0.00	Community Access to Human Capital (labour force participation rate %)
CVR	21.69	0.14	Community Vulnerability/Risk (frequency of environmental disaster)

Source: Data Analysis

Table 3 Results of Policy Simulation 2009 - 2014

Variables	Base	s1	s2	s3	s4	s5
Oil palm harvested area (1000 Ha)	7465.1	0.000	15.000	0.175	-0.330	-0.154
Oil palm yield (MT/Ha)	3.6409	0.000	11.464	0.088	-0.173	-0.085
Indonesia total CPO production (1000 MT)	27444.1	-0.001	28.244	0.277	-0.524	-0.248
Indonesian CPO supply (1000 MT)	8343.2	0.036	55.292	0.548	-1.034	-0.452
Indonesian CPO domestic demand (1000 MT)	7156.5	-0.011	0.068	0.000	-0.003	-0.013
CPO demand for food use (1000 MT)	4703.8	-0.017	0.104	0.002	-0.002	-0.019
Real domestic price of CPO (Rp/Kg)	11398.1	-0.016	-16.665	-0.165	0.311	0.131
Indonesian CPO export (1000 MT)	19949.1	-0.017	15.212	0.149	-0.281	-0.150
Malaysian CPO export (1000 MT)	17445	0.008	-0.116	-0.001	0.002	0.009
Total World CPO Export (1000 MT)	39243.9	-0.005	7.682	0.075	-0.142	-0.072
China CPO Import in (1000 MT)	6176.2	-0.389	5.393	0.045	-0.087	-0.431
India CPO Import (1000 MT)	7717.3	-0.060	0.876	0.008	-0.017	-0.067
Total World CPO Import (1000 MT)	28936.4	-0.099	1.421	0.012	-0.023	-0.111
CPO international market price (USD/MT)	808.4	0.334	-4.886	-0.049	0.087	0.371
CPO Export Price (USD/tonne)	504.2	0.298	-6.525	-0.060	0.119	0.357
Land Use Change (% of land use emission (CO_2))	169.1	0.000	11.354	0.118	-0.237	-0.059
Community Access to Natural Capital (% of prov. land area un-degraded by oil palm prod.)	20.3376	0.001	-34.302	-0.337	0.636	0.301
Community access to physical capital (% of household with main roof and access to electricity)	45.9136	0.039	0.608	0.005	-0.009	0.034
Community Access to Financial Capital (Rp.1000 per capita)	353.5	0.198	14.229	0.113	-0.198	0.085
Community Access to Social Capital (% of population above poverty line)	89.3137	0.009	0.658	0.005	-0.010	0.004
Community Access to Human Capital (labour force participation rate %)	70.0504	0.000	-0.002	0.284	0.256	0.539
Community vulnerability/Risk (frequency of environmental disaster)	427.1	0.000	1.100	0.000	-0.023	-0.023

Table 4 Results of Economic Surplus for year 2009 - 2014

		Business as usual			Improvement
Surplus in Rp.1000	S1	S2	S3	S4	s5
Producer	49.40	52126.19	515.91	-971.45	-408.88
Consumer	12.88	13593.77	134.54	-253.34	-106.63
Govt Revenue	-174436.98	160413299.54	1569932.78	-2965428.58	-1580504.71
net national surplus	-174374.69	**160479019.51**	1570583.23	-2966653.37	**-1581020.23**

Description: S1: increase Export tax by 5%;
S2: increase oil palm harvested area by 15%;
S3: increase net enrolment ratio to secondary school by 5%;
S4: increase wage by 10%;
S5: combination of s1, s3, and s4

Simultaneous Determinants of Fiscal Policy, Monetary Policy, Income Inequality, Trade, Domestic Credit to Private Sector and Economic Growth: Case of Emerging Market Economy

Dipyaman Pal*[1], ArpitaGhose**

**Bethune College, Kolkata, West Bengal, India; Email: dipyaman.pal@gmail.com*
***Jadavpur University, Kolkata, India; Email: arpitaju@gmail.com*

Abstract

A panel-VAR model is used to determine the existence of simultaneous-relationship between economic-growth, income-inequality, fiscal- policy, monetary-policy, domestic-credit to private sector and total-trade of the 13 emerging market economy (EMEs) as a group for the period 1980-2010. After establishing the existence of simultaneity between the above relationships a simultaneous panel model has been formulated and estimated incorporating the non-linearity among the variables as suggested by the existing literature. An inverted U-shape relationship is evident between (i) economic-growth, income-inequality and total-trade, in economic-growth equation, (ii) income-inequality, economic growth and per-capita income in income-inequality equation, (iii) total-trade and economic-growth, in total-trade equation and (iv) monetary-policy and fiscal-policy, in monetary-policy equation. Also, a U-shaped relationship between monetary-policy and fiscal- policy is observed in fiscal-policy equation. Thus, the existence of a two-way non-linear relationship is highlighted between economic-growth, income-inequality, total-trade and monetary-policy. Apart from these non-linear relationships, positive and significant effect of (i) gross capital formation, inflation, population growth, human capital, fiscal policy, monetary policy and domestic-credit to private sector on economic-growth; (ii) civil liabilities on income inequality; (iii) gross capital formation and inflation on total trade; (iv) total trade, population growth 65 years and above, political system on fiscal-policy; (v) per-capita GDP, total reserves, fiscal-policy and domestic-credit to the private-sector on monetary-policy and (vi) money-supply and gross domestic savings on domestic-credit to the private sector is highlighted. Also, negative and significant effect of (i) fiscal-policy on income-inequality; (ii) income-inequality on fiscal policy; (iii) total-trade on domestic-credit to the private-sector is revealed.

Keywords: Economic Growth, Fiscal Policy, Monetary Policy, Income Inequality, Panel-VAR, Panel Unit Root

[1] Corresponding author

1. Introduction

The reduction of economic disparities is one of the most challenging public policy topics in macroeconomic literature. An innermost concern of this debate is that whether the role government policies may play a vital role in reducing economic inequalities, and determining the effects on economic growth rate (Bénabou, (2000, 2002, 2005) and Seshadri and Yuki (2004)) or not.
The political economy literature reveals the theoretical background of the empirical models, where fiscal policy, inequality and growth are jointly determined in democratic societies. These political economy models of inequality and growth pointed out that the fiscal policy can play a major role in explaining the development of both macro aggregates. In this context, fiscal policy which is an endogenous variable reflects, through political processes, the voters' preferences for income distribution (each individual behaves like an economic agent and a citizen who votes on the distributive policies) (Drazen, 2000; chapter 11 and Persson and Tabellini, 2000; chapter 14). Under the assumption of perfect capital markets early political economy models shows a negative relationship between inequality and growth (Alesina and Rodrik, 1994, Bértola, 1993 and Persson and Tabellini, 1994). This traditional idea does not seem very supportive by the later empirical contributions using cross-country data. Recently, the political economy literature wanted to loosen up the main assumptions of the abovementioned approaches. Bénabou (2000) argues how countries with similar preferences and technologies as well as equal democratic political systems, can however make very different choices with respect to fiscal policies. Muinelo-Gallo and Roca-Sagalés (2013) analysed the relationship between income inequality and economic growth through fiscal policy. They presented and estimated two systems of structural equations with error components through which gross income inequality determines different fiscal policy outcomes, which subsequently affects the evolution of economic growth and net income inequality. The empirical results, obtained using an unbalanced panel data of 21 high-income OCDE countries during the period 1972–2006, suggested that gross income inequality is a significant determinant of fiscal policy outcomes. Additionally, the results showed that distributive expenditures and direct taxes may produce significant reductions in GDP growth and net income inequality reflecting the standard efficiency–equity trade-off associated to certain fiscal policy measures. Finally, the results also indicated that the most adequate fiscal policy strategy in a context of fiscal consolidation is to cut non distributive expenditure, since this could increase GDP growth while reducing income inequality.

Earlier studies like Bénabou (2000); Muinelo-Gallo and Roca-Sagalés (2013) etc have considered the joint determination of economic growth, income inequality and fiscal policies. But the limitations of these studies are as follows: First of all, they did not take into account the effect of monetary policy on growth. In fact there are some literature which reflects the joint relationship between economic growth, government expenditure and money supply (Albatel (2000) for Saudi Arabia and Mohammad et. al. (2009) for Pakisthan). Mohammad et. al. (2009) argued that public expenditure and inflation are negatively related to economic growth in long run while M2 is positively impacts on economic growth in long run. The reason behind the negative association among public expenditure, inflation and economic growth is the most of public expenditure is non development and inflation is due to adverse supply shock (cost push inflation) in case of Pakistan. Demary (2004) found that unanticipated money growth affects real output and employment in case of West Germany. Georgantopoulos and Tsamis (2013) established the short and long term relationship between money supply, inflation and economic growth in Cyprus and Tabar et.al (2016) for Iran. Georgantopoulos and Tsamis (2013) Tabar et.al (2016) and the studies argued that

public expenditures promote economic development. Monir et al. (2015) established that the money supply in the banking system of Bangladesh has a positive impact on the following macroeconomic variable: nominal interest rate, bank rate, and remittance, but has an adverse consequence on the following variables: such as interest rate and deposit inflation.

Secondly, domestic credit to private sector is also a major determinant of economic growth (Ea et al., 2015; Okafor et al., 2016 etc.). The interrelationship between financial sector development and economic growth was established by Dudian et al. (2013) for the region central and eastern Europe taking into account a panel of eight countries from the region and by Alkhuzaim(2014) for Qatar. Dudian et al. (2013) measured financial sector by broad money growth (annual%), domestic credit to private sector (% GDP), domestic credit to private sector (% GDP) annual growth, interest rate spread (lending rate minus deposit rate,%) and nonperforming loans (% total loans), while Alkhuzaim(2014) measured financial sect by three alternative indicators: a broad money supply (M2) to GDP ratio, bank credit to the private sector as ratio to GDP, and domestic credit provided by bank sector as ratio to GDP. The economic growth is measured by the growth rate of real GDP by both Dudian et al. (2013) and Alkhuzaim(2014). Dudian et al. (2013) found that increase nonperforming loans and interest rate spreads negatively affect economic growth and increase in domestic credit to private sector negatively affect GDP growth, but increase its growth rate positively affects GDP. Also broad money growth is less relevant for economic growth. Alkhuzaim(2014) argued that a positive long-run equilibrium relationship exists between all three financial development indicators and the growth rate of real GDP. Arıç (2014) found that Domestic Credit to Private Sector as % of GDP affects economic growth negatively, Capitalization Ratio and Money and Quasi Money M2 as % of GDP affect growth positively. Ea et al (2015) obtained a negative relationship between domestic credit and economic growth for eight countries in ASEAN member states excluding Myanmar and Lao PDR. Okafor et al. (2016) established a unidirectional causal relationship between deposit money bank credit and economic growth in Nigeria. However, the linkage between domestic credit to private sector and economic growth are missing in Muinelo-Gallo and Roca-Sagalés (2013).

Thirdly, Alihodžić (2016) etc also suggests that domestic credit to private sector depends on the money supply of the economy. It is well known fact that one of the major determinants of money supply is domestic credit to private sector. Thus there exists a bi-directional relationship between money supply and domestic credit to private sector. The possibility of the existence of linkage between money supply and domestic credit to private sector was not considered by Muinelo-Gallo and Roca-Sagalés (2013).

Fourthly, there also exist some views in the literature regarding the causal direction of the effects of trade openness on economic growth. Michaely (1977), Feder (1982), Marin (1992), Thornton (1996) found that countries exporting a large share of their output seem to grow faster than others. Grossman and Helpman (1991), Rivera-Batiz and Romer (1991), Romer (1990) hypothesize that expanded international trade increases the number of specialized inputs, increasing growth rates because economies become open to international trade. Buffie (1992) considers how export shocks can produce export-led growth (Ribeiro Ramos, 2001). The export-led growth hypothesis (Zuniga, 2000) broadly focuses on whether a country is better served by orienting trade policies to export promotion or import substitution. The favorable impact of exports on economic growth has been well established in the literature (Kruger, 1975; Balassa, 1978; Williamson, 1978; Bhagawati,

1982; Srinivasan, 1985; Love and Chandra, 2004; Mah, 2007; Ziramba, 2011 among others). In the Growth Led Export (GLE) case, export expansion could be stimulated by productivity gains which caused by increase in domestic levels of skilled-labor and technology (Bhangwati, 1988; Krugman, 1984). Neoclassical trade theory typically argues that the causality that runs from home-factor endowments and productivity to the supply of exports (Findlay, 1984). The product life cycle hypothesis developed by Vernon (1996) has also concerned considerable attention among international trade theorists in recent years. Segerstrom et al. (1990), for example, use the product life cycle hypothesis as a basis for analyzing north_south trade in which research and development competition between firms determines the rate of product innovation in the north (Ribeiro Ramos, 2001). The third alternative is that of import-lead growth (ILG) shows that economic growth could be driven primarily by growth in imports (Coe and Helpman, 1995). Growth in imports can serve as a medium for the transfer of growth-enhancing foreign R&D knowledge from developed to developing countries (Lawrence and Weinstein, 1999; Mazumdar, 2000). The most interesting economic scenarios suggest a two-way causal relationship between growth and trade. According to Bhagwati (1988), increased trade produces more income (increased GDP), and more income facilitates more trade. So, the result suggests a 'virtuous circle'. This type of feedback has also been noted by Grossman and Helpman (1991) in their models of north_south trade. But Muinelo-Gallo and Roca-Sagalés (2013) did not take into account possible bi-directional linkage between trade and economic growth.

It may also be mentioned that, only a limited number of studies are available for a panel of countries (Muinelo-Gallo and Roca-Sagalés (2011b) for OECD). More specifically, there is dearth in studies which estimated the simultaneous relationship for the emerging market economy (EME) as a group. In 1981, Agtmael defined an emerging market economy (EME) as a developing economy with low to middle per capita income, pursuing reform programmes in the market-oriented line and gradually becoming as significant players in the global economy (Agtmael 2007). The potential causes for the creation of an EME are the failure of state-led economic development, its tremendous negative impact and the need for capital investment which had pushed those countries to adopt open door policies, to replace their traditional state interventionist policies, undertake economic and political reforms and to change from the state being in charge of the economy to facilitate economic growth along market-oriented lines. Hence it will be interesting to see what kind of relationship hold among the above mentioned variables for the EME as a group. Therefore, the first objective of the paper is to check whether there exists any long run and short run simultaneous relationship between economic growth, inequality, fiscal policies, monetary policies, domestic credit to private sector and total trade or not using a VAR frame work by considering a panel of 13 EME [Brazil (BRA), Chile (CHL), China (CHN), Colombia (COL), Ecuador (ECU), India (IND), Malaysia (MYS), Mexico (MEX), Morocco (MAR), Pakistan (PAK), Philippines (PHL), South Africa (ZAF) and Venezuela (VEN) (Based on The International Monetary Fund classification)] over the period of 1980-2010. In order to test long run relationship in the first step panel unit root test is applied by Levin and Lin (1992, 1993) and Im, Pesaran, and Shin (IPS) method. The results of panel unit root test by LLC and IPS method are presented in Table-1. From the results it can be concluded that by both method all the variables are stationary at their level. So, all the series are integrated of order 0. So, one may not be able to run the panel co-integration analysis to find out the long run relationship between these variables. However, one can find out the short run relationship between the variables by applying panel VAR model.

All the results of panel VAR model are presented in Table-2 to Table-7. From the results of the panel VAR model it can be concluded that there exists short run relationship between Economic Growth, Income Inequality, Fiscal Policy, Monetary Policy, domestic credit to private sector and total tread[2].

The perusal of the literature suggests that the relationship between these above mentioned variables can in-fact be of non-linear type (Henderson and Wang (2015); Lin et. al (2014); Kim and Lin (2009); Cotarelli, et. al. (2005); etc). However, such non-linearity has not been captured in the above results as described in Table 2 to Table 7. The perusal of the literature suggests that there is dearth in the studies capturing the existence of non-linearity among the endogenous variables in a simultaneous panel setup. The present paper adds to the literature in this direction. Therefore, to take into account of this fact a simultaneous panel model has been formulated incorporating the existence of possible non-linearity as suggested by the existing literature.

The proposed model is then estimated using a seemingly unrelated regression (SUR) framework and each regression was adjusted for contemporaneous correlation (across units) and cross section heteroscedasticity keeping in mind the following issues: First of all, to see how economic growth is affected by income inequality and other institutional, demographic and economic explanatory factors jointly with the fiscal policy, monetary policy and Trade. Secondly, to check how income inequality is affected by fiscal policies and growth. Thirdly, how fiscal policy in turn affected by income inequality and monetary policy. Fourthly, to see how trade is affected by growth along with other institutional, demographic and economic explanatory factors. Fifthly, how monetary policy in turn is affected by economic growth, fiscal policy and domestic credit along with the other determinants. Finally, to check how domestic credit to private sector is affected by monetary policies along with other determinants.

The rest of the paper unfolds as follows. Section II specifies the model. Section III describes the methodology and data sources. Section IV provides the empirical results and section V concludes.

[2] Current period's Economic Growth may be significantly affected by the previous two years lags of economic growth, Income Inequality, Fiscal Policy, Monetary Policy, domestic credit to private sector and total tread when economic growth is taken as dependent variable. If one considers Income Inequality as the dependent variable, then it is evident from the results that current period's Income Inequality is significantly affected by the previous two years lag of Economic Growth and Government Expenditure and by its own one year's lag. Current period's total tread is significantly affected by the previous two year's own lag and economic growth implying that there exists short run relationship between total tread and economic growth. Similarly, if one considers Government Expenditure as the dependent variable then it is also evident from the results that current period's Government Expenditure is significantly affected by the previous two period's lag of Government Expenditure, total tread, Income Inequality and money supply. Considering monetary Policy equation current period monetary policy is significantly affected by the previous two year's own lag, lags of economic growth, domestic credit to private sector and fiscal policy implying that there exists short run relationship between monetary policy, domestic credit to private sector and economic growth. Lastly, current period's domestic credit to private sector is significantly affected by previous two periods own lag, lags of economic growth and monetary policy implying the existence of short run relation between domestic credit to private sector and monetary policy.

2. Model

As describe above the proposed model of this paper consist of six simultaneous equations representing the behavior of economic growth, income inequality, trade, fiscal policy, monetary policy and domestic credit to private sector. The specification of each of the equation is as follows:

Economic Growth Equation:

Based on the available literature the economic growth equation can be specified as follows:

$$Gr = f\ (\ In, In^2, TD, TD^2, GCF, IF, Pop, HC, MS, DCandGE)$$

Gini of Income Inequality (In): From the existing literature it can be concluded that there exists a relationship between economic growth and income inequality (Henderson, Qian and Wang, 2015; Lin, Huang and Yeh, 2014; Chen, 2003). So, in this paper Income Inequality can be taken as one of the major determinant of Growth. In-fact, the relationship between economic growth and income inequality to be non-linear (Henderson and Wang (2015); Lin et. al (2014) etc.).

Population Growth (Pop): According to the empirical literature population growth is one of the significant control variables of economic growth (Kim, 2016; Muinelo-Gallo and Roca-Sagalés, 2013). It is expected that as population growth increases economic growth decreases. So, one can find a negative relationship between population growth and economic growth.

Human Capital (HC): Another important control variable of economic growth is human capital (Chen, 2003; Muinelo-Gallo and Roca-Sagalés, 2013). As human capital increases economic growth increases. So, human capital has a positive effect on the economic growth. Here human capital is measures as average years of schooling of the population aged 25 and over collected from Barro and Lee (2010).

Total Trade (TD): There are huge number of empirical as well as theoretical literature which shows that there exists a relationship between trade and economic growth (Balassa, 1978; Bhagwati, 1988; Edwards, 1998; Kruger, 1975; Williamson, 1978; Bhagawati, 1982; Srinivasan, 1985; Love and Chandra, 2004; Mah, 2007; Ziramba, 2011; Nanda and Panda, 2011; Aditya and Acharyya, 2012; etc.). Most of the literature suggested that trade openness can be measured by total trade which is defined as Export plus Import as a percentage of GDP. Kim and Lin (2009) found significant threshold effects in the relationship between trade and growth. So, in this study higher polynomial of trade has been considered as one determinant of economic growth.

Inflation (IF): Inflation is another important control variable for economic growth (Lin, Huang and Yeh, 2014; Chen, 2003; Muinelo-Gallo and Roca-Sagalés, 2013; Vu and Mukhopadhaya, 2011; Marchionne and Parekh, 2015 etc.). The existing literature suggested that there exists a negative relationship between the economic growth and inflation. In this paper Inflation is taken as December-to-December change in consumer price index in logs (CPI).

Gross Capital formation (GCF): Another important control variable is gross capital formation Abida and Sghaier (2012). Now, there exists a positive relationship between the gross capital formation and economic growth.

Money Supply (MS) and Domestic credit to private sector (DC): These two control variables are two important and significant explanatory variables of economic growth. These two variables represent the level of financial intermediation (Tabassum and Majeed, 2008; Ea et al, 2015).

General government final consumption expenditure (GE): Causality running from growth to the government consumption variable exists for Mexico (Murthy, 1993), South Africa (Chang, Liu and Caudill, 1994), China (Narayan, Nielsen and Smyth, 2008), India (Mohsin, Naidu and Kamaiah, 1995; Murthy, 1981), Pakistan (Khan, 1990) and the Philippines (Jodylyn and Dante, 2006). Now, this variable is taken as the measures of fiscal policy (Muinelo-Gallo and Roca-Sagalés (2013) and one can expect a positive relationship between economic growth and general government final consumption expenditure.

Inequality Equation:
The perusal of the literature suggest that Income Inequality equation can be written as:

$$In = f\ (\ Gr, Gr^2, PCGDP, PCGDP^2, CL, GE)$$

Growth (Gr): The literature suggests that there exists a relationship between income inequality and economic growth (Galbraith and Kum, 2003 etc.). So, in this paper a relationship between income inequality and economic growth has been considered. According to Kuznets hypothesis there may exists an Inverted-U shaped relationship between economic growth and income inequality. Thus, in this study higher polynomial of growth has been considered as one determinant of income inequality.

Civil liberties (CL): Another important control variable for income inequality is civil liabilities (Muinelo-Gallo and Roca-Sagalés (2013)). Here, civil liabilities make it possible to consider the political control of the richest segment of society and its influence on income distribution, given this segment's political ability to protect its wealth. In this paper CL is measured as Freedom House: index on a scale of 1 to 7, with 1 representing the higher level and 7 representing the lower level.

Income (PCGDP): Income is another important control variable for income inequality. According to Kuznets hypothesis there exists an inverted-U shaped relationship between income inequality and income of the economy. So in order to test Kuznets hypothesis higher polynomial of per capita income has been considered as one determinant of income inequality in this study. In this paper Per capita GDP in constant price is taken as a measure of Income.

General government final consumption expenditure (GE): According to Muinelo-Gallo and Roca-Sagalés (2013) and many others fiscal policy variable is one of the important explanatory variable of income inequality. According to the literature distributive government expenditure such as expenditure on health, education etc. affects income inequality in negative and significant way. On the other hand Non distributive expenditures such as expenditure on General public services, Defence, Public order and safety or Economic affairs may affects inequality in positive way because the relevant amount of public expenditure is spending on a particular group of people it in turn may increase income inequality. These class of literature call for a public expenditure in the form of redistributing wealth from the rich (whose marginal productivity of investment is relatively low, due to decreasing returns on individual investments) to the poor (whose marginal productivity of investment is relatively high, but who cannot invest more than their limited

endowments). Such kind of transfer would enhance aggregate efficiency and growth (see Bénabou (2000); Muinelo-Gallo and Roca-Sagalés (2013)).

Total Trade (TD) Equation:
In tune with the existing literature Total Trade equation can be defined as:

$$TD = f(Gr, Gr^2, REER, REER^2, GCF, IF)$$

The variation in Total Trade is explained by considering the following variables:

Economic Growth (Gr): Economic growth leads to an increase in Total Trade through technological innovation and an increase in productivity, thereby increasing competitiveness (Vernon, 1966). Finally, Giles and Williams (2000) argue that economic growth may lead to the enhancement of skills and technology which creates a comparative advantage and thereby facilitates exports, while higher output growth can stimulate higher investment, a part of which can be for increasing export capacity (Kemal et al., 2002). Kim and Lin (2009) found significant threshold effects in the relationship between trade and growth. So, in this study higher polynomial of economic growth has been considered as one determinant of trade.

Real effective exchange rate (REER): Conceptually REER is defined as a weighted average of nominal exchange rate adjusted for relative price differential between domestic and foreign currencies, relates to purchasing power parity hypothesis. REER[3] is basically dependent on the movement of the term $[(e/e_i)(p/p_i)]$
Where, e represents exchange rate of home currency,
e_i denotes foreign exchange rate,
p is home country's price
p_i denotes foreign country's price
Thus increase in REER can be due to increase in either (p/p_i) or (e/e_i). As (e/e_i) increases foreign demand for home country's export increases because of depreciation of home currency in terms of foreign currencies. Considering the effect of (p/p_i) it can be said that as (p/p_i) increases home country's export will be less competitive in the international market as a result of which her export is likely to fall. The net effect can either be positive or negative depending on two forces. Similar argument is for Total Trade. Thus there may exists a threshold limit between REER and total trade. Initially an increase in the REER may increase the total trade but beyond some point REER may affect total trade in reverse way.

Domestic investment size or Gross Capital formation (GFC): It is motivating to test the hypothesis that whether domestic investment size enhances or hinders economic growth. It is quite possible that with rise in domestic investment size, economic growth may rise.

Inflation (IF): Inflation is one of the important factor behind the variation of Total Trade because as inflation goes up so domestic price increases. Now, if exchange rate is constant then an increase in domestic price will reduce export or increase import. But if there is a change in exchange rate then the effect may ne ambiguous because it depends upon the relative strengths.

[3] Real effective exchange rate is the nominal effective exchange rate (a measure of the value of a currency against a weighted average of several foreign currencies) divided by a price deflator or index of costs.

Fiscal Policy Equation:

As suggested by the existing literature formulation of fiscal policy equations can be specified as:

$$GE = f(TD, Pop65, In, PS, MS \text{ and } MS^2)$$

Total Trade (TD): There are so many literatures which show that there exists a relationship between trade and fiscal policy by the government. Earlier empirical works have found that more open economies have larger governments. This might reflect the increased demand for social insurance in more open (and hence, more risky) economies but it might also reflect readily available tax bases resulting from taxes on exports and imports. To take these hypotheses into account, a measure of a country's openness is considered, defined as Total Trade.

Population ages 65 and above as a percentage of the total population (Pop65): Most of the empirical work on the size of government finds strong correlations between the demographic composition of the population and government expenditures, where older populations are associated with larger governments. To consider these aspects, we include the percentage of the population aged 65 years old or more.

Income Inequality (In): Another important factor behind the variation of fiscal policy is the income inequality. Now, as income inequality increases government has to change the fiscal policy in order to reduce the income inequality. So, there may exist a negative relationship between fiscal policy (particularly non distributive government expenditure) and income inequality.

Political system (PS): The policy outcomes may reflect many economic, social, cultural and historical factors besides any influence that the analysis may receive from inequality measures. Persson and Tabellini (2000, 2003) argued that institutional, demographic and economic variables have been considered as additional control variables for fiscal policy. Thus, in this paper incorporate one fundamental aspect of constitutions: the forms of government in the fiscal policy equations. This factor determines how the power to make decisions on economic policy can be exercised once in office and how conflicts between elected representatives can be resolved. The considered constitutional variable takes the values of either 2 (in parliamentary regimes), 1 (in assembly-elected presidential regimes), or 0 (in presidential regimes). According to the separation-of-powers argument, presidential regimes should be associated with less rent extraction and lower taxation and expenditures than parliamentary regimes. According to the confidence requirement argument, they should also be associated with more targeted programs at the expense of broad expenditure programs. Overall, parliamentary regimes should have larger governments (more expenditures and revenues) than presidential ones (Persson et al. 1997, 1998, 2000; Persson and Tabellini, 2000, 2003). In this paper data on political system has been collected from Database of Political Institutions (DPI-2015) of The World Bank.

Money Supply (MS): Fatima et al., 2003; Mohammad et al., 2009; Tabar et al., 2016 etc pointed out that there may exists joint interaction between monetary policy and fiscal policy. Thus, Money Supply is also one of the important significant control variables for fiscal policy. Bertella et al. (2015) argued that there exists non-linear relation between monetary policy and fiscal policy. Thus, in order to capture the non-linear relationship between monetary policy and fiscal policy higher polynomial of monetary policy has been considered as one determinant of fiscal policy.

Monetary Policy Equation:
The existing literature suggests that Monetary policy equation can be written as:

$$MS = f(IF, IF^2, Gr, PCGDP, TR, GE, GE^2 \text{ and } DC)$$

Inflation (IF): Inflation is one of the important control variables for money supply in the economy. As inflation increases money supply also increases. Thus there exists a positive relationship between inflation and money supply of the economy.

Economic Growth (Gr): Economic Growth is one of the impotent determinants of the money supply. There exist so many literatures (Dudian et al., 2013; Tyavambiza et al., 2015; Alkhuzaim, 2014 and many more) which shows a positive relation between economic growth and money supply.

Income (PCGDP): Income Measured by Per Capita GDP is also one of the major determinates of money supply. As income increases savings of the economy increases thus there is an decrease in the money supply of the economy.

Total Reserves (TR): Total Reserves indicates one of the financial indicator which affects the money supply of the economy. Feldstein and Stock (1994) investigated the possibility of using the money supply (M2) with the aim of targeting quarterly growth rate of nominal GDP. The study results showed that the Federal Reserve could probably use the M2 to reduce both the long-term average inflation rate and variance relating to the mean annual growth rate of GDP.

Fiscal Policy (GE): General government final consumption expenditure as a percentage of GDP is one of the main indicator of money supply. In recent years, the relative effectiveness of monetary and fiscal policy action on economic activity has been the source of considerable debate among economists. Empirical studies using monetarist models suggest that monetary actions have a greater impact on economic activities of the developed countries. On the other hand, studies using the structural models suggest that fiscal actions appear to have a dominant influence on economic activity in these countries (Chowdhury, 1986). While a macroeconomic policy regime consists of the monetary and fiscal policy strategies that are implemented, the monetary and fiscal policy strategies are interacting and their joint implementations affect macroeconomic adjustments. Even in the simple framework, there are clear interrelations between monetary and fiscal policy rule. The design of the monetary rule will affect the macroeconomic conditions, which on their turn affect the fiscal policy (Aarle *et al.*, 2003). According to Bertella et al. (2015) there exists non-linear relation between monetary policy and fiscal policy. So, higher polynomial of fiscal policy has been considered as one determinant of monetary policy.

Domestic Credit to Private Sector (DC): Domestic credit to private sector as a percentage of GDP is one of the important determinants of the money supply. As Domestic credit to private sector increases money supply increase.

Domestic Credit to Private Sector Equation:
In accordance with the existing literature Domestic credit to private sector equation can be written as:

$$DC = f(MS, TD, PCGDP, \text{and } GDS)$$

Income (PCGDP): Égert, et. al. (2006) investigates the determinants of the domestic bank credit to the private sector as a percentage of GDP in 11 CEE countries. The GDP per capita was found to have a positive effect on the dependent variable. Cotarelli, et. al. (2005) also found long-term relations between bank credit to the private sector to GDP ratio. So one can considered per capita GDP is one of the major determinates of domestic credit to private sector.

Total Trade (TD): Total Trade as a percentage of GDP is one of the major determinates of domestic credit to private sector (Masood et al., 2011). One can expect a positive relationship between trade and domestic credit to private sector.
Money Supply (MS): Money Supply as a percentage of GDP is also an important determinates of domestic credit to private sector (Masood et al, 2011; Alihodžić, 2016**).** There exists a positive relationship between these two variables.

Gross Domestic Savings (**GDS):** Masood et al, 2011 found that Gross Domestic Savings as a percentage of GDP is one of the major influencing determinants of domestic credit to private sector and one may expect a positive relationship between these two variables.
So, we have system of six equations showing the joint determination of Growth, Inequality, Fiscal Policy, Monetary Policy and Domestic Credit to Private Sector and Total Trade

$$Gr = f\ (\ In, In^2, TD, TD^2, GCF, IF, Pop, HC, MS, DCandGE) \quad \text{… (1)}$$
$$In = f\ (\ Gr, Gr^2, PCGDP, PCGDP^2,\ CL, GE) \quad \text{… (2)}$$
$$TD = f(Gr, Gr^2, REER, REER^2, GCF, IF) \quad \text{… (3)}$$
$$GE = f(TD, Pop65, In, PS, MS\ and\ MS^2) \quad \text{… (4)}$$
$$MS = f(IF, IF^2, Gr, PCGDP, TR, GE, GE^2\ and\ DC) \quad \text{… (5)}$$
$$DC = f(MS, TD, PCGDP, and\ GDS) \quad \text{… (6)}$$

3. Methodology and Data sources

In order to estimate this simultaneous model consisting of six equations one need to check both rank and order condition of simultaneous equation system. In fact, the model is over identified. We have solved the identification problem by imposing exclusion restrictions. It is found that each of the six equations contains separate variables and hence the mongrel equation can easily differentiable from other equations and hence all the equation is identified.

Estimation of simultaneous panel Models

For estimating the model Hausman test is used for testing whether fixed effect model is a better fitted model over the random effect model or not and then the model is estimated under fixed effect considering a SUR framework and each regression was adjusted for contemporaneous correlation (across units) and cross section heteroscedasticity.
Since the model consisting of six over identified simultaneous equations the two stage method is used for estimation.

Two stage estimation method:

Stage 1: Replacing the inequality, fiscal policies, monetary policies, domestic credit to private sector and total trade from equation (2 to 6) into economic growth equation one can express economic growth as a function of other exogenous variables except inequality, fiscal policies, monetary policies, domestic credit to private sector and total trade. This is the reduced form equation of economic growth. Similarly, replacing economic growth from equation (1) to

inequality equation (2) one can get income inequality as a function of other variables except economic growth. This is the reduced form equation of income inequality. Similarly, the reduced form equations for other dependent variables like fiscal policy, monetary policy. Domestic credit to private sector and total trade can be found. Now, from the reduced form equations one can get estimates of the parameter and estimated values of endogenous variables of this model.

Stage 2: Replacing this estimated value of inequality, fiscal policies, monetary policies, domestic credit to private sector and total trade as obtained from stage 1 in economic growth equation one can get the final estimate of the economic growth using the panel model under SUR framework. Similarly, one can get estimated value for inequality, fiscal policies, monetary policies, domestic credit to private sector and total trade using the panel setup. The proposed setup of the panel model uses fixed effect under a SUR framework where each regression was adjusted for contemporaneous correlation (across units) and cross section heteroscedasticity.

Data sources:
The data on per capita GDP in constant price, Population Growth, Export and Import as a percentage of GDP, Inflation, Gross Capital formation as a percentage of GDP, Broad money as a percentage of GDP, Domestic credit to private sector as a percentage of GDP, General government final consumption expenditure as a percentage of GDP, Gross Domestic Savings as a percentage of GDP, Total Reserves, population ages 65 and above as a percentage of the total population are collected from World Development Indicators of World Bank (WDI). Data on income inequality are taken from UNU-WIDER version 3. Data on political system has been collected from Database of Political Institutions (DPI-2015) of The World Bank. Data on civil liabilities are taken from Freedom House Index.

We have considered five-year averages of all variables because first of all year-to-year changes in fiscal and monetary policy variables are not expected to have an annual effect on the other variables particularly on economic growth. Secondly, taking five-year averages one may be able to reduce the short-run fluctuations. So, it may be able to reduce the influence of the economic cycle and can focus on the structural relationships. Thirdly, by using five-year means one may get more balance dataset of income inequality. One point has to be made that considering five-year averages will not result in much loss of information because the aggregate measures of inequality are relatively stable over time. Such type of averaging method is also used by Muinelo-Gallo and Roca-Sagalés (2013).

4. Empirical Findings

All the results are presented in Table-1 to Table-9. Estimated Results of Simultaneous Panel model Involving Equations (1) to (6). All the results of simultaneous panel estimation are presented in Table-8 and Table-9. Joint Determination of Economic Growth, Income Inequality, Total Tread, Monetary Policy, Domestic Credit to Private Sector and Fiscal Policy. From the results of estimation of growth equation, it can be concluded that there exists an inverted U shape relationship between growth and income inequality implying that there exists a threshold limit beyond which inequality of income distribution may affect the economic growth of the economy in reverse way. The overall marginal effect of income inequality is negative implying that on a whole the effect of inequality on economic growth is negative. On the other hand there exists an inverted U shaped relationship between total trade and economic growth implying that as total

trade increases economic growth increases but after some threshold limit increase in total trade may affect economic growth in negative way. The overall marginal effect of total trade is positive implying that on a whole total trade may increase the economic growth. Moreover, population growth and inflation has a significant positive effect on the economic growth process. Implying that as population growth increases overall demand increases thus increase in the economic growth. The positive relation between inflation and economic growth implies that moderate inflation may increase the economic growth. On the other hand human capital and investment (measured by Gross Capital Formation) have positive and significant effect on the growth process. This result is as expected. The fiscal policy variable, i.e., Government expenditure has a significant positive effect on the growth. The effect of monetary policy on the economic growth is positive implying the existence of Peguion effect. The domestic credit to private sector has positive and significant effect on the growth suggesting that effect of financial variable has a significant effect on economic growth.

From the inequality equation it can be concluded that there exists an inverted U shape relationship between inequality and growth showing that there exists a limit beyond which growth of the economy may affect the inequality of income in the reverse way. The overall marginal effect of economic growth on income inequality is negative implying as growth increases income inequality decreases. Also there exists an inverted U shaped relationship between income and income inequality indicating that as income increases then inequality increases in the first stage but beyond a limit increase in income may decrease the inequality. The marginal effect of income on inequality is negative suggesting that as per capita income increases then income inequality decreases. On the other hand civil liabilities have a positive and significant effect on the inequality of income showing that richest segment of society has more political control and thus may have influence on income distribution. In case of government expenditure there exists a negative and significant effect on the income inequality which suggests that in order to decrease the inequality of Income distributive expenditures of the Government such as expenditure on Social protection, Health, Housing and community, amenities and Education has to increase (Muinelo-Gallo and Roca-Sagalés (2013)).

From the results of the total trade equation it can be concluded that there exists an inverted U shaped relationship between economic growth and total trade implying that as economic growth increases total trade increases but after a limit economic growth may affect total trade in reverse way. The overall marginal effect is positive implying that on a whole economic growth has a positive effect on total trade. The domestic investment i.e gross capita formation has a positive and significant effect on total trade and on the other hand inflation has a positive and significant effect on total trade.

Now from the fiscal policy equation it can be suggested that total trade, population growth for 65 years and above and political system has significant positive effect on the Government expenditure, i.e. on fiscal policy. Now positive relation between fiscal policy and population growth for 65 years and above implies that an increase in population growth for 65 years and above will increase the government expenditure and positive relation between fiscal policy and political system implies that parliamentary regimes should have larger governments (more expenditure) than presidential ones. Moreover, income inequality has a negative and significant effect on the Government expenditure. There exists a U shaped relationship between monetary policy and fiscal

policy implies that monetary policy may decrease the fiscal policy at first stage but beyond some point monetary policy may increase the fiscal policy. The explanation of this fact is that as monetary policy increases (i.e. increase in money supply) inflation increases and to control the inflation rate government may decrease the government expenditure. Now as government expenditure decreases aggregate demand falls implies fall in the inflation rate. This situation continues up to that point when inflation rate is so low that economy moves towards a stagnant position. Now to overcome this situation government may increase the expenditure and thus one can get a U shaped relationship between monetary policy and fiscal policy. The overall marginal effect of monetary policy on fiscal policy is negative implies that as monetary policy increases inflation increases thus government expenditure decreases.

Now from the monetary policy equation it can be suggested that there exists an inverted U shaped relationship between inflation and monetary policy implies that as inflation increases in the first stage government may increase the money supply for increasing the purchasing power of the economy. Now as purchasing power increases there is an increase in the aggregate demand and this further increase in the inflation but further increase in the inflation may insist government to move towards fiscal control rather than monetary control and thus money supply decrease. The overall marginal effect of inflation on monetary policy is positive implies that as inflation increases money supply increases. Further there exists an inverted U shaped relationship between fiscal policy and monetary policy implies as government expenditure increases aggregate demand increases thus there is an increase in the inflation rate. Now, as inflation rate increases money supply increase in the first stage but in the second stage further increase in the money supply may further increase the inflation rate and to control this inflation government may decrease the government expenditure. The overall marginal effect of fiscal policy on monetary policy is positive implies that as government expenditure increases there is an increase in the aggregate demand and thus inflation increase. So as inflation increases government may increase the money supply. From the domestic credit to private sector equation it can be concluded that money supply, per capita real income and gross domestic savings has positive and significant effect on the domestic credit to private sector.

5. Conclusion

The present study estimates simultaneous- relationship of growth with income inequality, fiscal policy, monetary policy, domestic credit to private sector and total trade of the 13 emerging market economy (EMEs) as a group over the period 1980-2010. Use of panel unit root test suggests that all the series are stationary at level implying absence of co-integrating relationship between these variables. However, there may exists short run relationship between these variables. In order to find out the interaction between these variables a simultaneous Panel model is resorted. The results suggest that there exists bi-directional relationship between economic growth and (i) income inequality, (ii) monetary policy and (iii) total trade, (iv) fiscal policy and (v) domestic-credit to private sector. The estimated growth equation shows existence of an inverted U shape relationship between (i) growth and income inequality and between (ii) total trade and economic growth implying that there exists a threshold limit beyond which either increase in inequality of income distribution or total trade may have a negative effect on growth. The marginal-effect of income inequality is negative, whereas the same for total trade is positive. Moreover, population growth, inflation and human capital and investment (measured by Gross Capital Formation), the government expenditure i.e., fiscal policy variables, the monetary policy (i.e., money supply) and

the domestic credit to the private has a significant positive effect on the economic growth. Similarly, moderate inflation may increase the economic growth. The estimated inequality equation supports that there exists an inverted U shape relationship between (i) inequality and growth and between (ii) per-capita income and income inequality, suggesting that exists a limit beyond which either increase in growth or per capita income may have a negative effect on the inequality of income. The marginal-effect of both economic growth and income on income inequality is negative. On the other hand civil liabilities have a positive and significant effect on the inequality of income. The effect of fiscal policy on income inequality is negative. The estimated total trade equation shows that there exists an inverted U shaped relationship between economic growth and total trade, with positive marginal-effect of growth. The domestic investment i.e gross capita formation and inflation has a positive and significant effect on total trade. The estimated fiscal policy equation suggests that total trade, population growth for 65 years and above and political system has significant positive effect on the Government expenditure, i.e. on fiscal policy. Moreover, income inequality has a negative and significant effect on the Government expenditure. There exists a U shaped relationship between monetary policy and fiscal policy. The marginal-effect of monetary policy on fiscal policy is negative. The estimated monetary policy equation suggests that there exists an inverted U shaped relationship between (i) inflation and monetary policy and between (ii) fiscal policy and monetary policy. The overall marginal-effect of both inflation and fiscal policy on monetary policy is positive. The estimated domestic credit to private sector equation shows it is positively and significantly influenced by money supply, per capita real income and gross domestic savings. The paper thus supports the role of monetary policy, fiscal policy, income inequality, total trade and domestic credit to private sector in explaining growth.

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Table: 1 Results of Panel Unit Root Test LLC and IPS Method in Level of the Series

	LLC		IPS	
	Statistic	**Prob.**	**Statistic**	**Prob.**
Gr	-3.32954*	0.0004	-3.09659*	0.001
IN	-3.50305*	0.0002	-1.49633**	0.0673
TD	-2.00412**	0.0225	-2.48397*	0.0065
GE	-5.33012*	0	-4.03993*	0.00
MS	-2.59706*	0.0047	-2.60106*	0.0046
DC	-3.41731*	0.0003	-4.24451*	0.00

**Significant at 1%; **Significant at 5%; ***significant at 10%.*

Table: 2 Results of Panel VAR Analysis (Growth as Dependent Variable)

	Gr as Dependent Variable		
Variable	**Coefficient**	**t-Statistic**	**Prob.**
C	0.038565*	2.886656	0.0041
Gr(-1)	1.717326*	57.79413	0.00
Gr(-2)	-0.72557*	-25.3228	0.00
IN(-1)	-0.00179**	-2.26824	0.0239
IN(-2)	0.002283*	2.819556	0.0051
TD(-1)	0.001811*	7.090122	0.00
TD(-2)	-0.00153*	-5.6379	0.00
GE(-1)	-0.00299*	-4.51728	0.00
GE(-2)	0.002859*	4.394186	0.00
MS(-1)	-1.47E-05*	-4.84943	0.00
MS(-2)	1.29E-05*	4.919077	0.00
DC(-1)	-0.00035	-3.50755	0.00
DC(-2)	0.000351	3.678472	0.00

**Significant at 1%; **Significant at 5%; ***significant at 10%.*

Table: 3 Results of Panel VAR Analysis (Inequality as Dependent Variable)

	IN as Dependent Variable		
Variable	**Coefficient**	**t-Statistic**	**Prob.**
C	18.6009*	141.7918	0.00
Gr(-1)	4.936138*	15.59322	0.00
Gr(-2)	-1.76562*	-5.45532	0.00
GE(-1)	-0.04589*	-3.99722	0.00
GE(-2)	0.197614*	16.9908	0.00
IN(-1)	-4.22E-04**	-3.27442	0.00
IN(-2)	-1.69E-05	-0.12901	0.90

**Significant at 1%; **Significant at 5%; ***significant at 10%.*

Table: 4 Results of Panel VAR Analysis (Total Trade as Dependent Variable)

	TD as Dependent Variable		
Variable	**Coefficient**	**t-Statistic**	**Prob.**
C	-3.82132**	-2.47606	0.0137
Gr(-1)	-6.73771*	-2.75045	0.0063
GR(-2)	7.562415*	3.028393	0.0026
TD(-1)	1.80148*	73.029	0.00
TD(-2)	-0.85191*	-32.8505	0.00

**Significant at 1%; **Significant at 5%; ***significant at 10%.*

Table: 5 Results of Panel VAR Analysis (Fiscal Policy as Dependent Variable)

	GE as Dependent Variable		
Variable	**Coefficient**	**t-Statistic**	**Prob.**
C	0.668936*	5.058738	0.00
GE(-1)	1.713267*	78.08255	0.00
GE(-2)	-0.77709*	-36.9496	0.00
TD(-1)	-0.00081*	-6.1703	0.00
TD(-2)	0.000719*	8.23555	0.00
IN(-1)	0.057425*	3.474057	0.00
IN(-2)	-0.05325*	-3.18776	0.00
MS(-1)	6.99E-05*	7.299216	0.00
MS(-2)	-8.21E-05*	-6.15104	0.00

**Significant at 1%; **Significant at 5% ; ***significant at 10%.*

Table: 6 Results of Panel VAR Analysis (Monetary Policy as Dependent Variable)

	MS as Dependent Variable		
Variable	**Coefficient**	**t-Statistic**	**Prob.**
C	-7.22901	-0.30809	0.7582
MS(-1)	1.778854*	62.30662	0.00
MS(-2)	-0.83656*	-31.188	0.00
Gr(-1)	-104.269*	-4.24454	0.00
Gr(-2)	110.5888*	4.232768	0.00
DC(-1)	2.931843*	5.593391	0.00
DC(-2)	-2.49044*	-4.8778	0.00
GE(-1)	1.811949	3.571645	0.00
GE(-2)	-1.15949	-3.07762	0.00

**Significant at 1%; **Significant at 5% ; ***significant at 10%*

Table: 7 Results of Panel VAR Analysis (Domestic Credit to Private Sector as Dependent Variable)

	DC as Dependent Variable		
Variable	**Coefficient**	**t-Statistic**	**Prob.**
C	1.683862*	9.208023	0.00
DC(-1)	1.743176*	77.3782	0.00
DC(-2)	-0.77444*	-36.3243	0.00
MS(-1)	-0.0287*	-52.2769	0.00
MS(-2)	0.0296*	53.33333	0.00
TD(-1)	0.08715	4.167264	0.00
TD(-2)	0.0847	3.904485	0.00

**Significant at 1%; **Significant at 5% ; ***significant at 10%*

Table: 8 Results of Simultaneous Panel Estimation (Method: Panel EGLS (Cross-section SUR))

	Coefficient	Std. Error	t-Statistic	Prob.
Growth Equation				
C	-58.9197*	1.4894	-39.5596	0.00
IN	2.6319*	0.0607	43.3798	0.00
IN2	-0.0301*	0.0006	-47.0234	0.00
TD	0.0902*	0.0055	16.3799	0.0003
TD2	-0.0009*	0.0001	-14.4613	0.00
GCF	0.0052*	0.0011	4.5874	0.00
IF	0.0002*	0.0000	12.4219	0.00
POP	0.1116*	0.0078	14.3752	0.00
HC	0.0170*	0.0025	6.9050	0.00
MS	0.0002*	0.0000	53.5385	0.00
DC	0.0020*	0.0003	7.8125	0.00
GE	0.0873*	0.0106	8.2176	0.00
Adjusted R-squared		0.999725		
F-statistic		63469.56*		
Prob(F-statistic)		0.00		
Inequality Equation				
C	-200.2994*	6.2520	-32.0374	0.00
Gr	43.3008*	1.4819	29.2192	0.00
Gr2	-2.7429*	0.0923	-29.7117	0.00
PCGDP	0.0001*	0.0000	6.6071	0.00
PCGDP2	0.0000*	0.0000	-21.5748	0.00
GE	-5.6845*	0.0536	-106.0367	0.00
CL	0.3160*	0.0090	34.9405	0.00
Adjusted R-squared		0.997969		
F-statistic		10974.17*		
Prob(F-statistic)		0.00		
Total Trade Equation				
C	-529.3351*	23.6407	-22.3908	0.00
Gr	114.8408*	6.4965	17.6774	0.00
Gr2	-4.0739*	0.4084	-9.9759	0.00
REER	30.0498*	3.8941	7.7168	0.00
REER2	-2.5577*	0.4181	-6.1177	0.00
GCF	0.7501*	0.0231	32.5171	0.00
IF	0.0043*	0.0003	14.1639	0.00
Adjusted R-squared		0.996317		
F-statistic		6042.232*		

Prob(F-statistic)		0.00		
Fiscal Policy Equation				
C	22.4656*	1.5163	14.8158	0.00
TD	0.0909*	0.0024	37.5651	0.00
POP65	1.6282*	0.0223	73.1362	0.00
IN	-0.2294*	0.0349	-6.5695	0.00
PS	0.1863*	0.0399	4.6670	0.00
MS	-0.0015*	0.0001	-27.0455	0.00
MS2	0.0000000813*	0.0000000069	11.8513	0.00
Adjusted R-squared		0.996032		
F-statistic		5607.561*		
Prob(F-statistic)		0.00		
Monetary Policy Equation				
C	-208928.3000*	10090.5400	-20.7054	0.00
IF	0.3467**	0.1379	2.5136	0.0124
IF2	-0.0002*	0.0001	-2.6015	0.0098
Gr	74.0720*	11.0828	6.6835	0.00
Gr2	-4.5590*	0.6215	-7.3358	0.00
PCGDP	0.7100*	0.0307	23.1091	0.00
TR	4713.7710*	182.4772	25.8321	0.00
GE	819.6300*	52.2240	15.6945	0.00
GE2	-30.9000*	5.0371	-6.1345	0.00
DC	6.609497*	0.911211	7.2535	0.00
Adjusted R-squared		0.953855		
F-statistic		396.6943*		
Prob(F-statistic)		0.00		
Domestic Credit Equation				
C	17.79596*	1.685319	10.5594	0.00
MS	0.006163*	0.000595	10.35329	0.00
TD	-0.30437*	0.03027	-10.055	0.00
PCGDP	0.0009*	0.000279	3.231794	0.00
GDS	1.417457*	0.035565	39.85594	0.00
Adjusted R-squared		0.974523		
F-statistic		962.0682*		
Prob(F-statistic)		0.00		

**Significant at 1%; **Significant at 5%; ***significant at 10%.*

Table: 9 Results of Marginal Effects

Growth Equation		Inequality Equation		Total Trade Equation		Fiscal Policy Equation	Monetary Policy Equation		
IN	**TD**	**GR**	**PCGDP**	**GR**	**REER**	**MS**	**GR**	**IF**	**GE**
-0.1445	0.0013	-1.0722	-0.0001	48.9360	6.6392	-0.0015	0.3199	0.3263	3.4724

Testing Commodity Futures Market Efficiency under Time-Varying Risk Premiums and Heteroscedastic Prices

Duminda Kuruppuarachchi[*], Hai Lin[**], I. M. Premachandra[***]

[*]*Department of Decision Sciences, University of Sri Jayewardenepura, Sri Lanka, Email: duminda@sjp.ac.lk.*
[**]*School of Economics and Finance, Victoria University of Wellington, New Zealand. Email: Hai.lin@vuw.ac.nz*
[***]*Department of Accountancy and Finance, University of Otago, New Zealand. Email: i.premachandra@otago.ac.nz*

Abstract

We propose a test to measure market efficiency while estimating the time-varying risk premiums of commodity futures, given that the prices are heteroscedastic. The risk premium is estimated using a state-space model with a Kalman filter modified for heteroscedasticity. Using 79 commodity futures traded on 16 exchanges during the period 2000–2014 and a Monte Carlo simulation, we demonstrate that the proposal produces robust results compared with conventional approaches. The global financial crisis has improved the efficiency and affected the trading volumes of commodity futures, but it has had no effect on the average or the volatility of risk premiums.

Keywords: Commodity Futures; Market Efficiency; Futures Risk Premium; State-Space Model; Kalman Filter.

JEL Classification: G13, G14, G15

1. Introduction

This study proposes a new approach to test market efficiency and estimate the time-varying risk premiums of commodity futures, assuming that the prices are conditionally heteroscedastic. Contrary to the time-varying risk premium assumption in the proposed test, the conventional futures market efficiency tests in the literature (e.g., Bilson (1981), Baillie & Bollerslev (1989)) are mostly based on the joint assumptions of risk neutrality and rationality (i.e., speculators cannot make excess returns). This joint assumption, commonly referred to as the unbiasedness hypothesis, is derived from an uncovered interest rate parity theory in currency markets (Hansen & Hodrick (1980), Baillie, Lippens, & McMahon (1983)), and therefore its theoretical appropriateness for futures markets has been argued by authors such as Brenner & Kroner (1995).

The existence of a time-varying risk premium in futures has been documented by Fama (1984), Engle *et al.* (1987), Wolff (1987), McCurdy & Morgan (1992), Cheng (1993) and Baillie & Bollerslev (1994) for currency markets, and Fama & French (1987), Hirshleifer (1988, 1989), Trolle & Schwartz (2009), Basu & Miffre (2013) and Szymanowska, Roon, Nijman, & Goorbergh (2014) for commodity markets. Moreover, Bessembinder (1992) investigates both financial and commodity markets and examines the roles of systematic risk and hedging pressure in explaining time-varying futures risk premiums. McKenzie and Holt (2002) test market efficiency and unbiasedness separately and allowing the risk premium to vary (linearly and nonlinearly) over time. They found that markets are efficient and unbiased in the long-run, but in the short-run futures markets show a different behaviour for different commodities. Beck (1994), who identified the absence of a constant risk premium in commodity futures, suggests that any bias in these futures markets is not related to the presence of risk premium and might be related to informational inefficiencies. Brooks (2012) documents that when such futures risk premiums exist, the cost of hedging programmes would directly be affected. These studies extensively justify the incorporation of a time-varying risk premium component in a market efficiency test.

It is evident from the literature that most of the studies (e.g., Chowdhury (1991), Schroeder & Goodwin (1991), Beck (1994), Wang & Ke (2005), Andreou & Pierides (2008), Gebre-Mariam (2011), Pederzoli & Torricelli (2013)) that involve testing the unbiasedness hypothesis tend to reject the efficient market hypothesis, especially for commodity futures markets. Hodrick & Srivastava (1986) suggest that a futures market efficiency test is more appropriate in the presence of a risk premium component rather than risk neutrality. Furthermore, Brenner & Kroner (1995) document that the theory of unbiasedness is more relevant for currency markets than commodity markets, shedding some light on the high rejection rate of the unbiasedness hypothesis, especially in commodity markets. Brenner & Kroner (1995) further argue that market efficiency tests are biased towards the rejection of the unbiasedness hypothesis due to the stochastic properties of the differences between the contemporaneous futures prices and realized spot prices. The findings suggest the necessity of a test which is capable of testing the market efficiency and estimating the risk premium simultaneously. In the case of conventional efficiency tests which assume zero or constant risk premium, it is hard to justify whether a rejection of an efficient market hypothesis is purely due to the actual market inefficiency or due to inappropriate modelling of the underlying risk premium component. Motivated by these findings, the proposed test investigates the market efficiency while estimating the underlying risk premium component using a more general autoregressive (AR) model compared to the conventional approaches. The time-varying risk

premium component of the proposed test is estimated through a state-space model which uses a Kalman filter modified for heteroscedastic prices.

Apart from considering the time-varying risk premium, another important feature of the proposed test compared with the conventional approaches is that it assumes conditional heteroscedasticity in spot prices. The importance of this assumption in testing market efficiency has already been documented by Westerlund & Narayan (2013). We modify the traditional Kalman filter in this paper to take into account the conditional heteroscedasticity of spot prices. The proposed test is demonstrated using a comprehensive sample of 79 commodity futures traded on 16 exchanges worldwide during the period 2000–2014. In addition to the empirical evidence, we use a Monte Carlo simulation to demonstrate that the incorporation of a time-varying risk premium component and conditional heteroscedasticity in the proposed efficiency test minimizes the potential estimation biases of the conventional approaches documented in Hodrick & Srivastava (1986) and Brenner & Kroner (1995). Thus, the robustness of the proposed method under varying market conditions is well justified.

We use commodity futures markets to demonstrate the proposed methodology for two reasons. First, the presence of a risk premium is more prominent in commodity futures due to the existence of spot premia and term premia (Szymanowska *et al.*, 2014). Second, the commodity futures markets have emerged as a popular asset class in many financial institutions since 2000. According to the Futures Industry Association, the volume of commodity futures traded worldwide in 2012 represents 29% of the total futures trading. Moreover, from 2007 to 2016, the number of contracts traded in the agricultural, energy and non-precious metals categories rose from 1.16 billion to 5.77 billion depicting a remarkable growth in commodity investments. Hence, a proper understanding of the efficiency of commodity futures markets and their risk premiums is vital, as they could impact, for example, the hedging decisions of companies and the investment decisions of financial institutions.

This study contributes to the strand of literature on testing market efficiency in several ways. First, we propose a new approach for testing market efficiency in the presence of a time-varying risk premium and conditional heteroscedasticity of spot prices. Second, we perform a comprehensive analysis of the market efficiency of 79 commodity futures traded globally during the period 2000–2014. Empirical results show that the market efficiency and the size of the risk premium vary significantly not only across individual commodities but also among major market sectors. Third, we investigate the impact of the global financial crisis (GFC) in 2008 on commodity futures market efficiency and risk premiums. We find that the GFC has not made any significant permanent impact on the market efficiency and risk premiums of commodity futures apart from short-term deviations during the crisis period. Fourth, using a Monte Carlo simulation, we demonstrate that the proposed approach produces superior and robust results under varying market conditions compared with the conventional approaches with restrictions on the risk premiums.

The rest of the paper is organized as follows. Section II discusses conventional market efficiency tests and introduces the proposed approach for testing market efficiency. Section III examines the market efficiency and risk premiums of 79 commodities using the proposed approach. In Section III, the proposed approach is also compared with conventional approaches empirically to demonstrate the effect of time-varying risk premiums and heteroscedasticity assumptions on the

market efficiency tests. Section IV is devoted to a simulation study where we numerically investigate the sensitivity of the risk premium and heteroscedasticity assumptions on the performance of the proposed test compared with the conventional tests under varying market conditions. Section V concludes the paper.

2. Testing Futures Market Efficiency

Under the assumption of risk neutrality, the conventional market efficiency tests assume that the current futures price is an unbiased predictor of the future spot price at maturity; that is, these tests are based on the relationship in (1) which does not have a risk premium component.

$$E_\delta[S(t_i)] = F(t_i^\delta) \quad (1)$$

Here, $F(t_i^\delta)$ is the futures price of contract i ($i = 1,2,3,\dots,N$) of a commodity on δ days prior to the maturity day (t_i), while $S(t_i)$ is the spot price of the underlying commodity at maturity. N is the number of futures contracts (or number of maturity cycles) of the commodity during the sample period. $E_\delta[S(t_i)]$ is the expectation of $S(t_i)$, formed δ days prior to the maturity of a contract, conditional on the information set at time t_i^δ.

Consistent with our motivation in this study, Hodrick & Srivastava (1986) theoretically argue that the relationship in equation (1) does not hold when the stochastic behaviour of spot and futures prices is considered, suggesting the incorporation of a risk premium component in (1). This implies that a continuous form equilibrium relationship between the expected future spot price and the current futures price, as in equation (2), should hold. That is, the phenomenon, known as the rational expectation model (see Hull (2008), p. 119) illustrated in (2), must hold for an efficient futures market in the presence of a risk premium.

$$E_\delta[S(t_i)] = F(t_i^\delta)e^{\pi(t_i^\delta)} \quad (2)$$

Here, $\pi(t_i^\delta)$ is the δ −day risk premium for a contract i at time t_i^δ that is sufficiently large to yield a competitive expected return to holding inventory. The proposed efficiency test is based on the rational expectation model in (2) instead of (1), which allows the risk premium, $\pi(t_i^\delta)$, to vary across successive term structures.

A. Conventional Futures Market Efficiency Tests

The conventional tests of futures market efficiency briefly mentioned in Section I test the expectation relationship in equation (1) commonly referred to as the unbiasedness hypothesis under the risk neural assumption. One class of such conventional tests assumes a constant risk premium. For instance, Bilson (1981) introduces a test of futures (forward) market efficiency using a change-regression model such that $s(t_i) - s(t_i^\delta) = \beta_0 + \beta_1\left[f(t_i^\delta) - s(t_i^\delta)\right] + \varepsilon_\delta(t_i)$. Here, $f(t_i^\delta)$ and $s(t_i^\delta)$ are the log of futures ($F(t_i^\delta)$) and spot ($S(t_i^\delta)$) prices, respectively, at time t_i^δ, and $s(t_i)$ is the log of spot price on the maturity day, t_i. The unbiasedness hypothesis is implied by testing for the joint hypothesis, $\beta_0 = 0$, $\beta_1 = 1$, and non-existence of serial correlation in $\varepsilon_\delta(t_i)$. Since then, the same model has been used in the market efficiency literature, such as Hodrick & Srivastava (1986), Barnhart & Szakmary (1991), Serletis (1991), Switzer & El-Khoury (2007) and many others. Most of these studies find evidence against the unbiasedness hypothesis

and also result in negative estimates for β_1 in most cases. Brenner & Kroner (1995) provide theoretical evidence for observing such negative values for β_1 by using the cointegration theory of Engle & Granger (1987).

Another class of market efficiency tests that has become popular argues that if the future spot and current futures prices have a stochastic trend, then a necessary condition for the unbiasedness hypothesis to hold is to have a cointegration relationship between $s(t_i)$ and $f(t_i^\delta)$ with a cointegrating vector (1, -1). Thus, the cointegrating regression, $s(t_i) = \beta_0 + \beta_1 f(t_i^\delta) + \varepsilon_\delta(t_i)$, should satisfy the joint restriction, $\beta_0 = 0$, $\beta_1 = 1$, under the unbiasedness hypothesis. The two-step procedure of Engle & Granger (1987) was used to test the cointegration relationship between $s(t_i)$ and $f(t_i^\delta)$, which includes fitting the cointegration regression and testing for the joint restriction, $\beta_0 = 0$, $\beta_1 = 1$, and then testing for the stationarity of residuals $\varepsilon_\delta(t_i)$. See, for example, Baillie & Bollerslev (1989), Barnhart & Szakmary (1991), Bessler & Covey (1991), Chowdhury (1991) and Schroeder & Goodwin (1991) for details of such tests. However, Miljkovic (1999) documents various limitations of the above-mentioned two-step procedure employed for testing the cointegration between $s(t_i)$ and $f(t_i^\delta)$.

Later, Johansen & Juselius (1990) propose a maximum-likelihood cointegrating rank test to test both the cointegration relationship between $s(t_i)$ and $f(t_i^\delta)$ and the restrictions on the cointegrating vector in a single test in a multivariate context. This approach has become quite popular for testing the unbiasedness hypothesis in later studies. For example, among others, Lai & Lai (1991) and Masih & Masih (1995) use the cointegration rank test of Johansen & Juselius (1990) to test the efficiency in currency futures, Ackert & Racine (1999) for equity index futures and Wang & Ke (2005) for commodity futures. Even though the cointegration rank test of Johansen & Juselius (1990) is believed to be superior to the two-step procedure of Engle & Granger (1987) in testing the unbiasedness hypothesis, the former may also fail due to β_0 not being equal to zero as a result of a non-zero risk premium or due to the existence of a serial correlation in the residuals ($\varepsilon_\delta(t_i)$) (see Brenner & Kroner (1995)).

B. Proposed Test of the Market Efficiency Hypothesis

In order to construct the proposed efficiency test, we consider the natural logarithmic form of the expectation model in equation (2), which is illustrated as in equation (3):[1]

$$E_\delta[s(t_i)] = f(t_i^\delta) + \pi(t_i^\delta) - 0.5\sigma_\delta^2(t_i) \tag{3}$$

Here, $\sigma_\delta^2(t_i) = Var_\delta[s(t_i)]$ is the conditional variance of $s(t_i)$ on δ days ahead of time t_i. If a market for a particular commodity futures is efficient, with an expected risk premium of $\pi(t_i^\delta)$, then the equation (3) should hold.

[1] In equation (2), if we assume that $S(t_i)$ follows a lognormal distribution, then $E_\delta[S(t_i)] = e^{\mu_\delta(t_i)+0.5\sigma_\delta^2(t_i)}$ where $\mu_\delta(t_i) = E_\delta[ln\{S(t_i)\}]$ and $\sigma_\delta^2(t_i) = Var_\delta[ln\{S(t_i)\}]$. Then the logarithmic transformation of the expectations model in equation (2) can be written as $E_\delta[s(t_i)] = f(t_i^\delta) + \pi(t_i^\delta) - 0.5\sigma_\delta^2(t_i)$. We test the validity of the log-normal distribution assumption of $S(t_i)$ by testing the normality of residuals ($\varepsilon_\delta(t_i)$) in (4a) using Jarque–Bera and Shapiro-Wilk. Results from 79 futures indicate that 91% of the futures do not reject the normality assumption at 5% level according to the Jarque-Bera test and 86% according to the the Shapiro-Wilk test. The results are available on request.

An absolute measure of the time-varying risk premium, $\pi(t_i^\delta)$, in equation (3) is not observable. Various authors have attempted to estimate such unobservable risk premiums using various approaches. For example, Hirshleifer (1988) estimates the futures risk premium using its systematic risk and residual risk components. More recently, Casassus & Collin-Dufresne (2005) use the method of maximum likelihood to estimate the risk premium as a state variable by inverting the principal components of observed variables. A state-space model with Kalman filtering is an alternative approach that could be used to estimate such unobservable variables without using external proxies. This approach has already been used by Wolff (1987) and then by Cheng (1993) to estimate exchange rate risk premiums, and by Schwartz (1997), Chiou Wei & Zhu (2006) and Trolle & Schwartz (2009) to estimate commodity market risk premiums. The proposed market efficiency test also uses a state-space model to estimate the time-varying risk premium, but with a modified Kalman filtering, which allows the conditional variance of spot prices $[\sigma_\delta^2(t_i)]$ to vary with the time according to a GARCH process.

The state-space specification of equation (3) can be introduced as in equations (4a) and (4b):

(4a) $$s(t_i) = \beta_1 f(t_i^\delta) + \pi(t_i^\delta) - 0.5\sigma_\delta^2(t_i) + \varepsilon_\delta(t_i)$$

(4b) $$\pi(t_i^\delta) = \gamma_0 + \gamma_1 \pi(t_{i-1}^\delta) + \eta(t_i^\delta).$$

Equation (4a) is the measurement equation with a random error term, $\varepsilon_\delta(t_i)$, and equation (4b) is the state equation, which assumes an AR(1) process to model the time-varying risk premium with a white noise error term, $\eta(t_i^\delta)$. Here, $\pi(t_{i-1}^\delta)$ represents the δ-day risk premium during $[t_{i-1}^\delta, t_{i-1}]$, that is, the corresponding risk premium of the previous contract of a commodity. A reasonable justification for assuming an AR(1) process for the risk premium (apart from other ARMA specifications) can be found in Wolff (1987), Cheng (1993) and Chiou Wei & Zhu (2006). It should be noted that the intercept term of equation (4a) represents a time-varying risk premium $\pi(t_i^\delta)$, unlike the constant term β_0 in conventional approaches. The error terms $\varepsilon_\delta(t_i)$ and $\eta(t_i^\delta)$ are assumed to be serially uncorrelated and bivariate-normally distributed as illustrated in (4c):

(4c) $$\begin{pmatrix} \varepsilon_\delta(t_i) \\ \eta(t_i^\delta) \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} R^\delta & C^\delta \\ C^\delta & Q^\delta \end{pmatrix} \right].$$

Here, R^δ and Q^δ are unconditional variances of $\varepsilon_\delta(t_i)$ and $\eta(t_i^\delta)$ respectively, and C^δ is the covariance between $\varepsilon_\delta(t_i)$ and $\eta(t_i^\delta)$. The standard Kalman filter assumes $C^\delta = 0$. In the proposed test, we relax this assumption by assuming that $C^\delta \neq 0$, which allows us to create a more general market efficiency test where both $\varepsilon_\delta(t_i)$ and $\eta(t_i^\delta)$ are correlated due to the possibility of sharing common information from the market at time t_i^δ. We use the method proposed by Cheng (1993)[2] to estimate the covariance term C^δ.

Furthermore, the standard Kalman filter assumes that the variance, $Var[\varepsilon_\delta(t_i)] = R^\delta$ (a constant), ignoring its time-varying properties. However, this assumption may not be realistic due to the heteroscedastic nature of spot prices. Therefore, in the proposed efficiency test, we modify the

[2] See Cheng (1993) for the proof of the proposed modified estimation.

standard Kalman filter by allowing $\varepsilon_\delta(t_i)$ in equation (4a) to follow a GARCH (1,1) process[3] as illustrated in (4d) and (4e),

(4d) $$\varepsilon_\delta(t_i) = \xi(t_i)\sigma_\delta(t_i)$$

(4e) $$\sigma_\delta^2(t_i) = \varphi_0 + \varphi_1\varepsilon_\delta^2(t_{i-1}) + \varphi_2\sigma_\delta^2(t_{i-1}),$$

where $\xi(t_i) \sim N(0,1)$, and $\sigma_\delta^2(t_i)$ is the conditional variance which follows a GARCH (1,1) process. That is, we estimate the coefficients in equation (4) by letting the conditional variance $\sigma_\delta^2(t_i)$ vary with time instead of assuming it a constant, R^δ. The modified version of the Kalman filter that we used in the proposed efficiency test is illustrated in Appendix A. We follow the Seo (2007) method to estimate the likelihood function of the Kalman filter, with a conditional variance of $\sigma_\delta^2(t_i)$ as illustrated in (4e).

The proposed efficiency test is composed of two steps. First, according to Baillie & Bollerslev (1989), Bessler & Covey (1991), Chowdhury (1991), Chow (1998), Kellard, Newbold, & Rayner (1999), Wang & Ke (2005), Westerlund & Narayan (2013) and many others, a cointegration relationship between $s(t_i)$ and $f(t_i^\delta)$ is a necessary condition for the existence of market efficiency but not a sufficient condition, as the cointegrating vector $s(t_i) - \beta_0 - \beta_1 f(t_i^\delta)$ may deviate from (1 0 -1) (when testing under risk neutrality). Therefore, we use this as a necessary condition in the proposed test as well (in the presence of a time-varying stationary risk premium). That is, in step-(i) we test for the cointegration relationship in equation (4a). Second, if the efficient market hypothesis in equation (3) holds for a selected futures contract, then the condition $\beta_1 = 1$ should hold in the measurement model in equation (4a). Therefore, in step-(ii) we test the null hypothesis $\beta_1 = 1$. It is to be noted here that the traditional *t*-test cannot be used to test $\beta_1 = 1$ in the cointegration relationship, and hence the likelihood ratio test is used instead. In summary, the two-step procedure adopted in the proposed test (hereinafter referred to as PROP) to test the market efficiency of a commodity future at a particular time lag δ prior to its maturity is illustrated below.
Step-(i): Test for the stationarity of the residuals (H_0), $\varepsilon_\delta(t_i)$, in equation (4a) using the Phillips & Ouliaris (1990)[4] test. This is equivalent to testing the existence of a cointegration relation between $s(t_i)$ and $f(t_i^\delta)$ in (4a).

Step-(ii): If the residuals in step-(i) are stationary, then test for the restriction, H_0: $\beta_1 = 1$, in equation (4a) using the likelihood ratio test described below.

We compute the log likelihood (say LL_{ur}^δ) of the unrestricted model in equation (4) and the log likelihood (say LL_r^δ) of the restricted version of equation (4) for an efficient market by imposing the restriction, $\beta_1 = 1$. Under the null hypothesis that the market is efficient (i.e., $\beta_1 = 1$), we

[3] Various GARCH models have been considered to model the volatility in financial data, but we consider a GARCH (1,1) model, as it is the most common and the simplest model for the estimation, with a minimum number of model parameters.

[4] When a cointegrating relationship between $s(t_i)$ and $f(t_i^\delta)$ exists, $\varepsilon_\delta(t_i)$ in equation (4a) should be stationary because both $\pi(t_i^\delta)$ and $\sigma_\delta^2(t_i)$ are stationary. If $|\gamma_1| < 1$ in equation (4b), the risk premium $\pi(t_i^\delta)$ always satisfies the stationarity condition. This condition is examined numerically by testing the hypothesis H_0: $|\gamma_1| \geq 1$ vs. H_1: $|\gamma_1| < 1$, and we found the stationarity condition is accepted by the entire sample of futures in this study. Also, $\sigma_\delta^2(t_i)$ is stationary, as it is generated from a GARCH (1,1) process such that $\varphi_1 + \varphi_2 < 1$.

compute the log likelihood ratio test statistic, LLR^{δ} , as in equation (5), following the Neyman-Pearson Lemma:

(5) $$LLR^{\delta} = -2(LL_r^{\delta} - LL_{ur}^{\delta}) \sim \chi_v^2$$

Here, v is the number of restrictions in the null hypothesis, which is one in this case. If LLR^{δ} is significantly greater than the corresponding critical value $\chi_{v,\alpha}^2$, we conclude that the efficient market hypothesis is rejected for the corresponding futures contract at time lag δ.[5] If both the stationarity null hypothesis in step-(i) and the null hypothesis, H_0: $\beta_1 = 1$, in step-(ii) are not rejected, we conclude that the corresponding futures market is efficient at time lag δ on its spot market at the maturity. If the stationarity in step-(i) is not rejected but the restriction in step-(ii) is rejected, then we conclude that the market is inefficient, even though a cointegrating relationship between $s(t_i)$ and $f(t_i^{\delta})$ may exist. Finally, if the stationarity in step-(i) is rejected, we do not proceed on to step-(ii), concluding that the futures market has no cointegrating relationship with its spot market, and hence the market efficiency hypothesis is rejected. As a result, such contracts are also classified as inefficient.

We also notice that the frequency of the available contracts is not evenly distributed throughout the year. For example, the corn futures traded on the Chicago Mercantile Exchange (CME) are available for March, May, July, September and December maturities only. When the contract months of a commodity future are unevenly distributed like in this case, the time distances between successive contracts become unequal, which may possibly introduce a bias in estimating the risk premium in equation (4b). In order to overcome this problem in the proposed test, we estimate an intermediary risk premium following the method proposed by Jones (1980) (see Appendix A). Using this approach, we are able to keep the time distances equal when estimating the AR(1) model in equation (4b) and thereby avoid any possible biases. In cases where the contracts are available in all months during the year, such an estimation of the intermediary risk premium is not necessary.

3. Empirical Evidence

In this section, we first employ the proposed market efficiency test, PROP, to compare the market efficiencies and the risk premiums associated with 79 commodity futures chosen from major market sectors such as energy & fuel, precious metals, agricultural & livestock and industrial materials during the 2000–2014 period. The results from PROP are compared with three other tests – TEST1, TEST2 and TEST3 – in order to test for the robustness of the proposal. These three tests are variations of PROP derived simply by imposing restrictions on the parameters in (4).

TEST1: In (4a) we assume a constant risk premium ($\pi(t_i^{\delta}) = \beta_0$) with homoscedastic errors ($\sigma_{\delta}^2(t_i) = \sigma_{\delta}^2$).

TEST2: In (4a) we assume a constant risk premium ($\pi(t_i^{\delta}) = \beta_0$) with heteroscedastic errors as in equations (4d) and (4e).

TEST3: Equivalent to the proposed PROP, but with homoscedastic errors ($\sigma_{\delta}^2(t_i) = \sigma_{\delta}^2$).

[5] It is to be noted here that the parameter estimates in (4) are specific for each lag δ (i.e., time t_i^{δ}), but we drop the superscript δ from the parameters$\beta_1, \gamma_0, \gamma_1, \varphi_0, \varphi_1$, and φ_2 to simplify the notations.

TEST1 is consistent with the conventional efficiency tests used by Baillie & Bollerslev (1989) and others thereafter. TEST2 is an extension of TEST1 with the heteroscedastisity condition and it represents the conventional test used by Westerlund & Narayan (2013). TEST3 is a simplified version of PROP where the errors are assumed to be homoscedastic. We also employ the proposed efficiency test to investigate the effect of the GFC on the commodity futures market efficiency and risk premiums. Consistent with Westerlund and Narayan (2013), we define the pre-GFC sample period as January 2000 to August 2008 and the post-GFC sample period as September 2008 to December 2014. We have an adequate number of data points for each sub-sample period analysis.

A. Sample Data

We retrieve daily nearby futures prices of a cross-sectional sample of 79 commodities traded on 16 futures exchanges worldwide from Bloomberg. A list of individual commodities selected along with the time spans covered in the dataset is illustrated in Appendix B along with their descriptive statistics. In order to ensure the adequacy of data points in the sub-sample period analysis, we consider only the commodity futures with data available from 1 January 2000. For those commodity futures, the data are retrieved up to 31 December 2014.[6] We prefer nearby futures contracts, since more distant contracts are less actively traded and hence less volatile. The existence of a risk premium associated with nearby futures may also be important in investigating arbitrage opportunities. Our sample of futures consists of nine commodities from the energy & fuel sector, 10 commodities from the precious metals sector, 51 commodities from the agricultural & livestock sector and nine commodities from the industrial materials sector. All prices are converted into US dollar values in order to minimize the exchange rate fluctuation effects in local currencies. The spot price at the maturity of a contract is approximated by using the corresponding futures price on the same date, assuming that both prices are the same under no-arbitrage conditions.[7]

Futures contracts are traded on different cycles, depending on the commodity as well as the exchange where those futures are traded on. Therefore, the frequency of maturity dates of a particular commodity could possibly be monthly or less. For example, WTI futures traded on CME allows us to extract a monthly dataset, whereas the corn futures traded on the same exchange has a dataset in March, May, July, September and December cycles. Such datasets are then organized for all commodities with the price at the maturity (we use the last date of trading as the day of maturity in each contract) against the futures price $\delta -$days prior to the maturity. We use 20 business days (one month) prior to the maturity of the contract as the lagged time period, that is, $\delta = 20$.

B. Market Efficiency Test Results for Commodity Futures

The augmented Dickey-Fuller unit root tests find that the price series of all the commodity futures in Appendix B are unit root processes.[8] This test is necessary to justify the validity of the

[6] The time period for individual commodities depends on the availability of data during the sample period, 2000–2014. See Appendix B for the time periods of each commodity in the sample.
[7] Futures contracts often amalgamate commodities with different qualities; as a result, there is no one-and-only spot commodity that can be used as the underlying asset of a futures contract, especially in sectors like industrial materials, agricultural and livestock. To address this concern, futures prices at maturity are often used as proxies for spot prices (see Fama & French (1987) and Schwartz (1997) among others).
[8] The Schwarz Information Criteria (SIC) is used to determine the lag structure of the augmented Dickey-Fuller test. The results of unit root tests at the 5% level of significance are available upon request.

cointegrating relationship in step-(i) of the proposed approach. Having found that price series follow unit root processes, we test for the market efficiency of these commodity futures by following step-(i) and (ii) of the proposed efficiency test (PROP) and TEST1-3, and the corresponding results are illustrated in Table 1. In order to investigate the characteristics of the estimated risk premiums, they are transformed into the annualized risk premiums, using $\pi_{an}(t_i^{\delta}) = 252\left[\pi(t_i^{\delta})/\delta\right] \times 100\%$. The average estimated annualized risk premiums, corresponding parameter estimates from the state-space model and other relevant test results are also illustrated in Table 1.

[Insert Table 1 around here]

The 12th column of Table 1 tests for the stationarity of the residual series, $\varepsilon_{\delta}(t_i)$, using the Phillips & Ouliari (1990) test, as in step-(i) of the proposed approach. It can be seen that the residuals of all commodities in the table are stationary at the 1% level of significance (Phillips & Ouliari's (1990) critical value is -3.3865), implying that a cointegration relationship illustrated in equation (4a) exits between spot and futures prices of all the commodities. In addition, the Ljung-Box Q-test in the 13th column of Table 1 confirms that there are no autocorrelations left in the residual series at the 1% level. Having satisfied the necessary condition in step-(i) of the proposed efficiency test, we proceed on to step-(ii) and test for the market efficiency hypothesis, $\beta_1 = 1$, for each commodity using PROP and TEST1-3, and the results are illustrated in columns 3–6 of Table 1.

In Table 1, the market efficiency test results vary considerably among the four tests. According to PROP, all commodities except nine agricultural & livestock commodities (Panel A) and two precious metal commodities (Panel D) are efficient during the full sample period 2000–2014 at the 1% or 5% level of significance. The inefficient precious metal commodities are gold futures traded on CME and Silver Mini futures traded on Multi Commodity Exchange-India. Among inefficient agricultural commodities, four of them (soybean meal, lean hogs, oats, coffee) belong to the US market, while others are mostly from the Asian region (India and Japan) except for bread milling wheat futures traded on the South African Futures Exchange. Mainly, over-speculation and government intervention may cause market inefficiencies in the agricultural sector (Wang & Ke (2005) and Brooks, Prokopczuk, & Wu (2015)), while macroeconomic influence could cause inefficiencies in precious metals (Christie-David, Chaudhry, & Koch (2000), Batten, Ciner, & Lucey (2010), Narayan, Narayan, & Zheng (2010), Shafiee & Topal (2010), Apergis (2014)).

Columns 7–11 of Table 1 illustrate the estimated parameters of the proposed model in (4). The autoregressive coefficient, γ_1, used to estimate the time-varying risk premium in (4b) is significant only for six commodities out of 79, but it seems to take fairly large values close to 0.6 for most of the commodities. This implies some instability in the model parameters as well as the fact that the risk premiums do not carry long-term memory for most of the commodities, and therefore they are not predictable. This is something that we can expect due to the potential existence of the Samuelson effect (Samuelson (1965)) in nearby futures. Furthermore, the parameter estimates in columns 9–11, which represent the heteroscedasticity component of commodity prices, reveal that the GARCH effect (φ_2) is more prominent than the ARCH effect (φ_1) in all the sectors. Overall, the GARCH effect is significant for 46.8% of the commodity futures and the ARCH effect is

significant for 36.7% of the commodities, implying the importance of considering the heteroscedasticity of commodity prices in market efficiency tests.

Finally, we compare the performance of the proposed test (PROP) against the conventional approaches TEST1-2 and the simplified version of PROP (TEST3) by summarising the results of Table 1 in Table 2. In Section IV, we perform a simulation study to compare the performance of the four approaches numerically under varying market conditions and find that PROP is the most robust test.[9] Given this fact, Table 2 demonstrates how well the conventional approaches perform compared with PROP in a real-life application.

[Insert Table 2 around here]

In Table 2, PROP classifies 68 commodities as efficient and 11 as inefficient during the full sample period 2000–2014. The number of commodities classified as efficient and inefficient by TEST1-3 are illustrated in the table as percentages of the numbers (68 and 11) corresponding to PROP. That is, we use PROP's classification as a benchmark for comparison with 100% accuracy. Table 2 suggests that TEST1-3 classify only 86.8%, 75% and 92.6% of the commodities as efficient compared with 100% by PROP. TEST3 provides the closest result to PROP, which is understandable due to the underlying time-varying risk premium assumption in both tests. As far as the inefficient commodity futures are concerned, TEST1-3 classify only 27.3%, 27.3% and 45.5% of the commodities as inefficient compared with 100% by PROP. Again, Test 3 is the second best test. Table 2 also reveals that TEST1-3 are biased towards misclassifying inefficient commodities as efficient (with percentages 72.2%, 72.7% and 54.5%, respectively) compared with misclassifying efficient commodities as inefficient (with percentages 13.2%, 25% and 7.4%, respectively). The results suggest that both the time-varying risk premium and conditional heteroscedasticity assumptions play a vital role in the performance of the futures market efficiency tests. Therefore, it is evident from the proposed test that the predictive ability of futures prices on their future spot prices need to be tested after adjusting for the risk premium and conditional heteroscedasticity. Otherwise, a test would result biased conclusions.

C. An Analysis of the Risk Premiums of Commodity Futures

This section investigates the nature of estimated annualized risk premiums[10] of the 79 commodity futures considered in this study over the sample period 2000–2014 by market sectors. We use averages and standard deviations of time-varying annualized risk premiums corresponding to each commodity's futures to examine the cross-sectional differences in the levels and volatilities of risk premiums. As the commodity futures vary based on the sector they belong to (e.g., energy & fuels vs. industrial materials), as well as on their individual characteristics such as momentum and valuation ratios, investors may be exposed to different levels and volatilities in risk premiums. A positive risk premium indicates a backwardated market which is an indication of tight inventory conditions in the underlying commodity where an investor is exposed to a high premium for immediate access to physical commodity. In contrary, a negative risk premium indicates a contango market which reflects a high inventory levels and low premiums for immediate access to the underlying commodity. Therefore, the both sign and the size of the risk premium are

[9] See Section IV for simulated evidence.

[10] It is to be noted here that we present winsorized risk premium values in order to reduce the effect of possible spurious outliers.

important for investors for their investment decisions. Table 3 summarizes results for the estimated risk premiums where Panel A illustrates the average annualized risk premiums and Panel B reports the volatility of annualized risk premiums.

[Insert Table 3 here]

It is evident from Panel A of Table 3 that the average annualized risk premium of nearby futures varies considerably across market sectors. The highest risk premium (1%) is for the energy & fuels sector commodities and the lowest (0.29%) is for the agricultural & livestock sector. The overall average risk premium when all commodity markets are considered as a whole is 0.422%. It is also evident that the risk premiums vary between -4% and 5.6% in the entire commodity sectors. High kurtosis and skewness values indicate the asymmetry in average risk premiums across all cross-sectional groups of commodities. The average risk premiums show a positive cross-sectional skewness. Moreover, third-quartile values are greater in magnitudes compared with the corresponding first-quartile values. This indicates the potential of a positive risk premium in commodity markets during the years 2000 and 2014 and hence a potential of backwardation rather than contango in nearby futures reflecting tight inventories in commodities. Furthermore, the stem-and-leaf plot in Panel A of Table 3 shows that there are two extremely low (< -1.9%, i.e., below the first quartile minus 1.5 times the inter-quartile range) and seven extremely high (> 2.5%. i.e., above 1.5 times the third quartile plus the inter-quartile range) risk premiums. Confidence intervals of average risk premiums for the full sample over the period 2000–2014 are in a positive interval (0.115%, 0.729%), whereas the intervals corresponding to individual market sectors take alternative signs. This implies that the long-term return on investments is not guaranteed through nearby futures of the same commodity sector, but guaranteed from a diversified portfolio of commodity futures. It should also be noted that the size of the annualized risk premiums is relatively small for the nearby futures contracts. Furthermore, Panel A of Table 3 presents the percentage of positive average risk premiums among the commodities. It is evident that the majority of commodities from the full sample (62%) provides positive risk premiums on average indicating log-term backwardation in commodity futures markets. The least backwardated market is the agricultural sector which depicts 55% positive average risk premiums among those contracts.

Panel B of Table 3 illustrates the standard deviations of monthly annualized risk premiums over the full sample period depicting the short-term volatility in market risk premiums to which investors may be exposed. It is evident that precious metals (8%) record the highest average volatility in risk premiums, while industrial materials (4.5%) record the lowest. Overall, from Panel B, it is apparent that the volatility in expected returns from the underlying risk premiums is subjected to variation across the sectors as well as among the commodities within a sector. This finding is consistent with existing literature such as Bessembinder & Chan (1992) among others, where futures risk premiums are known to be time varying and affected by different forces of economic states. It should also be noted that the relatively a high amount of volatility in risk premiums is inevitable for nearby futures due to the Samuelson effect (Samuelson, 1965). We next demonstrate the impact of a macroeconomic event such as the GFC (2007–2009) on the efficiency and risk premiums of the commodity futures market.

D. Impact of the GFC

Table 4 illustrates the market efficiency and risk premiums estimated from PROP, and the average trading volumes of commodity futures during the pre-GFC and post-GFC periods. Panels A–D present results for each commodity's futures by market sectors, while Panel E compares the pre- and post-GFC results. As far as the market efficiencies in columns 3 and 4 are concerned, mixed results can be found between the pre- and post-GFC periods. It is evident from the agricultural and livestock sector in Panel A that a substantial number (15) of previously inefficient markets have become efficient after the GFC, while the opposite is true for the energy & fuel sector in Panel B. Brent crude oil traded on ICE and gasoline and kerosene traded on the Tokyo Commodity Exchange have become inefficient after the GFC. The market inefficiency of ICE Brent oil is interesting, as this is one of the two benchmarks for crude oil. Liu, Schultz, and Swieringa (2015) document evidence for deviations in Brent oil prices from WTI oil after the GFC, which could be the main reason for the observed inefficiency in Brent oil futures during the post-GFC period. Moreover, among the limited literature related to agricultural and livestock sector, Pederzoli & Torricelli (2013) investigate the market efficiency of corn futures traded on CME during the period 1998–2011 and document that they are not efficient and the market efficiency is not affected by the GFC. However, our results contradict Pederzoli & Torricellis (2013) by providing evidence for market efficiency in corn futures for all periods. In the industrial materials sector, only aluminium traded on the Shanghai Futures Exchange during the pre-GFC period and aluminium alloy traded on the London Metal Exchange during the post-GFC period are inefficient at the 5% level. Apart from these aluminium futures, all other industrial materials futures are efficient during both sub-sample periods. Consistent with our findings for industrial materials, the copper market was found efficient during the period 1999–2009 in Fung, Liu, & Tse (2010). It is also interesting to note that the prices of all precious metals futures are efficient in both the sub-sample and full-sample periods at the 5% level.

Narayan *et al.* (2010) document that the oil and gold futures markets during the period 2002–2008 are interrelated, and therefore one market is predictable based on the other one. They conclude that both markets are inefficient, which contradicts our conclusion, as we found both markets to be efficient. Later, Westerlund & Narayan (2013) employ a conventional approach with a heteroscedastic assumption on a 2005–2011 dataset to document that crude oil futures are inefficient during the full period as well as during both the pre- and post-GFC periods, which again contradicts our findings. According to Panel E of Table 4, the percentage of efficient commodities has increased to 88.6% during the post-GFC period from 83.5% during the pre-GFC period. This implies that commodity futures have become more efficient after the GFC, possibly due to the information flow into financial markets as a result of the crisis. It is also evident from the Wilcoxon Signed Rank test results in the same panel that neither the risk premium nor its standard deviation have been significantly affected by the GFC, but the trading volume has. The increase in the average trading volume during the post-GFC period indicates that the demand has risen for commodity futures as a result of the financialization process, as documented by Tang & Xiong (2012).

One possible reason for the contrasting findings discussed above could be the differences in the sample periods used in various studies. More importantly, the contradictory results of market efficiency documented in this study could be due to the risk-neutral or constant risk premium and homoscedastic assumptions in the conventional efficiency tests compared with the proposed test, as demonstrated in our simulation experiment in Section IV and also according to Brenner &

Kroner (1995) and Hodrick & Srivastava (1986). The averages and the standard deviations reported in columns 7–10 of Table 4 are all non-zero, indicating that a time-varying risk premium component exists in all the commodity futures in the sample. Moreover, in the unreported results[11] for the sub-sample periods as well as the reported results for the full-sample period in Table 1, we have provided evidence for the existence of heteroscedasticity in futures prices. Therefore, our findings demonstrate the importance of considering the time-varying risk premium and the conditional heteroscedasticity in a market efficiency test, such as the proposed, compared with conventional approaches.

[Insert Figure 1 here]

In order to get an idea about the behaviour of the estimated risk premiums, we compare the estimated risk premiums corresponding to the four major commodities traded on CME with their futures and spot prices and average trading volumes in Figure 1. We select these commodities due to their high trading volumes on CME. It is interesting to see in Figure 1 that the estimated risk premiums of crude oil and copper futures are more volatile than the corn and gold futures, implying a greater level of uncertainty in the risk premiums of crude oil and copper markets compared with corn and gold futures. According to Gorton, Hayashi, & Rouwenhorst (2013), the state of inventories is informative about the futures' risk premiums of storable commodities. This could be a possible cause for the larger volatilities of risk premiums of crude oil and copper markets. The US Energy Information Administration[12] provides evidence to support this argument, in which they argue that crude oil stocks dropped by 20% during the June 2007 to December 2007 period and increased again by 30% in April 2009, to record the highest variation in supplies during the 2000–2014 period.

It is also evident from Figure 1 that there is an increasing trend in the average trading volume in all four commodities during the period 2000–2014. This provides further evidence for the financialization of commodity markets where the demand could arise not only from the consumers of commodities but also from investors entering into these markets for the purpose of hedging (Tang and Xiong (2012)). In addition, a specific reason for the increasing demand for corn could be due to the increasing trend of using grains such as corn for biofuels. For example, Abbot, Hurt, & Tyner (2011) report that it took 27% of the 2010–2011 corn crop to meet the demand for corn to produce ethanol, compared with 10% for the 2005–2006 crop. On the other hand, gold futures seem to be the least-affected commodity by the GFC due to gold's consistent flow in prices during the sample period, which could be due to the speculation on the gold market against the risk due to the GFC (Vivian & Wohar (2012)).

4. Simulation Experiment to Test the Robustness of the Proposed Test

The purpose of this section is twofold: (i) To provide a comparison of the proposed efficiency test (PROP) with the conventional approaches to see how effective the proposed efficiency test is under varying market conditions. As the conventional approaches are special cases of the proposed test, this comparison also allows us to examine the sensitivity of the proposed approach on the time-varying risk premium and heteroscedasticity assumptions. (ii) To examine the sensitivity of the proposed and conventional approaches on the sample size, *N*.

[11] The results are available upon request.
[12] We retrieve monthly US ending stocks of crude oil from http://www.eia.gov for the period 2000–2014.

A. Design of the Experiment

We simulate log spot prices and log futures prices corresponding to a single commodity with N number of contracts using a data-generating process similar to the one in equations (4a)–(4e). Prices are simulated for the nearest futures contract (i.e., time lag $\delta = 20$), which is consistent with our empirical analysis in Section III. For the parameters $\gamma_0, \varphi_0, Q^{\delta}, C^{\delta}$ and the initial values of $f(t_i^{\delta})$ and $\pi(t_i^{\delta})$ in (4a)-(4e), we assume the values corresponding to the WTI crude oil traded on CME. The simulation experiment is designed to investigate the sensitivity of the parameters $\beta_1, \gamma_1, \varphi_1$ and φ_2 on the outcome of the efficiency tests as follows. First, we simulate the prices from an efficient market (i.e., set $\beta_1 = 1$) with varying risk premiums (γ_1) and the degree of heteroscedasticity in prices (i.e., by varying φ_1 and φ_2). By changing these parameters in the simulation model, we expect to create varying market conditions to test the robustness of the proposed test. The market efficiency of prices simulated in 5000 runs is tested using the proposed test PROP and TEST1-3, and the results are reported in Table 5. In Table 5, the simulation is repeated for a different number of contracts, N = 30, 60, 120, 240, 480, to investigate the size effect. The simulation experiment in Table 5 is repeated in Table 6, where we test the efficiency of prices simulated from an inefficient market (i.e., $\beta_1 \neq 1$). Table 6 considers four inefficient markets with $\beta_1 = 0.9, 0.99, 1.01, 1.1$, respectively.

[Insert Table 5 and 6 here]

B. Results of the Simulation Experiment

In Table 5, we test the market efficiency given that the simulated market is efficient. It is evident from the first two panels of Table 5 that the proposed test PROP or its simplified version (TEST3) delivers the highest percentage of acceptance of the efficient market hypothesis compared with the conventional tests TEST12 given that the market is efficient and prices are heteroscadesitic ($\varphi_1, \varphi_2 \neq 0$). PROP outperforms the other three tests when the number of contracts (i.e., sample size N) is greater than, 60 which is usually the case in a real-life application, such as the one that we discussed in Section III (see Appendix B for the sample sizes of the contracts, where the average sample size is 112). In the third panel, when the heteroscedasticity is not present ($\varphi_1, \varphi_2 = 0$), PROP outperforms other tests, even when N is as small as 30. In all three panels, it can also be noticed that the percentages of acceptance of the efficient market hypothesis decreases in most of the cases when γ_1 in the risk premium model increases. The mean values of the estimated $\hat{\beta}_1$ show that both PROP and TEST3 produce unbiased estimates of the true value $\beta_1 = 1$ for an efficient market with the minimum underlying standard deviations compared with the conventional approaches, TEST1 and TEST2, especially when conditional heteroscedasticity is present in the prices. Consistent with this finding, Brenner & Kroner (1995), Hodrick & Srivastava (1986) and many others document that the conventional approaches, such as TEST1 and TEST2, produce biased, and more specifically, low estimated values for β_1. Such a downward estimation bias in TEST1 and TEST2 also reduces their power, as those tests have the tendency to accept the efficient market hypothesis, $\beta_1 = 1$, even for values such as $\beta_1 = 1.01$, as demonstrated in Table 6. The RMSE significantly drops in all the tests when heteroscedasticity is not present. Overall, the results in Table 5 reveal that the performance of a market efficiency test improves due to the time-varying risk premium and heteroscedasticity assumptions in the test, as documented in Westerlund & Narayan (2013).

In Table 6, we test market efficiency using prices from a simulated inefficient market. Overall, the results in Table 6 reveal that TEST3 and PROP outperform conventional tests TEST1-2 by giving the lowest percentage of acceptance of the efficient market hypothesis. TEST3 and PROP produce very similar results, except when the simulated market efficiency is closer to the null hypothesised value (i.e., when $\beta_1 = 0.99, 1.01)$, in which case TEST3 demonstrates a remarkably better performance.

5. Conclusion

This paper proposes a new approach for testing the futures market efficiency under time-varying risk premiums and heteroscedastic prices. The proposal is demonstrated by re-examining the market efficiency of 79 commodity futures traded on 16 exchanges globally. The proposed test uses a state-space model with a modified Kalman filter for conditional heteroscedasticity. An interesting feature of the test is that it is capable of testing the futures market efficiency while estimating the time-varying risk premium. These new features of the proposed test allow us to test the predictive ability of futures prices on the underlying spot prices after controlling for risk premiums and conditional heteroscedasticity. Empirical results based on a sample of 79 commodity futures chosen from four commodity market sectors – agricultural & livestock, precious metals, industrial materials and energy & fuel – reveal that the market efficiency varies across market sectors. We also find that the percentage of efficient commodity futures has increased after the GFC, implying an increase in information flow to these markets as a result of the GFC. A comparison of the averages and the volatilities of the estimated annualized risk premiums among commodity futures reveal that they are not consistent among either commodities or market sectors. It is found that most of the commodities depict backwardated markets providing a compensation to the investors on their perceived risk. However, the size of the average risk premiums is relatively low for nearest futures with a high magnitude in volatility. Moreover, a pre- and post- comparison shows that GFC has not significantly affected the average and the volatility of risk premiums, but the average trading volume has increased after the GFC. Thus the economic impact of the GFC is not evident from commodity risk premiums and volatility of risk premiums over the time as far as nearest futures are concerned. A Monte Carlo simulation demonstrates that the proposed test is robust against different market conditions, such as the time-varying risk premiums of commodities and the conditional heteroskedasticity in spot prices, compared with the conventional approaches. Further research may focus on extending the proposed market efficiency test and estimation method of risk premiums for contracts further to the nearest futures. Extensions of the study can also be proposed to non-commodity market sectors.

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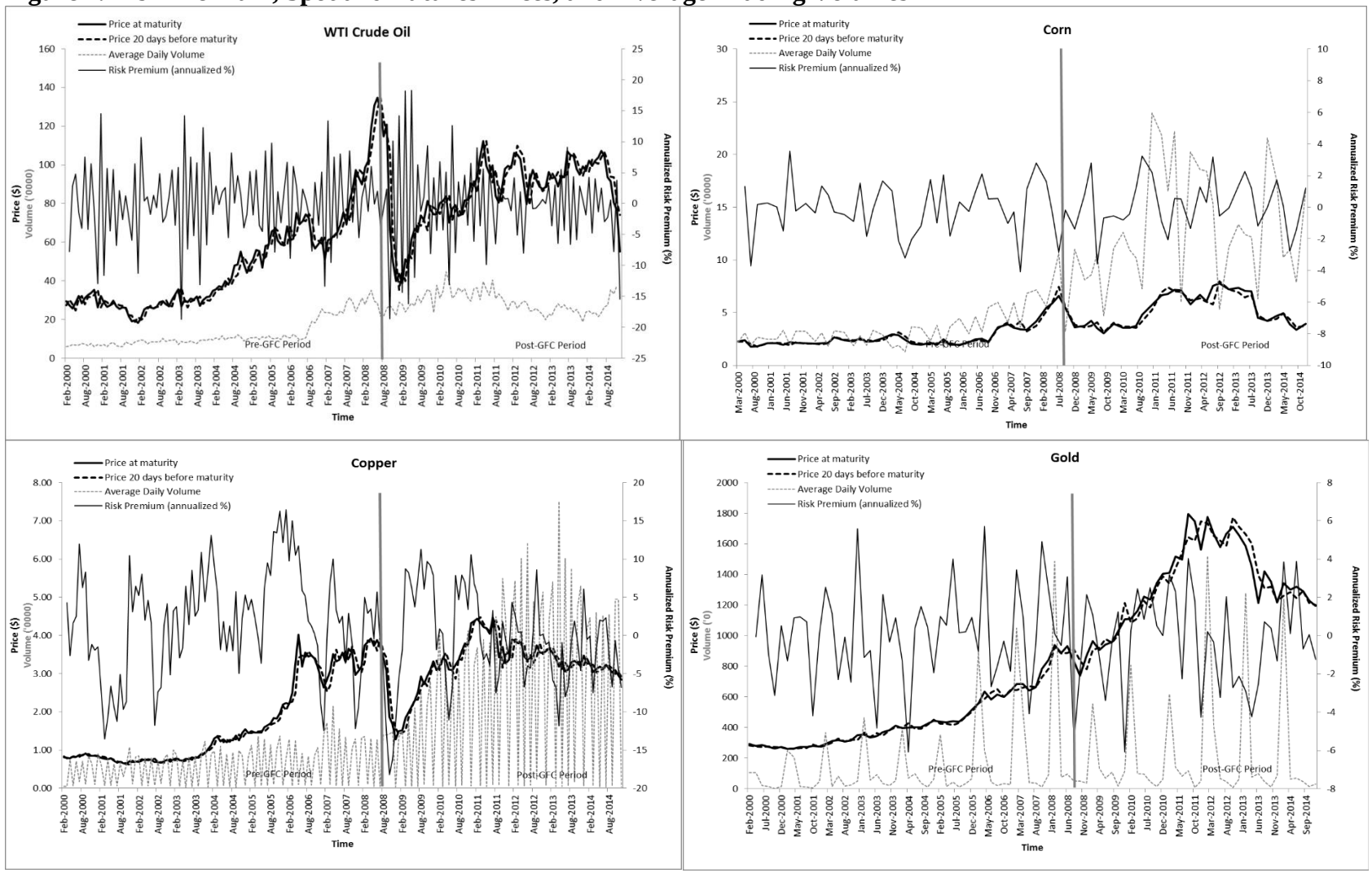
Figure 1. Risk Premium, Spot and Futures Prices, and Average Trading Volumes



This figure illustrates annualized risk premiums, spot and futures prices, and average trading volumes of four major commodities traded on CME from four market sectors. Vertical line in each graph divides the sample into pre- (January 2000-August 2008) and post-GFC periods (September 2008-December 2014).

Table 1. Results of Market Efficiency Tests for Full Sample Period

This table illustrates the results from the proposed market efficiency test (PROP) and conventional market efficiency tests (TEST-TEST3) corresponding to the sample of 79 futures traded worldwide for the full sample period, 2000-2014. The first and second columns present Bloomberg ticker and name of the contract of each futures. Columns 3-6 illustrate the estimated value of β_1 in equation (4) for PROP and TEST1-3 respectively and the market efficiency test results. Rejecting $H_0: \beta_1 = 1$ means the market is not efficient and they are marked with an asterisk *. Columns from seventh to eleventh present other parameter estimates of equation (4) for PROP. All parameters are tested for significance using the LLR test statistic in equation (5).The twelfth column presents the results of the stationarity test of the residual series $\varepsilon_\delta(t_i)$ in step-(i) of the proposed test using the Phillips & Ouliaris (1990) test (POT) where the null hypothesis is: $H_{0:}$. The thirteenth column presents the test results for residual autocorrelations using the Ljung-Box test (LBQ) with 6 lags. ***, **, and * denote significance at 1%, 5%, and 10% respectively. An efficient market is identified by the significance of the stationarity in column twelve (i.e., rejection of H_0 in Phillips & Outliers (1990) test) and acceptance of $H_0: \beta_1 = 1$ (step-(ii) for each test).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Panel A: Agricultural & Livestock												
Ticker	*Name*	$\hat{\beta}_1$ *(PROP)* $H_0: \beta_1 = 1$	$\hat{\beta}_1$ *(TEST 1)* $H_0: \beta_1 = 1$	$\hat{\beta}_1$ *(TEST 2)* $H_0: \beta_1 = 1$	$\hat{\beta}_1$ *(TEST 3)* $H_0: \beta_1 = 1$	$\hat{\gamma}_0$ $H_0: \gamma_0 = 0$	$\hat{\gamma}_1$ $H_0: \gamma_1 = 0$	$\hat{\varphi}_0$ $H_0: \varphi_0 = 0$	$\hat{\varphi}_1$ $H_0: \varphi_1 = 0$	$\hat{\varphi}_2$ $H_0: \varphi_2 = 0$	*POT*	*LBQ*
AC	Corn	0.9994	0.9742	0.9857	0.9990	-1E-06	0.0078	0.0002*	0.9077	0.00001	-8.00771	2.188 (0.902)
AK	No.1 Soybeans	1.0012	0.9997	1.0004	1.0011	0.0001	0.848	0.000033	0.9125	0.0465	-6.90354	8.441 (0.208)
AE	Soybean Meal	1.0025	0.9902	0.9814	1.0020*	0.0003	-0.826	0.0014*	0.5961	0.1296	-12.4391	6.248 (0.396)
C	Corn	1.0010	1.0023	1.0016	0.9992	0.0000	-0.0509	0.0000	0.9976	0.0000	-8.38364	5.817 (0.444)
S	Soybeans	1.0059	0.9867	0.9808	1.0038**	-2E-06	-0.5957	0.0015**	0.6629	0.0062	-10.9632	8.811 (0.184)
BO	Soybean Oil	0.9967	0.9764	0.9768	0.9949	0.000022	0.8887	0.00001	0.9933	0.000027	-10.0755	6.083 (0.414)
SM	Soybean Meal	1.0042** *	1.0033	0.9901***	1.0036***	0.000011	-0.8875*	0.0007	0.8595	0.0192	-11.4535	6.538 (0.366)
W	Wheat	1.0027	0.9833	0.9895*	1.0006	0.0002	-0.7131	0.0004**	0.9451	0.0127	-7.2910	8.733 (0.189)
YP	Mini-sized Wheat	1.0110*	0.9477	0.9642	1.0104	0.0001	0.8283	0.0014	0.8878	0.00007	-6.24326	11.392 (0.077)
LC	Live Cattle	0.9906*	1.002	1.0173***	0.9749*	0.000052	-0.7475	0.0005***	0.2234	0.4766***	-10.9555	12.471 (0.052)
LH	Lean Hogs	0.9371** *	0.9393*	0.9548	0.9397***	0.0001	-0.8964	0.0005	0.9252	0.0016	-12.7804	4.962 (0.549)
FC	Feeder Cattle	1.0125	1.0043	1.0066	1.0124	-9.4E-05	0.4634	0.0001	0.8694	0.0126	-11.1612	24.836 (0.000)
DA	Class III Milk (Basic Milk)	0.9992	0.9679	0.9729	0.9985**	-0.00006	0.6054	0.0022**	0.1382	0.0668	-12.0773	7.958 (0.241)
KV	Class IV Milk	1.0002	0.9828	0.9963	0.9999*	-0.0003	0.5616	0.0003***	0.7974	0.1024***	-9.25217	16.722 (0.010)
LE	Nonfat Dry Milk	0.9961	0.9927	1.0002***	0.9974*	-0.0002	0.7278	0.0003	0.4655**	0.3620***	-8.68857	19.259 (0.004)

O	Oats	1.0274**	0.9727	0.9724	1.0231	-6.3E-05	0.8143	0.0003	0.9701	0.00001	-7.53012	5.175 (0.522)
RR	Rough Rice	0.9986	0.9923	0.9855	0.9965	-3.7E-05	-0.849	0.0006	0.7427	0.1043	-9.04631	1.235 (0.975)
LB	Random Length Lumber	0.9968	1.0318	1.0357	0.9961*	-5.5E-05	0.9000*	0.0005	0.9379	0.00003	-8.40335	7.871 (0.248)
RS	Canola	1.0030*	0.9898	0.9922	1.0027*	-8.1E-05	-0.0017	0.0001	0.9605	0.00001	-9.47995	6.087 (0.414)
CC	Cocoa	0.9998	0.9351***	0.9286***	0.9999	-0.000017*	-0.0086	0.00001	0.9788*	0.000010*	-9.09549	6.063 (0.416)
KC	Coffee C	0.9423** *	0.9335***	0.9327***	0.9308***	-3.1E-05	-0.3596	0.0003	0.9513	0.00003	-6.98585	7.086 (0.313)
CT	Cotton No. 2	0.9528*	0.9059***	0.9146***	0.9543**	0.0002	0.7989	0.0011	0.8738	0.0013	-7.0860	4.336 (0.631)
SB	Sugar No. 11	0.9959	0.983	0.9716**	0.9966	-0.0002	0.6513	0.0006**	0.6606***	0.2583***	-11.9515	8.932 (0.177)
S9	Crude Palm Oil	1.0004	0.9759	0.9884	0.9984	-3.5E-05	0.6861	0.0008***	0.7026**	0.0976**	-8.92198	12.325 (0.055)
Q8	Soy Bean	0.9981	1.0099	1.0082	0.9971	0.0002	0.2473	0.0031***	0.0297	0.0464	-8.55118	2.107 (0.910)
M7	Soy oil	0.9974	1.0014	0.9997	0.9978	0.00001	0.5345	0.0003	0.7664	0.000086	-10.3735	4.893 (0.558)
M1	Mustard seed	0.9995	0.9945	0.9982	1.0003	-0.000005**	0.5915	0.000074** *	0.9497**	0.0001	-10.4168	8.677 (0.193)
M3	Pepper	0.9983**	0.9946	0.9845	0.9985*	0.000000**	0.8999	0.00001	0.9728**	0.0002***	-9.60715	2.638 (0.853)
Q6	Turmeric	0.9952**	1.0303	1.0420*	0.9995*	-0.000016**	-0.8761	0.0003***	0.7984***	0.1883	-6.2399	16.230 (0.013)
QC	Cocoa	1.0020	0.9361***	0.9386***	1.0018	0.000036	0.8335	0.0003	0.9265	0.0107	-7.94312	2.267 (0.894)
EP	Corn	1.0014	0.9558*	0.9662	1.0001	0.000037	0.7888	0.000088**	0.9801**	0.0125**	-8.74738	10.125 (0.119)
QK	Feed Wheat	1.0015	0.9666	0.9710	1.0009	0.000011	0.0035	0.0021	0.5205	0.00001	-8.91894	3.985 (0.679)
CA	Milling Wheat	1.0015*	0.9847	0.9896	1.0011	-0.00008	-0.0024	0.000077** *	0.9990**	0.00001	-11.5243	14.163 (0.028)
QW	White Sugar	1.0003	0.9851	0.9765	0.9998	0.0001	-0.385	0.000054	0.8917***	0.0806	-8.14816	12.381 (0.054)
IJ	Rapseed	1.0006	0.9995	1.0000	1.0002	-6.1E-05	-0.6149	0.0002	0.9493	0.000053	-6.48397	4.311 (0.635)
AX	Arabica Coffee	1.0023	0.9486***	0.9403***	1.0011	-2.1E-05	0.8651	0.001	0.8536	0.0025	-7.17964	6.595 (0.360)
LS	Live Cattle	1.0005	1.0107	1.0156	1.0005*	0.000017	-0.6585	0.0013***	0.2491	0.3088**	-13.0283	7.678 (0.263)
AQ	Corn	0.999	1.0016	1.0000	0.9999	0.000098	0.6093	0.000077	0.7004***	0.2994***	-10.2102	7.770 (0.255)
FS	Frozen Shrimp	0.9975	0.9421**	0.9716	0.9954**	0.000002	0.6725	0.000015	0.8428***	0.1492***	-12.838	5.886 (0.436)
SJ	Raw Sugar	1.0008**	0.9625***	0.9795***	1.0019*	-0.0002	-0.3153	0.000049** *	0.6874***	0.2128	-8.91527	5.897 (0.435)

MW	Hard Red Spring Wheat	1.0026	0.9766	0.9843	1.0031	0.000064	-0.7947	0.0044**	0.051	0.2003**	-7.67497	3.540 (0.739)
WZ	White Maize	1.0039	0.9551	0.9527*	1.0037	0.0001**	0.8982	0.0072***	0.000017	0.1533**	-8.29453	5.838 (0.442)
YW	Yellow Maize	1.0000	0.9737	0.9797	1.0000	-7E-06	0.0414	0.00001	0.000011	0.0694*	-7.93956	5.542 (0.476)
EB	Bread milling wheat	1.0040***	0.9784	0.9722	1.0035***	-1.8E-05	0.7764	0.0005	0.8445	0.000016	-8.89109	8.045 (0.235)
SY	Soybeans of Class SB	0.9996	0.9828	0.9847	0.9985	-2.1E-05	0.0886	0.003	0.5291	0.000012	-8.39984	2.361 (0.884)
SU	Sunflower Seed	1.0017	0.9691	0.9800**	1.0013	0.000041	0.3973	0.0004*	0.944	0.00005	-8.06202	8.795 (0.185)
JC	Corn	1.0016	1.0062	1.0033	1.0007	0	-0.4221	0.0006	0.9273	0.0002	-9.45344	3.830 (0.700)
JS	Soybean	1.0014	0.9769	1.0084	1.0006	-0.0002	0.8402	0.0021	0.8338	0.0027	-8.65314	3.556 (0.736)
JZ	Arabica Coffee	1.0012***	0.9010***	0.8986	0.9995***	-0.0004	0.8992	0.01	0.2681	0.0002	-7.85066	26.723 (0.000)
JR	Raw Sugar	1.0034	1.0049	1.0075	0.9986	0.0018	-0.756	0.0006***	0.999	0.000011	-10.0979	2.896 (0.822)

Panel B: Energy & Fuels

Ticker	*Name*	$\hat{\beta}_1$ *(PROP)* $H_0: \beta_1 = 1$	$\hat{\beta}_1$ *(TEST 1)* $H_0: \beta_1 = 1$	$\hat{\beta}_1$ *(TEST 2)* $H_0: \beta_1 = 1$	$\hat{\beta}_1$ *(TEST 3)* $H_0: \beta_1 = 1$	$\hat{\gamma}_0$ $H_0: \gamma_1 = 0$	$\hat{\gamma}_1$ $H_0: \gamma_1 = 0$	$\hat{\varphi}_0$ $H_0: \varphi_0 = 0$	$\hat{\varphi}_1$ $H_0: \varphi_1 = 0$	$\hat{\varphi}_2$ $H_0: \varphi_2 = 0$	*POT*	*LBQ*
KO	Crude Palm Oil	1.0013	0.9837	0.9727**	1.0008	-6.2E-05	0.8543*	0.0006	0.7673***	0.1427***	-11.6476	16.730 (0.010)
FO	Fuel Oil	1.0004	0.9658*	0.9674*	0.9991	-0.0001	0.7044	0.0009	0.697	0.0758	-9.23774	6.995 (0.321)
CL	Light Sweet Crude Oil (WTI)	1.0014	0.9791	0.9860***	1.0001	0.0001	-0.7743	0.0044***	0.4083	0.1181**	-13.8924	3.329 (0.767)
NG	Natural Gas (Henry Hub)	0.9957	0.9214***	0.9523***	0.9908	-0.00004	-0.399	0.00001	0.9916**	0.000010***	-13.0072	6.617 (0.358)
HO	Heating Oil	0.9972	0.9802*	0.9795**	0.9881*	-0.00002	0.8967*	0.0006**	0.7162***	0.1770***	-13.3526	2.363 (0.883)
CO	ICE Brent Crude	1.0033	0.9766**	0.9829***	1.0017	-0.0003	-0.4545	0.0005*	0.7406	0.2174***	-11.6494	13.066 (0.042)
QS	ICE Gasoil	1.0012*	0.9754**	0.9749**	1.0017**	0.0003	-0.6579	0.0003	0.8466***	0.0963***	-13.4884	9.695 (0.138)
JV	Gasoline	1.0008	0.9903	0.9958*	1.0005	-3.5E-05	0.7033	0.00001	0.9926*	0.000074**	-12.6334	3.635 (0.726)
JX	Kerosene	1.0007	0.9851	0.9878	1.0008	-8E-06	0.7521	0.0001	0.9118**	0.0673**	-13.4518	4.726 (0.579)
CP	Crude Oil	1.0011	0.9836*	0.9929	0.9997	-0.0001	0.6634	0.0005**	0.6267***	0.2429***	-11.0454	5.080 (0.534)

Panel C: Industrial Materials

Ticker	*Name*	$\hat{\beta}_1$ *(PROP)* $H_0: \beta_1 = 1$	$\hat{\beta}_1$ *(TEST 1)* $H_0: \beta_1 = 1$	$\hat{\beta}_1$ *(TEST 2)* $H_0: \beta_1 = 1$	$\hat{\beta}_1$ *(TEST 3)* $H_0: \beta_1 = 1$	$\hat{\gamma}_0$ $H_0: \gamma_1 = 0$	$\hat{\gamma}_1$ $H_0: \gamma_1 = 0$	$\hat{\varphi}_0$ $H_0: \varphi_0 = 0$	$\hat{\varphi}_1$ $H_0: \varphi_1 = 0$	$\hat{\varphi}_2$ $H_0: \varphi_2 = 0$	*POT*	*LBQ*
CU	Copper Cathode	1.0007	0.9913	1.0003	1.0011*	0.000001	0.8164	0.0005	0.7369*	0.1603***	-14.7415	4.934 (0.552)
AA	Aluminum	1.0002	0.9722	0.9857***	1.0005	0.000003	0.7253	0.000075	0.8618***	0.0735***	-13.4104	10.177 (0.117)
HG	Copper	1.0037	0.9942	0.9991	1.0017	-2.9E-05	0.7029	0.0005***	0.6953	0.1797***	-12.9371	1.213 (0.976)
S4	Nickel	1.0002	0.9706	0.9887	1.0011	0.00001	-0.7461	0.000028	0.9827***	0.000082***	-9.57958	7.580 (0.271)
LA	Aluminium	1.0004	0.9705*	0.9729	1.0000	0.00003	-0.8704***	0.0001***	0.8944*	0.0533**	-13.0441	13.958 (0.030)
LY	Aluminium Alloy	1.0003*	0.9813	0.9929	1.0003	0.000052***	-0.3216	0.0006***	0.0104	0.9896***	-11.6146	10.952 (0.090)
LP	Copper	1.0008	0.9942	0.9983	1.0010	-8.6E-05	0.6585	0.0002	0.8263***	0.1188***	-11.8638	8.298 (0.217)
LX	Zinc	1.0003	0.9836	0.9962	1.0000	0.000018	-0.6255	0.000042	0.9296***	0.0677***	-13.2289	5.925 (0.432)
JN	Rubber	1.0031	0.9889	0.9860	0.9988	0.000004	0.8637	0.000013	0.9965	0.000019	-13.3672	6.383 (0.382)

Panel D: Precious Metals

Ticker	*Name*	$\hat{\beta}_1$ *(PROP)* H_0: $\beta_1 = 1$	$\hat{\beta}_1$ *(TEST 1)* H_0: $\beta_1 = 1$	$\hat{\beta}_1$ *(TEST 2)* H_0: $\beta_1 = 1$	$\hat{\beta}_1$ *(TEST 3)* H_0: $\beta_1 = 1$	$\hat{\gamma}_0$ H_0: $\gamma_1 = 0$	$\hat{\gamma}_1$ H_0: $\gamma_1 = 0$	$\hat{\varphi}_0$ H_0: $\varphi_0 = 0$	$\hat{\varphi}_1$ H_0: $\varphi_1 = 0$	$\hat{\varphi}_2$ H_0: $\varphi_2 = 0$	*POT*	*LBQ*
GC	Gold	1.0017**	0.9929	0.9911	1.0002	-3E-06	0.0079	0.0012***	0.000084	0.4406*	-9.50594	3.761 (0.709)
SI	Silver	1.0017	0.9700**	0.9936***	1.0002	0.000044	0.7223	0.0018***	0.437	0.2355	-11.0303	10.735 (0.097)
PA	Palladium	0.9978	0.9647	0.9582*	0.9973	-4.8E-05	0.1502	0.00001	0.9792	0.00001	-9.03038	8.037 (0.235)
Z7	Gold	1.0008	0.9801	1.0012	1.0002	0.0001	-0.0447	0.0006*	0.3779***	0.4568***	-10.9924	8.044 (0.235)
U5	Gold	1.001	0.9789	0.9849	1.0009	0.0001	0.5817	0.00001	0.9865	0.000014	-8.83942	4.158 (0.655)
SN	Silver M	1.0025***	0.9963	0.9944	1.0027	-0.0002	-0.7246	0.0029***	0.5786	0.0343***	-8.46502	3.530 (0.740)
JG	Gold	1.0009	0.9936	0.9994	0.9990	0.000013***	0.8493	0.001	0.3733	0.0989***	-9.75593	3.256 (0.776)
JI	Silver	0.9801	0.9873	0.9804	0.9886	-0.0002	-0.6454	0.0038	0.8245	0.00001	-9.50134	4.072 (0.667)
JA	Platinum	1.0011	0.9806	0.9753***	1.0005	0.000007	0.4284	0.0008***	0.3737**	0.4017***	-8.09886	8.137 (0.228)
JM	Palladium	1.0033	1.0228	1.0253	1.0015	0.000042	0.8993*	0.0007	0.8293*	0.0454***	-9.72711	4.400 (0.623)

Table 2. Comparing Results of Market Efficiency Tests

This table summarises the efficiency test results in Table 1 corresponding to the proposed market efficiency test (PROP) and TEST1-TEST3. In Table 1, the PROP identifies a total of 68 commodities as efficient and 11 commodities as inefficient in the entire sample and they are indicated in the two rows of this Table. The number of commodities identified by TEST1-3 as efficient and inefficient in Table 1 are expressed in this Table as a percentage of the number classified as efficient (i.e., 68) and inefficient (i.e., 11) by PROP for comparison purpose.

		TEST1				**TEST2**				**TEST3**			
		Inefficient		**Efficient**		**Inefficient**		**Efficient**		**Inefficient**		**Efficient**	
		Count	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**
PROP	Inefficient (11)	3	27.3%	8	72.7%	3	27.3%	8	72.7%	5	45.5%	6	54.5%
	Efficient (68)	9	13.2%	59	86.8%	17	25.0%	51	75.0%	5	7.4%	63	92.6%

Table 3. Summary of Estimated Risk Premiums by PROP

This table summarises the estimated annualized risk premiums of the 79 commodities in the sample using PROP during the sample period 2000 to 2014. Average and the volatility of the annualized time-varying risk premiums of each commodity are reported in Panel A and B respectively. Results are summarized for the full sample as well as by market sectors. The last column presents the Stem-and-Leaf plots of average risk premiums and the volatility of each commodity for the full sample period 2000-2014.

Panel A: Analysis of average annualized risk premiums

	Annualized Risk Premium					*Stem-and-Leaf Plot for the Full Sample*	
	Full Sample	*Agricultural & Livestock*	*Energy & Fuels*	*Industrial Materials*	*Precious Metals*	*Frequency*	*Stem & Leaf*
Mean	0.422	0.290	0.998	0.535	0.475	2.00	Extremes (=<-1.9)
95% Confidence Interval for Mean	(0.115,0.729)	(-0.105, 0.686)	(-0.396,2.392)	(-0.392, 1.461)	(-0.087,1.038)	2.00 7.00	-1 . 12 -0 . 5577799
Median	0.179	0.106	0.470	0.067	0.347	19.00	-0 . 0000000112222233344
Std. Deviation	1.371	1.407	1.814	1.206	0.786	25.00	0 . 0000000111222223333444444
Minimum	-4.012	-4.012	-0.235	-0.585	-0.181	9.00	0 . 555667899
Maximum	5.611	5.018	5.611	3.320	2.574	6.00	1 . 022244
Skewness	1.251	0.824	2.520	1.796	2.480	2.00	1 . 58
Kurtosis	4.796	3.965	6.759	3.461	6.949	7.00	Extremes (>=2.5)
Quartile 1	-0.235	-0.337	-0.021	-0.192	-0.006	Stem width:	1.00
Quartile 3	0.695	0.669	1.236	1.108	0.550	Each leaf:	1 case(s)
% Positive avg. risk premiums	62%	55%	67%	78%	80%		

Panel B: Analysis of volatility of annualized risk premiums

	Standard Deviation of Annualized Risk Premiums					*Stem-and-Leaf Plot for the Full Sample*	
	Full Sample	*Agricultural & Livestock*	*Energy & Fuels*	*Industrial Materials*	*Precious Metals*	*Frequency*	*Stem & Leaf*
Mean	6.817	6.860	7.577	4.495	7.999	11.00	0 . 00000000111
95% Confidence Interval for Mean	(5.791,7.842)	(5.620,8.100)	(4.338,10.816)	(1.462,7.529)	(3.678,12.321)	10.00 17.00	0 . 2222223333 0 . 44444455555555555
Median	6.160	6.623	6.404	4.055	5.975	16.00	0 . 6666666666777777
Std. Deviation	4.578	4.408	4.214	3.946	6.041	9.00	0 . 888888889
Minimum	< 0.001	0.001	3.863	< 0.001	0.265	5.00	1 . 00111
Maximum	19.635	19.635	18.121	11.362	19.204	6.00	1 . 223333
Skewness	0.838	0.681	2.341	0.445	0.877	5.00	Extremes (>=17)
Kurtosis	0.616	0.352	6.152	-0.797	0.044		
Quartile 1	3.864	3.695	5.285	0.516	3.921	Stem width:	10.00
Quartile 3	8.829	8.931	6.404	7.578	11.982	Each leaf:	1 case(s)

Table 4. Market Efficiency, Risk Premiums and Trading Volumes during pre- and post-GFC Periods

This table compares market efficiency, risk premiums estimated from PROP, and average volumes during pre- and post-GFC periods corresponding to the sample of 79 futures traded worldwide. The first and second columns present Bloomberg ticker and name of the contract of each futures. Third and fourth columns illustrate the estimated value of β_1 in equation (4) and market efficiency test results using PROP for during pre- and post-GFC periods. Fifth and sixth columns present parameter estimates corresponding to the autoregressive coefficient of the risk premium specification in equation (4). All parameters are tested for significance using the LLR test statistic in equation (5).Seventh and eighth columns present averages of estimated annualized risk premiums for pre- and post-GFC periods while ninth and tenth columns present standard deviation of estimated annualized risk premiums. Eleventh and twelfth columns present average daily trading volumes of each futures during pre- and post-GFC periods. ***, **, and * denote significance at 1%, 5%, and 10% respectively. Panels A-D summarize results by market sectors while Panel E compares results between pre-GFC (January 2000-August 2008) and post-GFC (September 2008-December 2014) periods. The inefficient markets where the null hypothesis H_0: $\beta_1 = 1$ is rejected are marked with an asterisks *.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Agricultural & Livestock											
Ticker	*Name*	$\hat{\beta}_1$ *(Pre-GFC)* H_0: $\beta_1 = 1$	$\hat{\beta}_1$ *(Post-GFC)* H_0: $\beta_1 = 1$	$\hat{\gamma}_1$ *(Pre-GFC)* H_0: $\gamma_1 = 0$	$\hat{\gamma}_1$ *(Post-GFC)* H_0: $\gamma_1 = 0$	*Average Risk Premium (Pre-GFC)*	*Average Risk Premium (Post-GFC)*	*Stdev of Risk Premium (Pre-GFC)*	*Stdev of Risk Premium (Post-GFC)*	*Average Volume (Pre-GFC)*	*Average Volume (Post-GFC)*
AC	Corn	0.9998 ***	0.9989	0.2099 **	0.5475	-0.0328	0.7606	0.020	3.581	9561.35	2331.97
AK	No.1 Soybeans	1.0026 *	1.0002	0.8998	0.5078	-2.9190	-0.2156	13.866	8.451	15618.71	718.95
AE	Soybean Meal	1.0023 **	1.0025	-0.9000	-0.6234	2.5068	-6.4204	11.080	4.176	7794.96	7920.18
C	Corn	0.9918	1.0053	-0.1714	0.6025	0.2514	0.2584	7.682	3.228	51834.12	125570.88
S	Soybeans	1.0094 *	1.0030	0.6006	-0.8824	-0.8318	14.7986	3.917	18.103	34451.10	81869.92
BO	Soybean Oil	0.9925	1.0151	0.5872	0.7228	-0.8399	0.8655	3.685	5.648	13905.77	38248.24
SM	Soybean Meal	1.0040 *	1.0050 **	0.7026	-0.8999 *	-0.4340	0.7166	5.166	19.600	13872.48	28921.55
W	Wheat	1.0122	1.0018	-0.5748	-0.0766	-0.4254	1.6441	0.031	2.343	21369.56	48514.32
YP	Mini-sized Wheat	1.0264	1.0034	0.6521	-0.7017	9.8433	0.1453	30.990	0.325	97.88	309.24
LC	Live Cattle	0.9677	1.0287	-0.8358	-0.8187	-0.0734	-1.4337	12.623	8.332	9213.38	17674.16
LH	Lean Hogs	0.9298 *	0.9408	-0.9000	-0.8963	-8.4833	-0.4691	13.640	13.592	4638.43	10322.54
FC	Feeder Cattle	0.9582	1.0162 *	0.5392	0.4971	-0.1185	-0.0215	5.377	7.161	881.98	1277.76
DA	Class III Milk	0.9986	0.9998	0.2306	0.6703	0.2689	5.5723	1.737	5.875	58.20	165.03
KV	Class IV Milk	1.0007	1.0008	-0.6640 *	0.7860	-1.1438	-0.8457	5.923	9.926	0.34	1.07

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Agricultural & Livestock											
Ticker	*Name*	$\hat{\beta}_1$ *(Pre-GFC)* H_0: $\beta_1 = 1$	$\hat{\beta}_1$ *(Post-GFC)* H_0: $\beta_1 = 1$	$\hat{\gamma}_1$ *(Pre-GFC)* H_0: $\gamma_1 = 0$	$\hat{\gamma}_1$ *(Post-GFC)* H_0: $\gamma_1 = 0$	*Average Risk Premium (Pre-GFC)*	*Average Risk Premium (Post-GFC)*	*Stdev of Risk Premium (Pre-GFC)*	*Stdev of Risk Premium (Post-GFC)*	*Average Volume (Pre-GFC)*	*Average Volume (Post-GFC)*
LE	Nonfat Dry Milk	0.9848	1.0122 **	0.6663 **	0.8423	-1.0937	1.4024	5.351	10.507	0.07	3.74
O	Oats	1.0522 **	1.0180	0.8344	-0.0681	0.8663	0.7803	1.372	1.544	671.04	627.55
RR	Rough Rice	1.0063	0.9933	0.6910	0.5973	-0.0573	0.6755	0.070	8.032	280.90	652.96
LB	Random Length Lumber	0.9965	1.0012	0.8826	-0.2228	0.5415	-0.8570	10.327	1.288	577.82	524.58
RS	Canola	1.0033 **	1.0030 *	-0.4805	0.0009	-0.5596	-4.4141	4.670	0.883	4416.73	8870.11
CC	Cocoa	1.0015	0.9994	-0.5823	-0.5448	-0.0161	-2.5653	2.090	0.062	3420.44	6617.97
KC	Coffee C ®	0.9118 ***	0.9693	0.6135	-0.7226	-0.2979	1.1374	24.968	5.393	5107.96	6101.01
CT	Cotton No. 2	0.9662 *	0.8749 **	0.7749	0.8996	0.8464	-0.4804	6.308	13.823	7425.65	8989.05
SB	Sugar No. 11	0.9950 *	0.9979	0.4245	0.8999	-0.6867	0.1293	12.927	6.567	25096.64	49592.45
S9	Crude Palm Oil	0.9943	1.0012	0.4482	0.7955	0.3819	-5.3721	3.785	10.285	14.80	445.39
Q8	Soy Bean	1.0005	1.0002	0.6420	-0.6991	-6.2872	-0.7073	23.761	14.415	14377.16	69222.89
M7	Soy oil	0.9949 **	0.9979	-0.8984 **	-0.1551	2.6190	-25.3810	11.217	3.267	16157.98	72473.49
M1	Mustard seed	0.9983	0.9998	0.2429	0.1402	0.4554	-0.0794	9.325	3.841	17697.45	64193.16
M3	Pepper	0.9979	0.9969	0.8767	0.0191	-0.0187	-1.7944	0.298	0.040	4269.00	3811.74
Q6	Turmeric	0.9914 ***	1.0010	-0.8036	0.8952	3.4333	-2.1787	17.110	14.454	12550.00	13243.22
QC	Cocoa	1.0038	1.0021	0.6456	-0.9000 **	-0.7914	0.2336	2.940	18.145	2742.03	4899.26
EP	Corn	1.0034	0.9968	0.6708	0.9000	-0.9136	0.0882	3.711	16.680	177.50	702.28
QK	Feed Wheat	1.0016	0.9995	-0.0521	-0.5377	-0.0610	-0.0314	1.477	0.382	103.81	157.08
CAQ	Milling Wheat	1.0013	1.0010	0.4104	0.0098	0.6537	0.0045	2.079	1.042	517.42	12818.29
W	White Sugar	1.0008	1.0000	-0.6519	0.8999	-1.5898	-4.3671	5.949	17.061	3017.00	3560.75
IJ	Rapseed	0.9998	1.0027	0.7533	0.5421	-1.3269	-4.5791	5.099	0.663	367.83	2812.82
AX	Arabica Coffee	1.0059 *	0.9984	-0.8211	-0.8846	-0.3093	5.1937	5.017	5.374	634.39	607.12
LS	Live Cattle	0.9994	1.0014	-0.6288	0.0913	0.3590	0.2340	2.186	2.945	42.33	1801.53

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Agricultural & Livestock											
Ticker	*Name*	$\hat{\beta}_1$ *(Pre-GFC)* H_0: $\beta_1 = 1$	$\hat{\beta}_1$ *(Post-GFC)* H_0: $\beta_1 = 1$	$\hat{\gamma}_1$ *(Pre-GFC)* H_0: $\gamma_1 = 0$	$\hat{\gamma}_1$ *(Post-GFC)* H_0: $\gamma_1 = 0$	*Average Risk Premium (Pre-GFC)*	*Average Risk Premium (Post-GFC)*	*Stdev of Risk Premium (Pre-GFC)*	*Stdev of Risk Premium (Post-GFC)*	*Average Volume (Pre-GFC)*	*Average Volume (Post-GFC)*
AQ	Corn	1.0009	0.9986	0.0235	0.4600	1.1450	0.0457	1.542	2.584	76.69	6.41
FS	Frozen Shrimp	0.9932 *	0.9996	-0.3090	0.5998	0.3517	5.6118	3.556	6.668	153.39	2.76
SJ	Raw Sugar	1.0022	1.0007	-0.8441	-0.7746 *	-0.3976	0.5680	3.456	8.893	9.69	2.86
MW	Hard Red Spring Wheat	1.0047	0.9998	-0.8422	0.1324	0.9293	-0.4295	2.278	0.370	2091.29	2207.21
WZY	White Maize	1.0066 ***	1.0045	0.6973	0.6968	-4.9046	0.5959	21.281	5.449	1548.44	1842.64
W	Yellow Maize	1.0000	1.0001	-0.5508	0.5525	-0.0002	2.1622	0.001	0.113	72329.93	125570.88
EB	Bread milling wheat	1.0046 **	1.0038	0.7521	-0.7527	0.0519	0.4371	9.460	7.364	454.75	1619.82
SY	Soybeans of Class SB	1.0023 ***	0.9988	0.8998	-0.2686	0.9068	0.2268	0.098	1.201	34.83	553.29
SU	Sunflower Seed	1.0028	1.0001	-0.4002	-0.8633	-3.4422	-0.0762	13.058	0.262	104.04	398.50
JC	Corn	1.0038	0.9996	0.3232	-0.6052	0.1410	-0.5247	0.724	2.377	401.40	79.30
JS	Soybean	1.0021	1.0040 ***	-0.0121	0.8198	-0.3076	0.0765	4.344	0.878	110.18	71.53
JZ	Arabica Coffee	1.0082 **	0.9908 ***	-0.8999	0.8986 ***	-2.9811	0.0465	21.251	40.638	105.64	7.03
JR	Raw Sugar	1.0004	1.0000	-0.8996	-0.7051	3.5979	0.2644	23.708	5.772	75.74	14.21
Panel B: Energy & Fuels											
Ticker	*Name*	$\hat{\beta}_1$ *(Pre-GFC)* H_0: $\beta_1 = 1$	$\hat{\beta}_1$ *(Post-GFC)* H_0: $\beta_1 = 1$	$\hat{\gamma}_1$ *(Pre-GFC)* H_0: $\gamma_1 = 0$	$\hat{\gamma}_1$ *(Post-GFC)* H_0: $\gamma_1 = 0$	*Average Risk Premium (Pre-GFC)*	*Average Risk Premium (Post-GFC)*	*Stdev of Risk Premium (Pre-GFC)*	*Stdev of Risk Premium (Post-GFC)*	*Average Volume (Pre-GFC)*	*Average Volume (Post-GFC)*
FO	Fuel Oil	1.0025	0.9994	0.6003	0.3453	-0.3947	-0.5827	3.553	9.575	3006.31	12816.97
CL	Crude Oil (WTI)	1.0035	1.0006	-0.5147	-0.8495	-0.0392	-1.3900	3.518	13.286	114045.40	251817.25
NG	Natural Gas (Henry Hub)	0.9999	0.9927	0.7388	0.8545	-0.2425	-0.5310	0.978	3.445	38698.17	106352.49
HO	Heating Oil	0.9933	0.9986	0.8988 **	0.6340	9.4872	-1.1770	12.992	4.863	24786.87	51981.68

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Agricultural & Livestock											
Ticker	*Name*	$\hat{\beta}_1$ *(Pre-GFC)* H_0: $\beta_1 = 1$	$\hat{\beta}_1$ *(Post-GFC)* H_0: $\beta_1 = 1$	$\hat{\gamma}_1$ *(Pre-GFC)* H_0: $\gamma_1 = 0$	$\hat{\gamma}_1$ *(Post-GFC)* H_0: $\gamma_1 = 0$	*Average Risk Premium (Pre-GFC)*	*Average Risk Premium (Post-GFC)*	*Stdev of Risk Premium (Pre-GFC)*	*Stdev of Risk Premium (Post-GFC)*	*Average Volume (Pre-GFC)*	*Average Volume (Post-GFC)*
CO	ICE Brent Crude	1.0070	1.0018 **	-0.4132	0.4445	0.6954	1.0308	3.961	12.071	55481.46	172056.62
QS	ICE Gasoil	1.0040	1.0001	-0.8422	0.1647	0.7077	0.6204	10.946	2.812	20377.14	58987.66
JV	Gasoline	1.0012	1.0021 **	0.3191	0.8991	-0.1502	0.6616	2.134	10.652	777.31	285.51
JX	Kerosene	1.0025 *	1.0014 **	0.4430	-0.7624	-0.0849	-0.1791	1.583	7.450	612.62	356.29
CP	Crude Oil	1.0022	1.0006	0.7765	0.4903	0.0806	0.0781	1.646	4.458	117.08	67.53

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel C: Industrial Materials											
Ticker	*Name*	$\hat{\beta}_1$ *(Pre-GFC)* H_0: $\beta_1 = 1$	$\hat{\beta}_1$ *(Post-GFC)* H_0: $\beta_1 = 1$	$\hat{\gamma}_1$ *(Pre-GFC)* H_0: $\gamma_1 = 0$	$\hat{\gamma}_1$ *(Post-GFC)* H_0: $\gamma_1 = 0$	*Average Risk Premium (Pre-GFC)*	*Average Risk Premium (Post-GFC)*	*Stdev of Risk Premium (Pre-GFC)*	*Stdev of Risk Premium (Post-GFC)*	*Average Volume (Pre-GFC)*	*Average Volume (Post-GFC)*
CU	Copper Cathode	1.0012	1.0004	0.8744 **	0.7268	1.7873	-0.4047	10.437	1.588	2841.28	10184.66
AA	Aluminum	1.0001 **	0.9996	0.4908 **	0.1857	1.2006	0.0576	4.950	3.929	1560.23	3744.63
HG	Copper	1.0103	0.9973	0.7317 **	-0.6241	2.2705	-0.0146	6.959	4.359	6467.63	22674.96
S4	Nickel	1.0065	0.9989	0.7901	0.2305	3.7353	-0.0269	6.920	0.018	3884.43	37947.64
LA	Aluminium	1.0004	1.0002	-0.7528	-0.7412	-0.5452	0.3124	6.414	10.064	3649.25	23913.00
	Aluminium		1.0008		0.8841						
LY	Alloy	1.0006	***	0.5029	**	-1.0483	-0.8308	3.330	10.143	13.19	201.97
LP	Copper	1.0011	1.0006	0.7489	0.5196	0.1032	-0.2872	7.845	3.713	1851.89	9383.14
LX	Zinc	0.9993	1.0005	0.8245	-0.8952	0.5946	-1.1018	10.075	16.503	1238.06	6197.45
JN	Rubber	1.0120	1.0024	0.8994	0.8841	3.5287	-1.0786	4.156	10.356	416.69	79.67

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel D: Precious Metals											
Ticker	*Name*	$\hat{\beta}_1$ *(Pre-GFC)* H_0: $\beta_1 = 1$	$\hat{\beta}_1$ *(Post-GFC)* H_0: $\beta_1 = 1$	$\hat{\gamma}_1$ *(Pre-GFC)* H_0: $\gamma_1 = 0$	$\hat{\gamma}_1$ *(Post-GFC)* H_0: $\gamma_1 = 0$	*Average Risk Premium (Pre-GFC)*	*Average Risk Premium (Post-GFC)*	*Stdev of Risk Premium (Pre-GFC)*	*Stdev of Risk Premium (Post-GFC)*	*Average Volume (Pre-GFC)*	*Average Volume (Post-GFC)*
GC	Gold	1.0015	1.0009	-0.4137	-0.8730	0.6334	-1.7954	3.704	12.274	29270.57	69395.57
SI	Silver	1.0080 *	0.9962	-0.1081* **	-0.8899	0.0341	19.2679	5.942	8.696	9845.13	21496.61
PA	Palladium	0.9990	0.9977	-0.9000	0.7870	2.6162	8.6087	11.444	10.659	450.69	2226.30
Z7	Gold	1.0005	1.0003	0.0014	-0.6990	0.6558	5.6302	3.419	5.597	64250.08	104903.28
U5	Gold	1.0013	1.0008	-0.5703	-0.5633	-0.2000	2.5024	3.138	4.577	356144.18	33657.13
SN	Silver M	1.0035	1.0036	0.6902	-0.0152	-1.8001	2.1528	3.302	1.922	10910.77	78730.04
JG	Gold	1.0020 *	1.0029	-0.0510	0.6932	1.0235	2.4285	4.082	10.988	655.12	290.66
JI	Silver	0.9794	0.9516	0.7848	0.8896	16.5195	4.3960	4.398	33.460	700127.43	2297785.95
JA	Platinum	1.0028	0.9984	-0.6056	0.7067	0.6820	0.2862	1.547	19.364	472.20	67.28
JM	Palladium	0.9968	1.0059	-0.0201	0.8286	0.2244	-0.2171	6.926	17.404	44.88	5.33

Panel E: Comparison between two sub periods			*Post-GFC*		*Total*
			Inefficient	*Efficient*	
Market efficiency at 5% level					
Pre-GFC	*Inefficient*	Count	1	12	13
		% of Total	1.3%	15.2%	16.5%
	Efficient	Count	8	58	66
		% of Total	10.1%	73.4%	83.5%
Total		Count	9	70	79
		% of Total	11.4%	88.6%	100.0%

Wilcoxon Signed Ranks Tests for Significant Differences H_0: There is no difference in averages				
		Mean	*Test Statistic*	*P-value*
Average Risk Premium	Pre-GFC	0.385	-0.264	0.792
	Post-GFC	0.253		
Stdev of Risk Premium	Pre-GFC	6.747	-1.276	0.202
	Post-GFC	7.822		
Average Trading Volume	Pre-GFC	23200.5	-5.449	< 0.001
	Post-GFC	53462.7		

Table 5. Simulation Results: The size test results corresponding to an efficient market i.e., $\beta_1 = 1$

This table compares the performance of the proposed test PROP and TEST3 with the conventional tests TEST1-2 discussed in section 2.1. TEST1-3 are derived by relaxing the time varying risk premium and heteroscedasticity assumptions in PROP. TEST1-2 represent conventional market efficiency tests and TEST3 is a simplified version of PROP. Here, the time-varying property of the risk premium is simulated by varying γ_1 of equation (4b) in column one of the Table. The degree of the conditional heteroscedasticity of spot prices is introduced by varying the parameters φ_1 and φ_2 of equation (4e) in different panels. Results are based on 5000 simulation runs from an efficient market, $\beta_1 = 1$, using the DGP in equations (4a)-(4e). The RMSE is the root mean square of residuals. *N* is the number of contracts (sample size).

γ_1		% of acceptance of efficient market hypothesis at 5% Level				Mean (Stdev) of $\hat{\beta}_1$				Residual $[\hat{\varepsilon}_\delta(t_i)]$ RMSE			
$(\varphi_1 = 0.2)$ $(\varphi_2 = 0.6)$	*N*	TEST1	TEST2	TEST3	PROP	TEST1	TEST2	TEST3	PROP	TEST1	TEST2	TEST3	PROP
0	30	65.50	45.42	90.04	82.86	0.900 (0.074)	0.907 (0.101)	0.997 (0.092)	1.001 (0.005)	0.0520	0.0525	0.0500	0.0543
0	60	65.04	51.52	93.26	91.16	0.949 (0.037)	0.957 (0.051)	1.001 (0.004)	1.001 (0.003)	0.0562	0.0567	0.0549	0.0564
0	120	67.24	58.52	93.16	93.74	0.975 (0.019)	0.982 (0.023)	1.001 (0.003)	1.001 (0.002)	0.0602	0.0605	0.0586	0.0597
0	240	66.78	64.86	93.02	95.32	0.987 (0.010)	0.992 (0.010)	1.001 (0.002)	1.001 (0.002)	0.0629	0.0631	0.0606	0.0618
0	480	66.94	71.16	89.68	95.94	0.994 (0.005)	0.996 (0.004)	1.000 (0.002)	1.000 (0.002)	0.0649	0.0651	0.0620	0.0637
0.5	30	64.40	45.26	90.36	83.32	0.901 (0.074)	0.909 (0.099)	0.995 (0.226)	1.001 (0.005)	0.0519	0.0524	0.0499	0.0538
0.5	60	67.34	52.34	93.26	91.10	0.947 (0.039)	0.957 (0.054)	1.001 (0.003)	1.001 (0.003)	0.0569	0.0572	0.0553	0.0573
0.5	120	66.46	57.76	91.70	93.80	0.974 (0.019)	0.981 (0.023)	1.001 (0.003)	1.001 (0.002)	0.0600	0.0603	0.0581	0.0593
0.5	240	66.60	63.58	91.24	95.08	0.987 (0.009)	0.992 (0.010)	1.001 (0.002)	1.001 (0.002)	0.0629	0.0631	0.0606	0.0619
0.5	480	66.62	71.36	86.96	94.58	0.994 (0.005)	0.996 (0.004)	1.001 (0.002)	1.001 (0.002)	0.0650	0.0652	0.0621	0.0638
0.7	30	64.90	44.28	89.66	82.36	0.898 (0.076)	0.906 (0.105)	0.998 (0.137)	1.001 (0.005)	0.0513	0.0520	0.0492	0.0531
0.7	60	65.56	52.32	91.22	89.66	0.950 (0.038)	0.956 (0.057)	1.001 (0.006)	1.001 (0.003)	0.0570	0.0574	0.0552	0.0571
0.7	120	65.82	57.38	90.68	92.90	0.974 (0.019)	0.981 (0.025)	1.001 (0.003)	1.001 (0.002)	0.0604	0.0608	0.0586	0.0600
0.7	240	66.10	65.64	86.28	93.02	0.987 (0.010)	0.992 (0.010)	1.001 (0.002)	1.001 (0.002)	0.0630	0.0633	0.0607	0.0620
0.7	480	68.88	71.98	78.76	91.58	0.994 (0.005)	0.996 (0.004)	1.001 (0.002)	1.001 (0.002)	0.0649	0.0651	0.0622	0.0636
$(\varphi_1 = 0.6)$ $(\varphi_2 = 0.2)$	*N*	TEST1	TEST2	TEST3	PROP	TEST1	TEST2	TEST3	PROP	TEST1	TEST2	TEST3	PROP
0	30	67.06	47.84	90.34	89.50	0.899 (0.072)	0.906 (0.083)	1.000 (0.029)	1.001 (0.011)	0.0616	0.0621	0.0605	0.0632
0	60	67.72	50.28	92.92	94.56	0.948 (0.037)	0.956 (0.040)	1.001 (0.003)	1.001 (0.003)	0.0655	0.0657	0.0645	0.0655
0	120	68.50	54.02	93.90	95.26	0.974 (0.018)	0.978 (0.020)	1.001 (0.002)	1.001 (0.002)	0.0677	0.0679	0.0666	0.0672
0	240	69.02	59.70	93.50	95.34	0.987 (0.009)	0.989 (0.010)	1.001 (0.002)	1.001 (0.002)	0.0688	0.0688	0.0673	0.0679
0	480	68.82	65.00	91.56	95.50	0.994 (0.005)	0.994 (0.005)	1.000 (0.002)	1.000 (0.002)	0.0698	0.0698	0.0677	0.0685
0.5	30	67.58	47.50	89.78	89.70	0.899 (0.074)	0.909 (0.083)	0.999 (0.053)	1.001 (0.005)	0.0613	0.0618	0.0599	0.0629
0.5	60	68.24	51.24	92.86	94.18	0.948 (0.036)	0.955 (0.041)	1.001 (0.003)	1.001 (0.003)	0.0655	0.0657	0.0645	0.0655
0.5	120	69.54	54.48	92.60	94.68	0.975 (0.019)	0.979 (0.020)	1.001 (0.002)	1.001 (0.002)	0.0677	0.0678	0.0665	0.0671
0.5	240	68.58	58.78	91.58	94.70	0.987 (0.009)	0.989 (0.009)	1.001 (0.002)	1.001 (0.002)	0.0692	0.0693	0.0676	0.0682
0.5	480	68.86	65.10	88.74	94.58	0.994 (0.005)	0.994 (0.005)	1.001 (0.002)	1.001 (0.002)	0.0698	0.0699	0.0678	0.0685
0.7	30	67.58	47.50	89.78	89.70	0.899 (0.074)	0.909 (0.083)	0.999 (0.053)	1.001 (0.005)	0.0613	0.0618	0.0599	0.0629
0.7	60	68.24	51.24	92.86	94.18	0.948 (0.036)	0.955 (0.041)	1.001 (0.003)	1.001 (0.003)	0.0655	0.0657	0.0645	0.0655
0.7	120	69.08	54.64	90.16	93.60	0.974 (0.019)	0.978 (0.020)	1.001 (0.002)	1.001 (0.002)	0.0676	0.0677	0.0665	0.0671
0.7	240	68.28	60.12	88.22	93.44	0.987 (0.009)	0.989 (0.010)	1.001 (0.002)	1.001 (0.002)	0.0689	0.0689	0.0673	0.0678
0.7	480	69.06	66.38	81.58	91.68	0.994 (0.005)	0.994 (0.005)	1.001 (0.002)	1.001 (0.002)	0.0698	0.0698	0.0678	0.0685

Table 5 contd.

$(\varphi_1 \to 0)$ $(\varphi_2 \to 0)$	*N*	TEST1	TEST2	TEST3	PROP	TEST1	TEST2	TEST3	PROP	TEST1	TEST2	TEST3	PROP
0	30	70.38	46.08	92.80	91.04	0.897 (0.071)	0.911 (0.073)	1.000 (0.088)	1.000 (0.002)	0.0293	0.0294	0.0276	0.0283
0	60	69.54	49.66	94.02	96.80	0.948 (0.036)	0.954 (0.037)	1.000 (0.001)	1.000 (0.001)	0.0305	0.0306	0.0282	0.0285
0	120	69.42	52.92	93.32	96.36	0.974 (0.018)	0.977 (0.018)	1.000 (0.001)	1.000 (0.001)	0.0311	0.0311	0.0282	0.0285
0	240	69.96	56.36	91.58	94.68	0.987 (0.009)	0.988 (0.009)	1.000 (0.001)	1.000 (0.001)	0.0314	0.0314	0.0283	0.0284
0	480	70.38	56.68	88.52	91.50	0.993 (0.005)	0.994 (0.005)	1.000 (0.000)	1.000 (0.001)	0.0315	0.0315	0.0283	0.0283
0.5	30	68.32	45.32	92.16	90.34	0.898 (0.072)	0.910 (0.077)	0.998 (0.151)	1.000 (0.003)	0.0292	0.0294	0.0276	0.0283
0.5	60	69.12	49.18	93.04	96.24	0.947 (0.036)	0.954 (0.037)	1.000 (0.001)	1.001 (0.001)	0.0304	0.0305	0.0283	0.0285
0.5	120	68.80	53.18	89.56	94.68	0.973 (0.018)	0.976 (0.019)	1.000 (0.001)	1.001 (0.001)	0.0310	0.0310	0.0282	0.0284
0.5	240	69.00	55.68	85.10	91.44	0.987 (0.009)	0.988 (0.009)	1.000 (0.001)	1.001 (0.001)	0.0314	0.0314	0.0282	0.0284
0.5	480	69.16	55.88	74.36	82.48	0.993 (0.005)	0.994 (0.005)	1.000 (0.000)	1.000 (0.000)	0.0315	0.0315	0.0283	0.0284
0.7	30	68.20	43.96	89.92	88.76	0.900 (0.071)	0.912 (0.074)	0.995 (0.356)	1.001 (0.013)	0.0292	0.0294	0.0276	0.0284
0.7	60	68.54	49.16	88.54	93.78	0.947 (0.036)	0.954 (0.038)	1.001 (0.001)	1.001 (0.001)	0.0305	0.0306	0.0282	0.0285
0.7	120	69.00	53.76	83.20	90.78	0.974 (0.018)	0.976 (0.018)	1.001 (0.001)	1.001 (0.001)	0.0311	0.0311	0.0282	0.0285
0.7	240	70.84	55.86	70.90	82.46	0.987 (0.009)	0.988 (0.009)	1.001 (0.000)	1.001 (0.001)	0.0314	0.0314	0.0283	0.0285
0.7	480	61.36	49.30	41.46	55.44	0.993 (0.005)	0.994 (0.004)	1.001 (0.000)	1.001 (0.001)	0.0315	0.0315	0.0283	0.0284

Table 6. Simulation Results: The power test results corresponding to an inefficient market, $\beta_1 \neq 1$

This table compares the power of the proposed test PROP with the three approaches TEST1-3. The simulated dataset is obtained by setting the value of β_1 in equation (4a) around unity i.e., $\beta_1 = 0.9, 0.99, 1.01, 1.1$ to simulate inefficient markets. The degree of heteroscedasticity of pricess is modelled by varying the parameters φ_1 and φ_2 in equation (4e). Results are based on 5000 simulation runs using the DGP in equations (4a)-(4e) when $\gamma_1 = 0.5$

β_1		% of acceptance of efficient market hypothesis at 5% Level				Mean (Std.dev) of $\hat{\beta}_1$				Residual $[\hat{\varepsilon}_\delta(t_i)]$ RMSE			
$(\varphi_1 = 0.6)$ $(\varphi_2 = 0.2)$	*N*	TEST1	TEST2	TEST3	PROP	TEST1	TEST2	TEST3	PROP	TEST1	TEST2	TEST3	PROP
0.9	30	10.76	7.48	0.12	0.28	0.746 (0.124)	0.747 (0.127)	0.901 (0.017)	0.895 (0.051)	0.0557	0.0561	0.0545	0.0569
0.9	60	0.64	2.56	0.02	0.02	0.819 (0.067)	0.822 (0.067)	0.901 (0.003)	0.900 (0.018)	0.0589	0.0591	0.0579	0.0588
0.9	120	0.02	0.86	0.00	0.00	0.860 (0.034)	0.862 (0.034)	0.901 (0.002)	0.901 (0.003)	0.0611	0.0612	0.0598	0.0603
0.9	240	0.00	0.48	0.00	0.00	0.880 (0.018)	0.882 (0.017)	0.901 (0.004)	0.901 (0.002)	0.0623	0.0623	0.0606	0.061
0.9	480	0.00	0.22	0.00	0.00	0.890 (0.009)	0.891 (0.008)	0.900 (0.002)	0.900 (0.002)	0.0628	0.0629	0.0607	0.0613
0.99	30	62.88	42.94	47.62	63.78	0.819 (0.140)	0.820 (0.143)	0.991 (0.024)	0.980 (0.071)	0.0609	0.0614	0.0598	0.0631
0.99	60	58.70	39.30	27.38	43.12	0.903 (0.073)	0.905 (0.073)	0.991 (0.003)	0.990 (0.017)	0.0650	0.0652	0.0641	0.0651
0.99	120	46.24	30.78	13.78	23.82	0.945 (0.039)	0.947 (0.038)	0.991 (0.003)	0.991 (0.004)	0.0671	0.0672	0.0659	0.0665
0.99	240	20.88	16.16	7.70	12.58	0.968 (0.019)	0.969 (0.019)	0.991 (0.002)	0.991 (0.002)	0.0683	0.0684	0.0668	0.0672
0.99	480	1.86	3.26	2.26	4.22	0.979 (0.010)	0.980 (0.009)	0.991 (0.003)	0.991 (0.002)	0.0691	0.0692	0.0671	0.0678
1.01	30	70.34	48.58	38.82	58.16	0.838 (0.140)	0.839 (0.142)	1.010 (0.054)	1.000 (0.074)	0.0623	0.0629	0.0611	0.0643
1.01	60	75.10	57.72	15.38	33.72	0.920 (0.076)	0.922 (0.076)	1.010 (0.064)	1.010 (0.023)	0.0659	0.0662	0.0651	0.0663
1.01	120	80.20	65.70	7.42	15.16	0.963 (0.040)	0.966 (0.039)	1.011 (0.003)	1.011 (0.003)	0.0686	0.0687	0.0675	0.0681
1.01	240	87.64	78.36	5.22	12.60	0.992 (0.012)	0.994 (0.012)	1.009 (0.008)	1.010 (0.006)	0.0697	0.0698	0.0681	0.0687
1.01	480	82.90	76.02	7.08	11.58	0.999 (0.007)	0.999 (0.007)	1.006 (0.006)	1.008 (0.005)	0.0705	0.0705	0.0684	0.0692
1.1	30	86.82	65.16	1.48	0.60	0.915 (0.154)	0.916 (0.156)	1.101 (0.029)	1.088 (0.081)	0.0675	0.0680	0.0663	0.0697
1.1	60	78.52	62.92	2.24	0.42	1.001 (0.084)	1.004 (0.084)	1.101 (0.004)	1.099 (0.027)	0.0720	0.0723	0.0711	0.0724
1.1	120	42.80	35.48	3.18	0.24	1.017 (0.034)	1.019 (0.037)	1.102 (0.007)	1.104 (0.004)	0.0739	0.0741	0.0729	0.0737
1.1	240	7.88	8.08	3.86	0.04	1.024 (0.019)	1.044 (0.032)	1.101 (0.007)	1.097 (0.003)	0.0759	0.076	0.0743	0.0751
1.1	480	0.22	2.20	4.82	0.02	1.024 (0.006)	1.082 (0.014)	1.099 (0.010)	1.103 (0.000)	0.077	0.0771	0.0749	0.0759

Table 6 contd.

($\varphi_1 = 0.2$) ($\varphi_2 = 0.6$)	*N*	TEST1	TEST2	TEST3	PROP	TEST1	TEST2	TEST3	PROP	TEST1	TEST2	TEST3	PROP
0.9	30	11.86	7.68	0.44	0.36	0.739 (0.141)	0.749 (0.140)	0.900 (0.044)	0.873 (0.109)	0.0466	0.0472	0.0445	0.0481
0.9	60	1.08	1.84	0.06	0.02	0.816 (0.076)	0.832 (0.070)	0.901 (0.005)	0.894 (0.046)	0.0509	0.0512	0.0492	0.0507
0.9	120	0.02	0.80	0.00	0.02	0.857 (0.042)	0.871 (0.034)	0.901 (0.003)	0.900 (0.017)	0.0542	0.0546	0.0523	0.0533
0.9	240	0.02	0.46	0.00	0.00	0.879 (0.020)	0.888 (0.014)	0.901 (0.003)	0.901 (0.004)	0.0567	0.0569	0.0544	0.0554
0.9	480	0.00	0.16	0.00	0.00	0.889 (0.010)	0.895 (0.006)	0.901 (0.003)	0.901 (0.003)	0.0585	0.0586	0.0556	0.0570
0.99	30	61.84	40.08	38.80	45.78	0.813 (0.156)	0.825 (0.155)	0.990 (0.053)	0.956 (0.124)	0.0514	0.0519	0.0493	0.0533
0.99	60	56.96	42.46	22.56	26.92	0.896 (0.085)	0.914 (0.078)	0.991 (0.005)	0.981 (0.059)	0.0560	0.0564	0.0542	0.0561
0.99	120	44.56	35.66	11.64	15.60	0.941 (0.046)	0.957 (0.037)	0.991 (0.003)	0.989 (0.023)	0.0596	0.0600	0.0579	0.0590
0.99	240	20.74	18.60	6.62	9.06	0.966 (0.023)	0.977 (0.016)	0.991 (0.003)	0.991 (0.006)	0.0622	0.0625	0.0600	0.0612
0.99	480	2.22	3.14	2.16	2.18	0.978 (0.011)	0.984 (0.007)	0.991 (0.002)	0.991 (0.002)	0.0645	0.0647	0.0616	0.0632
1.01	30	68.48	46.38	33.44	41.82	0.828 (0.158)	0.839 (0.156)	1.011 (0.024)	0.977 (0.121)	0.0521	0.0527	0.0503	0.0546
1.01	60	72.68	57.16	16.34	21.76	0.915 (0.086)	0.932 (0.078)	1.011 (0.004)	1.002 (0.056)	0.0565	0.0570	0.0549	0.0566
1.01	120	78.44	69.86	7.96	15.74	0.961 (0.046)	0.977 (0.037)	1.011 (0.003)	1.010 (0.017)	0.0610	0.0613	0.0593	0.0604
1.01	240	84.06	73.36	4.48	11.70	0.985 (0.024)	0.996 (0.017)	1.011 (0.003)	1.011 (0.005)	0.0639	0.0642	0.0616	0.0629
1.01	480	81.66	57.46	6.00	7.88	0.998 (0.012)	1.004 (0.007)	1.011 (0.003)	1.011 (0.002)	0.0654	0.0656	0.0624	0.0642
1.1	30	82.84	57.94	2.22	1.10	0.900 (0.171)	0.914 (0.170)	1.100 (0.036)	1.055 (0.142)	0.0566	0.0572	0.0546	0.0594
1.1	60	76.70	52.42	3.32	0.26	0.996 (0.094)	1.016 (0.087)	1.101 (0.004)	1.088 (0.067)	0.0623	0.0627	0.0607	0.0629
1.1	120	43.76	22.84	3.68	0.08	1.047 (0.050)	1.065 (0.039)	1.101 (0.007)	1.099 (0.024)	0.0666	0.0671	0.0648	0.0662
1.1	240	9.24	4.14	4.32	0.04	1.074 (0.025)	1.085 (0.017)	1.101 (0.004)	1.101 (0.009)	0.0693	0.0696	0.0671	0.0685
1.1	480	0.22	1.44	5.36	0.00	1.087 (0.012)	1.093 (0.007)	1.101 (0.003)	1.101 (0.002)	0.0716	0.0719	0.0687	0.0706

Appendix A.

A Modified Kalman Filter for Heteroscedasticity

The following state-space model is estimated using the modified Kalman Filter.

$$s(t_i) = \beta_1 f(t_i^\delta) + \pi(t_i^\delta) - 0.5\sigma_\delta^2(t_i^\delta) + \varepsilon_\delta(t_i)$$
$$\pi(t_i^\delta) = \gamma_0 + \gamma_1 \pi(t_{i-1}^\delta) + \eta(t_i^\delta)$$
$$\varepsilon_\delta(t_i) = \xi(t_i)\sigma_\delta(t_i)$$
$$\sigma_\delta^2(t_i) = \varphi_0 + \varphi_1 \varepsilon_\delta^2(t_{i-1}) + \varphi_2 \sigma_\delta^2(t_{i-1})$$

Traditional linear Kalman filter equations are transformed into a univariate context and the coefficient of the state variable in the measurement model is set to unity, assuming that the risk premium, $\pi(t_i^\delta)$ carries the total bias between $s(t_i)$ and $f(t_i^\delta)$. Measurement error and state error variances are assumed to be correlated as in Cheng (1993). In each iteration, the conditional variance of error in the measurement equation is assumed to vary according to a GARCH (1,1) process rather than assuming a constant error variance estimate, R^δ, as in the standard Kalman filtering. Likelihood function of the Kalman filter is modified to obtain the estimates of GARCH (1,1) process in parallel with other model parameters. In order to achieve an efficient convergence of the Kalman filter, the initial values are estimated using an OLS regression, $s(t_i) = \beta_1 f(t_i^\delta) + \pi(t_i^\delta) + \varepsilon_\delta(t_i)$ and an AR(1)-GARCH(1,1) for the residual series $\varepsilon_\delta(t_i)$.

Steps in Kalman Filter

The following steps are repeated from the first maturity day (t_1) to the last maturity day (t_N) in each run.

Step-1: Compute Kalman gain; $K^\delta = P^\delta / \left[P^\delta + \sigma_\delta^2(t_i)\right]$

Step-2: Compute measurement error; $\varepsilon_\delta(t_i) = s(t_i) - \beta_1 f(t_i^\delta) - \pi(t_i^\delta) + 0.5\sigma_\delta^2(t_i)$

Step-3: Update state value; $\pi^{new}(t_i^\delta) = \pi(t_i^\delta) + K^\delta \varepsilon_\delta(t_i)$

Step-4: Update state-update error variance; $P^{\delta,new} = (1 - K^\delta)P^\delta$

Step-5: Compute measurement error; $\varepsilon_\delta^{new}(t_i) = s(t_i) - \beta_1 f(t_i^\delta) - \pi^{new}(t_i^\delta) + 0.5\sigma_\delta^2(t_i)$

Step-6: Project next conditional variance; $\sigma_\delta^2(t_{i+1}) = \varphi_0 + \varphi_1 \left[\varepsilon_\delta^{new}(t_i)\right]^2 + \varphi_2 \sigma_\delta^2(t_i)$

Step-7: Project state value; $\pi(t_{i+1}^\delta) = \gamma_0 + \gamma_1 \pi^{new}(t_i^\delta) + C^\delta \varepsilon_\delta(t_i) / \left[P^\delta + \sigma_\delta^2(t_i)\right]$

Step-8: Project state-update error variance; $P^{\delta,next} = P^{\delta,new}{\gamma_1}^2 + Q^\delta - \frac{\left(C^\delta\right)^2}{\left[P^\delta + \sigma_\delta^2(t_i)\right]} - 2\gamma_1 C^\delta K^\delta$

Step-9: Cumulative (negative) log likelihood;

$$LL^{\delta} = LL^{\delta,old} + 0.5\left[ln\{P^{\delta} + \sigma_{\delta}^{2}(t_i)\} + \{\varepsilon_{\delta}^{new}(t_i^{\delta})\}^{2}/\{P^{\delta} + \sigma_{\delta}^{2}(t_i)\}\right]$$

After *N* iterations, the final likelihood value is obtained for each run. We iterate the procedure until the log likelihood is maximized with respect to the parameter vector $[\beta_1, \gamma_0, \gamma_1, \varphi_0, \varphi_1, \varphi_2, C^{\delta}, Q^{\delta}]$. Constrains are applied for feasible estimates of GARCH parameters (φ_0, φ_1, φ_2) and state model error variance Q^{δ}.

Estimating an Intermediary Risk Premium

Suppose contracts are available for the commodity at time t_1 and t_3, but not at t_2 ($t_1 < t_2 < t_3$). Since there is no contract at t_2, we estimate the risk premium, $\pi(t_3^{\delta})$ corresponding to the maturity day t_3 using $\pi(t_i^{\delta}) = \gamma_0 + \gamma_1\pi(t_{i-1}^{\delta}) + \eta(t_i^{\delta})$, but in two steps namely; (a) first estimate an intermediary risk premium, $\pi(t_2^{\delta})$ for the time period $[t_2^{\delta}, t_2]$ using $\pi(t_1^{\delta})$ and then (b) estimate $\pi(t_3^{\delta})$ using $\pi(t_2^{\delta})$ for the time period $[t_3^{\delta}, t_3]$ following Jones (1980). We also estimate the intermediary priory estimate covariance parameter, P^{δ} of $\pi(t_2^{\delta})$ using the available futures price at t_2. We do not calculate the log likelihood function (Step-9 in Kalman filter) for the above mentioned intermediary step.

Appendix B. List of Commodities Considered in This Study

Market Sector	Bloomberg Ticker	Contract Name	Exchange	Period	Sample Size (N)	Unit of Price	Spot Price		Lagged Futures Price		Average Trading Volume
							Mean	Stdev	Mean	Stdev	
AL	AX	Arabica Coffee	Bolsa de Mercadorias & Futuros	25-Feb-2000 to 25-Dec-2014	75	$/kg	145.45	145.21	72.43	75.28	622.81
AL	LS	Live Cattle	Bolsa de Mercadorias & Futuros	31-Oct-2000 to 31-Dec-2014	171	$/kg	35.60	35.48	15.66	15.40	824.19
AL	C	Corn	Chicago Mercantile Exchange	14-Feb-2000 to 14-Dec-2014	75	Cents/Bushel	3.80	3.78	1.82	1.76	83141.35
AL	S	Soybeans	Chicago Mercantile Exchange	14-Feb-2000 to 14-Dec-2014	119	Cents/Bushel	9.19	9.07	3.71	3.64	54584.23
AL	BO	Soybean Oil	Chicago Mercantile Exchange	14-Feb-2000 to 14-Dec-2014	119	Cents/Bushel	0.33	0.34	0.14	0.14	24241.12
AL	SM	Soybean Meal	Chicago Mercantile Exchange	14-Feb-2000 to 14-Dec-2014	119	$/Short Tom	280.54	272.44	109.53	102.40	20262.03
AL	W	Wheat	Chicago Mercantile Exchange	14-Feb-2000 to 14-Dec-2014	75	Cents/Bushel	4.99	5.03	2.05	2.03	32894.71
AL	YP	Mini-sized Wheat	Chicago Mercantile Exchange	15-May-2003 to 15-Dec-2014	57	Cents/Bushel	5.75	5.62	1.93	1.88	212.61

Market Sector	Bloomberg Ticker	Contract Name	Exchange	Period	Sample Size (N)	Unit of Price	Spot Price		Lagged Futures Price		Average Trading Volume
							Mean	Stdev	Mean	Stdev	
AL	LC	Live Cattle	Chicago Mercantile Exchange	31-Jan-2000 to 31-Dec-2014	90	Cents/Pound	0.97	0.95	0.24	0.23	12785.71
AL	LH	Lean Hogs	Chicago Mercantile Exchange	10-Feb-2000 to 10-Dec-2014	120	Cents/Pound	0.73	0.71	0.18	0.17	7051.79
AL	FC	Feeder Cattle	Chicago Mercantile Exchange	22-Feb-2000 to 22-Dec-2014	179	Cents/Pound	1.15	1.14	0.33	0.32	1050.02
AL	DA	Class III Milk (Basic Milk)	Chicago Mercantile Exchange	31-Jan-2000 to 31-Dec-2014	180	Cents/Cwt	14.86	14.86	3.87	3.89	103.31
AL	KV	Class IV Milk	Chicago Mercantile Exchange	31-Aug-2000 to 31-Dec-2014	173	Cents/Cwt	14.78	14.81	3.83	3.82	0.66
AL	LE	Nonfat Dry Milk	Chicago Mercantile Exchange	31-Aug-2001 to 31-Dec-2014	161	Cents/Pound	1.20	1.20	0.37	0.37	1.80
AL	O	Oats	Chicago Mercantile Exchange	14-Feb-2000 to 14-Dec-2014	75	Cents/Pound	2.50	2.43	1.04	0.96	652.58
AL	RR	Rough Rice	Chicago Mercantile Exchange	14-Feb-2000 to 14-Dec-2014	89	Cents/Cwt	10.59	10.61	4.45	4.45	438.87
AL	LB	Random Length Lumber	Chicago Mercantile Exchange	15-Feb-2000 to 15-Dec-2014	89	$/1000mbf	276.19	281.66	65.88	58.99	555.21
AL	AC	Corn	Dalian Commodity Exchange	10-Nov-2004 to 10-Dec-2014	60	Metric Ton	272.55	272.04	87.65	89.03	5057.80
AL	AK	No.1 Soybeans	Dalian Commodity Exchange	10-May-2002 to 10-Dec-2014	75	Metric Ton	524.48	520.47	174.95	175.04	8168.83
AL	AE	Soybean Meal	Dalian Commodity Exchange	10-Sep-2000 to 10-Dec-2014	113	Metric Ton	405.68	396.91	148.26	144.91	7850.29
AL	RS	Canola	ICE Futures-US	14-Feb-2000 to 14-Dec-2014	74	$/Metric Ton	367.42	362.86	154.01	147.75	6307.55
AL	CC	Cocoa	ICE Futures-US	19-Feb-2000 to 19-Dec-2014	75	Cents/Pound	2042.76	2044.65	711.47	734.55	4778.05
AL	KC	Coffee C ®	ICE Futures-US	22-Feb-2000 to 22-Dec-2014	75	Cents/Pound	1.21	1.21	0.53	0.54	5529.59
AL	CT	Cotton No. 2	ICE Futures-US	13-Feb-2000 to 13-Dec-2014	75	Cents/Pound	0.68	0.68	0.27	0.27	8089.44
AL	SB	Sugar No. 11	ICE Futures-US	31-Jan-2000 to 31-Dec-2014	180	$/Pound	0.14	0.14	0.07	0.07	35439.32
AL	AQ	Corn	Kansai Commodity Exchange	28-Feb-2000 to 31-Dec-2014	90	$/Metric Ton	211.13	210.84	90.40	90.28	46.85
AL	FS	Frozen Shrimp	Kansai Commodity Exchange	10-Nov-2002 to 10-Dec-2014	146	$/1.8 kg	16.10	16.32	3.43	3.45	74.98
AL	SJ	Raw Sugar	Kansai Commodity Exchange	02-Mar-2000 to 31-Dec-2014	89	$/Metric Ton	344.46	341.56	128.79	130.11	6.79
AL	KO	Crude Palm Oil	Malaysia Derivatives Exchange	14-Feb-2000 to 14-Dec-2014	179	$/Metric Ton	608.21	603.93	279.55	278.80	508.02
AL	MW	Hard Red Spring Wheat	Minneapolis Grain Exchange	14-Feb-2000 to 14-Dec-2014	75	$/Bushel	5.86	5.77	2.71	2.54	2140.51

Market Sector	Bloomberg Ticker	Contract Name	Exchange	Period	Sample Size (N)	Unit of Price	Spot Price		Lagged Futures Price		Average Trading Volume
							Mean	Stdev	Mean	Stdev	
AL	S9	Crude Palm Oil	Multi Commodity Exchange of India	22-Mar-2004 to 22-Dec-2014	130	$/kg	7.61	7.62	2.32	2.30	266.53
AL	Q8	Soy Bean	National Commodity and Derivatives Exchange of India	20-Jan-2004 to 20-Dec-2014	66	$/Quintal	46.04	46.62	14.39	13.56	45955.01
AL	M7	Soy oil	National Commodity and Derivatives Exchange of India	20-Apr-2004 to 20-Dec-2014	97	$/Quintal	11.21	11.33	2.03	2.09	49336.11
AL	M1	Mustard seed	National Commodity and Derivatives Exchange of India	20-Jan-2004 to 20-Dec-2014	88	$/Quintal	29.77	29.33	26.35	26.40	44467.70
AL	M3	Pepper	National Commodity and Derivatives Exchange of India	20-May-2004 to 20-Dec-2014	85	$/Quintal	422.98	413.53	217.10	216.57	3997.50
AL	Q6	Turmeric	National Commodity and Derivatives Exchange of India	20-Dec-2004 to 20-Dec-2014	70	$/Quintal	113.61	110.62	79.45	70.86	12985.41
AL	QC	Cocoa	NYSE.liffe	20-Feb-2000 to 20-Dec-2014	75	$/Metric Ton	2181.49	2161.07	754.67	782.55	3657.95
AL	EP	Corn	NYSE.liffe	05-Feb-2000 to 05-Dec-2014	74	$/Metric Ton	201.85	201.87	69.22	70.20	400.31
AL	QK	Feed Wheat	NYSE.liffe	23-Feb-2000 to 23-Dec-2014	74	$/Metric Ton	190.32	189.99	80.20	80.64	126.42
AL	CA	Milling Wheat	NYSE.liffe	10-Feb-2000 to 10-Dec-2014	74	$/Metric Ton	203.48	201.40	86.16	82.93	5740.13
AL	QW	White Sugar	NYSE.liffe	15-Feb-2000 to 15-Dec-2014	75	$/Metric Ton	382.44	384.96	162.32	166.65	3247.87
AL	IJ	Rapseed	NYSE.liffe	31-Jan-2000 to 31-Dec-2014	60	$/Metric Ton	395.12	395.10	164.54	157.54	1400.16
AL	WZ	White Maize	South African Futures Exchange	26-Feb-2000 to 26-Dec-2014	75	$/Metric Ton	185.93	185.16	62.94	62.88	1673.35
AL	YW	Yellow Maize	South African Futures Exchange	26-Feb-2000 to 26-Dec-2014	75	$/Metric Ton	95.21	95.20	1.26	1.25	101861.45
AL	EB	Bread milling wheat	South African Futures Exchange	26-Feb-2000 to 26-Dec-2014	75	$/Metric Ton	296.74	291.79	98.78	96.90	949.41
AL	SY	Soybeans of Class SB	South African Futures Exchange	26-May-2002 to 26-Dec-2014	62	$/Metric Ton	403.97	400.96	125.48	126.88	294.06
AL	SU	Sunflower Seed	South African Futures Exchange	23-Feb-2000 to 22-Dec-2014	75	$/Metric Ton	398.22	400.74	151.85	155.62	229.06
AL	JC	Corn	Tokyo Grain Exchange	15-Feb-2000 to 15-Dec-2014	90	$/1000kg	207.40	206.89	90.17	86.68	264.64
AL	JS	Soybean	Tokyo Grain Exchange	16-Feb-2000 to 16-Dec-2014	89	$/1000kg	399.96	397.26	151.75	148.40	93.77
AL	JZ	Arabica Coffee	Tokyo Grain Exchange	20-Feb-2000 to 20-Dec-2014	89	$/69kg	176.36	179.03	85.40	87.88	63.77
AL	JR	Raw Sugar	Tokyo Grain Exchange	02-Mar-2000 to 31-Dec-2014	89	$/1000kg	336.56	332.06	182.23	155.84	49.61
EF	CL	Light Sweet Crude Oil (WTI)	Chicago Mercantile Exchange	22-Feb-2000 to 22-Dec-2014	179	$/Gallon	65.01	65.00	29.41	29.44	172540.71

Market Sector	Bloomberg Ticker	Contract Name	Exchange	Period	Sample Size (N)	Unit of Price	Spot Price		Lagged Futures Price		Average Trading Volume
							Mean	Stdev	Mean	Stdev	
EF	NG	Natural Gas (Henry Hub)	Chicago Mercantile Exchange	25-Feb-2000 to 28-Dec-2014	179	$/mmBtu	5.25	5.31	2.24	2.31	67422.91
EF	HO	Heating Oil	Chicago Mercantile Exchange	28-Feb-2000 to 31-Dec-2014	179	$/Gallon	1.89	1.88	0.90	0.90	36333.27
EF	CO	ICE Brent Crude	ICE Futures-Europe	15-Feb-2000 to 15-Dec-2014	179	$/Barrel	67.66	67.17	33.73	33.62	104977.06
EF	QS	ICE Gasoil	ICE Futures-Europe	12-Feb-2000 to 12-Dec-2014	179	$/Metric Ton	586.71	583.46	288.75	289.65	36770.43
EF	FO	Fuel Oil	Shanghai Futures Exchange	31-Dec-2004 to 31-Dec-2014	121	$/Metric Ton	574.41	577.98	165.59	167.39	9168.38
EF	JV	Gasoline	Tokyo Commodity Exchange	24-Feb-2000 to 24-Dec-2014	179	$/Kiloliter	516.70	515.48	230.60	229.50	568.50
EF	JX	Kerosene	Tokyo Commodity Exchange	24-Feb-2000 to 24-Dec-2014	179	$/Kiloliter	523.19	521.11	237.92	238.19	503.79
EF	CP	Crude Oil	Tokyo Commodity Exchange	30-Oct-2001 to 30-Dec-2014	159	$/Kiloliter	438.31	438.11	200.51	200.95	93.40
IM	HG	Copper	Chicago Mercantile Exchange	25-Feb-2000 to 28-Dec-2014	179	$/Pound	2.37	2.36	1.23	1.23	13348.96
IM	LA	Aluminium	London Metal Exchange	16-Feb-2000 to 16-Dec-2014	179	$/Metric Ton	1947.36	1945.84	461.44	460.89	12252.85
IM	LY	Aluminium Alloy	London Metal Exchange	16-Feb-2000 to 16-Dec-2014	179	$/Metric Ton	1775.23	1771.06	434.47	431.62	93.35
IM	LP	Copper	London Metal Exchange	16-Feb-2000 to 16-Dec-2014	179	$/Metric Ton	5194.27	5156.87	2694.92	2689.79	5049.52
IM	LX	Zinc	London Metal Exchange	16-Feb-2000 to 16-Dec-2014	179	$/Metric Ton	1761.44	1757.21	808.97	808.65	3343.72
IM	S4	Nickel	Multi Commodity Exchange of India	30-Jun-2004 to 31-Dec-2014	127	$/kg	20.30	20.20	7.96	7.80	24268.72
IM	CU	Copper Cathode	Shanghai Futures Exchange	15-Feb-2000 to 15-Dec-2014	179	$/Metric Ton	6048.54	5995.97	3047.40	3050.37	5959.14
IM	AA	Aluminum	Shanghai Futures Exchange	15-Jun-2001 to 15-Dec-2014	163	$/Metric Ton	2206.98	2202.29	345.11	340.96	2578.72
IM	JN	Rubber	Tokyo Commodity Exchange	23-Feb-2000 to 26-Dec-2014	179	$/kg	2.11	2.08	1.24	1.22	273.60
PM	GC	Gold	Chicago Mercantile Exchange	25-Feb-2000 to 28-Dec-2014	90	$/Troy Ounce	829.21	824.53	488.06	486.25	46306.88
PM	SI	Silver	Chicago Mercantile Exchange	28-Feb-2000 to 28-Dec-2014	89	$/Troy Ounce	14.47	14.50	9.58	9.85	14792.12
PM	PA	Palladium	Chicago Mercantile Exchange	27-Feb-2000 to 28-Dec-2014	60	$/Troy Ounce	464.45	466.48	223.52	227.64	1204.58
PM	Z7	Gold	Dubai Gold and Commodities Exchange	25-Feb-2000 to 28-Dec-2014	90	$/Troy Ounce	9168.76	9180.91	1855.90	1842.37	81510.65
PM	U5	Gold	Multi Commodity Exchange of India	05-Feb-2004 to 05-Dec-2014	66	$/kg	338.46	337.52	150.03	150.21	169052.46

Market Sector	Bloomberg Ticker	Contract Name	Exchange	Period	Sample Size (N)	Unit of Price	Spot Price		Lagged Futures Price		Average Trading Volume
							Mean	Stdev	Mean	Stdev	
PM	SN	Silver M	Multi Commodity Exchange of India	05-Apr-2004 to 05-Dec-2014	53	$/kg	635.79	620.39	321.65	312.11	50866.31
PM	JG	Gold	Tokyo Commodity Exchange	24-Feb-2000 to 26-Dec-2014	90	$/Gram	26.60	26.49	15.68	15.62	500.37
PM	JI	Silver	Tokyo Commodity Exchange	24-Feb-2000 to 26-Dec-2014	90	$/Gram	1.36	1.37	1.29	1.28	137846.89
PM	JA	Platinum	Tokyo Commodity Exchange	24-Feb-2000 to 26-Dec-2014	90	$/Gram	36.57	36.47	14.25	14.15	300.28
PM	JM	Palladium	Tokyo Commodity Exchange	24-Feb-2000 to 26-Dec-2014	90	$/Gram	15.08	14.90	7.36	7.20	28.09

§ AL- Agricultural & Livestock EF - Energy & Fuel IM - Industrial Materials PM - Precious Metals

Does Energy Consumption Fuel Long-Run Productivity Growth? Panel Evidence from Global Data with New Policy Insights[1]

Badri Narayan Rath[a*], Vaseem Akram[a], Debi Prasad Bal[b], Mantu Kumar Mahalik[c]

[a]*Department of Liberal Arts, Indian Institute of Technology Hyderabad, India*[2].
[b]*Department of Humanities and Social Sciences, National Institute of Technology, Sikkim, India.*
[c]*Department of Humanities and Social Sciences, National Institute of Technology (NIT), Odisha India.*

Abstract

By using the panel data of 1980-2014 for a sample of 42 countries (e.g. Developed, Developing, European, Latin America, Asian and African regions), this study explores the long-run relationship between total factor productivity (TFP) and energy consumption. This study also examines the long-run relationship between TFP and different components of total primary energy consumption (e.g. electricity, coal, natural gas and petroleum). Empirical findings from using both Pedroni and Westerlund panel cointegration tests confirm the long-run relationship between energy consumption and total factor productivity both at the aggregate panel and panels of Developed, Developing, European, Latin America, and Asian except for the African region countries. Further, our results only support the evidence of long-run relationship between TFP and other forms of energy consumption like electricity, natural gas and petroleum. Results also supported the existence of bi-directional relationship between TFP and energy consumption in the long-run. From a policy perspective, our findings suggest that the greater energy-consuming countries of the world should reduce energy usage further to enhance productivity growth which is crucial for their sustainable environmental-friendly economic development in the long-run.

Keywords: Energy consumption, Total Factor Productivity, Panel Cointegration, Panel Causality, DOLS

JEL Codes: C33, O47, Q43

[1] This manuscript is work on progress and it should be not referred.

[2] Corresponding author at: Email: badri@iith.ac.in, Tel: +91-40-23016052.

1. Introduction

It is evident that energy consumption plays a crucial role in the evolution of human life. One can't have economic growth and prosperity without energy consumption because energy is widely used as one of the inputs in the process of economic activities. This shows that energy use has contributed to the progress and development of agriculture, industrial and services sectors of any economy. Given that significance of energy use in various economic activities, the topic of energy consumption – economic growth nexus has been a subject of debate in the mind of economists, environmentalists and policy makers. Recently Shahbaz et al. (2015) argued that too much energy consumption may help higher economic growth but at the cost of environmental quality via discharging higher CO_2 emissions into the atmosphere. This implies that massive use of energy due to rapid economic growth is not beneficial for the natural environment.

Unsurprisingly, there is a voluminous literature that examines relationship between energy consumption and economic growth in the last few decades for both single country and multi countries studies and find mixed evidence (see, for instance, Stern, 2000; Soytas and Sari, 2006; Lee and Chang, 2007; Narayan and Smyth, 2008; Sadorsky, 2009; Narayan and Popp, 2012; Apergis and Tang, 2013; Tiwari, 2014; Smyth and Narayan, 2015). The recent study by Smyth and Narayan (2015) nicely present the merits and demerits of different econometric techniques which have been used in the literature for examining the relationship between energy consumption and economic growth. Similarly, handful of studies also investigated the link between energy consumption and economic growth through prevalence of four hypotheses (growth, conservative, feedback, and neutrality) (see Ozturk, 2010). *Energy consumption-led growth hypothesis* (or growth hypothesis) refers to a situation in which energy consumption is the driving factor to economic growth, indicating that there exists unidirectional causality from energy use to economic growth. This shows that any energy conservation policies designed by policy makers to reduce the usage of energy that will adverse effect on economic growth. This hypothesis has been confirmed for country level studies (Soytas et al., 2001; Paul and Bhattacharya, 2004; Ang, 2007; Wang et al., 2011; Shahbaz et al., 2013a).

Moreover, *growth-led energy consumption hypothesis* (or conservation hypothesis) implies the existence of unidirectional causality running from energy consumption to economic growth. This hypothesis has been confirmed by many studies based on single country (Kraft and Kraft, 1978; Yoo and Kim, 2006; Zamani, 2007; Ang, 2008; Zhang and Cheng, 2009; Bartleet and Gounder, 2010; Baranzini et al., 2013). F*eedback hypothesis* also refers to the existence of bidirectional causality between energy consumption and economic growth. This further indicates that both energy consumption and economic growth are interdependent each other. This hypothesis has been supported by many empirical studies (see, for instance, Hwang and Gum, 1991; Glasure, 2002; Hondroyiannis et al., 2002; Acaravci, 2010; Chang, 2010; Ahamad and Islam, 2011; Zhang, 2011; Zhixin and Xin, 2011; Alam et al., 2012; Shahbaz et al., 2012; Shahbaz and Lean, 2012; Shahbaz et al., 2013b). In such line, energy conservation strategies aimed at decreasing energy consumption for environmental quality may lower economic growth performance. Similarly, any growth policy aimed at reducing economic activities for lowering carbon emissions will lower the usage of energy. Finally, *neutrality hypothesis* implies no causal relationship between energy consumption and economic growth. This further indicates that economic growth is possible without energy usage and energy usage is possible without

economic growth, indicating that both the series are not related to each other. This hypothesis has also been confirmed for individual studies (Kraft and Kraft, 1980; Ghali and El-Sakka, 2004; Jobert and Karanfil, 2007; Payne, 2009; Soytas and Sari, 2009). In this context, energy conservation strategies aimed at minimizing the usage of energy for environmental protection seems to be ineffective with respect to economic growth.

Influenced by the seminal work of Kraft and Kraft (1978), many studies exist on the causal nexus between energy economic growth and energy consumption at the single country and multi-country levels (see Table 1A in the appendix). These studies considering both country and multi-country cases have applied various time series and panel approaches to examine the causal linkage between energy consumption and economic growth and provided conflicting and mixed results. It is thus argued that the conflicting and mixed findings are not helpful for policy makers to design energy and growth policies for sustainable growth and environmental quality of a nation. Based on the contributions of the pioneering studies on the relationship between energy consumption and economic growth, our paper differs from the existing literature in following ways. First, previous studies mainly focus on the causal relationship between energy consumption and economic growth, but present study investigates relationship between energy consumption and productivity by considering total factor productivity as a measure of economic performance instead of GDP. Total Factor Productivity (TFP) is the central concept and measure of economic performance (Solow, 1957; Marrocu et al., 2014). Study by Easterly and Levine (2001) suggests that growth economists should emphasize on TFP growth rather than factor accumulation. The relationship between energy consumption and TFP was first examined by Schurr (1983) and Jorgenson (1984) and found energy consumption has a positive impact on TFP. Subsequently, few recent studies which examine the relationship between energy consumption and TFP are (Chang and Hu, 2010; Kumar and Kumar, 2013; Ladu and Meleddu, 2014; Tugcu and Tiwari, 2016). To the best of our knowledge, yet no published research has been found using the global data set to examine the causal linkage between energy consumption and total factor productivity for 43 countries in a panel framework.

However, this unaddressed research gap motivates us to add novelty to the existing energy economic literature by examining nexus between total primary energy consumption along with its various types (coal use, natural gas consumption, petroleum use) and total factor productivity for the case of developed, developing, European, Latin American, Asian and African Countries. In doing so, our study contributes to the existing literature several counts. First, this study appears to be the important one to exhibit an extensive survey on the nexus between energy consumption and economic growth at the country and multi-country specific cases. Second, this study makes an empirical attempt in examining the linkage between energy consumption and total factor productivity (TFP) not only for aggregate panel using sample of 43 countries but also for sub-panels like (developed, developing, European, Latin American, Asian and African economies). This allows us taking into account of heterogeneity within a region and comparing the findings between sub-panels. Third, the battery of Pedroni and Westerlund panel cointegration tests are used to confirm the long-run relationship between energy consumption – TFP. Fourth, dynamic ordinary least squares (DOLS) are also used to examine the long-run impact of primary energy consumption and patterns of energy consumption (coal consumption, electricity consumption, and natural gas use) on total factor productivity for these panel of

countries. Finally, we examine the short-run and long-run causality between energy consumption – TFP by applying panel Granger causality technique.

The empirical findings based on Pedroni and Westerlund panel cointegration tests confirm the long-run relation relationship between energy consumption and total factor productivity for aggregate and sub-panels levels based on income category and regions except African countries. Further, results support the evidence of long-run relationship between TFP and other forms of energy consumption like electricity, natural gas and petroleum. Results based on panel Granger causality also show a feedback hypothesis in the long run and conservation hypothesis in the short run.

The rest of the paper is set out as follows. In section 2, we discuss the framework, data and methodology while section 3 reports the empirical results. Finally, section 4 ends up with conclusive remarks and policy implications.

2. Framework, Methodology and Data

2.1. Framework

This paper uses the conventional Cobb–Douglas production within the augmented Solow framework (Solow, 1956). The per capita output can be defined as:

$$y_t = A_t K_t^{\alpha}, \alpha > 0 \quad (1)$$

Where A is the stock of technology, K is the capital per worker and α is the profit share.
The Solow model assume that the growth of technology is given by

$$A_t = A_0 e^{gT} \quad (2)$$

In equation (2), A_0 is the initial stock of technology at time T. We can also extend the Solow model by following (Rao, 2010; Kumar and Kumar, 2013)

$$A_t = f(EG) \quad (3)$$

Where is EG refers to energy consumption. The effect of energy consumption on total factor productivity (TFP) can be captured when EG is entered to production function adding as a shift variable apart from other inputs.
We can rewrite equation (2) as,

$$A_t = A_0 e^{gT} EG_t^{\beta} \quad (4)$$

In case of Solow model the growth of technology is known as technological progress, which is also treated as the total factor productivity.

2.2. Methodology

2.2.1. Unit root test

In the first step, we apply the Im–Pesaran–Shin (IPS) (Im et al. 2003) unit root test to check the stationary property of each variable used in the paper. We perform this test over Levin–Lin–Chu (Levin et al. 2002) because certain advantages. First, IPS test allows for heterogeneous coefficients. They recommend unit root tests for dynamic heterogeneous panels based on the mean of individual unit root test statistics. Second, IPS proposed a standardized t-bar test statistic based on the (augmented) Dickey-Fuller statistics averaged across the groups. However, the tests have little power if deterministic terms are included in the analysis. On the contrary, Levin–Lin–

Chu (Levin et al. 2002) test has its limitations. First, there are some cases in which contemporaneous correlations cannot be removed by simply subtracting cross-sectional averages. Secondly, the assumption that all individuals are identical with respect to the presence or absence of a unit root is, in some sense, restrictive. Therefore, we consider Im–Pesaran–Shin (IPS, 2003) unit root test in our analysis. For a sample of N groups observed over T time periods, the IPS panel unit root regression of the conventional ADF test can be written as in the following form:

$$\Delta y_{i,t} = \alpha_i + \pi_i t + \beta_i y_{i,t-1} + \sum_{j=1}^{k} \psi_{i,j} \Delta y_{i,t-j} + \varepsilon_{i,t} \qquad (5)$$

where y signifies the time series, Δ is the first difference operator, $\varepsilon_{i,t}$ is a white noise disturbance term with variance σ^2, $i = 1,2,\ldots,N$ show countries and $t = 1,2,\ldots,T$ represents times. The $\Delta y_{i,t-j}$ terms on the right-hand side in Equation (5) allow serial correlation with the goal of achieving white noise disturbance term.

2.2.2. Panel cointegration test

Next, to examine the long-run relationship between TFP and primary energy consumption in a panel framework, this study uses Pedroni (2004) panel cointegration approach which allows for considerable heterogeneity among individual members of the panel. This test also contained heterogeneity in both the long run cointegrating vectors as well as in the dynamics related with short run deviations from these one. This test has asymptotic distributions of seven different statistics: four are related to pooling along within-dimension, and three are based on pooling along between-dimension. Within-dimension statistics termed as panel cointegration statistics and between-dimension statistics called as group mean panel cointegration statistics.

Apart from the energy consumption (same as primary energy consumption), this study examined the various forms of energy consumption with total factor productivity. The panel cointegration approach developed by Pedroni (2004) is as follows:

Model 1: $lnTFP_{it} = \alpha_{0i} + \beta_{1i} lnPEC_{it} + \varepsilon_{it}$ (6)
Model 2: $lnTFP_{it} = \alpha_{0i} + \beta_{1i} lnELC_{it} + \varepsilon_{it}$ (7)
Model 3: $lnTFP_{it} = \alpha_{0i} + \beta_{1i} lnTCC_{it} + \varepsilon_{it}$ (8)
Model 4: $lnTFP_{it} = \alpha_{0i} + \beta_{1i} lnNGC_{it} + \varepsilon_{it}$ (9)
Model 5: $lnTFP_{it} = \alpha_{0i} + \beta_{1i} lnPC_{it} + \varepsilon_{it}$ (10)

where $\varepsilon_{it} = \acute{\eta}_i \; e_{i(t-1)} + \mu_{it}$ are the estimated residuals from the panel regression. The null hypothesis tested is whether μ_{it} is unity. TFP_{it} is the total factor productivity. α_{0i} implies a country-specific intercept. Similarly, PEC, ELC, TCC, NGC, and PC are primary energy consumption, electricity consumption, total coal consumption, natural gas consumption, and petroleum consumption, respectively. All the variables are expressed in logarithm.

Further to check the robustness, we apply another panel cointegration test proposed by Westerlund (2007). This test assumes that the null hypothesis of no cointegration which are based on structural rather than residual dynamics, and hence do not impose any common factor restriction. This test is useful to test whether the error correction term in a conditional error correction model is equal to zero. There are four statistics: first two is used to test the alternative

hypothesis that the panel is cointegrated as a whole, while the other two tests use to check the alternative that there is at least one individual that is cointegrated. Westerlund panel cointegration test is found to be more accurate by looking better size accuracy and higher power than the residual-based tests developed by Pedroni (2004).

2.2.3. Dynamic Ordinary Least Square

In order to estimate the long-run effect of energy consumption on TFP, we use dynamic ordinary least squares (DOLS) developed by Stock and Watson (1993) and the panel DOLS estimator suggested by Kao and Chiang (1999), which contains leads and lags of the exogenous variables. This test is superior to OLS and fully modified OLS particularly in case of small panel size, i.e. when N and T are up to 60.

2.2.4. Panel Granger causality test

Finally, we check the panel Granger causality between energy consumption and TFP. According to Engle and Granger (1987) if two non-stationary variables are cointegrated, a vector auto-regression in first differences will be miss-specified. Therefore, for testing the Granger causality, we can specify a model with dynamic error correction representation. The following models are estimated:

Model 6: $$\Delta TFP_{it} = \theta_{1i} + \sum_{p} \theta_{11ip}\, \Delta TFP_{it-p} + \sum_{p} \theta_{12ip}\, \Delta PEC_{it-p} + \lambda_{it}\, ECT_{t-1} + e_{it} \quad (11)$$

$$\Delta PEC_{it} = \theta_{1i} + \sum_{p} \theta_{11ip}\, \Delta PEC_{it-p} + \sum_{p} \theta_{12ip}\, \Delta TFP_{it-p} + \lambda_{it}\, ECT_{t-1} + e_{it} \quad (12)$$

Model 7: $$\Delta TFP_{it} = \theta_{1i} + \sum_{p} \theta_{11ip}\, \Delta TFP_{it-p} + \sum_{p} \theta_{12ip}\, \Delta ELC_{it-p} + \lambda_{it}\, ECT_{t-1} + e_{it} \quad (13)$$

$$\Delta ELC_{it} = \theta_{1i} + \sum_{p} \theta_{11ip}\, \Delta ELC_{it-p} + \sum_{p} \theta_{12ip}\, \Delta TFP_{it-p} + \lambda_{it}\, ECT_{t-1} + e_{it} \quad (14)$$

Model 8: $$\Delta TFP_{it} = \theta_{1i} + \sum_{p} \theta_{11ip}\, \Delta TFP_{it-p} + \sum_{p} \theta_{12ip}\, \Delta TCC_{it-p} + \lambda_{it}\, ECT_{t-1} + e_{it} \quad (15)$$

$$\Delta TCC_{it} = \theta_{1i} + \sum_{p} \theta_{11ip}\, \Delta TCC_{it-p} + \sum_{p} \theta_{12ip}\, \Delta TFP_{it-p} + \lambda_{it}\, ECT_{t-1} + e_{it} \quad (16)$$

Model 9: $$\Delta TFP_{it} = \theta_{1i} + \sum_{p} \theta_{11ip}\, \Delta TFP_{it-p} + \sum_{p} \theta_{12ip}\, \Delta NGC_{it-p} + \lambda_{it}\, ECT_{t-1} + e_{it} \quad (17)$$

$$\Delta NGC_{it} = \theta_{1i} + \sum_{p} \theta_{11ip}\, \Delta NGCC_{it-p} + \sum_{p} \theta_{12ip}\, \Delta TFP_{it-p} + \lambda_{it}\, ECT_{t-1} + e_{it} \quad (18)$$

Model 10: $$\Delta TFP_{it} = \theta_{1i} + \sum_{p} \theta_{11ip}\, \Delta TFP_{it-p} + \sum_{p} \theta_{12ip}\, \Delta PC_{it-p} + \lambda_{it}\, ECT_{t-1} + e_{it} \quad (19)$$

$$\Delta PC_{it} = \theta_{1i} + \sum_{p} \theta_{11ip}\, \Delta PC_{it-p} + \sum_{p} \theta_{12ip}\, \Delta TFP_{it-p} + \lambda_{it}\, ECT_{t-1} + e_{it} \quad (20)$$

The Δ shows the first difference of the variables, *ECT* is the error-correction term, *p* denotes the lag length of the models. The lag length in each case is selected based on the Akaike information criterion. The significance of first-differenced variables provides evidence of short-run Granger causality where one period lagged error correction term indicates long run Granger causality.

2.3. Data

Our study centers by using data on both developed and developing countries. We include 42 countries based on availability of data for total primary energy consumption, various types of energy consumption and total factor productivity. The analysis is based on balanced panel data using 42 countries (see Table 2A in Appendix) for the period of 1980 to 2014. Further, we divide 42 countries into smaller panels based on regions named as Asian, African, European and Latin American. This study makes use of annual data on total factor productivity (TFP) and primary energy consumption (PEC), and its various forms such as electricity consumption, petroleum consumption, coal consumption and natural gas consumption. The data on energy consumption and its various patterns are collected from Energy Information Administration

(EIA) database. Rather than estimating the total factor productivity, the present study directly collected the TFP data form the Penn World Table (PWT) version 9.0 constructed by Feenstra et al., (2015).

3. Empirical results and discussion

In this section, we discuss the empirical results. The results of summary statistics are presented in Table 1, and we noticed that mean (and median) value of primary energy consumption (lnPEC) is around 1.00 in case of developed countries, whereas for developing countries it is around 0.60 which less than the developed countries. The other regions such as Aggregate, European, Latin American, Asian, and African are very different in terms of mean (and median) values of primary energy consumption (lnPEC), petroleum consumption (lnPC), total coal consumption (lnTCC), natural gas consumption (lnNGC) and electricity consumption (lnELC) which implies that there exists heterogeneity among the panels. We also observed from the mean value of total factor productivity (lnTFP) growth that developing countries are more productive than developed countries. Similarly, we can see the variation in terms of productivity among the regions. To figure out the variation, further we look at the standard error and the coefficients of standard deviation of all the variables provide an evidence of presence of heterogeneity.

[Insert Table 1 around here]

The unit root test has been carried out for the variables under investigation to check the stationarity. The Im, Pesaran, and Shin (IPS, 2003) panel unit root test are performed both on levels and first differences of the variables taking both with constant and constant with trend. The results of panel unit are presented in the Table 2 and results indicate that lnTFP and lnPEC are nonstationary at constant and trend in case of all the panels whereas the unit root results are mixed for other variables such as lnPC, lnTCC, lnNGC and lnELC across the panels. Results of the panel unit root tests permits to conclude that the variables are integrated I(1) which gives signal for applying panel cointegration test.

[Insert Table 2 around here]

To check the long-run relationship between TFP and energy consumption, we have applied Pedroni cointegration test for aggregate panel which combines 42 countries as well as region named Asian, African, Latin American, European and panels based on income such as Developed and Developing countries. We have five forms of energy consumption such as primary energy consumption (lnPEC), petroleum consumption (lnPC), electricity consumption (lnELC), natural gas consumption (lnNGC) and total coal consumption (lnTCC). We run panel cointegration for each of these variables with total factor productivity following equations (6-10). Further, we run the panel integration of each pair (lnTFP – lnPEC), (lnTFP – lnELC), (lnTFP – lnTCC), (lnTFP – lnNGC), (lnTFP – lnPC) for aggregate panel, panels based on region and panels based on income category. The panel cointegration results are presented in Tables 3 to 7. Table 3 represents the Model 1 which shows the long-run relationship between total factor productivity growth (lnTFP) and primary energy consumption (lnPEC). Our results show that at least 4 out of 7 statistics reject the null of no cointegration for all panels except African region. This allows us to conclude that there exists a long run relationship between lnTFP and lnPEC. On the overall, we found a long-run relationship between total factor productivity and energy consumption. The African region is the least developed countries with low economic growth (lower TFP) in the world. Our sample for African region also only consists of four countries

namely, Egypt, Morocco, Nigeria, and Tunisia. The energy consumption of these countries is also much low as compared to other regions. Thus, it could be one of the plausible reasons for not finding the long-run relationship between total factor productivity and energy consumption.

[Insert Table 3 around here]

Model 2 describes the long-run relationship between total productivity (lnTFP) and electricity consumption (lnELC). Results reported in Table 4 show that at least 4 out of 7 statistics reject the null of no cointegration for aggregate, developing, Asian, African and Latin American regions, which implies that there exist a long-run relationship between electricity energy consumption and total factor productivity. On the contrary, we did not find any long-run relationship between total factor productivity growth and electricity consumption in case of Developed countries and European regions.

[Insert Table 4 and 5 around here]

In Model 3, we consider total coal consumption (lnTCC) as one of the form of energy consumption and examine its long-run relationship with total factor productivity. The results are presented in Table 5. The results based on panel cointegration do not support any evidence of long-run relationship between coal consumption and TFP in case of aggregate panel, panel based on developed countries and three regions namely African, European and Latin American. However, we found a long-run cointegrating relationship for developing countries and Asian region. Similarly, model 4 provides the relationship between TFP and natural gas consumption and model 5 provide nexus between TFP growth and petroleum consumption. The results are disseminated in Tables 6 and 7. Both the tables clearly indicate the existence of long-run relationship for aggregate panel, developing countries, Asian, and Latin American regions. We do not find any cointegrating relationship between TFP – natural gas consumption and TFP – petroleum consumption for developed countries, European and African regions.

[Insert Table 6 and 7 around here]

After finding the long-run relationship between TFP and energy consumption and TFP with various types of energy consumption, in the next step, we try to find out the long-run impact of energy consumption on productivity growth by applying DOLS dynamic ordinary least square (DOLS). The DOLS results are presented in Table 8. Further, we present DOLS results by applying only constant and constant with trend models. However, model with constant and trend is more suitable since we have taken 35 years data. Therefore, this paper considers results based on constant with a trend are more appropriate and hence interpreted those results. Table 8 only disseminates the long-run elasticity coefficients for those panels which we found a cointegrating relation. Let us first look at the results of model 1. The DOLS results based on model 1 (lnTFP – lnPEC) indicate that primary energy consumption has a long-run positive and significant impact on productivity growth for aggregate panel as well as most of the sub-panels based on regions and income. The result from aggregate panel shows that 1% increase in primary energy consumption on an average raise the total factor productivity growth by 0.21%. Similarly, the coefficient obtained from panel of developed countries indicates that 1% increase in primary energy consumption boost the productivity growth on an average by 0.36%. The results of model 1 further show that increase in primary energy consumption in case of Latin American region

affect the TFP growth by 0.53%, which is the most among all regions. Similarly, results obtain from the developing countries indicate that 1% increase in primary energy consumption on an average increase the TFP growth by 0.11%. That implies that raising energy consumption does not necessarily boost the productivity growth in case of developing countries as compared to developed countries. The results also show a positive impact of energy consumption on total factor productivity growth in case of Asian region (based on constant model).

[Insert Table 8 around here]

Next in Table 8, we examine whether various types of energy consumption (models 2 to 5) have any long-run impact on total factor productivity growth. The results based on model 2 indicate that 1% increase in electricity consumption on an average increase the total factor productivity growth by 0.27% for aggregate panel, 0.21% for developing countries and 0.53% for Latin American region. Surprisingly, the electricity consumption does not affect the TFP growth of developed countries and European region as we did not find any long-run relationship between electricity consumption and TFP. Then we look at DOLS results based on model 3 (lnTFP – lnTCC) and found total coal consumption does not significantly affect the total factor productivity growth for none of the panel. Although few of the countries in our sample consume coal as the highest form of energy consumption out of total energy consumption, however, none of these coefficients are statistically significant. Further by analyzing model 4 which examine the long-run elasticity of TFP growth with respect to change in natural gas consumption. The results show a positive impact of natural gas consumption on total factor productivity growth on aggregate, developing and Latin America region, however, its impact is very much negligible. The result derived from aggregate panel shows that 1% increase in natural gas consumption on an average boost the TFP growth by 0.02% only. Finally, Table 8 shows the results based on model 5 (lnTFP – lnPC). Petroleum consumption is one of the key factors for economic growth. The coefficients show a positive and statistically significant impact on aggregate, developing, Asian and Latin American regions. This coefficienct is highest in case of Latin American region. One percent increase in petroleum consumption leads to increase the TFP growth by 0.27%, whereas, petroleum consumption affect the TFP growth of aggregate panel by 0.14%. From these results, we conclude that primary energy consumption and its other forms are important factors to make an economy more productive but in some cases these factors are found insignificant.

[Insert Table 9 around here]

This study after finding the long-run impact of energy consumption and its various forms on total factor productivity growth, in next step, we examine the panel Granger causality relation between energy consumption and TFP growth. We demonstrated the results in Table 9. We observe that the coefficients of error correction term (ECM) are significant almost for all panels and for most forms of energy consumption except total coal consumption. These results based on ECM imply long-run panel causality between energy consumption and TFP growth. The coefficient of error correction term shows the speed of adjustment with its equilibrium. Our results based on Table 9 do corroborate with *a priori* expectation with regard to sign of ECM coefficients. Table 9 also presents the short-run panel Granger causality between these variables. By looking at the results obtained from model 6, we find uni-directional Granger causality runs from TFP growth to energy consumption in case of aggregate, developing countries, European, and Latin American regions. However, in case of Asian region we found a bi-directional short-run Granger causality between TFP growth and primary energy consumption. However, we

notice different results by examining the short-run Granger causality between electricity consumption and TFP growth. Although the results found a bi-directional causality between electricity consumption and TFP growth for aggregate, developing countries, Asian and African regions, but electricity consumption negatively causes the TFP growth and TFP growth positively causes the electricity consumption in short-run. Similarly, we do not notice any short-run Granger causality between TFP growth and natural gas consumption for most of the panels. Finally, short-run panel Granger causality runs from TFP growth to petroleum consumption only in case of aggregate panel and developing countries, but not vice-versa. From our results, we conclude that total factor productivity growth is causing the energy consumption and its different forms in the short-run although the story is different in the long-run.

3.1. Results of robustness checking

[Insert Table 10 around here]

To check the robustness of our results, we further apply the Westerlund panel cointegration test and results are presented in Table 10. The results of model 1 show the existence of long-run relationship between total factor productivity and energy consumption for aggregate panel, developing countries, Asian, and Latin American regions. However, we did not find any long-run relationship between total factor productivity and energy consumption for panels of advanced countries, European, and African regions. These results based on Westerlund panel cointegration do corroborate with the findings obtain from Padroni panel cointegration in Table 3. Similarly, results of Westerlund tests for other models are presented in Table 10. It can be concluded that these results are consistent with the panel cointegration tests by Pedroni.

4. Conclusive remarks and policy implications

By using global panel data set of 1980-2014 for a sample of 42 countries (e.g. Developed, Developing, European, Latin America, Asian and African regions), this study makes an empirical contribution with new policy insights to the economic growth–energy consumption literature by considering total factor productivity as the measure of economic performance. In fact, Easterly and Levine (2001) in their seminal work suggest that the growth economists should rely on total factor productivity rather than factor accumulation. This may be because productivity growth mainly enables countries to grow and compete with other countries of the connected and competitive world. This is the novel context which motivates us not only to examine the relationship between total factor productivity and energy consumption but also examine the relationship between different forms of energy consumption and total factor productivity for 42 developed and developing countries. The data availability was only the basis for selecting 42 developed and developing countries for the variables of interest in our panel analysis. To examine the relationship between productivity and energy consumption, we divided the 42 countries and form two panels based on income category and four panels based on regions.

Methodologically, we followed five steps to analyze the relationship between total factor productivity (TFP) and energy consumption. First, we checked the stationary property of all variables using Im, Pesaran, and Shin (2003) panel unit root test. If non-stationarity issues are present, in the second step, we performed panel cointegration test in order to investigate the

existence of a long-run relationship between total factor productivity and energy consumption and, relationship between total factor productivity and with various patterns of energy consumption. We used the Pedroni panel cointegration tests. In the third step, we employ the dynamic ordinary least square (DOLS) to find out the long-run elasticity of TFP with respect to change in energy consumption. Fourth, we used the panel Granger causality tests to find out the direction of causality between total factor productivity and energy consumption. Finally, we employed the Westerlund panel cointegration tests to examine the robustness of the results.

Empirical findings based on panel cointegration tests confirm the existence of long-run relationship between energy consumption and total factor productivity for aggregate panel, developed and developing countries panels and all the regional panels (European, Latin American and Asian countries) of the world except for the African region. Further, our results also support the evidence of long-run relationship between TFP and different components of total primary energy consumption like electricity, natural gas and petroleum. However, we did not find any strong evidence of long-run relationship between total factor productivity and total coal consumption. The overall results of DOLS strongly support the positive impact of energy consumption on productivity for aggregate panel, but the results have varied across different panels by income category panels based on regions. The panel Granger causality results provided mixed results. We found the long-run **feedback hypothesis** between TFP and energy consumption, indicating that both the series are interconnected and influencing each other over the period of time. However, we also supported the **conservation hypothesis** between the series, implying that total factor productivity growth causes energy consumption in short-run only. The panel based on developed countries found no evidence of long-run relationship between TFP and with the various forms of energy consumption. Similarly, we also did not find any strong evidence of long-run as well as Granger causality relationships between TFP and energy consumption and its various forms for European and African regions. These findings have implications for policy, suggesting that the greater energy-consuming countries of the world should reduce energy usage further to enhance productivity which is essential for promoting environmental-friendly sustainable economic growth and development in the long-run. Since the findings supported feedback hypothesis, then in the name of energy conservation policies, reducing energy use will not only save environmental quality but also retard the long-run productivity growth of both developed and developing countries. Therefore, energy saving technology must be welcomed into the process of production for improving environmental quality.

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Table 1: Summary statistics

Variables	Mean	Median	Max.	Min.	Std. Dev.	Obs.
Aggregate						
lnTFP	-0.05	-0.02	0.43	-0.62	0.14	1470
lnPC	6.23	6.03	9.94	3.04	1.24	1470
lnPEC	0.85	0.74	4.81	-2.63	1.33	1470
lnTCC	9.03	9.40	15.36	-2.58	2.66	1470
lnNGC	5.66	5.95	10.19	-0.92	1.96	1470
lnELC	4.32	4.17	8.53	0.83	1.38	1470
Developed						
lnTFP	-0.05	-0.01	0.40	-0.50	0.13	805
lnPC	6.26	5.90	9.94	3.04	1.35	805
lnPEC	1.00	0.80	4.62	-2.63	1.34	805
lnTCC	9.73	10.01	13.94	4.42	2.03	805
lnNGC	5.89	5.99	10.19	0.00	1.90	805
lnELC	4.61	4.44	8.27	1.22	1.33	805
Developing						
lnTFP	-0.04	-0.02	0.43	-0.62	0.15	665
lnPC	6.20	6.13	9.35	3.95	1.08	665
lnPEC	0.68	0.64	4.81	-2.07	1.30	665
lnTCC	8.19	8.38	15.36	-2.58	3.06	665
lnNGC	5.38	5.88	8.76	-0.92	2.01	665
lnELC	3.97	3.88	8.53	0.83	1.36	665
European						
lnTFP	-0.06	-0.02	0.40	-0.50	0.13	560
lnPC	5.84	5.61	7.72	3.04	0.99	560
lnPEC	0.62	0.57	2.43	-2.63	1.02	560
lnTCC	9.17	9.49	12.48	4.42	1.90	560
lnNGC	5.49	5.63	8.16	0.00	1.54	560
lnELC	4.22	4.22	6.16	1.22	1.01	560
Latin American						
lnTFP	0.01	0.00	0.43	-0.31	0.12	245
lnPC	6.18	6.07	8.05	4.56	0.98	245
lnPEC	0.67	0.66	2.55	-1.05	0.96	245
lnTCC	7.70	7.70	7.70	7.70	7.70	245
lnNGC	5.68	5.79	7.85	2.14	1.35	245
lnELC	4.04	3.97	6.25	2.16	1.00	245
Asian						
lnTFP	-0.10	-0.06	0.25	-0.62	0.15	280
lnPC	6.68	6.60	9.35	4.84	0.99	280
lnPEC	1.28	1.19	4.81	-1.11	1.33	280
lnTCC	10.18	10.11	15.36	3.74	2.47	280
lnNGC	5.72	6.37	8.76	-0.92	2.24	280
lnELC	4.55	4.41	8.53	2.24	1.36	280

African						
lnTFP	-0.03	0.01	0.17	-0.43	0.16	140
lnPC	5.26	5.37	6.68	3.95	0.76	140
lnPEC	-0.51	-0.50	1.30	-2.07	0.86	140
lnTCC	5.08	5.56	8.89	-2.58	2.85	140
lnNGC	4.21	4.76	7.54	-0.36	2.08	140
lnELC	2.67	2.55	4.96	0.83	0.97	140

Note: lnTFP =Total Factor Productivity; lnPC=Petroleum consumption; lnPEC=Primary Energy Consumption; lnTCC=Total coal consumption; lnNGC=Natural Gas Consumption; and lnELC=Electricity Consumption. All Variables converted into natural algorithm.

Table 2: Summary of unit root test (Im, Pesaran and Shin, 2003)

Country	**lnTFP**		**lnPC**		**lnPEC**		**lnTCC**		**lnNGC**		**lnELC**	
	C	**C&T**	**C**	**C&T**	**C**	**C&T**	**C**	**C&T**	**C**	**C&T**	**C**	**C&T**
Aggregate	-0.29 (0.38)	0.82 (0.79)	2.26 (0.98)	2.17 (0.99)	-1.16 (0.12)	7.41 (1.00)	-1.13 (0.13)	1.16 (0.88)	-2.01** (0.02)	3.69 (0.99)	-4.13* (0.00)	5.16 (1.00)
Developed	0.03 (0.51)	2.88 (0.99)	-0.08 (0.47)	2.83 (0.99)	-2.42* (0.01)	8.34 (1.00)	-1.23 (0.11)	-0.53 (0.30)	-2.31* (0.01)	4.33 (1.00)	-5.95* (0.00)	6.55 (1.00)
Developing	-0.46 (0.32)	-1.98** (0.02)	3.43 (0.99)	0.14 (0.55)	0.89 (0.81)	1.82 (0.97)	-0.56 (0.29)	2.18 (0.99)	-0.48 (0.31)	0.73 (0.77)	0.39 (0.65)	0.39 (0.66)
European	-0.18 (0.43)	3.77 (0.99)	-1.32 (0.11)	1.03 (0.84)	-1.54*** (0.07)	5.63 (1.00)	-0.20 (0.42)	-2.22** (0.01)	-1.39 (0.10)	5.63 (1.00)	3.81* (0.00)	2.95 (0.99)
Latin American	2.92 (0.98)	-1.62** (0.05)	3.69 (0.99)	1.63 (0.95)	2.63 (0.99)	2.73 (0.99)	0.54 (0.71)	0.14 (0.56)	1.09 (0.87)	1.27 (0.90)	1.95 (0.88)	0.44 (0.67)
Asian	0.54 (0.70)	-1.77** (0.04)	1.01 (0.85)	-1.16 (0.12)	2.12 (0.98)	2.12 (0.98)	-1.12 (0.13)	0.84 (0.79)	-1.76 (0.11)	1.08 (0.86)	-1.02 (0.15)	0.62 (0.73)
African	2.21 (0.98)	0.45 (0.67)	0.98 (0.83)	2.21 (0.12)	-0.01 (0.49)	2.62 (0.15)	-0.31 (0.37)	3.33 (0.99)	-0.07 (0.47)	-1.53 (0.10)	0.90 (0.81)	-0.66 (0.25)

Note: C=intercept; C&T=intercept with trend. lnTFP =Total Factor Productivity; lnPC=Petroleum consumption; lnPEC=Primary Energy Consumption; lnTCC=Total coal consumption; lnNGC=Natural Gas Consumption; and lnELC=Electricity Consumption. All Variables converted into natural algorithm. Where *, **, and *** are significance level at 1%, 5% and 10% respectively. P-values are given in the parenthesis

Table 3: Pedroni panel cointegration (lnTFP – lnPEC)

Model -1				
Panels	**C**	**C&T**	**C**	**C&T**
Aggregate			**Developing**	
Panel v-Statistic	0.57 (0.28)	0.16 (0.44)	2.65* (0.00)	2.15*(0.01)
Panel rho-Statistic	-0.27 (0.39)	0.79 (0.79)	-2.42*(0.01)	-0.48 (0.32)
Panel PP-Statistic	-1.34***(0.08)	-2.15**(0.02)	-3.34*(0.00)	-1.75**(0.04)
Panel ADF-Statistic	-2.19* (0.01)	-2.74*(0.00)	-3.74*(0.00)	-2.16* (0.01)
Group rho-Statistic	-0.71 (0.24)	1.49 (0.93)	-1.29***(0.09)	1.19 (0.88)
Group PP-Statistic	-2.81*(0.00)	-2.45*(0.01)	-3.03*(0.00)	-0.69 (0.24)
Group ADF-Statistic	-3.21* (0.00)	-4.09*(0.00)	-3.35(0.00)	-2.09**(0.02)
Developed			**Latin American**	
Panel v-Statistic	-1.51 (0.93)	-2.11 (0.98)	1.19 (0.12)	4.42*(0.00)
Panel rho-Statistic	1.71 (0.96)	1.69 (0.95)	-1.22***(0.10)	-1.41***(0.07)
Panel PP-Statistic	1.54 (0.94)	-1.46* (0.07)	-2.48*(0.01)	-2.78*(0.00)
Panel ADF-Statistic	0.63 (0.74)	-2.05**(0.02)	-2.88*(0.00)	-2.53*(0.01)
Group rho-Statistic	0.21 (0.58)	0.92 (0.82)	-1.03 (0.15)	0.10 (0.54)
Group PP-Statistic	-1.05 (0.15)	-2.68*(0.00)	-2.68* (0.00)	-1.71**(0.04)
Group ADF-Statistic	-1.29***(0.09)	-3.61*(0.00)	-2.57*(0.00)	-1.30***(0.09)
European			**Asian**	
Panel v-Statistic	-1.50 (0.93)	-2.04 (0.98)	3.80*(0.00)	0.66 (0.25)
Panel rho-Statistic	1.62 (0.95)	1.42 (0.92)	-2.53*(0.01	-0.37 (0.35)
Panel PP-Statistic	1.52 (0.94)	-1.37***(0.08)	-2.19* (0.01)	-1.78** (0.05)
Panel ADF-Statistic	0.69 (0.75)	-1.74**(0.04)	-2.68* (0.00)	-1.64**(0.05)
Group rho-Statistic	-0.27 (0.39)	-0.13 (0.45)	-1.12 (0.13)	0.68 (0.75)
Group PP-Statistic	-1.71** (0.04)	-4.11* (0.00)	-1.84**(0.03)	-0.37 (0.35)
Group ADF-Statistic	-1.81**(0.03)	-2.72* (0.00)	-2.85* (0.00)	-1.69**(0.04)
African				
Panel v-Statistic	0.31 (0.37)		-0.61(0.72)	
Panel rho-Statistic	-0.76 (0.22)		0.68 (0.75)	
Panel PP-Statistic	-1.09 (0.23)		0.19 (0.57)	
Panel ADF-Statistic	-0.79 (0.21)		-0.33 (0.36)	
Group rho-Statistic	0.13 (0.55)		1.51 (0.93)	
Group PP-Statistic	-0.45 (0.32)		1.27 (0.89)	
Group ADF-Statistic	0.12 (0.54)		0.81 (0.79)	

Note: C=intercept; C&T=intercept with trend, TFP = total factor productivity, and PEC = primary energy consumption. *, **, and *** are significance level at 1%, 5% and 10% respectively. *P*-values are given in the parenthesis.

Table 4: Pedroni panel cointegration (lnTFP – lnELC)

Model -2				
Panels	**C**	**C&T**	**C**	**C&T**
Aggregate			**Developing**	
Panel v-Statistic	2.19* (0.01)	0.33 (0.38)	3.74*(0.00)	2.49*(0.00)
Panel rho-Statistic	-1.01 (0.15)	-0.61 (0.27)	-2.91*(0.00)	-2.15*(0.01)
Panel PP-Statistic	-1.83**(0.03)	-3.92*(0.00)	-3.63*(0.00)	-3.99*(0.00)
Panel ADF-Statistic	-3.09* (0.00)	-4.61*(0.00)	-4.53*(0.00)	-5.28*(0.00)
Group rho-Statistic	-0.30 (0.38)	1.21(0.88)	-1.16 (0.12)	0.19 (0.58)
Group PP-Statistic	-1.78**(0.04)	-2.19*(0.01)	-2.79*(0.00)	-2.19*(0.01)
Group ADF-Statistic	-3.98*(0.00)	-3.76*(0.00)	-3.41*(0.00)	-3.69*(0.00)
Developed			**Latin American**	
Panel v-Statistic	-0.63 (0.73)	-2.26 (0.98)	1.52**(0.06)	2.85*(0.00)
Panel rho-Statistic	1.47 (0.92)	1.48 (0.93)	-1.18 (0.11)	-1.99**(0.02)
Panel PP-Statistic	1.54 (0.93)	-1.27***(0.10)	-2.06* (0.01)	-3.18*(0.00)
Panel ADF-Statistic	0.57 (0.71)	-0.79 (0.21)	-2.54*(0.01)	-4.02*(0.00)
Group rho-Statistic	0.64 (0.73	1.45 (0.92)	-0.86 (0.19)	-0.53 (0.29)
Group PP-Statistic	0.13 (0.55)	-0.98 (0.16)	-2.19*(0.01)	-2.34*(0.00)
Group ADF-Statistic	-2.28*(0.01	-1.74**(0.04)	-2.23*(0.01)	-3.45*(0.00)
European			**Asian**	
Panel v-Statistic	-0.83(0.79)	-2.25 (0.99)	3.52*(0.00)	0.68 (0.24)
Panel rho-Statistic	1.47(0.93)	1.39(0.91)	-2.27*(0.01)	-0.10 (0.45)
Panel PP-Statistic	1.59(0.94)	-0.92(0.17)	-1.97**(0.02)	-1.66**(0.05)
Panel ADF-Statistic	0.81(0.79)	-0.21 (0.41)	-3.67*(0.00)	-2.08**(0.03)
Group rho-Statistic	0.59(0.72)	1.05(0.85)	-0.72 (0.23)	0.92 (0.82)
Group PP-Statistic	0.06 (0.52)	-1.33***(0.09)	-1.42***(0.07)	-1.22***(0.06)
Group ADF-Statistic	-1.40***(0.08)	-0.60(0.27)	-2.79*(0.00)	-1.02***(0.10)
African				
Panel v-Statistic	1.97**(0.02)		0.74 (0.23)	
Panel rho-Statistic	-2.21*(0.01)		-2.21*(0.01)	
Panel PP-Statistic	-2.81* (0.00)		-3.96*(0.00)	
Panel ADF-Statistic	-1.37***(0.08)		-4.60*(0.00)	
Group rho-Statistic	-0.37 (0.35)		-0.18 (0.43)	
Group PP-Statistic	-1.19 (0.11)		-1.36***(0.08)	
Group ADF-Statistic	-0.54 (0.29)		-2.01**(0.02)	

Note: C=intercept; C&T=intercept with trend, TFP = total factor productivity, and ELC = electricity consumption. *, **, and *** are significance level at 1%, 5% and 10% respectively. *P*-values are given in the parenthesis.

Table 5: Pedroni panel cointegration (lnTFP – lnTCC)

Model -3				
Panels	**C**	**C&T**	**C**	**C&T**
Aggregate			**Developing**	
Panel v-Statistic	-0.16 (0.56)	-2.21 (0.91)	2.20*(0.01)	-0.43 (0.66)
Panel rho-Statistic	0.11(0.54)	2.23(0.98)	-0.97(0.16)	0.06 (0.52)
Panel PP-Statistic	-0.62(0.26)	0.29(0.61)	-1.16(0.12)	-0.10***(0.10)
Panel ADF-Statistic	-1.48**(0.06)	-0.07(0.39)	-2.06*(0.01)	1.47 (0.81)
Group rho-Statistic	1.58(0.94)	3.81(0.99)	-0.22(0.41)	-1.45***(0.08)
Group PP-Statistic	0.02(0.50)	1.90(0.97)	-1.54***(0.06)	-0.54(0.29)
Group ADF-Statistic	-0.85(0.19)	0.04(0.51)	-2.06*(0.01)	-1.94**(0.02)
Developed			**Latin American**	
Panel v-Statistic	-1.48(0.93)	-2.42 (0.99)	1.59**(0.05)	-0.84(0.80)
Panel rho-Statistic	0.93(0.82)	3.40(0.99)	-0.88(0.18)	0.63(0.73)
Panel PP-Statistic	0.47(0.68)	2.47(0.99)	-1.02(0.15)	-0.12(0.45)
Panel ADF-Statistic	0.28(0.61)	3.00 (0.99)	-1.36***(0.08)	-0.03(0.48)
Group rho-Statistic	2.48(0.99)	4.04 (1.00)	-0.11(0.45)	1.21(0.88)
Group PP-Statistic	1.79(0.96)	3.53(0.99)	-0.99(0.15)	0.04(0.51)
Group ADF-Statistic	1.31(0.90)	2.46(0.99)	-0.89(0.18)	-0.76(0.22)
European			**Asian**	
Panel v-Statistic	-1.46(0.92)	-2.31(0.98)	2.82*(0.00)	0.03(0.48)
Panel rho-Statistic	0.83(0.79)	3.01(0.99)	-1.86**(0.03)	-1.14***(0.06)
Panel PP-Statistic	0.36(0.64)	2.20(0.98)	-1.91**(0.02)	-0.64(0.25)
Panel ADF-Statistic	0.36(0.64)	2.73(0.99)	-2.69*(0.00)	-1.64**(0.05)
Group rho-Statistic	2.04(0.97)	3.51(0.99)	-0.71(0.24)	0.94(0.82)
Group PP-Statistic	1.02(0.84)	3.30(0.99)	-1.75**(0.03)	-0.22(0.41)
Group ADF-Statistic	1.08(0.86)	2.63(0.99)	-2.95*(0.00)	-1.95**(0.02)
African				
Panel v-Statistic	-0.07(0.52)		0.57(0.28)	
Panel rho-Statistic	0.56(0.71)		-0.939(0.17)	
Panel PP-Statistic	0.65(0.74)		-1.61**(0.05)	
Panel ADF-Statistic	0.26(0.60)		-1.21(0.11)	
Group rho-Statistic	0.67(0.74)		0.22(0.58)	
Group PP-Statistic	0.43(0.66)		-0.92(0.17)	
Group ADF-Statistic	0.86(0.80)		-0.46(0.32)	

Note: C=intercept; C&T=intercept with trend, TFP = total factor productivity, and TCC = total coal consumption. *, **, and *** are significance level at 1%, 5% and 10% respectively. *P*-values are given in the parenthesis.

Table 6: Pedroni panel cointegration (lnTFP – lnNGC)

Model - 4				
Panels	**C**	**C&T**	**C**	**C&T**
Aggregate			**Developing**	
Panel v-Statistic	1.23***(0.10)	-0.56(0.71)	1.91**(0.02)	1.83**(0.03)
Panel rho-Statistic	-1.32***(0.09)	1.159(0.87)	-1.94**(0.03)	-1.16(0.12)
Panel PP-Statistic	-2.56*(0.00)	-1.14***(0.10)	-3.08*(0.00)	-2.49*(0.01)
Panel ADF-Statistic	-2.57*(0.01)	-2.01**(0.02)	-3.43*(0.00)	-3.55*(0.00)
Group rho-Statistic	0.92(0.82)	-2.19*(0.01)	-0.25(0.40)	0.42(0.66)
Group PP-Statistic	-1.42***(0.07)	-0.38(0.35)	-2.22*(0.01)	-1.75**(0.04)
Group ADF-Statistic	-2.31*(0.01)	-2.29*(0.01)	-2.23*(0.01)	-2.89*(0.00)
Developed			**Latin American**	
Panel v-Statistic	-0.37(0.64)	-2.61(0.99)	0.71(0.23)	1.85**(0.03)
Panel rho-Statistic	0.25(0.60)	2.77(0.99)	-0.80(0.21)	-1.72**(0.04)
Panel PP-Statistic	-0.18(0.42)	1.10(0.86)	-2.24*(0.01)	-2.89*(0.00)
Panel ADF-Statistic	0.31(0.62)	1.22(0.86)	-2.29*(0.01)	-3.23*(0.00)
Group rho-Statistic	1.46(0.92)	2.58(0.99)	-0.41(0.34)	-0.24(0.40)
Group PP-Statistic	0.10(0.54)	1.07(0.85)	-2.14*(0.01)	-2.18*(0.01)
Group ADF-Statistic	-1.09(0.13)	-0.46(0.32)	-1.86**(0.03)	-2.26*(0.01)
European			**Asian**	
Panel v-Statistic	-0.40(0.65)	-2.62(0.99)	2.75*(0.00)	1.58**(0.05)
Panel rho-Statistic	0.33(0.63)	2.49(0.99)	-1.82**(0.03)	-0.60(0.27)
Panel PP-Statistic	-0.01(0.49)	0.95(0.82)	-1.86**(0.03)	-1.07***(0.10)
Panel ADF-Statistic	0.47(0.68)	1.22(0.88)	-2.49*(0.00)	-2.49*(0.00)
Group rho-Statistic	0.97(0.83)	1.84(0.96)	-0.33(0.37)	0.42(0.66)
Group PP-Statistic	-0.45(0.32)	0.02(0.50)	-1.24***(0.10)	-0.62(0.26)
Group ADF-Statistic	0.50(0.69)	-0.81(0.20)	-1.74**(0.04)	-2.43*(0.00)
African				
Panel v-Statistic	0.18(0.42)		-0.39(0.65)	
Panel rho-Statistic	-0.94(0.17)		0.42(0.66)	
Panel PP-Statistic	-1.25***(0.10)		-0.11(0.45)	
Panel ADF-Statistic	-1.03(0.15)		-0.06(0.47)	
Group rho-Statistic	0.47(0.68)		0.63(0.73)	
Group PP-Statistic	-0.23(0.40)		-0.03(0.48)	
Group ADF-Statistic	0.06(0.52)		0.12(0.55)	

Note: C=intercept; C&T=intercept with trend, TFP = total factor productivity, and NGC = natural gas consumption. *, **, and *** are significance level at 1%, 5% and 10% respectively. *P*-values are given in the parenthesis.

Table 7: Pedroni panel cointegration (lnTFP – lnPC)

Model -5				
Panels	**C**	**C&T**	**C**	**C&T**
Aggregate			**Developing**	
Panel v-Statistic	0.10(0.45)	-0.67(0.74)	2.13**(0.02)	1.31***(0.09)
Panel rho-Statistic	-0.42(0.33)	-1.38***(0.10)	-1.77**(0.03)	-0.48(0.31)
Panel PP-Statistic	-1.80**(0.03)	-0.69(0.24)	-2.66*(0.00)	-1.64**(0.05)
Panel ADF-Statistic	-2.17*(0.01)	-2.01**(0.02)	-3.56*(0.00)	-1.84**(0.03)
Group rho-Statistic	0.17(0.57)	- 2.78*(0.01)	-0.96(0.16)	1.44(0.92)
Group PP-Statistic	-2.84*(0.00)	-0.36(0.35)	-2.64*(0.00)	-0.44(0.32)
Group ADF-Statistic	-3.48*(0.00)	-1.94**(0.02)	-2.94*(0.00)	-1.98**(0.02)
Developed			**Latin American**	
Panel v-Statistic	-1.72(0.95)	-2.48(0.99)	0.83(0.20)	2.26*(0.01)
Panel rho-Statistic	0.98(0.83)	2.61(0.99)	-1.09(0.13)	-0.75(0.22)
Panel PP-Statistic	0.11(0.54)	0.93(0.82)	-2.52*(0.00)	-1.77**(0.03)
Panel ADF-Statistic	0.54(0.70)	-0.91(0.18)	-2.94*(0.00)	-1.89**(0.02)
Group rho-Statistic	1.11(0.86)	2.45(0.99)	-1.19***(0.10)	0.55(0.70)
Group PP-Statistic	-1.44***(0.07)	-0.07(0.46)	-2.93*(0.00)	-1.09***(0.10)
Group ADF-Statistic	-2.03**(0.03)	-1.72**(0.04)	-2.808(0.00)	-1.19***(0.09)
European			**Asian**	
Panel v-Statistic	-1.65(0.95)	-2.30(0.98)	3.64*(0.00)	0.58(0.27)
Panel rho-Statistic	1.09(0.86)	2.34(0.99)	-2.29*(0.01)	-0.55(0.29)
Panel PP-Statistic	0.44(0.67)	1.02(0.84)	-1.95**(0.03)	-1.12***(0.10)
Panel ADF-Statistic	0.70(0.75)	-0.44(0.32)	-2.78*(0.00)	-2.10*(0.01)
Group rho-Statistic	1.61(0.94)	2.25(0.98)	-0.54(0.29)	0.72(0.76)
Group PP-Statistic	-0.62(0.26)	0.03(0.51)	-1.16(0.12)	-1.47***(0.06)
Group ADF-Statistic	-0.17(0.43)	0.18(0.52)	-1.89**(0.02)	-1.61**(0.05)
African				
Panel v-Statistic	-0.02(0.50)		-0.48(0.68)	
Panel rho-Statistic	0.01(0.50)		0.49(0.69)	
Panel PP-Statistic	-0.14(0.44)		0.08(0.53)	
Panel ADF-Statistic	-0.19(0.42)		0.57(0.71)	
Group rho-Statistic	0.25(0.60)		1.40(0.92)	
Group PP-Statistic	-0.23(0.40)		1.14(0.87)	
Group ADF-Statistic	-0.03(0.48)		1.71(0.95)	

Note: C=intercept; C&T=intercept with trend, TFP = total factor productivity, and PC = petroleum consumption. *, **, and *** are significance level at 1%, 5% and 10% respectively. *P*-values are given in the parenthesis.

Table 8: DOLS results

Country	lnTFP - lnPEC		lnTFP - lnELC	
	Constant	**Constant with Trend**	**Constant**	**Constant with Trend**
Aggregate	0.09*(0.00)	0.21*(0.00)	0.07*(0.00)	0.27*(0.00)
Developed	0.22*(0.00)	0.36*(0.00)	-	-
Developing	0.07*(0.00)	0.11**(0.02)	0.05*(0.00)	0.21*(0.00)
European	0.23*(0.00)	0.44*(0.00)	-	-
Latin American	-0.01 (0.84)	0.53*(0.00)	-0.014(0.56)	0.53*(0.00)
Asian	0.108*(0.00)	0.02 (0.62)	0.08*(0.00)	-0.02 (0.68)
African	-	-	0.04 (0.13)	0.43*(0.00)
Country	**lnTFP - lnTCC**		**lnTFP - lnNGC**	
	Constant	**Constant with Trend**	**Constant**	**Constant with Trend**
Aggregate	-	-	0.03*(0.00)	0.02*(0.00)
Developed	-	-	-	-
Developing	-0.003(0.96)	0.01 (0.14)	0.02*(0.00)	0.01**(0.04)
European	-	-	-	-
Latin American	-	-	0.01 (0.58)	0.11* (0.00)
Asian	0.03**(0.02)	0.001(0.89)	0.02*(0.00)	0.001(0.93)
African	-	-	-	-
Country	**lnTFP - lnPC**			
	Constant		**Constant with Trend**	
Aggregate	0.11*(0.00)		0.14*(0.00)	
Developed	-		-	
Developing	0.08*(0.00)		0.04***(0.09)	
European	-		-	
Latin American	-0.01(0.76)		0.27*(0.00)	
Asian	0.13*(0.00)		-0.07 (0.16)	
African	-		-	

Note: C=intercept; C&T=intercept with trend. TFP = total factor productivity, PEC = primary energy consumption, ELC = electricity consumption, TCC = total coal consumption, NGC = natural gas consumption, and PC = petroleum consumption; *, **, and *** are significance level at 1%, 5% and 10% respectively. *P*-values are given in the parenthesis. We only provide the results of DOLS for those panels and models for which we found presence of panel cointegration.

Table 9: Results of panel Granger causality

Panels	**Model 6 (lnTFP – lnPEC)**			**Model 7 (lnTFP – lnELC)**		
Aggregate						
variables	ΔTFP	ΔPEC	ECM(-1)	ΔTFP	ΔELC	ECM(-1)
ΔTFP	-	0.01(0.74)	-0.07*(0.00)	-	-0.03***(0.06)	-0.08*(0.00)
ΔPEC	0.12*(0.01)	-	-0.03*(0.00)	0.33*(0.00)	-	-0.03*(0.00)
Developed						
ΔTFP	-	0.007(0.72)	-0.04*(0.00)	-	-	-
ΔPEC	0.26*(0.00)	-	-0.001 (0.28)	-	-	-
Developing						
ΔTFP	-	-0.003 (0.90)	-0.11* (0.00)	-	-0.05**(0.04)	-0.04*(0.00)
ΔPEC	0.19*(0.00)	-	-0.02* (0.00)	0.29*(0.00)	-	-0.02*(0.00)
European						
ΔTFP	-	0.01 (0.74)	-0.04*(0.00)	-	-	-
ΔPEC	0.21* (0.01)	-	-0.05*(0.00)	-	-	-
Latin American						
ΔTFP	-	0.09 (0.13)	-0.16*(0.00)	-	-0.30 (0.55)	-0.16*(0.00)
ΔPEC	0.31*(0.09)	-	- 0.02**(0.04)	0.32*(0.00)	-	-0.22*(0.01)
Asian						
ΔTFP	-	0.14**(0.03)	-0.08*(0.00)	-	-0.03(0.52)	-0.09*(0.00)
PEC	0.04* (0.57)	-	-0.03*(0.00)	0.19*(0.01)	-	-0.02*(0.00)
African						
ΔTFP	-	-	-	-	-0.05 (0.18)	-0.03**(0.03)
ΔPEC	-	-	-	0.45**(0.03)	-	- 0.02***(0.08)
Model 8 (lnTFP – lnTCC)				**Model 9 (lnTFP – lnNGC)**		
Aggregate						
variables	ΔTFP	ΔTCC	ECM(-1)	ΔTFP	ΔNGC	ECM(-1)
ΔTFP	-	-	-	-	0.002(0.44)	-0.07*(0.00)
ΔTCC	-	-	-	0.24 (0.25)	-	-0.06*(0.00)
Developed						
ΔTFP	-	-	-	-	-	-
ΔTCC	-	-	-	-	-	-
Developing						
ΔTFP	-	0.005**(0.05)	-0.09*(0.00)	-	0.002(0.67)	-0.10*(0.00)
ΔTCC	0.18 (0.69)	-	-0.13*(0.00)	0.26 (0.43)	-	0.02**(0.00)
European						
ΔTFP	-	-	-	-	-	-

ΔTCC	-	-	-	-	-	-
Latin American						
ΔTFP	-	-	-	-	0.01(0.24)	-0.11*(0.00)
ΔTCC	-	-	-	0.33(0.32)	-	-0.14 (0.19)
Asian						
ΔTFP	-	0.001(0.81)	-0.08*(0.00)	-	0.003(0.70)	-0.06*(0.00)
ΔTCC	0.37(0.43)	-	0.10*(0.00)	-0.42(0.40)	-	-0.02*(0.01)
African						
ΔTFP	-	-	-	-	-	-
ΔTCC	-	-	-	-	-	-
Model 10 (lnTFP – lnPC)						
Aggregate						
variables	ΔTFP		ΔTCC		ECM(-1)	
ΔTFP	-		-0.004(0.77)		-0.08*(0.00)	
ΔPC	0.25*(0.00)		-		-0.03*(0.00)	
Developed						
ΔTFP	-		-		-	
ΔPC	-		-		-	
Developing						
ΔTFP	-		-0.01(0.74)		-0.11*(0.00)	
ΔPC	0.18*(0.00)		-		-0.02*(0.00)	
European						
ΔTFP	-		-		-	
ΔPC	-		-		-	
Latin American						
ΔTFP	-		0.03(0.48)		-0.17*(0.00)	
ΔPC	0.398(0.00)		-		-0.03***(0.06)	
Asian						
ΔTFP	-		-0.04 (0.33)		-0.10*(0.00)	
ΔPC	0.01(0.88)		-		-0.01*(0.00)	
African						
ΔTFP	-		-		-	
ΔPC	-		-		-	

Note: TFP = total factor productivity, PEC = primary energy consumption, ELC = electricity consumption, TCC = total coal consumption, NGC = natural gas consumption, and PC = petroleum consumption; *, **, and *** are significance level at 1%, 5% and 10% respectively. *P*-values are given in the parenthesis. We only provide the results of panel Granger causality for those panels and models for which we found presence of panel cointegration.

Table 10: Westerlund panel cointegration test

Panels	Model 1	Model 2	Model 3	Model 4	Model 5
Aggregate					
Gt	-2.52*(0.00)	-2.12*(0.01)	-2.01**(0.05)	-2.08*(0.01)	-2.01**(0.02)
Ga	-8.28***(0.08)	-6.42 (0.80)	-6.62 (0.73)	-6.42 (0.80)	-6.77***(0.10)
Pt	-13.09*(0.00)	-11.53*(0.01)	-11.95*(0.01)	-12.93*(0.00)	-11.50*(0.01)
Pa	-4.54(0.32)	-5.62*(0.03)	-4.82 (0.19)	-5.69**(0.02)	-4.56 (0.49)
Developed					
Gt	-2.20*(0.01)	-1.82 (0.39)	-1.63(0.77)	-1.78(0.48)	-1.74(0.56)
Ga	-6.84(0.60)	-5.65(0.90)	-3.73(0.99)	5.13(0.96)	-4.51(0.99)
Pt	-9.19*(0.01)	-5.56(0.91)	-8.55**(0.52)	-7.44(0.30)	-7.01(0.47)
Pa	-3.57(0.75)	-2.54(0.97)	-3.42(0.80)	-3.75(0.69)	-3.03(0.90)
Developing					
Gt	-2.91*(0.00)	-2.48*(0.00)	-2.43*(0.0)	-2.44*(0.00)	-2.43*(0.00)
Ga	-10.01*(0.01)	-7.36 (0.42)	-10.13*(0.00)	-7.98(0.25)	-9.51**(0.02)
Pt	-9.48*(0.01)	-10.14*(0.00)	-8.94*(0.01)	-10.17*(0.00)	-9.14*(0.00)
Pa	-5.80***(0.06)	-6.94*(0.00)	-7.13*(0.00)	-7.45*(0.00)	-6.47*(0.01)
European					
Gt	-2.24*(0.01)	-1.71 (0.61)	-1.76 (0.52)	-1.81(0.42)	-1.39 (0.95)
Ga	-7.29 (0.45)	-5.49(0.88)	-3.80(0.99)	-5.69(0.85)	-3.21(0.99)
Pt	-7.79**(0.02)	-4.27(0.93)	-7.45**(0.04)	-6.27(0.31)	-5.72(0.52)
Pa	-3.46 (0.75)	-2.28(0.96)	-3.41(0.77)	-3.74(0.67)	-2.89(0.88)
Latin American					
Gt	-3.10*(0.00)	-2.71*(0.00)	-2.52*(0.01)	-2.55*(0.01)	-2.54*(0.01)
Ga	-9.67**((0.04)	-7.90 (0.35)	-9.89***(0.09)	-10.1***(0.07)	-9.99***(0.08)
Pt	-6.83*(0.00)	-6.84*(0.00)	-6.08*(0.01)	-7.05*(0.00)	-6.77*(0.00)
Pa	-4.93(0.33)	-7.14**(0.04)	-8.79*(0.003)	-8.52*(0.01)	-6.62***(0.07)
Asian					
Gt	-3.23*(0.00)	-2.46*(0.01)	-2.99*(0.00)	-2.88*(0.00)	-2.35**(0.03)
Ga	13.92*(0.00)	-7.12(0.50)	-13.88*(0.00)	-8.13(0.30)	-10.40**(0.04)
Pt	-6.88*(0.00)	-5.60***(0.06)	-6.50*(0.01)	-6.55*(0.01)	-6.26*(0.01)
Pa	-8.18*(0.01)	-6.79**(0.05)	-9.30*(0.00)	-7.73*(0.01)	-8.77*(0.00)
African					
Gt	-1.92(0.37)	-2.13***(0.10)	-1.17(0.91)	-1.38(0.81)	-2.39***(0.08)
Ga	-6.30(0.62)	-6.91(0.53)	-3.06(0.93)	-3.96(0.87)	-6.90(0.53)
Pt	-3.30(0.34)	-4.61**(0.04)	-2.92(0.48)	-3.40(0.30)	-2.90(0.49)
Pa	-5.00(0.36)	-8.79**(0.02)	-3.52(0.62)	-5.15(0.33)	-4.08(0.52)

Note: *, **, and *** are significance level at 1%, 5% and 10% respectively. *P*-values are given in the parenthesis.

Appendix

Table 1A: Summary of the empirical findings reached by the previous studies[3]

	a) Country-specific studies on the causal nexus between energy consumption (EC) and economic growth (GDP)				
No.	Study	Sample	Region/Country	Methodology	Findings
1	Kraft and Kraft (1978)	1947-1974	United States	Granger causality approach.	GDP $\Rightarrow$ EC.
2	Kraft and Kraft (1980)	1950-1970	United States	Sim's test.	EC $\neq$ GDP.
3	Yu and Hwang (1984)	1947-1979	United States	Sim's test.	EC $\neq$ GDP.
4	Erol and Yu (1987)	1973-1984	United States	Bivariate Granger Causality Test.	EC $\neq$ GDP.
5	Ramcharran (1990)	1970-1986	Jamaica	Granger causality procedure.	ECC $\Rightarrow$ GDP.
6	Hwang and Gum (1991)	1961-1990	Taiwan	Cointegration, ECM.	EC $\Leftrightarrow$ GDP.
7	Yu and Jin (1992)	1974-1990	United States	Cointegration, Granger Causality Test.	EC $\neq$ GDP.
8	Stern (2000)	1948-1994	United States	MVAR Model.	EC $\Rightarrow$ GDP.
9	Yang (2000)	1954-1997	Taiwan	Hsiao's version of Granger Causality Test.	ECC $\Leftrightarrow$ GDP.
10	Soytas et al. (2001)	1960-1995	Turkey	Cointegration, Granger Causality Procedures.	EC $\Rightarrow$ GDP.
11	Ghosh (2002)	1950-1997	India	Granger Causality Procedure.	GDP $\Rightarrow$ ECC.
12	Glasure (2002)	1961-1990	South Korea	VECM Procedure.	EC $\Leftrightarrow$ GDP.
13	Hondroyiannis et al. (2002)	1960-1996	Greece	Cointegration, ECM, Variance Decompositions Procedures.	EC $\Leftrightarrow$ GDP.
14	Oh and Lee (2004)	1970-1999	South Korea	VECM Procedure.	EC $\Leftrightarrow$ GDP.
15	Ghali and El-	1961-1997	Canada	Hsiao's version of	EC $\neq$ GDP.

[3] We have put our best effort to review all the studies published in peer-reviewed quality journals that investigated the causal nexus between energy consumption and economic growth both at the country-specific and multi-country levels. By mistake if a study has been misrepresented, we extend our apologies to the concerned authors.

	Sakka (2004)			Granger Causality Test.	
16	Jumbe (2004)	1970-1999	Malawi	Granger causality, ECM procedures.	ECC $\Leftrightarrow$ GDP.
17	Paul and Bhattacharya (2004)	1950-1996	India	Granger causality, ECM procedures.	EC $\Rightarrow$ GDP.
18	Shiu and Lami (2004)	1971-2000	China	Cointegration, ECM, Procedures.	GDP $\Rightarrow$ ECC.
19	Wolde-Rufael (2004)	1952-1999	Shanghai	A modified version of Granger Causality Procedure.	EC $\Rightarrow$ GDP.
20	Lee and Chang (2005)	1954-2003	Taiwan	Johansen-Juselius, Cointegration, ECM, Procedures.	EC $\Rightarrow$ GDP.
21	Narayan and Smyth (2005)	1966-1999	Australia	Cointegration, Granger causality, ECM procedures.	GDP $\Rightarrow$ ECC.
22	Yoo (2005)	1970-2002	South Korea	VECM procedure.	EC $\Leftrightarrow$ GDP.
23	Yoo and Jung (2005)	1972-2002	Korea	VECM procedure.	NEC $\Rightarrow$ GDP.
24	Yoo and Kim (2006)	1971-2002	Indonesia	Hsiao's version of Granger Causality Test.	GDP $\Rightarrow$ EC.
25	Jobert and Karanfil (2007)	1960-2003	Turkey	Cointegration, Granger Causality Procedures.	EC $\neq$ GDP.
26	Ang (2007)	1960-2000	France	Cointegration, VECM procedures.	EC $\Rightarrow$ GDP.
27	Narayan and Smyth (2007)	1966-1999	Australia	Multivariate Granger Causality Procedure.	GDP $\Rightarrow$ ECC.
28	Narayan and Singh (2007)	1971-2002	Fiji Islands	Cointegration, Granger Causality Procedures.	ECC $\Rightarrow$ GDP.
29	Yuan et al. (2007)	1978-2004	China	Cointegration Procedure.	ECC $\Rightarrow$ GDP.
30	Zamani (2007)	1967-2003	Iran	Granger Causality, Cointgeration, VECM Procedures.	GDP $\Rightarrow$ EC.
31	Ang (2008)	1971-1999	Malaysia	Johansen Cointgeration, VECM Procedures.	GDP $\Rightarrow$ EC.
32	Tang (2008)	1972-2003	Malaysia	ARDL Approach, ECM, Granger Causality	ECC $\Leftrightarrow$ GDP.

				Procedures.	
33	Yuan et al. (2008)	1963-2005	China	Johansen Cointgeration, ECM Procedures.	ECC $\Rightarrow$ GDP.
34	Ankilo (2009)	1980-2006	Nigeria	Johansen-Juselious Cointgeration, VEC Procedures.	ECC $\Rightarrow$ GDP.
35	Ghosh (2009)	1985-2005	India	ARDL Bounds testing Approach, Granger Causality.	GDP $\Rightarrow$ ECC.
36	Odhiambo (2009)	1971-2006	South Africa	Granger Causality Technique.	EC $\Leftrightarrow$ GDP.
37	Payne (2009)	1949-2006	United States	Toda-Yamamoto Approach.	EC $\neq$ GDP.
38	Soytas and Sari (2009)	1960-2000	Turkey	Toda-Yamamoto Approach.	EC $\neq$ GDP.
39	Zhang and Cheng (2009)	1960-2007	China	Granger Causality Technique.	GDP $\Rightarrow$ EC.
40	Acaravci (2010)	1968-2005	Turkey	Cointgeration, VECM Procedures.	EC $\Leftrightarrow$ GDP.
41	Bartleet and Gounder (2010)	1960-2004	New Zealand	Granger Causality Technique.	GDP $\Rightarrow$ EC.
42	Chang (2010)	1981-2006	China	Causality test based on VECM technique.	EC $\Leftrightarrow$ GDP.
43	Chandran (2010)	1971-2003	Malaysia	ARDL Bounds test.	ECC $\Leftrightarrow$ GDP.
44	Payne and Taylor (2010)	1957-2006	United States	Toda-Yamamoto Approach.	NEC $\neq$ GDP.
45	Shahbaz et al. (2011)	1971-2009	Portugal	ARDL Bounds Test, UECM Procedure.	ECC $\Leftrightarrow$ GDP.
46	Ahamad and Islam (2011)	1971-2008	Bangladesh	VECM Technique.	EC $\Leftrightarrow$ GDP.
47	Wang et al. (2011)	1972-2006	China	Cointgeration, ARDL Bounds test.	EC $\Rightarrow$ GDP.
48	Zhang (2011)	1970-2008	Russia	Cointgeration, Granger Causality Approach.	EC $\Leftrightarrow$ GDP.
49	Zhixin and Xin (2011)	1980-2008	China	Cointgeration, Granger Causality Approach.	EC $\Leftrightarrow$ GDP.
50	Alam et al. (2012)	1972-2006	Bangladesh	ARDL Bounds Approach.	EC $\Leftrightarrow$ GDP.
51	Shahbaz et al. (2012)	1972-2011	Pakistan	VECM Procedure.	EC $\Leftrightarrow$ GDP.

52	Shahbaz and Feridun (2012)	1971-2008	Pakistan	ARDL Bounds Approach.	GDP ⇒ ECC.
53	Shahbaz and Lean (2012)	1972-2009	Pakistan	VECM Procedure.	EC ⇔ GDP.
54	Wolde-Rufael (2012)	1977-2007	Taiwan	Toda-Yamamoto Granger Causality Test.	NEC ≠ GDP.
55	Yildirim et al. (2012)	1949-2010	Unites States	Toda-Yamamoto Granger Causality Test.	REC ≠ GDP.
56	Aslan and Cam (2013)	1985-2009	Israel	Bootstrap Corrected Causality Approach.	NEC ⇒ GDP.
57	Baranzini et al. (2013)	1950-2010	Switzerland	ARDL Bounds Test, VECM Procedure.	GDP ⇒ EC.
58	Shahbaz et al. (2013a)	1971-2011	China	ARDL Bounds Test, VECM Procedure.	EC ⇒ GDP.
59	Shahbaz et al. (2013b)	1975-2011	Indonesia	ARDL Bounds Test, VECM, Innovation Accounting Approach.	EC ⇔ GDP.
60	Pao and Fu (2013)	1980-2010	Brazil	VECM Approach.	REC ⇔ GDP.
61	Amri (2017)	1980-2012	Algeria	ARDL Bounds Testing Approach.	Mixed.
62	Sbia et al. (2017)	1975-2011	United Arab Emirates	ARDL Bounds Testing Approach, VECM Granger Causality technique.	ECC ⇔ GDP.

No.	***b) Cross-country studies on the causal nexus between energy consumption and GDP***				
1	Yu and Choi (1985)	1950-1976	5 countries	Granger causality test.	EC ⇒ GDP, GDP ⇒ EC, EC ≠ GDP.
2	Erol and Yu (1987)	1952-1982	6 industrialized countries	Granger causality test.	EC ⇔ GDP, GDP ⇒ EC, EC ⇒ GDP, EC ≠ GDP.
3	Nachane et al. (1988)	1950-1985	16 countries	Co-integration, Sims and Granger causality test.	EC ⇔ GDP.
4	Ebohon (1996)	1960-1984)	Nigeria, Tanzania	Engle-Granger Causality Approach	EC ⇔ GDP.
5	Masih and Masih (1996)	1955-1990	6 Asian countries	Cointegration, ECM.	EC ⇒ GDP(India) GDP ⇒ EC (Indonesia & Pakistan) GDP ≠ EC(Malaysia,

					Philippines & Singapore).
6	Glasure and Lee (1998)	1961-1990	South Korea, Singapore	Cointegration, ECM.	EC ≠ GDP.
7	Asafu-Adjaye (2000)	1971-1995 1973-1995	India & Indonesia (1973-1995) Philippines & Thailand (1971-1995)	Cointegration, Granger Causality Based ECM.	EC ≠ GDP (Philippines & Thailand) EC ⇒ GDP (India & Indonesia).
8	Soytas and Sari (2003)	1950-1992	G-7 countries	VECM methodology.	GDP ⇒ EC, EC ⇔ GDP.
9	Fatai et al. (2004)	1960-1999	6 countries	Granger and Toda-Yamamoto Procedure.	GDP ⇒ EC, EC ⇔ GDP.
10	Lee (2005)	1975-2001	18 developing countries	Panel VECM methodology.	EC ⇒ GDP.
11	Wolde-Rufael (2005)	1971-2001	19 African countries	Toda-Yamamoto's Granger Causality Test.	Mixed [EC ⇒ GDP, EC ⇔ GDP, GDP ⇒ EC, EC ≠ GDP].
12	A1-Iriani (2006)	1970-2002	6 countries of GCC	Panel Cointegration, GMM.	GDP ⇒ EC.
13	Lee (2006)	1947-1974	11 major industrialized countries	Toda-Yamamoto Procedure.	Mixed [GDP ⇒ EC, EC ⇔ GDP, EC ≠ GDP].
14	Soytas and Sari (2006)	1960-2004	G7-countries	Co-integration, ECM, Generalized Variance Decompositions.	Mixed [EC ⇒ GDP, EC ⇔ GDP, GDP ⇒ EC].
15	Wolde-Rufael (2006)	1971-2001	17 African Countries	Toda-Yamamoto Procedure.	Mixed [GDP ⇒ ECC, ECC ⇒ GDP, ECC ⇔ GDP].
16	Yoo (2006)	1971-2002	4 countries	Standard Granger Causality Test and Hsiao's version of Granger Causality method.	GDP ⇒ ECC, ECC ⇔ GDP.
17	Chen et al. (2007)	1971-2001	10 Asian countries	VECM methodology.	EC ⇒ GDP, GDP ⇒ EC.
18	Lee and Chang (2007)	1965-2002 1971-2002	22 developed countries 18 developing countries	Panel VARs and GMM.	GDP ⇒ EC (developing countries), EC ⇒ GDP (developed countries).
19	Mehrara (2007)	1971-2002	11 Oil Exporting Countries	Panel Cointegration Test.	GDP ⇒ EC.
20	Squalli (2007)	1980-2003	11 OPEC countries	Toda-Yamamoto Procedure.	EC ⇒ GDP, EC ⇔ GDP.
21	Akinlo	1980-2003	11 Sub-Sahara	ARDL bounds testing	GDP ⇒ EC, EC ⇔

	(2008)		African Countries	approach.	GDP, EC ≠ GDP.
22	Ciarreta and Zarrage (2008)	1970-2004	12 European countries	Panel cointegration, GMM, Panel Causlaity.	ECC ⇒ GDP, ECC ≠ GDP.
23	Huang et al. (2008)	1972-2002	82 low, middle and high income countries	GMM Model.	GDP ⇒ EC (Middle and high income countries).
24	Choiou-Wei et al. (2008)	1954-2006	8 countries	Panel VAR.	GDP ⇒ EC, EC ⇒ GDP.
25	Chontanawat et al. (2008)	1971-2000	30 OECD and 78 Bon-OECD countries	Granger Causality Test.	EC ⇒ GDP.
26	Lee and Chang (2008)	1971-2002	16 Asian countries	Panel cointegration, Panel ECM.	EC ⇒ GDP (long run) EC ≠ GDP (short run)
27	Lee et al. (2008)	1960-2001	22 OECD countries	Panel cointegration, Panel VEC model.	EC ⇔ GDP.
28	Narayan and Smith (2008)	1972-2002	G7 countries	Panel Cointegration, Granger Causality.	EC ⇒ GDP.
29	Narayan and Prasad (2008)	1954-2006	30 OECD countries	Bootstrapped Toda-Yamamoto procedure.	EC ⇔ GDP, EC ≠ GDP.
30	Payne (2009)	1980-2004	6 Central American countries	Pedroni Panel Cointgeration, Granger Causality.	EC ⇒ GDP.
31	Chang et al. (2009)	1997-2006	G7 countries	Threshold Estimation.	GDP ⇒ EC.
32	Narayan and Smyth (2009)	1974-2002	6 MENA countries	Panel cointegration, VECM methodology.	ECC ⇔ GDP
33	Sadorsky (2009)	1980-2005	G7 countries	Panel cointegration.	REC ⇒ GDP.
34	Wolde-Rufael (2009)	1971-2004	Algeria, Benin, South Africa	Toda and Yamamoto Procedure.	EC ⇔ GDP.
35	Apergis and Payne (2010a)	1985-2005	20 OECD countries	Panel cointegration, ECM.	EC ⇔ GDP.
36	Apergis and Payne (2010b)	1992-2007	13 Eurasian countries	Panel cointegration, ECM.	EC ⇔ GDP.
37	Apergis et al. (2010)	1984-2007	19 developed and developing countries	Panel VECM methodology.	NEC ⇒ GDP (short-run), NEC ⇔ GDP (long-run).
38	Apergis and Payne (2010c)	1980-2005	16 developed and newly developing countries	Panel VECM procedure.	NEC ⇒ GDP (long-run), NEC ⇔ GDP (short-run).

39	Ozturk et al. (2010)	1971-2005	51 countries	Panel Coinetgration, Panel Causality, Panel FMOLS, DOLS.	GDP ⇒ EC, EC ⇔ GDP.
40	Belke et al. (2011)	1981-2007	25 OECD countries	Panel cointegration, VECM procedure.	EC ⇔ GDP.
41	Lau et al. (2011)	1980-2006	17 Asian countries	FMOLS	EC ⇒ GDP (short-run), GDP ⇒ EC (long-run), EC ⇔ GDP.
42	Lee and Chiu (2011a)	1965-2008	6 highly industrialized countries	Toda and Yamamoto Procedure.	GDP ⇒ NEC, NEC ⇔ GDP, NEC ≠ GDP.
43	Lee and Chiu (2011b)	1971-2006	6 developed countries	Cointegration, Granger Causality test.	GDP ⇒ NEC (long-run), NEC ≠ GDP (short-run).
44	Tiwari (2011)	1965-2009	16 European and Eurasian countries	Panel VAR approach.	EC ⇔ GDP.
45	Apergis and Payne (2012a)	1990-2007	6 Central American countries	Panel cointegration technique.	EC ⇔ GDP.
46	Apergis and Payne (2012b)	1990-2007	80 countries	Panel ECM approach.	REC ⇔ GDP.
47	Salim and Rafiq (2012)	1980-2006	6 countries	Granger causality test.	REC ⇒ GDP (short-run), GDP ⇒ REC (long-run).
48	Bozoklu and Yilanchi (2013)	1965-2011	20 OECD countries	Granger causality test.	EC ⇒ GDP, GDP ⇒ EC.
49	Damette and Seghir (2013)	1990-2010	12 oil-exporting countries	Panel cointegration technique.	EC ⇒ GDP.
50	Ouedraogo (2013)	1980-2008	15 African countries	VAR technique.	GDP ⇒ EC (short-run), EC ⇒ GDP (long-run).
51	Chang et al. (2014)	1971-2011	G6 countries	Granger causality test.	NEC ⇔ GDP, GDP ⇒ NEC, NEC ≠ GDP, NEC ⇒ GDP.
52	Mohammadi and Parvaresh (2014)	1980-2008	14 oil-exporting countries	Panel fixed effect, Panel cointegration procedures.	EC ⇔ GDP.
53	Yildirim et al. (2014)	1971-2010	11 countries	Bootstrapped Autoregressive Metric Causality Procedure.	EC ⇔ GDP, EC ⇒ GDP.
54	Ahmed and	1960-2011	119 countries	Granger Causality Test.	Mixed.

	Azam (2016)				
55	Azam et al. (2016)	1980-2012	5-ASEAN countries	Johansen Cointgeration Test.	Mixed.
56	Sharmin and Khan (2016)	1990-2014	26 African countries	Johansen's Maximum Likelihood Test, ECM.	GDP $\Rightarrow$ EC (Except Tanzania)
No.	***b) Causal Relationship between EC and Total Factor Productivity (TFP)***				
1	Tugcu (2013)	1970-2011	Turkish Economy	ARDL, Cointegration, Dolado and Lutkephol's Granger Causality.	EC $\Leftrightarrow$ TFP.
2	Ladu and Meleddu (2014)	1996-2008	Italian Regions	Cobb-Douglas, Dynamic Panel Model, Panel Cointegration.	EC $\Leftrightarrow$ TFP.
3	Tugcu and Tiwari (2016)	1992-2012	BRICS	A Panel Bootstrap Granger Causality.	Mixed.
4	Moghadsasi and Pour (2016)	1974-2012	Iranian Agriculture	Kendrick's Model, Solow Residual, Johansen Cointegration Test.	Negative.

Note: EC $\Rightarrow$ GDP indicates the causality runs from energy consumption to economic growth. GDP $\Rightarrow$ EC implies that the causality runs from economic growth to energy consumption. EC $\Leftrightarrow$ GDP implies that bidirectional causality exists between energy consumption and economic growth. EC $\neq$ GDP indicates that no causality exists between energy consumption and economic growth. REC: renewable energy consumption, ECC: electricity consumption, NEC: Nuclear energy consumption, REC: renewable energy consumption and TFP: Total Factor Productivity Growth. In addition, ARDL: Auto Regressive Distributed Lag, VECM: Vector Error Correction, ECM: Error Correction Model, VAR: Vector Auto Regression, MVAR: Multivariate VAR, FMOLS: Fully Modified Ordinary Least Square, and GMM: Generalized Method of Moments.

Table 2A: List of countries

Aggregate	**Developed**	**Developing**
Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Colombia, Denmark, Egypt, Finland, France, Greece, Hungary, India, Indonesia, Iran, Israel, Italy, Japan, Luxembourg, Malaysia, Mexico, Morocco, Netherlands, New Zealand, Nigeria, Norway, Peru, Poland, Romania, Spain, Sweden, Switzerland, Thailand, Tunisia, Turkey, United Kingdom, United States, Venezuela	Australia, Austria, Belgium, Bulgaria, Canada, Denmark, Finland, France, Greece, Hungary, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Poland, Romania, Spain, Sweden, Switzerland, United Kingdom, United States	Argentina, Brazil, Chile, China, Colombia, Egypt, India, Indonesia, Iran, Israel, Malaysia, Mexico, Morocco, Nigeria, Peru, Thailand, Tunisia, Turkey, Venezuela
European	**Latin American**	**Asian**
Austria, Belgium, Bulgaria, Denmark, Finland, France, Hungary, Luxembourg, Netherlands, Norway, Poland, Romania, Spain, Sweden, Switzerland, United Kingdom	Argentina, Brazil, Chile, Colombia, Mexico, Peru, Venezuela	China, India, Indonesia, Iran, Israel, Malaysia, Thailand, Turkey
African		
Egypt, Morocco, Nigeria, Tunisia		

Capital-Enhanced Equilibrium Exchange Rate In The Presence Of Structural Breaks: Evidence From Selected EME's And Advanced Economies

Prabheesh K.P.[*1] & Bhavesh Garg[*]

[*]*Department of Liberal Arts, Indian Institute of Technology Hyderabad.*

Abstract

This paper investigates the interrelations between purchasing power parity (PPP) and uncovered interest parity (UIP) in selected developed and emerging market economies (EMEs), namely, India, Philippines, Russia, South Africa, France, Germany, Japan and U.K., by checking the validity of the capital-enhanced equilibrium exchange rate (CHEER) approach. The present study utilizes quarterly data ranging from 1996Q1 to 2016Q1and consider the U.S. economy as the representative foreign country. The study employs standard unit root tests and Johansen cointegration technique to identify the economic relationships. The cointegration results suggest the existence of two cointegrating vectors representing UIP and PPP conditions, with proportionality and symmetry conditions, respectively. For most of the countries, the data appear to support the hypothesis that the system contains UIP and PPP relations. However, each of the international parity hypotheses is strongly rejected when formulated in isolation (except for Russia). Hence, the overall results suggest that the CHEER is not valid and there is evidence of plausible economic relationship between the nominal exchange rate and each of the price and interest rate differentials between the home country and the foreign country.

Keywords: Purchasing Power Parity, Price Indexes, Interest Rate Differentials, Exchange Rate, Structural shifts, Cointegration.

JEL Classification: C58; C32; F31; F33

[1] Corresponding author: prabheesh@iith.ac.in

1. Introduction

Exchange rate is the linking factor between the domestic economy and the world economy through flows in trade and capital account, therefore it is highly desirable that a country attain its equilibrium level of exchange rate in order to use appropriate policy measures. There is a large and growing literature on the equilibrium exchange rates. Apart from the traditional approaches, such as the Purchasing Power Parity (PPP), there are a number of alternative approaches developed overtime.

Williamson (1985) proposed the 'fundamental equilibrium exchange rate' (FEER) approach, which is an alternative exchange rate determination model suitable for medium-run analysis. The FEER approach indicates that the exchange rate is at its equilibrium value when satisfies the condition of internal and external balance, simultaneously. The author interprets the external balance condition as the sustainability of the current account. Combining these two macroeconomic conditions, the FEER is the rate that equates the current account at full employment with sustainable net capital flows. Similar to the FEER approach is the desired equilibrium exchange rate approach presented by Bayoumi et al. (1994). An alternative approach about exchange rate determination is the natural real exchange rate (NATREX), which is referred in both medium-run and long-run periods. This exchange rate is consistent with simultaneous internal and external balance and equates the sustainable current account with saving and investment. Clark and MacDonald (1998) proposed the behavioral equilibrium exchange rate (BEER) as an approach of exchange rate determination. This approach is a short-run concept which involves the direct econometric analysis of the exchange rate behavior. It does not actually rely on any theoretical model and the equilibrium rate is designated by the long-run behavior of the macroeconomic variables. These authors also proposed the permanent equilibrium exchange rate (PEER) approach. The latter approach differs from the former in the way that the exchange rate is a function only of those variables that have a persistent effect on it.

However, the implementation of the above approaches on exchange rate determination requires a plethora of data, which may not be available, especially when one deals with emerging economies. An approach that avoids the problem of data availability, since it requires data that are available for the majority of the developing countries, has been initially implemented by Juselius (1991, 1995) and Johansen and Juselius (1992), and combines the PPP and the uncovered interest parity (UIP) conditions. This approach, which allows for interactions among exchange rates, prices and interest rates, is referred to as capital-enhanced equilibrium exchange rate (CHEER) (MacDonald, 2000, 2007; Égert et al., 2006).

Additionally, we employ CHEER because it has been shown by other researchers to be a useful methodology for studying equilibrium exchange rates (Driver and Westaway 2004). CHEER is also a reasonable method for analyzing equilibrium exchange rates for both developed countries as well as EMEs. This empirical study focuses on few selected countries, namely, India, Philippines, Russia, South Africa, France, Germany, Japan and U.K., while keeping the U.S. as the representative foreign country.

The CHEER approach is appropriate because in the Balance of Payments dynamics, both the current account and the capital account are interdependent with exchange rates as the linking factor between the two. A country with current account deficits is highly dependent on the capital flows

from foreign countries to finance its deficit and hence the causality generally runs in either direction (Garg and Prabheesh, 2015). Therefore, the question whether exchange rate is capital enhanced rather than determined through fundamentals is of utmost importance. Hence, this study aims to investigate the long-run relationships between the variables in a system containing price level, interest rate, and exchange rate employing cointegration technique. This system allows one also to test the empirical validity of the CHEERs model by combining UIP and PPP. The countries during the sample covered by this study (1996–2016) can be interpreted as financially open with flexible exchange rates and liberalized international capital flows. This makes them a candidate for investigating the validity of the PPP and the UIP hypotheses.

2. Theoretical Background and Overview of Literature

The PPP hypothesis postulates that exchange rates adjust to price differentials in open economies to restore international commodity market equilibrium. In other words, PPP is based on the arbitrage in the goods market, hence postulated as an adjusting mechanism for the current account equilibrium. The UIP, on the other hand, considers international asset markets, and asserts that exchange rates adjust to interest rate differentials. Therefore, equilibrium in capital account, on the other hand, may need adjustments in the variables determining UIP. By definition, balance of payments consists of the sum of current account and capital account. As a disequilibrium in one market may have repercussions on the other, the two international parity conditions may not be independent of each other in the long-run evolution of the BoP equilibrium. The interdependence of adjustments in the international asset and commodity markets, however, can make the definition of an equilibrium real exchange rate in terms of only one parity condition seriously misleading.

Johansen and Juselius (1992) and Juselius (1995) propose an approach taking into account both asset and good market adjustment dynamics by combining both international parities. This approach allowing for interactions among prices, interest rates and exchange rates is referred to as **c**apital en**h**anced **e**quilibrium **e**xchange **r**ates, or CHEERs by MacDonald (2000). As argued by MacDonald (2000, p.18), 'this approach captures the basic Casselian view of PPP,..., that an exchange rate may be away from its PPP determined rate because of non-zero interest differentials'. But, unlike the PPP condition, it indicates that the interest rates can have a medium-run, or business cycle, effect on exchange rates and may lead to interest rate differential. The UIP condition is based on the proposition that if the expected returns on domestic and foreign equivalent securities are different, then the economic agents will borrow at the low rate and invest the proceeds at the high rate, with the assumption of perfect capital mobility (MacDonald, 2000 and Egert et al. , 2006) . This will be taking place until the domestic rate is equalized with the foreign one plus the expected rate of change in the exchange rate. Thus, the UIP condition can be expressed in the following log-linear form:

$$\Delta s^{e}_{t+k} = i_t - i^{*}_t \tag{1}$$

where *s* denotes the natural logarithm of the exchange rate S, defined as units of domestic currency per unit of foreign currency. Also, *i*, *i** denote the domestic and foreign interest rates, respectively. Additionally, if the expected exchange rate s^{e}_{t+k} in equation (1) is determined by the relative prices, which means that the PPP condition is valid, then equation (1) can be transformed in the following form:

$$i_t - i_t^* = \beta_1(p_t - p_t^*) - s_t \quad (2)$$

where *p*, *p** denote the natural logarithms of the domestic and the foreign price indices, respectively.

Since interest rate differentials are usually found in the empirical studies to be non-stationary, i.e. I(1), processes (Juselius and MacDonald, 2000), some combination of an appropriate interest rate differential and the real exchange rate may cointegrate down to the following stationary process:

$$[s_t + \beta_1(p_t^* - p_t) + \beta_2(i_t - i_t^*)] \sim I(0) \quad (3)$$

In terms of cointegration, the CHEER approach involves exploiting the following vector:

$$y_t' = [s_t, p_t, p_t^*, i_t, i_t^*] \quad (4)$$

The validity of the CHEER approach is examined by many studies, by testing the long-run relationships between its variables in the model (3). For instance, MacDonald and Marsh (1997) investigated the CHEER approach using Johansen multivariate cointegration approach in the case of Germany, Japan and the UK, using the USA as foreign country, for the period that consisted of monthly observations from 1974:01 to 1989:09. Their results indicate that the forecast of exchange rate based on the CHEER approach outperformed the other models. MacDonald and Marsh (1999) extended the above the analysis for the sample (1983:01 to 1997:12), excluding UK. The novelty of the above study lied on the fact that the model was treated as tripolar. In other words, disequilibrium in either the yen–dollar or the mark–dollar market not only affects 'own' inflation and interest rates but also inflation and interest rates of the other system. Again, the results produce better forecasts than the benchmark random walk model of the exchange rate and they underscore the ability of simple fundamentals-based models to outperform a random walk.

Juselius and MacDonald (2000) investigated the CHEER approach using Germany as home country and the USA as foreign country. Their sample consisted of monthly observations from 1975:07 to 1998:01 and they used the Johansen multivariate cointegration approach. In brief, their results were in favor of the validity of the two parity conditions only when there is interdependence between them, or, in other words, only when the disequilibria in asset and commodity markets are considered jointly. Similar results were obtained from Özmen and Gökcan (2004), who examined the validity of the CHEER approach for Turkey by using the Johansen multivariate cointegration approach and using a sample consisting of monthly data from 1986:01 to 1999:04.

Ozimkovska and Kubielas (2013) also used CHEER approach to estimate the equilibrium level of the exchange rates of the Ukrainian hryvnia against the euro, US dollar and Russian ruble over the period from 2001Q4 to 2010Q1. They found that the hryvnia was mostly overvalued during the sample period but the sharp depreciation of the hryvnia at the end of 2008 was due to the convergence of the exchange rates to their equilibrium levels, thus, confirming the hypothesis.

Koukouritakis (2013) tested the validity of the CHEER approach for the four Visegrad new EU countries. The sample utilized monthly observations from the early 1990s to 2008:12 and used structural break unit root and cointegration technique. The results indicated that the CHEER approach is validated only for the Czech Republic, while for Poland and Slovakia there is evidence

of plausible economic relationships between the nominal exchange rate and each of the price and interest rate differential. Similarly, Giannellis and Koukouritakis (2013) calculated the exchange rate misalignments by employing the CHEER approach in the case of Brazil, Mexico, Uruguay and Venezuela. They found that the CHEER approach is not valid for any of the countries in question.

3. Data and Econometric Methodology

The current study utilizes quarterly data from 1996Q1 to 2016Q1 for all eight countries (India, Philippines, Russia, South Africa, France, Germany, Japan, U.K. and the U.S.). The U.S. has been treated as the representative foreign country given the fact that the U.S. interest rate policy is mostly followed by world nations and majority of the trade is invoiced in U.S. dollar (Casas et al. 2016). The sources and description of all the data is presented in Table 1.

[Insert Table 1 around here]

Before applying any econometric techniques, the statistical properties of the time series variables are needed to be verified. Thus, as a preliminary step in our analysis, we examine the time series properties of the variables by testing for a unit root. We uses unit root test by Dickey & Fuller (ADF) (1981), Phillip-Perron (P-P) (Phillip & Perron, 1988) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) (Kwiatkowski *et al*. 1992) to check the stationarity properties of all the time-series. However, as Dejong *et al.* (1992) pointed out since tests like ADF can be unreliable due to small sample size and poor power properties, we concluded whether a time-series is stationary or not based on two of the three results. We then examined the cointegration properties by using standard cointegration technique proposed by Johansen (1995).

4. Empirical Results and Discussions

4.1 Unit root results and Cointegration test results

The results of the ADF, PP and KPSS test are reported in Table 2. The results based on two of three tests indicate that all the variables cannot be rejected at the 5% significance level or better. This implies that all the variables are integrated of order one, I(1), which is a prerequisite for testing presence of cointegration relationships and test of restrictions of the CHEER approach.

[Insert Table 2 around here]

The results of the cointegration test are reported in Table 3. As shown in the table, the test indicate two cointegrating vectors for all countries[2].

[Insert Table 3 around here]

4.2 Testing the Structure of the Cointegrating Vectors

In this section the validity of the CHEER approach is examined by investigating the interrelations between the PPP and the UIP conditions. To do so, the tests proposed by Johansen and Juselius

[2] We would like to point out that initially we included more countries, namely, Brazil, Mexico, Thailand, Canada and Italy, however we found that there are three cointegrating vectors while the CHEER approach assumes only two cointegrating vectors. Hence, these countries were dropped out for testing the validity of CHEER approach.

(1992) and Juselius (1995) is used. In general, for a *p*-dimensional system restrictions on the cointegration structure can be tested by formulating $\beta = [H_1\psi_1, ..., H_r\psi_r]$, where H_i are $(p \times q_i)$ design matrices and ψ_i are $(q_i \times 1)$ vectors of q_i free parameters.

In the present study and based on the variables' order given by equation (4), we first test with the LR test statistic the hypothesis that the first cointegration vector describes the PPP condition with unrestricted interest rates (H_1), while the second cointegrating vector describes the UIP condition with unrestricted prices (H_2). This means that the cointegrating vectors are $\beta_1 = [1, -1, 1, \psi_{11}, \psi_{12}]$ and $\beta_2 = [1, \psi_{21}, \psi_{22}, -1, 1]$, while the respective design matrices have the following form:

$$H_1 = \begin{bmatrix} 1 & 0 & 0 \\ -1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad \text{and} \quad H_2 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

This LR test, which captures the proportionality and symmetry conditions, is distributed asymptotically as χ^2, with two degrees of freedom. If the above hypothesis cannot be rejected, which means that the nominal exchange rate is economically related with the interest rate and price differentials. Then, we perform the following two LR tests. The one test refers to the hypothesis that the first vector includes only the PPP condition (H_3), while the second vector includes only the UIP condition (H_4). In this case, the cointegrating vectors are $\beta_1 = [1, -1, 1, 0, 0]$ and $\beta_2 = [1, 0, 0, -1, 1]$, while the respective design matrices have the following form:

$$H_3 = \begin{bmatrix} 1 \\ -1 \\ 1 \\ 0 \\ 0 \end{bmatrix} \quad \text{and} \quad H_4 = \begin{bmatrix} 1 \\ 0 \\ 0 \\ -1 \\ 1 \end{bmatrix}$$

This LR test is distributed asymptotically as χ^2, with six degrees of freedom. The other test refers to the hypothesis that the first vector describes the PPP condition with unitary coefficients and restricting interest rates to have equal and opposite signs (H_5), while the second cointegrating vector the UIP condition with unitary coefficients and restricting prices to have equal and opposite signs (H_6). This test is performed since the adjustments in both asset and commodity markets may be interdependent in a financially open economy, and thus, the two parity conditions may be considered jointly. In this case, the cointegrating vectors are $\beta_1 = [1, -1, 1, \psi_{11}, \psi_{11}]$ and $\beta_2 = [1, \psi_{21}, \psi_{21}, -1, 1]$, while the respective design matrices have the following form:

$$H_5 = \begin{bmatrix} 1 & 0 \\ -1 & 0 \\ 1 & 0 \\ 0 & -1 \\ 0 & 1 \end{bmatrix} \quad \text{and} \quad H_6 = \begin{bmatrix} 1 & 0 \\ 0 & -1 \\ 0 & 1 \\ -1 & 0 \\ 1 & 0 \end{bmatrix}$$

This LR test is distributed asymptotically as χ^2, with four degrees of freedom. The results of these tests are shown in Table 4.

[Insert Table 4 around here]

As shown in column 1 of the Table 4, the hypothesis that the first vector describes the PPP and the second vector describes the UIP, with proportionality and symmetry conditions, can be rejected only in case of South Africa and France while the non-rejection of the above hypothesis in other six countries implies that the system contains UIP and PPP relations (H1 and H2). We then tested if the first vector includes only the PPP condition and the second vector includes only the UIP condition (i.e. the restrictions defined by the design matrices H3 and H4). As shown in column 2 of Table 4, this hypothesis is rejected at the 1% level of significance for all countries. This implies both the international parities when considered in isolation are strongly rejected. Finally, the last test described above, which refers to the hypothesis that the two parity conditions are considered jointly to verify CHEER (i.e. the restrictions defined by the design matrices H5 and H6), is performed. As shown in column 3 of Table 4, this hypothesis is strongly rejected at the 1% significance level for India, South Africa, Germany, Japan and U.K. while it is weakly rejected at 5% for Philippines and France. Surprisingly, the CHEER approach could not be rejected for Russia at 5% level or better. This implies that, for Russia, deviations from the PPP condition can be explained by the interest rate differential, and deviations from the UIP.

Overall, the results indicate that the CHEER approach is not validated. This means that the deviations from the PPP condition cannot be explained by the interest rate differential, and vice-versa. Moreover, the evidence shows that neither the PPP condition nor the UIP condition alone can be valid. This result is consistent with those of previous studies (Johansen and Juselius, 1992; Juselius, 1995; MacDonald and Marsh, 1997; Juselius and MacDonald, 2000; Özmen and Gökcan, 2004, Koukouritakis, 2013; Giannnellis and Koukouritakis, 2013).

5. Conclusion

This study investigated the validity of two important international parities, PPP and UIP, for selected developed and emerging market economies (EMEs), namely, India, Philippines, Russia, South Africa, France, Germany, Japan and U.K. The PPP and UIP hypotheses are often postulated as equilibrium conditions for international commodity and capital markets, respectively. As a disequilibrium in one market may have spillover effects on the other, the characterization of one parity condition as the equilibrium level for the whole economy may be misleading. Since the nominal exchange rates, the prices and the interest rates follow random walks, the CHEER approach was examined using unit root and cointegration tests in the presence of structural breaks

in the data. The cointegration test results in the presence of structural breaks show evidence of two cointegrating vectors in the system.

The data appear to support the hypothesis that the system contains UIP and PPP relations. However, each of the parity hypotheses is strongly rejected when formulated alone. However, the results further suggest that the CHEER is not validated in all countries except Russia. This can be explained by the fact that the exchange rates are not completely market driven, at least in the EMEs context. The results also indicate that capital flows are not free from market frictions causing a hindrance to free mobility of capital flows. The interaction between UIP and PPP has crucial implications for exchange rate targeting policies and exchange rate based stabilization programmes. If a policy is designed maintaining the hypothesis that the equilibrium exchange rate is determined by the goods market clearing PPP condition then it may be seriously misleading. Although we could not find evidence for both PPP and UIP holding jointly, there is evidence in favor of UIP and PPP conditions with unrestricted interest rates and prices implying plausible economic relationships between the nominal exchange rate and each of the price and interest rate differentials between the countries of interest and the US.

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Table 1. Sources and description of data.

Country	Exchange rate (national currency against US dollar)	Consumer price index	Interest rate
India	IFS	IFS	Reserve Bank of India
Philippines	IFS	IFS	IFS
Russia	IFS	IFS	IFS
South Africa	IFS	IFS	IFS
France	IFS	IFS	Banque de France
Germany	IFS	IFS	Deutsche Bundesbank
Japan	IFS	IFS	Bank of Japan
U.K.	IFS	IFS	Central Statistical Office
U.S.	IFS	IFS	Federal Reserve Bulletin

Notes: The time span of all the time series covers the period from 1996Q1 – 2016Q1. For some countries, we used data on short-term interest rates due to restrictions on data availability.

Table 2. Results of ADF, PP and KPSS unit root tests

Variables	ADF		PP		KPSS		
	At level	First Difference	At level	First Difference	At level	First Difference	Order of Integration
s	-1.567	-8.523*	-1.760	-8.522*	0.173*	0.123	I(1)
p	-1.527	-3.112	-1.032	-7.387*	0.272*		I(1)
i	-3.155	-7.668*	-3.327	-7.731*	0.204**	0.058	I(1)
Philippines							
s	1.138	-7.525*	0.953	-7.607*	0.344		I(1)
p	4.106	-2.797*	8.502	-2.585**	1.257*	0.401	I(1)
i	-1.668	-1.643	-2.238**		1.115*	0.256	I(1)
Russia							
s	-2.445	-4.394*	-2.279	-6.985*	0.167**	0.144	I(1)
p	-2.173	-4.324*	-1.730	-3.901**	0.264*	0.074	I(1)
i	-3.078	-6.356*	-3.263	-8.284*	0.278*	0.111	I(1)
South Africa							
s	-1.730	-7.939*	-2.022	-7.955*	0.118		I(1)
p	-3.098	-5.444*	-2.580	-5.382*	0.066		I(1)
i	-3.280	-5.699*	-2.516	-5.641*	0.110		
France							
s	-2.248	-9.089*	-2.244	-9.089*	0.751*	0.199	I(1)
p	-1.253	-2.980**	-1.206	-8.535*	1.106*	0.331	I(1)
i	-1.485	-5.034*	-1.231	-5.084*	0.965*	0.045	I(1)
Germany							
s	-1.594	-9.352*	-1.672	-9.352*	0.267*	0.035	I(1)
p	-1.119	-8.312*	-1.401	-8.319*	0.114		I(1)
i	-3.249	-4.267*	-2.445	-6.175*	0.119	0.038	I(1)
Japan							
s	-2.413	-3.969**	-2.266	-8.679*	0.100		I(1)
p	-1.690	-9.715*	-1.690	-9.710*	0.154**	0.114	I(1)
i	-2.120	-8.810*	-2.356	-8.814*	0.107		I(1)
U.K.							
s	-2.107	-8.000*	-2.242	-7.959*	0.159		I(1)

p	-0.881	-1.232	0.367	-10.263*	1.228*	0.307	I(1)
i	-1.199	-5.642*	-0.977	-5.728*	1.052*	0.060	I(1)
U.S.							
*p**	-1.893	-9.568*	-1.941	-7.238*	1.254*	0.327	I(1)
*i**	-2.080	-3.344**	-1.527	-6.595*	0.886*	0.049	I(1)

Note: *, ** and *** represent the 1%, 5% and 10% significance levels, respectively. In KPSS test, non-rejection of the null hypothesis indicates stationary process.

Table 3. Johansen cointegration tests.

Country	Hypothesized no. of CE(s)	Trace statistic	λ_{max}	$\hat{k}$
India	None	124.919*	52.606*	3
	At most 1	72.313*	32.389**	
	At most 2	39.923	17.298	
	At most 3	22.625	13.683	
	At most 4	8.942	8.942	
Philippines	None	109.297*	39.075**	3
	At most 1	70.222*	29.830	
	At most 2	40.391	17.209	
	At most 3	23.182	13.694	
	At most 4	9.488	9.488	
Russia	None	128.468*	55.762*	3
	At most 1	72.705*	37.841*	
	At most 2	34.863	18.917	
	At most 3	15.946	15.883	
	At most 4	0.062	0.062	
South Africa	None	117.732*	55.649*	4
	At most 1	62.083*	32.911**	
	At most 2	29.171	16.560	
	At most 3	12.611	9.152	
	At most 4	3.458	3.458	
France	None	117.789*	42.452*	3
	At most 1	69.336*	37.733*	
	At most 2	31.603	19.002	
	At most 3	12.600	6.941	
	At most 4	5.658	5.658	
Germany	None	108.344*	46.111*	3
	At most 1	62.233*	29.048**	
	At most 2	33.184	18.977	
	At most 3	14.206	10.303	
	At most 4	3.902	3.902	
Japan	None	102.692*	47.928*	3
	At most 1	54.764**	23.292	
	At most 2	31.471	15.588	
	At most 3	15.883	10.647	
	At most 4	5.236	5.236	
U.K.	None	90.722*	35.599**	3
	At most 1	55.123**	24.356	
	At most 2	30.766	19.711	
	At most 3	11.054	7.068	
	At most 4	3.985	3.985	

Notes: ** and *** denotes rejection of the null hypothesis at the 1%, 5% and 10% significance levels, respectively. k denotes the estimated lag length and λ_{max} is the Max-eigenvalue test statistic. The Trace test indicates presence of two cointegrating vectors in all cases.

Table 4. LR tests for the structure of cointegrating vectors

	H_1, H_2 (PPP with unrestricted interest rates, UIP with unrestricted prices)	H_3, H_4 (Only PPP, only UIP)	H_5, H_6 (PPP with interest rates with equal and opposite signs, UIP with prices with equal and opposite signs)
India	2.951	36.483*	32.452*
	(0.228, 2)	(0.000, 6)	(0.000, 4)
Philippines	1.485	18.388*	11.275**
	(0.475, 2)	(0.005, 6)	(0.023, 4)
Russia	3.275	55.062*	6.687
	(0.194, 2)	(0.000, 6)	(0.153, 4)
South Africa	10.012*	56.364*	44.462*
	(0.006, 2)	(0.000, 6)	(0.000, 4)
France	6.652**	37.281*	12.679**
	(0.035, 2)	(0.000, 6)	(0.012, 4)
Germany	0.596	40.212*	26.377*
	(0.742, 2)	(0.000, 6)	(0.000, 4)
Japan	1.579	23.400*	20.255*
	(0.453, 2)	(0.000, 6)	(0.000, 4)
U.K.	4.407	30.131*	20.380*
	(0.110, 2)	(0.000, 6)	(0.000, 4)

Notes: The LR tests are distributed asymptotically as χ^2. *p*-values and degrees of freedom are in parentheses. *, ** and *** denotes rejection of the null hypothesis at the 1%, 5% and 10% significance levels, respectively.

Is Stock Market Sensitive to Day-to-Day Monetary Operations? Evidence from an Emerging Economy

Radeef Chundakkadan*

**Research Scholar, Indian Institute of Technology Madras.*

Abstract

This study examines the effect of day-to-day monetary operations through Liquidity Adjustment Facility on daily stock returns in the Indian market. In this study, we employ fixed repo amount and term repo as proxy for the monetary policy variable. We find that stock return and term repo amount are positively related, controlling for macroeconomic variables. Further, small firms are more affected by monetary operation than large firms; and the effect of monetary policy is not uniform amount different sectors of the economy. These results are consistent with both OLS and M-estimation.

Keywords: Monetary Policy, OLS, Stock Markets

1. Introduction

Monetary authority uses different set of measures like open market operation (OMO), setting interest rate, maintaining statutory reserves etc. to drive economic growth and price stabilization. These measures affect economic activities like financial market investment, consumption via wealth effect, and international trades via exchange rate. Given the sensitivity of financial markets to the economic "news", the monetary operations and announcement could produce changes in the financial asset prices. In the case of stock market, an expansionary monetary policy either shoots up stock prices through liquidity effect (Hamburger, 1971) or because stocks become more attractive compared to bonds. A contractionary monetary policy can affect both the producers via the cost of borrowing, and the consumers via wealth effect (Bernanke and Kuttner, 2005) which results in fall in profits and stock prices. Monetary policy or announcements can influence the expectation and investment decisions of economic agents (Kurov and Gu, 2016). Finally, increase in the interest rate leads to higher discounting in the valuation of stocks.

Earlier, Reserve Bank of India (RBI) used conventional measure like Cash Reserve Ratio (CRR) as monetary policy[1]. Recently, India adopted day-to-day operations to maintain liquidity in the economy is called Liquidity Adjustment Facility (LAF). LAF allow banks to borrow/lend from/to RBI against government securities (as a collateral) with a promise of repurchase/resell the same on a predetermined date. Such monetary operations are called repo/reverse repo operation. RBI handles LAF through 2 windows (or auctions) called fixed repo/reverse repo window and term (or variable) repo/reverse repo window. The former allows banks to borrow/lend at a fixed interest rate[2] with a relatively short maturity period (say, overnight), and the latter allows banks to borrow/lend at market rates for a relatively longer maturity period. Since stock market behaves in harmony with economic conditions, it is expected that LAF can bring changes in the stock market in two ways: first is through upholding ideal liquidity in the market. Second, LAF operations deliver signals about the demand for money in the economy. A positive/negative net injection (repo amount *minus* reverse repo amount) signals to economic agents that economy is demanding more/less money, and thus higher/lower level of future output. Therefore, this study intends to examine the effect of repo operation on daily stock returns, and we expect a positive response on stock returns.

We choose India as ideal economy to study for the following reasons. India is one of the fastest growing economies ranking third on the purchasing power parity, with a well-developed banking and non-banking financial system, and with a multiple monetary policy objective (Sensarma and Bhattacharyya, 2016). Further, i) India registers a growth in Net Foreign Direct Investment about 204% during 2010-11 to 2015-16; ii) the value of Indian currency strength from 94.74 in 2010-11 to 76.45 in 2015-16[3]; iii) there is a growth of 75% in India's total foreign exchange reserves during 2010-11 to 2015-16; iv) in the case of the stock market, BSE Sensex[4] and BSE market

[1] CRR is the proportion of Net Demand and Time Liabilities that banks mandate to keep in RBI as reserve fortnightly.
[2] RBI announces the fixed interest rate in their bi-annual monetary policy statements.
[3] Nominal Effective Exchange Rate (NEER) of Indian rupee with export-based weight is used. NEER with trade-based weight is 93.54 in 2010-11 and 74.75 in 2015-16.
[4] BSE Sensex is an index of 30 well established and financially sound companies listed in Bombay Stock Exchange.

capitalization had a growth of 51% and 52% respectively during 2011-12 to 2015-16; v) while considering mutual funds, the net value mobilized by mutual funds increased from -454.13 billion rupees in 2011-12 to 1317.58 billion rupees in 2015-16, and the value of the asset under the management of mutual funds had increased from 5922.50 billion rupees to 12328.24 billion rupees during the same period.

There are two broad strands of studies on monetary policy and stock market. One strand focuses on policy effects and other strand focuses on announcement effects. Thorbeke (1997) and Bjornland and Leitemo (2009) used VAR methodology to prove significant monetary policy effects on US stock market. The studies focuses on announcement effects uses event study methodology (Ehrmann and Fratzscher (2004), Bernanke and Kuttner (2005) and Kurov and Gu (2016)) and identification through heteroscedasticity (IH) methodology (Rigobon and Sack (2004), Kholoilin et al. (2009) and Duran et al. (2012)). In India, Bhattacharyya and Sensarma, (2008) and Ray and Prabu (2013) used CRR and repo rates as monetary variable in their monthly data-VAR model and argued that stock market is insensitive to monetary policy. But, using monthly stock data may not always capture the effect that last only few days after a monetary operation. Recently, Prabu et al. (2016) examined the impact of the monetary announcement on Indian stock market, and found that monetary announcement had little effect on stock market. This may be because market participants anticipate the policy changes in scheduled announcement in advance and act accordingly.

Our study is different from above studies in several ways. First, we study the impact of RBI's day-to-day operations (LAF) on stock returns, which is perhaps the first time in the literature. In contrast to existing studies (Bhattacharyya and Sensarma, (2008) and Ray and Prabu (2013)), we use fixed and term repo/reverse repo amounts as monetary policy variable. It helps to understand how the RBI's short-term liquidity operations influence the stock market. Second, we use daily frequency data, which helps to capture the immediate variations in the stock market after the monetary operation. Sometimes, the variations in stock market after an event do not persist for a long time. Therefore, using daily data will helps to capture better variation in stock return than using monthly data. Third, to find the size effects of monetary policy, both size indices and portfolio of small firms are included in the study. Finally, to find industry specific effects of the monetary operation, 18 sector indices of NSE are used in the study.

The results of this study are as follows. In contrast to existing literature, we found a positive relationship between RBI's monetary operation via LAF and daily stock returns, and this effect came from term repo operation which have relatively higher maturity period. The result is qualitatively similar even after controlling for the macroeconomic variable, and by using robust regression (M-estimation). Another important finding is that monetary operation had a relatively higher impact on the smaller firms than the larger firms, which is similar to the US economy (Guo, 2004; Ehrmann and Fratzscher, 2004). Finally, the impact of monetary operation is not uniform among different industries. Higher impact accounts both in capital-intensive industries and in financial sectors.

The remaining part of this paper is organized as follows. Section 2 discusses the related empirical literature. Section 3 talks about Liquidity Adjustment Facility in India. Section 4 deals with the transmission mechanism of monetary policy. Section 5 describes data and methodology used in

this study. Section 6 shows the empirical results and discussion. Section 7 provides concluding remarks.

2. Empirical Literature

This impact of monetary policy on stock market had studied using different proxies for monetary policy. The studies that use money supply as the proxy for the monetary policy such as Keran (1971), Homa and Jaffee (1971), Hamburger et al (1971) found a positive relationship between stock returns and money supply. Pesando (1974) argued that this relationship is only because of specification error and peculiarity of the study period. Cooper (1974) showed the stock market is well enough to incorporate money supply information. Rogalski and Vinso (1977) argued that it is stock market induces change monetary policy, not the other way.

Another set of studies which uses interest rate as the proxy of monetary policy found monetary tightening (expansion) had a negative (positive) impact on stock market [(Thorbecke and Alami, 1994) and (Kurov and Gu, 2016)]. Chen (2007) and Kurov (2012) showed that monetary policy had a higher effect on the stock market during bear regime than the bull regime. The studies of Thorbecke and Coppock (1996), Ehrmann and Fratzscher (2004), and Guo (2004) argued monetary policy affect more on small firms' stocks than large firms' stocks. The effect of monetary policy on capital-intensive firms and on firms belongs to highly cyclical demand for their goods are severe than that of other firms [(Thorbecke and Coppock, 1996) and (Ehrmann and Fratzcher, 2004)].

The effect of monetary policy on Indian stock market has generated different opinions. On the one hand, Agarwal (2007) adopted event study methodology to show monetary announcement of CRR (Cash Reserve Ratio) change have impact on the stock market. On the other hand, Sasidharan (2009) used nonparametric approach to show CRR, Bank Rate, and Reverse Repo Rate announcement have no impact on the stock market before and after the event. Recently, Prabu, et. al. (2016) used IH (identification through heteroscedasticity) approach to identify the effect of monetary policy announcement on Indian stock market. They found that monetary announcement had a little impact on broad Indian stock index, but had weak effect for surprise announcements. Bhattacharyya and Sensarm (2008) and Ray and Prabu (2013) included CRR and repo rates in their VAR model and argued that monetary policy had a limited impact on Indian stock market.

3. Liquidity Adjustment Facility in India

Reserve Bank of India (RBI), the central bank of India, had gone through various monetary policy regimes to maintain liquidity in the economy. The overall liquidity or Net Liquidity Position (NPL) of RBI is generated through two ways. First is autonomous liquidity which is obtained from central bank's usual functions like lending money to government, lending to non bank domestic sectors, net foreign assets, and net other assets *minus* currency in circulation. Second is discretionary liquidity that is attained from RBI's liquidity operations, which is recommended by Committee on Banking Sector Reforms[5], such as Open Market Operations (OMOs), Market Stabilization Scheme (MSS), Marginal Standing Facility (MSF), Standing Liquidity Facilities (SLF), and LAF operations. OMOs generate liquidity through purchase and sale of government dated securities and

[5] This committee headed by M. Narasimha, recommended reforms in the RBI operation, banking system, capital adequacy, entry for foreign banks etc. in 1998. Later, it is modified by Working Group to Review the Operating Procedures of Monetary policy in India, chaired by Deepak Mohanty, in 2011.

treasury bills. SLF allows commercial banks to borrow money from RBI through Export Credit Refinance (ECR) facility against their export credits for a specific period. RBI issues securities/bonds that are not to fund government expenditure, but to mop excess liquidity in the economy is called MSS. The redemption of the same injects liquidity into the market. MSF allows banks to borrow money from RBI at higher rate than repo rate (which will discuss bellow) at the time of shortage of liquidity in inter-bank market.

LAF is RBI's most widely used short-term liquidity management operation on daily basis. RBI allows commercial banks to borrow money from RBI against government securities, as a collateral, with a promise to repurchase the same securities on a predetermined date; and banks can also park their excess money or liquidity in RBI by purchasing the government securities with a promise to resell the same on a predetermined date. The former facility is known as repo operation, and the latter is known as reverse repo operation. The objectives of these facilities are to bring short-term liquidity in market and guide path for call money rate, which is the operating target of RBI.

RBI conducts two types of operations under LAF. First, fixed repo/reverse repo operation on every Monday to Friday. Most of the times, fixed repo/reverse repo operation had an overnight maturity, and the interest rate charged/paid by RBI is called fixed repo/reverse repo rate. RBI predetermines the fixed repo/reverse repo rates and announce through its Bi-Monthly Monetary Policy Statement (BMMPS). The maximum amount banks can borrow through fixed repo window is 0.25% of their Net Demand and Time Liability (NDTL), and there is no restriction for the quantity of reverse repo amount (as per BMMPS issued on 5th August 2014). Second, RBI commenced term (variable) repo/reverse repo operation for the notified amount from 11th October 2013 onwards. The maturity period of these operations varies time to time, and the repo/reverse repo rates are determined through auction[6]. RBI conducts 14 days and 7 days maturity term repo auction on every Tuesday and Friday for an amount equals to 0.75% of NDTL of banking system, and for other maturity period on preannounced dates and amounts. Apart from this, RBI also conduct overnight maturity term repo/reverse repo auction on every Monday to Friday for an amount decided based on the liquidity condition and government cash balance.

[Insert Figure 1 and 2 around here]

Figure.1 shows RBI's monthly monetary injection through LAF (through fixed and term repo), MSF, MSS, and OMOs during October 2013 to October 2016. It is clearly evident that LAF is the dominating operation through out the period. Almost 90% (184496.16 billion rupees) of short-term liquidity is met through LAF operation, while other 10% (20561.87 billion rupees) is through MSF, MSS, and OMOs. Figure.2 shows that RBI's monthly monetary absorption through LAF (through fixed and term reverse repo), OMOs, and SLF[7]. The story of monetary absorption is not different. LAF accounts 97% (90375.83 billion rupees) of RBI's short-term monetary absorption.

[6] In repo/ reverse repo auction, commercial banks bid the amount along with repo/reverse repo rates that should be above/ below the fixed repo/reverse repo rate pre-determined by RBI. After bidding, all bids are arranged in descending/ascending order of quoted repo/reverse repo rates. Finally, cut off rate is decided where the cumulative bid amount equals the RBI notified amount.

[7] RBI reports only net amount of SLR. We included SLF in monetary absorption because monthly SLF is negative in most of the months.

From Figure.1 and Figure.2, it is clear that RBI uses LAF as major policy to meet short-term liquidity in the economy.
The objective of LAF is to inject/absorb money such a way to pave path for call money rates, which is the operating target of RBI, and to bring all interest rates into the same corridor. To assess this, Figure.3 give a plot of repo rates, monthly average call money rates, and reverse repo rates. It shows that call money rates moves on or between the repo and reverse repo rate, which is an evidence for the effectiveness of RBI's policy. The movement of 91-days Treasury bill rates, Government securities of maturity one year, five years and ten years is depicted in Figure.4 along with call money rates. It shows that all interest rates are moving together and therefore RBI's policy worked well to bring its policy variable and other interest rate to move in a same corridor.

[Insert Figure 3 and 4 around here]

It is expected that LAF can bring changes in the stock market in two ways: First is through generating ideal liquidity in the market. A repo operation leads to investors to have enough money to purchase the stock and companies will have enough money to fund their projects. On other hand, reverse repo mop up the liquidity and create opposite effect of repo operation in stock market. Second, LAF operations deliver signals about the demand for money in the economy. A positive/negative net injection (repo amount *minus* reverse repo amount) signals to economic agents that economy is demanding more/less money, and thus higher/lower level of future output. Therefore, it is expected a positive and negative response for a repo and reverse repo operations respectively.

3. Channel of Monetary Transmission.

Monetary policy can affect the economy through balance sheet channel. In a world of asymmetric information, monetary tightening will affect the balance sheet adversely and it affects future performances of the firms. An increase in interest rate (monetary tightening) will lead to a higher discounting of firms' assets in the balance sheet. The fall in net worth of the firms makes external funds costly. Due to asymmetric information, external fund demands higher interest rate than internal fund- which is called agency cost. Higher cost of borrowing reduces firms' current profit, which will again reduce future net-worth. The same process continues in future and economy will fall into recession (Bernanke and Gertler, 1989). This effect of monetary tightening will lead to falling stock price via fall in future earnings.

The effect of monetary policy on credit market condition is studied by Kashyap, et. al. (1992). He argued that two conditions are necessary for the effect of monetary policy on the economy. First, the assets of banks (loans and other form of asset, say commercial paper) should not be the perfect substitute for each other. If the monetary policy has any effect, the composition or a mix of these bank assets will change after the policy. Second, bank loans and other forms of debts (say, commercial paper) should not be a perfect substitute for each other. For the monetary policy to have any impact, firms are forced to move from bank borrowing into other forms of borrowings which are relatively costly. Therefore, monetary tightening pulls down firms' profit due to the higher cost of borrowing, and finally it affects stock adversely. The adverse effect of monetary tightening on the economy through credit market condition is called financial accelerator

(Bernanke et al., 1994). Bernanke et al. (1994) argued that an adverse shock to an economy weakens the financial condition of the firm. This will lead to lower credit access and lower production and spending. Finally economy faces a bad time. The limited availability of fund after the monetary tightening creates credit rationing in the economy. Therefore, the available fund in the economy moves to the most reputed or large firms from other firms referred as 'flight to quality' (Bernanke et al. 1994). The financial acceleration due to flight to quality reduces the future profit both by lower credit access and by higher cost of borrowing. Therefore, the stock market will be affected badly at the time of monetary tightening.

Another channel of transmission is through investors' sentiments. Kurov (2010) shows monetary policy affects investors' degree of speculation and it affects stock returns. He also argued that investors behave differently in a different state of the economy. Investors' interpretation of monetary policy at the time of recession will be different from that of the boom. Finally, monetary tightening increases the interest rate, which is the cost of borrowing. It will lead to falling in investment in the economy and finally it affects stock price too. This is known as interest rate channel.

4. Data and Methodology

In India, fixed repo operation happens on every Monday to Friday, while term repo operations for various maturities happen only on the dates RBI announces prior. There can be more than one term repo auction with different maturity and different term repo rate in a same day. RBI started term repo and term reverse repo auction on 11th October 2013, and therefore this study uses the data from 11th October 2013 to 30th October 2016[8]. There were 730 days where either fixed repo, term repo or term reverse repo windows were operated. The return on Nifty 50, which is a benchmark index of National Stock Exchange (NSE), is employed as stock returns[9]. NSE is the worlds' 4th largest stock market in term of trading volume and India's' largest stock market in terms of daily turnover. Nifty 50 includes 50 well-diversified stocks of 13 sectors, which represent 65% of free float market capitalization in NSE (NSE website). This study also includes other industry and size indices of the same stock exchange. The data on LAF is available on RBI website and data on stock indices are available on NSE website.

Following Ehrmann and Fratzscher (2004), Bernanke and Kuttner (2005) and Kurov (2012), this study begins the analysis with a regression model of stock return on monetary variable. We assume that RBI's money injection (through repo operation) affects stock returns on next day[10]. Therefore, following is used to study the impact daily repo operation on daily stock returns.

$$r_{t+1} = \alpha + \beta . MP_{\,t} + \sum \gamma . control + u_t \qquad \text{----------} \quad (1)$$

[8] This paper does not include the data beyond October 2016 because RBI demonetized 500 and 1000 rupee notes which create numerous uncertainties in the economy

[9] Prabu et. al. (2016) used Nifty 50 in their study. Studies of Sasidharan (2009) and Bhattacharyya and Senarm (2008) used BSE Sensex index, which is the benchmark index of Bombay Stock Exchange, as equity price. We also tried our analysis with BSE Sensex, but the result is qualitatively similar.

[10] It requires time to circulate money, and its affects to be getting reflected on economic activities and on stock market.

Where, r_t is the daily stock returns at time *t*, MP_t are the monetary injection through repo operation at time *t*. We also include control variables like past daily stock return to get the effect of monetary injection that is independent of past stock returns (which may include other information) and some macroeconomic variables too. Both the models are estimates by OLS and M-estimation method. M-estimation gives consistent estimator at the presence of outliers (Kurov and Gu, 2016). We should not use other time series model because term repo operation had no continuous data. The average number of days where repo operation happens is 9 days per month.

5. Empirical Results & Discussion

i) Summary statistics

Table.1 shows the descriptive statistics of the variables under this study. There are 730 days where repo operation, reverse repo operation, or both happened. Among them, RBI conducted fixed repo operation for 730, while term repo operation only in 356 days. Average amount of money injected to the economy on a LAF day is 252.66 billion rupees. Taking both repo operations separately, the average amount of injected through term repo operation (205.4 billion rupees) is higher than the average amount injected through fixed repo operation (152.5 billion rupees). At the same time, the variation in amount injected through term repo operation is more than the variation in amount injected through fixed repo operation.

[Insert Table 1 around here]

ii) The effect of repo operation on daily stock returns.

We used 3 specifications of equation (1) to examine the impact of repo operation on daily Nifty 50 returns. The first specification uses total repo amount (sum of fixed repo amount and term repo amount) injected by RBI as monetary variable. To get separate effect of fixed repo operation and term repo operation, we use fixed repo amount and term repo amount[11] as monetary variable in specification two and specification three respectively.

Table.2 reports the results of 3 specifications of equation (1) of the impact of repo operations on daily stock returns, estimated by OLS (Panel A) and M-estimation (Panel B). It indicates that total repo operation had a positive impact on stock market, and it is statistically significant at 10% level (column 2). While estimating equation (1) separately for fixed repo and term repo, coefficient of fixed repo suggest an insignificant response in stock market for RBI's short-term liquidity management (column 3). Most of the liquidity operations by RBI through fixed repo window had a maturity of overnight. Therefore, banks use this window to meet reserve requirement assigned by RBI or to meet other day-to-day unbalances in the account. Therefore, fixed repo operation may not influence the purchasing power of stock investors or it cannot bring much impact on firms' fundings on new projects. So, fixed repo operation may not bring much impact on the stock market. However, RBI's term repo operation had a positive significant effect on daily stock returns (column 4). While comparing column 1 and column 3, both the coefficients and the p-value of monetary variable are improved in term repo operation. For a 100 billion rupees injected through variable repo operation, there is 0.08% (on average) increase in stock returns. This finding

[11] We also tried with term repo rate; its coefficient is statistically insignificant at the conventional level.

contrasts the existing studies [Bhatachariya et al (2009), and Ray and Prabu (2013)] on impact of monetary policy on Indian stock market.

Panel B of Table.2 reports the results of equation (1) estimated by M-estimation method. It indicates that the results are not much quantitatively different from Panel A. For 100 billion injects to the economy by RBI through LAF, there is 0.06% (on average) increase on next day stock returns, and the coefficient is statistically significant at 5% level (column 7). The coefficients of total repo (column 5) and fixed repo (column 6) are statistically insignificant. Therefore, further analysis in this paper uses term repo amount as monetary injection variable.

The positive relationship between monetary injection and stock market may be due to two reasons. First, it creates liquidity in the market which increases purchasing power of stock traders and increase the availability of money to fund new projects for the firms. Second, it signals the future performance of the economy. More money injected signals higher demand for the fund and higher future performance of the economy. In comparison with previous studies, this study, the primary difference is that this paper uses the recent monetary variable, which maintains stable liquidity in the economy. Second, this paper employs daily stock data. Since stock market incorporates information quickly, using daily stock return helps to identify small variation in the stock market due to monetary policy.

[Insert Table 2 around here]

Thorbecke and Coppock (1996), Ehrmann and Fratzscher (2004), and Guo (2004) argued that monetary policy had a higher effect on small firms than on large firms. Monetary contraction creates credit crunch in the economy and therefore small firms are more affected due to "flight to quality" and agency cost (Bernanke et al. 1994). To examine the effect of monetary policy on different size classes, following method is used. First, the firms in the Nifty 500 index, which represents 94% of the total market capitalization of NSE, are sorted according to their market capitalization as on February 2017. Next, all 500 firms are divided into quintiles; Quintiles1 represent the portfolio of the smallest firm; Quintiles2, Quintiles3, and Quintiles4 represent the portfolio of second, third, and fourth smallest firms respectively; and Quintiles5 represent the portfolio of largest firms. Then, market capitalization weighted average daily stock returns of each portfolio are calculated. After that, we estimate the relationship between weighted average returns of each portfolio on term repo amount using equation (1) [12].

[Insert Table 3 and 4 around here]

Panel A of Table.3 reports the results of impact of term repo operation on different size quintiles, estimated using OLS. The coefficient of term repo amount is statistically significant at 5% level for all the size portfolios. Comparing the portfolio of largest firms (Quintiles5) and the portfolio of smallest firms (Quintiles1), smallest firms earned relatively higher than largest firms. For a 100 billion monetary expansion by RBI through variable repo operation, there is 0.13% (on average) increase in the return of smallest firms, which are 44 basis points higher than the return of largest firms. For the same monetary operation, Quintiles2, Quintiles3, and Quintiles4 earned 0.11%,

[12] We also carried out estimation using fixed repo amount as monetary policy variable. As expected, the coefficients monetary policy variables are statistically insignificant.

0.12%, and 0.11% respectively. These results are consistent with findings of Thorbecke and Coppock (1996), Ehrmann and Fratzscher (2004), and Guo (2004) that the impact of monetary policy is relatively higher on small firms than large firms. The same model estimated using M-estimation method in Panel B shows quantitatively similar result as in Panel A. For a 100 billion monetary expansion by RBI through variable repo operation, there is 0.07% (on average) increase in the return of smallest firms, which are 16 basis points higher than the return of largest firms.
Earlier studies [Thorbecke (1997), Ehrmann and Fratzscher (2004)] on the impact of monetary policy on various industries found that monetary policy affects the industries differently. They argued industries that are highly capital intensive and highly demand sensitive are affected more by monetary policy. To examine this heterogeneous effect of monetary policy on different industrial stocks, 18 indices of different sectors in NSE is used (see appendix for market capitalization and total trade of companies in different indices). We use equation (1) to examine the impact of repo operation on daily indices return on 18 industries.

The result reported in Table.4 is consistent with Ehrmann and Fratzscher (2004) that monetary operation affects industries in heterogeneous ways. The coefficients of term repo amount for 12 industrial indices are statistically significant at 5% level and for 2 industrial indices at 10% level in OLS regression, and for 7 industrial indices are statistically significant at 5% and for 2 industrial indices at 10% level in robust regression[13]. In OLS regression, the higher effect of monetary policy is seen in Public sector undertaking (PSU) banks. For a 100 billion injection of money by RBI through term repo auction leads to, on average, 0.23% increase in PSU bank returns. Followed by infrastructure (0.18%), metal (0.16%), PSU (0.13%), CPSE (0.13%), commodities (0.12%), banks (0.12%), private banks (0.11%), energy (0.11%), and financial service (0.10%) sectors account for two-digit basis point increase for 100 billion rupees through term repo auction. Then, FMCG (0.08%) and India consumption (0.07%) indices account for one-digit basis point increase for 100 billion rupees injected through term repo auction. It is evident that highly capital-intensive industries like infrastructure, metal, energy etc., and industries that are more sensitive to monetary operations like banks, financial services are more affect by monetary policy.

iii) Robustness check.

For robustness check, we used equation (1) with entire data consisting of 730 observations. The result of this regression using OLS and M-estimation is provided in Table. 5. It shows that term repo amount can bring positive impact on daily stock returns and it is qualitatively similar as above. For a 100 billion rupee injected through term repo auction, OLS and M-estimator suggest a 0.04% and 0.03% (on average) increase in daily stock returns and it is statistically significant at 5% and 10% level respectively.

[Insert Table 5 around here]

Stock returns can also be influenced by other daily macroeconomic variables. For example, Singh and Pattnaik (2010) and Ray and Prabu (2013) used variables such as exchange rate and call money rates in their model to examine the effect of macroeconomic variables on asset prices. To account daily variations in macroeconomic variables, rupee-dollar exchange rate, and call money rate is introduced in the equation (1) as control variables. The result of this regression as given in Table.6

[13] We also tried to estimate the relationship with fixed repo amount and industrial indices return. None of the coefficients of monetary variable are significant.

shows that RBI's Liquidity Adjustment Facility had an impact on daily stock return independent of macroeconomic variables used in both OLS and robust regression. For a 100 billion rupee injected to the economy via term repo auction brings (on average) 0.08% increase in daily stock returns in OLS regression and 0.05% increase in daily stock returns in robust regression. The coefficient of exchange rate shows than stock return increases when currency gains strength, but its coefficient is not significant at any conventional level. The coefficient of call money rate shows a positive relationship with the stock return, but it is statistically insignificant at the conventional level.

[Insert Table 6 around here]

6. Concluding remarks

This paper examined the effect of monetary policy on daily stock returns. The monetary proxy used in this study is both fixed and term repo/reverse repo amount. It is found that, in contrast to earlier studies, term repo and term reverse repo operations of RBI influences the Indian stock market. For 100 billion rupees injected into the economy by RBI through term repo auction, there will be a 0.08% increase in stock return on following day. This effect exists even after controlling for autocorrelation with its own past and macroeconomic variables like exchange rate and call money rates. This result is qualitatively similar to using robust regressions.

The study also used sector and size indices to examine the effect of heterogeneous effect of monetary policy on different sectors and size classes. The result suggests that the daily stock return of small firms moved up more than the daily stock returns of large firms due to monetary operations via LAF. An investor can earn abnormal profits of 44 basis points (on average) by investing in small firms than large firms, which shows the inefficiency of the Indian stock market. The study also shows evidence for monetary policy has a different impact on different industries. The effect is more pronounced in capital-intensive industries like infrastructure, metal, energy etc, and other financial and banking industries.

These results reiterate the role of monetary policy on Indian stock market. Therefore, looking from monetary authority's point of view, they should consider the impact on the stock market while implementing their policies. Not only that, looking from the view of equity investors, they can earn abnormal return using the information of previous day's term repo auction, which is also showing the inefficiency of the equity market in India.

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Figure 1: Monthly Monetary Injection

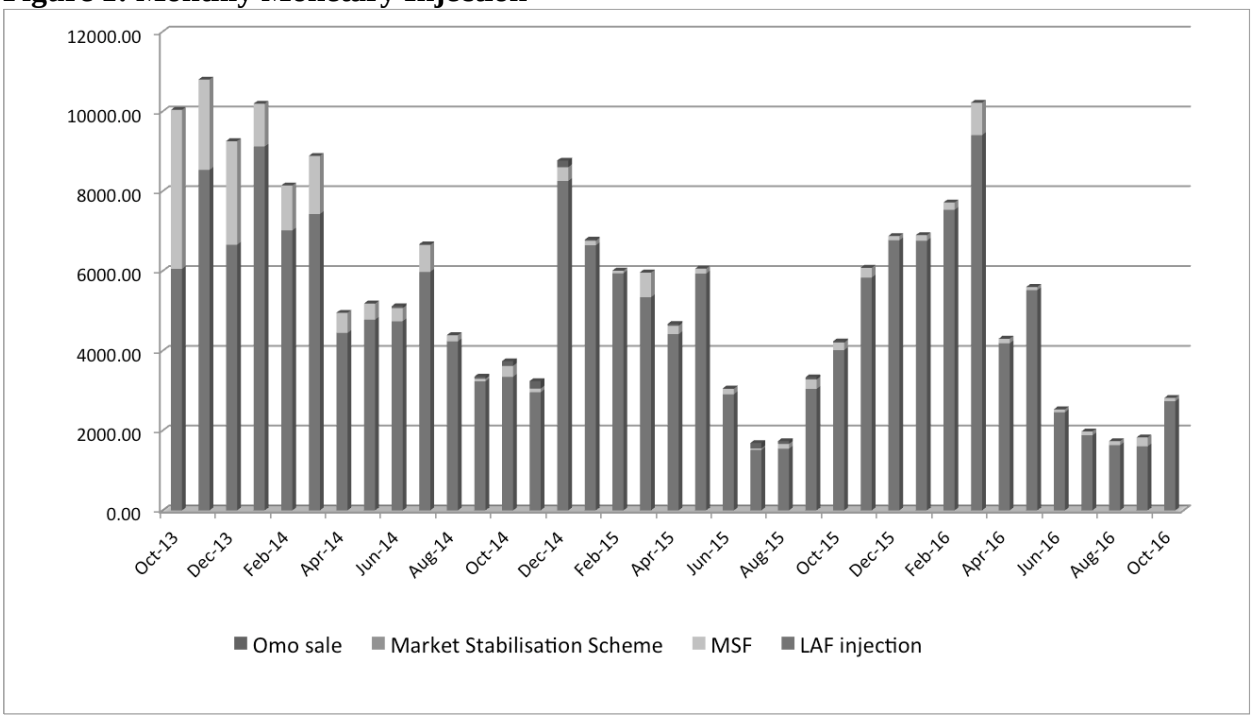

Figure 2: Monthly Monetary Absorption

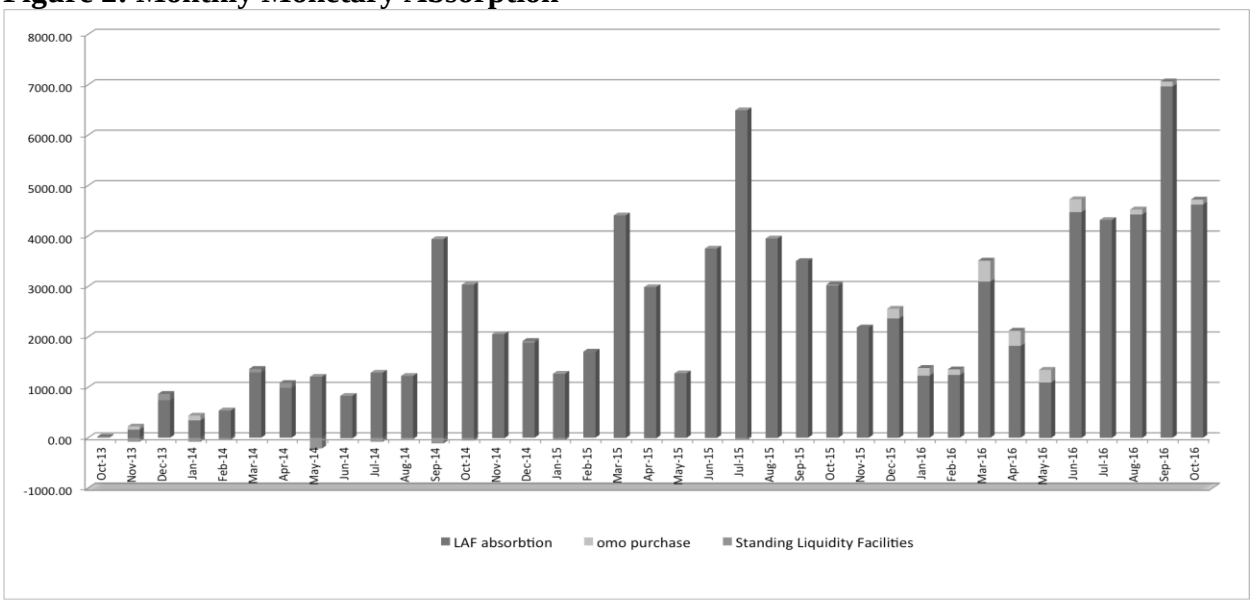

Figure 3: Monthly Repo, Call Money, and Reverse Repo Rates

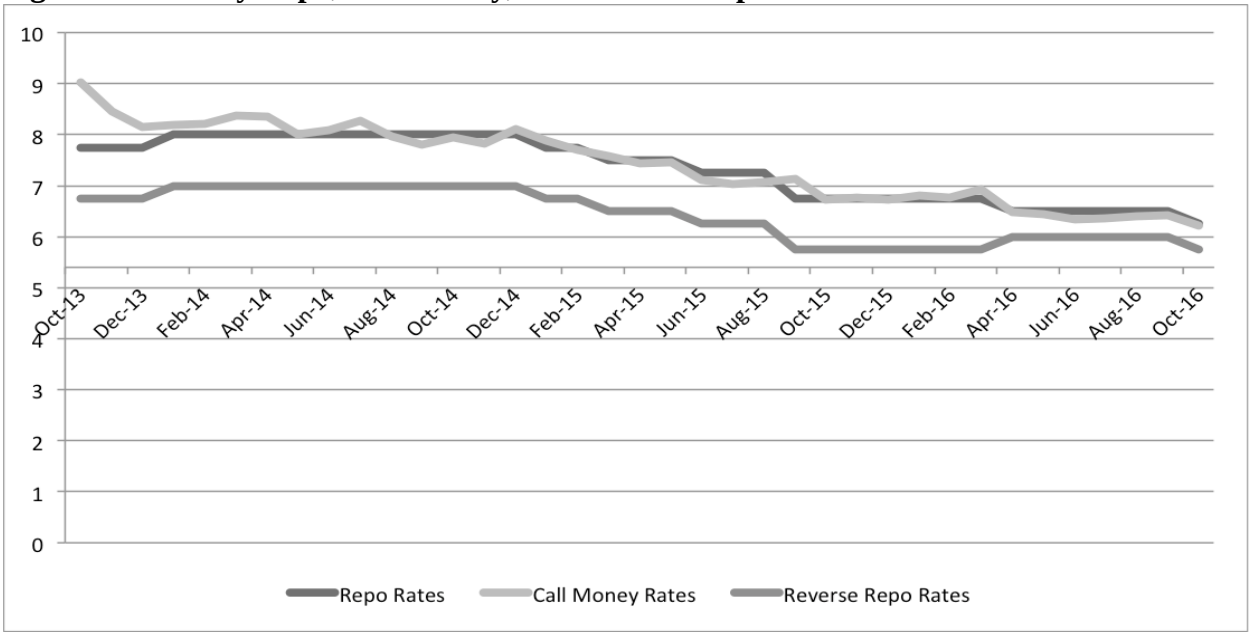

Figure 4: Monthly Call Money Rates, 91-TB, GSec1, Gsec5, and Gsec10

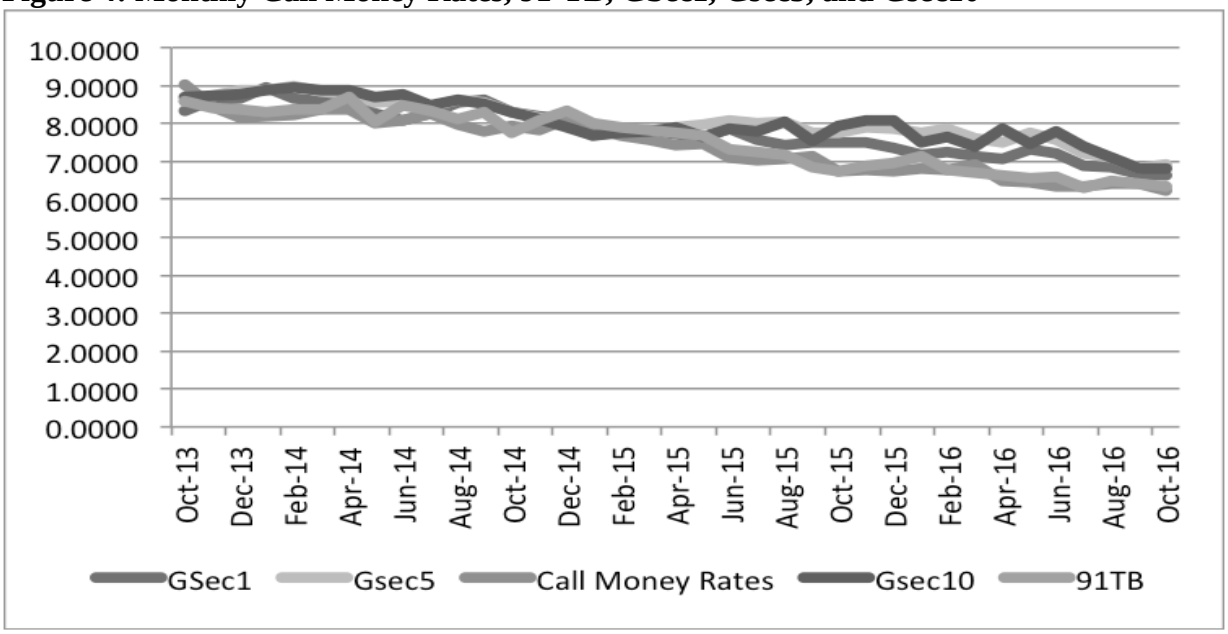

Table 1: Summary Statistics

	Fixed Repo	**Term repo**	**Total Repo**	**Nifty 50 return**
Min	5.34	2.75	5.34	-5.9151
1st quartile	56.74	100	100.02	-0.44237
Median	141.36	155.03	208.88	0.04068
Mean	152.5	205.4	252.66	0.04699
3rd quartile	206.44	275.34	380.56	0.57114
Max	412.9	789.27	954.65	3.36694
Std dev	109.080	158.6069	194.21	0.932628
Obs	730	356	730	738

Table 2: The effect of Repo operation on daily stock returns

VARIABLES	Panel A: OLS			Panel B: M-Estimation		
	Stock Returns	Stock Returns	Stock Returns	Stock Return	Stock Return	Stock Return
Total Repo	0.000336*			0.000203		
	(0.000172)			(0.000155)		
Past Returns	0.0996***	0.100***	0.138***	0.105***	0.106***	0.139***
	(0.0370)	(0.0369)	(0.0494)	(0.0360)	(0.0360)	(0.0451)
Fixed Repo		0.000230			-0.0000058	
		(0.000295)			(0.000264)	
Term Repo			0.000807**			0.000553**
			(0.000315)			(0.000280)
Constant	-0.0453	0.00460	-0.127	-0.00554	0.0463	-0.0593
	(0.0555)	(0.0573)	(0.0872)	(0.0505)	(0.0521)	(0.0781)
Observations	730	730	356	730	730	356
R-squared	0.015	0.011	0.036			

Note: This table shows regression results of 3 specification of equation $r_t = \alpha + \beta . MP_{t-1} + \delta . r_{t-1} + u_t$,estimated using OLS (Panel A) and M-estimation (Panel B). Where r is the daily Nifty 50 returns, and MP is the monetary injection variable such as total repo (column 2 and column 5), fixed repo (column 3 and column 6), and term repo (column 4 and column 7) amount used in each specifications. Robust standard error is reported in the parenthesis. Signif. codes: 1% '***' 5% '**' 10% '*'.

Table 3: The Effect of Repo operation on Size Quintiles

	Panel A: OLS				
VARIABLES	Quintiles1	Quintiles2	Quintiles3	Quintiles4	Quintiles5
Term Repo	0.00131**	0.00105**	0.00125***	0.00118***	0.000868***
	(0.000558)	(0.000469)	(0.000460)	(0.000431)	(0.000328)
Past Returns	0.235***	0.248***	0.268***	0.218***	0.158***
	(0.0727)	(0.0687)	(0.0741)	(0.0713)	(0.0569)
Constant	-0.0490	-0.0495	-0.115	-0.104	-0.104
	(0.143)	(0.120)	(0.116)	(0.116)	(0.0888)
R-squared	0.063	0.068	0.083	0.062	0.043
Observations	356	356	356	356	356
	Panel B: M-Estimator				
VARIABLES	Quintile1	Quintile2	Quintile3	Quintile4	Quintile5
Term Repo	0.000733*	0.000578	0.000742**	0.000789**	0.000571**
	(0.000391)	(0.000364)	(0.000343)	(0.000331)	(0.000288)
Past Returns	0.194***	0.232***	0.233***	0.186***	0.150***
	(0.0619)	(0.0611)	(0.0666)	(0.0617)	(0.0529)
Constant	0.154	0.107	0.0484	0.0480	-0.0118
	(0.106)	(0.0951)	(0.0935)	(0.0927)	(0.0781)
R2					
Observations	356	356	356	356	356

Note: This table shows regression results of equation $r_t = \alpha + \beta.MP_{t-1} + \delta.r_{t-1} + u_t$ estimated using OLS (Panel A) and M-estimation (Panel B). Where r is the market capitalization weighted average daily stock returns of 5 size quintile, and MP is the term repo amount. Quintiles1 represent the portfolio of the smallest firm; Quintiles2, Quintiles3, and Quintiles4 represent the portfolio of second, third, and fourth smallest firms respectively; and Quintiles5 represent the portfolio of largest firms. Robust standard error is reported in the parenthesis. Signif. codes: 1% '***' 5% '**' 10% '*'

Table 4: The Effect of Repo Operation on Different Industries

Panel A: OLS

Variables	Auto	Bank	CPSE	Commodities	Energy	Financial Service	FMCG	India Cons	Infrastructure
Term Repo	0.000790*	0.00115**	0.00133**	0.00125***	0.00105**	0.00103**	0.000789**	0.000724**	0.00175***
	(0.000423)	(0.000461)	(0.000645)	(0.000480)	(0.000475)	(0.000437)	(0.000364)	(0.000287)	(0.000525)
Past returns	0.157**	0.142***	0.129*	0.124**	0.107*	0.120**	0.0104	0.111*	0.181***
	(0.0627)	(0.0505)	(0.0760)	(0.0607)	(0.0594)	(0.0504)	(0.0547)	(0.0571)	(0.0665)
Constant	-0.0799	-0.181	-0.241*	-0.209*	-0.172	-0.159	-0.184*	-0.106	-0.283**
	(0.116)	(0.122)	(0.138)	(0.118)	(0.120)	(0.117)	(0.0946)	(0.0846)	(0.125)
Observations	356	356	356	356	356	356	356	356	356
R-squared	0.032	0.040	0.035	0.038	0.026	0.031	0.012	0.025	0.067

Variables	IT	Media	Metal	Pharma	Private Bank	PSE	PSU Bank	Realty	Service Sector
Term Repo	-8.19e-05	0.000410	0.00163**	0.000193	0.00108**	0.00134**	0.00227***	0.000964	0.000672**
	(0.000428)	(0.000497)	(0.000736)	(0.000406)	(0.000427)	(0.000568)	(0.000858)	(0.000757)	(0.000341)
Past returns	0.119*	0.0779	0.0780	0.0955	0.150***	0.170**	0.0876	0.168***	0.145***
	(0.0617)	(0.0623)	(0.0573)	(0.0581)	(0.0500)	(0.0793)	(0.0649)	(0.0604)	(0.0531)
Constant	0.0634	-0.00303	-0.312*	-0.0367	-0.141	-0.228*	-0.493**	-0.0587	-0.0860
	(0.103)	(0.138)	(0.164)	(0.105)	(0.117)	(0.125)	(0.199)	(0.189)	(0.0930)
Observations	356	356	356	356	356	356	356	356	356
R-squared	0.014	0.007	0.027	0.011	0.042	0.049	0.035	0.037	0.031

Panel B: M-Estimation

Variables	Auto	Bank	CPSE	Commodities	Energy	Financial Service	FMCG	India Cons	Infrastructure
Term Repo	0.000494	0.000716*	0.000614	0.000763**	0.000681*	0.000631	0.000666**	0.000565**	0.00127***
	(0.000355)	(0.000403)	(0.000452)	(0.000379)	(0.000380)	(0.000395)	(0.000285)	(0.000246)	(0.000393)
Past Return	0.121**	0.126***	0.0908	0.0913*	0.0859	0.0975**	-0.0182	0.0929*	0.139***
	(0.0561)	(0.0459)	(0.0595)	(0.0534)	(0.0539)	(0.0445)	(0.0520)	(0.0537)	(0.0535)
Constant	-0.00743	-0.0908	-0.0916	-0.0597	-0.0539	-0.0775	-0.125	-0.0529	-0.175
	(0.106)	(0.111)	(0.110)	(0.0998)	(0.102)	(0.104)	(0.0828)	(0.0750)	(0.108)
R2	0.022	0.035	0.016	0.023	0.175	0.234	0.125	0.024	0.052
Observations	356	356	356	356	356	356	356	356	356

Variables	IT	Media	Metal	Pharma	Private Bank	PSE	PSU Bank	Realty	Service Sector
Term Repo	8.11e-05	0.000116	0.00113**	0.000108	0.000765**	0.000568	0.00158**	0.000368	0.000396
	(0.000363)	(0.000419)	(0.000521)	(0.000367)	(0.000376)	(0.000393)	(0.000673)	(0.000640)	(0.000315)
Past Return	0.0808	0.0353	0.0624	0.0515	0.126***	0.0967*	0.0799	0.103**	0.132***
	(0.0527)	(0.0492)	(0.0556)	(0.0551)	(0.0459)	(0.0545)	(0.0520)	(0.0498)	(0.0460)
Constant	0.0397	0.0927	-0.185	0.0432	-0.0722	-0.0568	-0.364**	0.102	-0.0213
	(0.0936)	(0.114)	(0.137)	(0.0928)	(0.109)	(0.101)	(0.176)	(0.159)	(0.0862)
R2	0.009	0.002	0.018	0.004	0.036	0.019	0.026	0.019	0.029
Observations	356	356	356	356	356	356	356	356	356

Note: This table shows regression results of 18 specifications of equation $r_t = \alpha + \beta.MP_{t-1} + \delta.r_{t-1} + u_t$ estimated using OLS (Panel A) and M-estimation (Panel B). Where r is the daily returns on 18 different industrial indices used in each specification, and MP is the term repo amount. Robust standard error is reported in the parenthesis. Signif. codes: 1% '***' 5% '**' 10% '*'.

Table 5: Relationship between term amount and stock returns using entire data

	OLS	M-Estimation
VARIABLES	Stock return	Stock return
Term Repo	0.000436**	0.000341*
	(0.000220)	(0.000200)
Past Return	0.100***	0.106***
	(0.0370)	(0.0356)
Constant	-0.00404	0.0118
	(0.0407)	(0.0376)
Observations	730	730
R-squared	0.015	0.020

Note: This table shows regression results of equation $r_t = \alpha + \beta.MP_{t-1} + \delta.r_{t-1} + u_t$,estimated using OLS (column 2) and M-estimation (column 3). Where r is the daily Nifty 50 returns, and MP is the monetary injection variable -term repo. Robust standard error is reported in the parenthesis. Signif. codes: 1% '***' 5% '**' 10% '*'.

Table 6: Relationship between term amount and stock returns after controlling exchange rate and call money rate.

	OLS	M-Estimation
VARIABLES	Stock Return	Stock Return
Term Repo	0.000771**	0.000492*
	(0.000329)	(0.000291)
Past Return	0.136***	0.134***
	(0.0499)	(0.0463)
Exchange Rate	-0.00673	-0.0149
	(0.0306)	(0.0311)
Call Rate	0.0239	0.0155
	(0.0999)	(0.103)
Constant	0.145	0.802
	(2.544)	(2.599)
Observations	356	356
R-squared	0.037	0.040

Note: This table shows regression results of equation $r_t = \alpha + \beta.MP_{t-1} + \delta.r_{t-1} + \partial.Exchange\ rate + \emptyset.Call\ rate + u_t$,estimated using OLS (column 2) and M-estimation (column 3). Where r is the daily Nifty 50 returns, and MP is the monetary injection variable -term repo. Robust standard error is reported in the parenthesis. Signif. codes: 1% '***' 5% '**' 10% '*'.

Appendix

Index	Market Capitalization	Total trade in value	Index	Market Capitalization	Total trade in value
Nifty 100	77%	61%	Nifty Infrastructure	7.70%	8%
Nifty 200	86%	77%	Nifty It	12.15%	7%
Nifty 50	65%	46%	Nifty Media		
Nifty 500	94%	87%	Nifty Metal	2.60%	4.50%
Nifty Auto	8.60%	9.50%	Nifty Midcap 150	11.40%	19%
Nifty Bank	15.60%	12.50%	Nifty Midcap 50	5%	12%
Nifty C P S E	3.50%	3.20%	Nifty Midsmallcap 400	17%	28%
Nifty Commodities	13.80%	13%	Nifty Mnc	6%	5.80%
Nifty Energy	8.60%	5.80%	Nifty Next 50	12%	13%
Nifty Financial Services	19.20%	13%	Nifty Pharma	6.10%	7%
Nifty Fmcg	8.60%	4.50%	Nifty Private Bank Index	13.90%	8.80%
Nifty Free Float Midcap 100 Index	14%	21%	Nifty Pse	6.60%	6%
Nifty Free Float Smallcap 100 Index	3%	7%	Nifty Psu Bank	2.30%	4.90%
Nifty Full Midcap 100	9%	18%	Nifty Realty	0.40%	1.80%
Nifty Full Smallcap 100	3%	7%	Nifty Services Sector	37.40%	25.40%
Nifty India Consumption	17.50%	14.10%	Nifty Smallcap 250	5.60%	9%
Nifty Smallcap 50	2%	6%			

US Economic Uncertainty, EU Business Cycles and the Global Financial Crisis[1]

Taufiq Choudhry*, Syed S. Hassan**, Sarosh Shabi**

**University of Southampton, School of Business, UK*
*** University of Swansea, School of Management, UK*

Abstract

This paper investigates the impact of the US economic uncertainty on the business cycles (changes in the industrial production) of twelve European Union (EU) countries before and during the global financial crisis. Empirical tests are conducted using the linear and nonlinear causality tests, impulse response function and variance decomposition. Results show very little evidence of causality from the US uncertainty to EU business cycles during the pre-crisis era. All tests provide ample significant evidence of the spill-over effect when the crisis period is included in the analysis. Further, robustness investigation tests the role of US uncertainty as a short term predictor of the change in the industrial production of the twelve EU countries. Both the linear and non-linear tests confirm the significance of US uncertainty as a short-term predictor of business cycles of the EU. These results imply that EU economic policy makers must take into consideration the spill-over effect of the US economic uncertainty and the nonlinearity of the relationship.

Keywords:
Business Cycles
Jurado index
Uncertainty
Nonlinear Causality

JEL Classification: E3, E32

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1. Introduction

Research interest in the economic uncertainty modelling and its role in predicting macroeconomic fluctuations have revived in the recent years (Caldara et al., 2016; Baker et al., 2015; Dzielinski, 2012; Jurado et al., 2015). During periods of financial crisis, economic uncertainty arises because of negative news, which lowers expectations of future economic activity. During the recent global financial crisis the US experienced an exceptional increase in macroeconomics and financial uncertainty (Cesa-Bianchi et al., 2014). Caldara et al., (2016) claim that the global financial crisis have cast doubt on the traditional sources of business cycles fluctuations. And, in response recent research have pointed to economic uncertainty as alternative driver of economic fluctuation (Bloom, 2009; Bloom et al., 2014; Christiano et al., 2014; Gilchrist et al., 2014).

Lately, uncertainty has been defined in two different ways. First, according to Jurado et al. (2015) uncertainty is defined as the conditional volatility of a stochastic process that is not forecastable from the perspective of economic agents. Alternatively, Bloom (2009) and Baker et al. (2015) defined uncertainty as a situation where future state of the economy is not known with certainty.[2] They also report that the economic uncertainty is countercyclical i.e. uncertainty on average is much lesser in the expansionary times as compared to the recessions. This paper studies the effect of the global financial crisis on the spill-over effect of the US economic uncertainty on the European Union (EU) business cycles.

An increase in economic uncertainty can produce an adverse effect on the economy by reducing employment, investment and output through various channels (Bloom, 2009; Baker et al., 2013; Colombo, 2013; Born and Pfeifer, 2014; Jurado et al., 2015). Some of the channels identified in the existing literature are i) real options effect (Bernanke, 1983); ii) precautionary savings effect (Leland, 1968), and iii) financial frictions effect (Gilchrist et al., 2014). On the demand side, higher uncertainty leads to reduction in investment demand for firms and delays in the new projects. This is because, the firms gather new information and are concerned due to irreversibility of costs involved. Households also respond to the uncertainty in a similar way, by reducing consumption of durable goods and waiting for certainty (Bernanke, 1983; Bloom, 2009; Bloom et al., 2014). On the supply side, in times of higher economic uncertainty, the employers curb the employment opportunities that reflect costly adjustment of personnel (Bloom, 2009; Bloom et al., 2014). The firms' ability to raise capital and finance their investment initiatives reduces significantly as the creditors tend to expect higher rate of returns. This leads to decline in the output growth rate. This negative correlation between macroeconomic uncertainty and the output is indicated by Claessens et al., (2012). Caldara et al., (2016) also indicate a robust negative effect of economic uncertainty on economic activity. Research involving the US economic or economic policy uncertainty has predominantly focussed on the impact it has on the various US macroeconomic and financial variables. Many studies have highlighted that any significant shock that affects a leading economy, such as the US, is expected to result in a spill-over effect on to the macroeconomic variables as well as on to the financial markets of other countries (Favero and Giavazzi, 2008; Ehrmann and Fratzscher, 2009). However, evidence from literature on the spill-over effect of the US economic uncertainty shocks onto the economies of other countries is very limited.[3] This paper

[2]This uncertainty can be triggered by various factors such as changes in the economic fundamentals and policies, heterogeneous future growth prospects and productivity movements, geopolitical scenarios and natural disasters, etc, (Baker et al., 2015).

[3]Colombo (2013) finds a negative influence of the US uncertainty on macroeconomic variables of the total Euro area. In her research, though, Colombo does not apply individual EU countries' data. The 2013 IMF study shows

addresses this gap in the literature by analysing the impact of the US economic uncertainty on the business cycles of the twelve European Union (EU) countries using the linear and nonlinear causality tests, impulse response function, and variance decomposition. We address the question: "Does the US economic uncertainty cause the economic activities of the major EU countries?" In this context, some important empirical questions arise: Is there is a causal relationship between US economic uncertainty and the business cycles of the EU countries which runs in either direction? Furthermore, is the nature of this relationship linear or are there nonlinearities that need to be taken into consideration? Even further, given the jump in the US uncertainty during the financial crisis period has this causality changed during the crisis period? This paper aims to provide empirical evidence on these unexplored avenues of research.

Thus, this paper intends to contribute to the existing literature in the following ways. First, we empirically investigate the causal relationship between US economic uncertainty and the business cycles (represented by the industrial production growth rate) of twelve major countries within the EU. Specifically, we employ monthly data from January 1991 to December 2015 from Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Spain and the UK. This potential causal relationship can be explained in terms of interdependence and integration between the US economy and the EU economy. According to Arora and Vamvakidis (2004) US is the growth engine of the world economy. They maintain that the most obvious channel in this regard is the trade linkage. As changes in the US import demand directly reflects the variations in the net exports and productivity in other countries[4]. Bagliano and Morana (2012) also find that trade is the key channel for real activity shocks. Similarly, U.S. foreign direct and portfolio investment play a large and growing role in world financial flows. These financial linkages also serve as source of transmitting shocks to other countries.

The volume of trade during 2012 between the US and the EU was around $1500 billion and accounted for one third of the global trade flows. According to the Transatlantic Economy (2014), the US and EU account for 56.7% of inward stock of FDI and 71% of outward stock of FDI. 15 million workers are employed in mutually on shored jobs on both sides of the Atlantic. US investment since 2000 in many European countries has up surged significantly, e.g. in comparison to China, 14 times more in the Netherlands, 10 times more in the UK and 6 times more in the Ireland. Give the direct link between the two economies it is of empirical interest to study the relationship between US economic uncertainty and EU business cycles. A significant spill-over from the US to EU will have major implications for the EU policy makers and economy.

Second, the vast majority of studies employ linear Granger causality tests (Granger, 1969) when assessing the relationship between various macroeconomics variables despite the fact that there is clear evidence which points out to the existence of nonlinearities (Shiller, 1993, 2005; Hiemstra and Jones, 1994; Shin et al., 2013). Thus, we also apply non-linear tests to investigate the causality between the variables. To the best our knowledge, no other study has applied nonlinear bivariate tests to assess the relationship between US economic uncertainty and EU business cycles.

that the policy uncertainty shocks in the US and the Euro area affected growth in other world regions. Klößner and Sekkel (2014) report that the uncertainty around the US and the UK economic policies has a greater impact on six other developed countries.

[4] Grossman and Helpman (1989, 1990, 1991), Rivera-Batiz and Romer (1991a, 1991b), and Romer (1990) for a discussion of spillover effects from trade.

Third, we further study the potential effect of the global financial crisis on this causality. As stated earlier, there was a substantial increase in the US economic uncertainty during the global financial crisis. It is of empirical interest to see if the sudden jump in the US economic uncertainty imposed a substantial change in the spill-over from the US uncertainty to the EU business cycles. A substantial change in the spill-over will have significant policy and economic implications during the crisis era. Again, to the best of our knowledge, no other study empirically investigates the impact of the global financial crisis on the international spill over effect of the US economic uncertainty.

In this paper business cycles are measured as the monthly change in the industrial production of the twelve EU countries.[5]US economic uncertainty measures are adopted from Jurado et al. (2015). Following Jurado et al. (2015), uncertainty here is defined as *the conditional volatility of a disturbance that is unpredictable from the perspective of economic agents*.

Our results provide ample evidence of linear and nonlinear causality from the US uncertainty to the EU countries' business cycles when the crisis period is included in the analysis. During the pre-crisis period very little evidence of causality is found. Impulse response shows that innovations in the uncertainty trigger a significant change in the business cycles. Variance decomposition results further show that the US uncertainty shock explains a substantial share of variance of the forecast errors of the EU countries' business cycles. Finally, we employ both linear and nonlinear forecasting regressions and show that US economic uncertainty is an important short-term predictor of future economic activity within the EU countries. Overall, results indicate the need for EU policy makers to take into consideration both the US economic uncertainty spill-over effect and nonlinearities when assessing the EU economic outlook. This is especially true during, and after the global financial crisis.
The remainder of the paper is organised as follows. Section 2 describes the data and the methodological approach applied. Sections 3 and 4 provide a discussion of the empirical results. Finally, section 5 concludes.

2. Data Description and Methodology

2.1. The Data

As noted earlier we apply monthly data ranging from January 1991 to December 2015 from Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Spain and the UK. These countries represent the largest twelve economies from the EU.[6] Data regarding indices of industrial production for respective countries are obtained from Datastream. Figure 1 shows the growth rates in the industrial production indices of the major EU countries. The dip in the industrial production during the crisis period can be seen clearly in many cases, for example Finland, France, Italy, Spain and the UK. Uncertainty index data has been downloaded from Sydney Ludvigson's website[7]. Figure 2 presents the Jurado index of uncertainty (in levels) for the sample period. The sharp increase in uncertainty during the 2007-2008 global financial crisis is clearly visible. Figure 3 presents the changes in the Jurado index of uncertainty for the sample period. As noted earlier during the recent global financial crisis the US experienced an exceptional increase in macroeconomics and financial uncertainty (Cesa-Bianchi et al., 2014). Therefore, it is important to investigate the impact of the financial

[5]Bekaert et al. (2013) and Colombo (2013) also apply the changes in industrial production as the business cycles.
[6] Size of economies was based on real GDP in 2014 and 2015.
[7]Uncertainty index data have been downloaded from http://www.sydneyludvigson.com/data-and-appendices/

crisis in our study and provide some new evidence. Empirical tests are first conducted for the pre-crisis period (January 1991 to June 2007) and then tests are conducted using the total sample period (January 1991 to December 2015) which includes the global financial crisis era.[8] In this manner, the effect of the crisis on the uncertainty spill-over may be investigated. We provide a through comparison of the results from the two sample periods.
As per standard practices, augmented DF test proposed by Dickey and Fuller (1979) and Kwiatkowski et al. (1992) KPSS tests show that the first difference series of the underlying variables are stationary during both periods, which are then employed for linear and nonlinear causality tests.[9] These results are not provided to save space but are available on request.

[Insert Figures 1 and 2 around here]

2.2. Economic Uncertainty

Although Economic Policy Uncertainty (EPU) by Baker et al. (2015) has recently gained popularity, its main drawback lies in its inability to reflect 'true uncertainty' because it fails to provide a rationale for the decision-making process by drawing extensively from economy-wide data. Jurado's index rather focuses on ameliorating these limitations by econometrically extracting the non-forecastable component of uncertainty and providing a measure which can be used directly in macroeconomic analysis, without suffering too much from possible endogeneity issues. Jurado's index is free from the structure of specific theoretical models, and from dependencies on any single observable economic indicator. The application of the nonlinear causality tests and the Jurado index to represent the economic uncertainty makes this paper unique in the literature.

Jurado et al. (2015) argue that the conventional econometric measures are not the true measure of uncertainty. In fact, Jurado et al. (2015) argue that 'the conditions under which common proxies are likely to be tightly linked to the typical theoretical notion of uncertainty may be quite special'.[10] In view of these limitations, Jurado's index exploit a data-rich environment to provide direct econometric estimates of time-varying US macroeconomic uncertainty.

In particular, Jurado's index define a $h-$period ahead of uncertainty in variable $y_{jt} \in Y_t = (y_{1t},,y_{N_y t})'$, and denote $\mathrm{U}_{jt}^{y}(h)$ to be the conditional volatility of the purely unforecastable component of the future value of the series;

$$U_{jt}^{y}(h) = \sqrt{E[\left(y_{jt+h} - E[y_{jt+h} \mid I_t]\right)^2 \mid I_t]}, \tag{1}$$

where $E(.|I_t)$ is taken with respect to information I_t available to agents at time t. An (objective) measure or index of macroeconomic uncertainty is then described as an aggregation of individual uncertainty at each date using aggregation weights w_j:

$$U_t^{y}(h) \equiv plim_{N_y \to \infty} \sum_{j=1}^{N_y} w_j U_{jt}^{y}(h). \tag{2}$$

[8] The start of the collapse of the US sub-prime mortgage market during July/August 2007 is applied as the start of the crisis period in this paper.
[9] We do not provide the description of the unit root tests as they are available at many sources.
[10] For example, stock market volatility can change over time even if there is no change in uncertainty about economic fundamentals. Similarly, cross-sectional dispersion in individual stock returns can fluctuate without any change in uncertainty if there is heterogeneity in the loadings on common risk factors.

The distinguishing feature of this measure of uncertainty from other aggregate measures is its ability to remove forecastable component[11] $E[y_{jt+h} | I_t]$ before computing conditional volatility. Failure to do so often leads to estimates that 'erroneously categorize forecastable variations as 'uncertain''. It is argued that Jurado's index measure of uncertainty provides superior econometric estimates of uncertainty that are as free as possible from the structure of specific theoretical models, and from dependency on any single (or small number) of observable economic indicators.

2.3. Linear Causality

Vector autoregression (VAR) specification is used in this paper to test the Granger causality (Granger, 1969) between changes in the business cycles (i.e. industrial production growth rate) and changes in the economic uncertainty index proposed by Jurado et al. (2015). This is aimed at assessing linear causal relationship between the variables in terms of time precedence. The VAR specification applied in this research are in the following form:

$$BC_t = \alpha + \sum_{i=1}^{n} \beta_i BC_{t-i} + \sum_{i=1}^{n} \gamma_i EcoU_{US,t-i} + \varepsilon_{1t} \quad (3)$$

$$EcoU_{us,t} = \theta + \sum_{i=1}^{n} \omega_i BC_{t-i} + \sum_{i=1}^{n} \varphi_i EcoU_{us,t-i} + \varepsilon_{2t} \quad (4)$$

In equations (3) and (4) BC and $EcoU_{us}$ denote the changes in the business cycle of selected European countries and the US economic uncertainty index, respectively. Equations 3 and 4 test bivariate causality between BC and $EcoU_{us}$. There is evidence of causality from US economic uncertainty ($EcoU_{us}$) to business cycles (BC) of the selected European countrieswhen γ_i are significant. Here presence of linear dependency would imply a possible spill over effect between the US economic uncertainty and the business cycles of the European countries. Dependencies can be unidirectional or bidirectional between variables which would imply feedback effect. In equation 4 significant ω_i indicates causality from the EU business cycles (BC) to the US uncertainty ($EcoU_{us}$). We only present results for equation 3. Equation 4 is estimated for each country and a summary of the result is provided in footnotes.

2.3. Nonlinear Causality

Nonlinearities in the macroeconomic time series have been reported by a large number of studies (Hiemstra and Jones, 1994; Shin et al., 2013, Shiller, 1993, 2005). Nonlinear causality was highlighted in the economics/finance literature by Hiemstra and Jones (1994) and subsequent research papers have provided further evidence in a nonlinear setting with respect to various economic/financial variables (Silvapulle and Choi, 1999; Chen and Wuh-Lin, 2004; Diks and Panchenko, 2006; Bekiros and Diks, 2008a, 2008b; Shin et al., 2013; and Bekiros, 2014). Specifically, there are various factors such as transaction costs or information frictions which could give rise to nonlinearities and lead to non-convergence towards the long-run equilibrium. For example, Anderson (1997) argues that transaction costs are often ignored in studies of asset markets although in practice they could be substantial and prevent the adjustment of disequilibrium errors. Anderson (1997) further shows that estimated models which consider these nonlinearities outperform their linear counterparts. Other sources that may be responsible for nonlinearities include 'diversity in agents' beliefs' (Brock and LeBaron, 1996), 'heterogeneity in investors' objectives arising from varying investment horizons and risk profiles' (Peters, 1994), and 'herd behaviour' (Lux, 1995). Given the above, it is clear that the need for nonlinear and asymmetric adjustments is imperative. Hence, this research further aims at identifying the presence of nonlinear causality (spill-over effect) between the variables.

[11] From a large number of macroeconomic and financial variables.

Nonlinear causality is tested by means of the model proposed by Hiemstra and Jones (1994). This model is based on the correlation integrals, defined as the probability of the dynamic or lagged co-movement between the two stationary time series.

First, consider two strictly stationary and weakly dependent time series $\{X_t\}$ and $\{Y_t\}$, t = 1,2,….Denote the m-length lead vector of X_t by X_t^m and the Lx-length and Ly-length lag vectors of $X_t$andY_t, respectively, by X_{t-Lx}^{Lx} and Y_{t-Ly}^{Ly}. That is,

$$\begin{aligned} X_t^m &\equiv (X_t, X_{t+1}, ..., X_{t+m-1}), \quad m = 1, 2..., \ t = 1, 2, ..., \\ X_{t-Lx}^{Lx} &\equiv (X_{t-Lx}, X_{t-Lx+1}, ..., X_{t-1}), \\ &\qquad Lx = 1, 2, ..., \ t = Lx+1, Lx+2, ..., \\ Y_{t-Ly}^{Ly} &\equiv (Y_{t-Ly}, Y_{t-Ly+1}, ..., Y_{t-1}), \\ &\qquad Ly = 1, 2, ..., \ t = Ly+1, Ly+2, ..., \end{aligned} \tag{5}$$

As stated in Hiemstra and Jones (1994), given values of m, Lx and $Ly \geq 1$and for$e \geq 0$, Y does not strictly Granger cause X if:

$$\begin{aligned} &Pr\left(\left\|X_t^m - X_s^m\right\| < e \middle| \left\|X_{t-Lx}^{Lx} - X_{s-Lx}^{Lx}\right\| < e, \left\|Y_{t-Ly}^{Ly} - Y_{s-Ly}^{Ly}\right\| < e\right) \\ &= Pr\left(\left\|X_t^m - X_s^m\right\| < e \middle| \left\|X_{t-Lx}^{Lx} - X_{s-Lx}^{Lx}\right\| < e\right) \end{aligned} \tag{6}$$

In equation (6), Pr(·) denotes probability and ||·|| denotes the maximum norm. The left hand side of equation (6) is the conditional probability that the distance between two arbitrary m-length lead vectors of $\{X_t\}$ is less than e, given that the distance between the corresponding Lx-length lag vectors of $\{X_t\}$and Ly-length lag vectors of $\{Y_t\}$ is also less than e. The right hand side of equation (6) is the conditional probability that any two arbitrary m-length lead vectors of $\{X_t\}$are within a distance e of each other, given that their corresponding Lx-length lag vectors are also within a distance e of each other. For all countries in our paper, X_t represent the business cycle represented by the industrial production growth rate for selected EU countries and Y_t is the US economic uncertainty index proposed by Jurado et al. (2015) represented by the industrial production growth rate for selected EU countries. Therefore, if equation (6) is true, this implies that the US economic uncertainty does not affect the respective business cycles of the EU countries i.e. no spillover effect.

To implement a test based on equation (6), Hiemstra and Jones (1994) express the conditional probabilities in terms of the corresponding ratios of joint probabilities:

$$\frac{C1(m+Lx, Ly, e)}{C2(Lx, Ly, e)} = \frac{C3(m+Lx, e)}{C4(Lx, e)} \tag{7}$$

where$C1$, $C2$, $C3$, $C4$ are the joint probabilities.[12] For given values of m, Lx, and $Ly \geq 1$and $e > 0$ under the assumption that $\{X_t\}$ and $\{Y_t\}$ are strictly stationary and weakly dependent, if $\{Y_t\}$ does not strictly Granger cause $\{X_t\}$ then,

$$\sqrt{n}\left(\frac{C1(m+Lx, Ly, e, n)}{C2(Lx, Ly, e, n)} - \frac{C3(m+Lx, e, n)}{C4(Lx, e, n)}\right) \rightarrow N(0, \sigma^2(m, Lx, Ly, e)) \tag{8}$$

[12]For more details on these joint probabilities and on their corresponding correlation-integral estimators, see Hiemstra and Jones (1994).

The appendix of Hiemstra and Jones (1994) provides further details regarding the definition and the estimator of the variance $\sigma^2(m, Lx, Ly, e)$. To ensure robustness, this model is capable of testing the bidirectional causality to avoid any bias caused by the feedback effect.

[Insert Table 1 around here]

3. Results

Table 1 presents linear causality results for both the sample periods. During the total sample including the crisis period (1991-2015) there is a significant evidence of linear spill-over effect of the US economic uncertainty to the business cycles of all twelve EU countries. . Using the pre-crisis sample (1991-2007) there is limited evidence of causality. Only in the cases of Austria and Germany business cycles there is significant causality from the US uncertainty. For both sample periods, respective lag orders for Granger causality have been selected based on Aakiake and Hannan-Quin information criteria varying with maximum number of lags varying between 4 to 8 for different countries.

[Insert Table 2 around here]

Table 2 presents the nonlinear causality test results. These results are similar to the linear results. Using the total period there is significant evidence of nonlinear causality from the US uncertainty to the business cycles for nine out of the twelve EU countries. Only in the cases of France, Germany, and Greece do results fail to indicate any causality. The weak French and German results could be due to the strained ties between the US and these countries lately caused by the declining economies and resource crunch in these countries (Ahearn, 2008; Ahearn and Belkin, 2010). Once again during the pre-crisis period results only provide evidence of causality for Austria and Germany. This result is similar to the linear causality test. As expected there is clear evidence of increased causality from the US uncertainty to the EU business cycles when the crisis period is included in the analysis. This evidence is provided by both the linear and nonlinear tests.[13] The increase in both the causality when applying the crisis period is due to the increased economic uncertainty during the crisis period and increased economic linkage between the US and the EU.

[Insert Figures 4 and 5 around here]

Figures 4 and 5 presents the impulse response functions to a one-standard deviation shock to the uncertainty index for the pre-crisis and total samples, respectively. Impulse responses trace out the responsiveness of the dependent variables (business cycles) in the VAR to shocks to each of the variables (US uncertainty). The responses of business cycles of all countries are significant during both periods. During the total era including the crisis period (table 5) the responses of the Danish, French, Irish, Italian, Spanish and the UK business cycles suggest an immediate decline in production; for example, the lowest value for the French business cycle is reached after five months at more than -8%. Then these slowly return to their pre-shock

[13] As note earlier, linear and nonlinear tests are also conducted to study the unidirectional causality the other way around that is the business cycles of the EU countries causing economic uncertainty in the US. These tests have been conducted for both pre and including financial crisis periods. Linear causality results show that the US economic uncertainty is not affected by most of the countries' business cycles except Germany and Netherlands where relatively weaker impact is observed at 10 percent significance level. In case of nonlinear tests, business cycles of the EU countries do not cause economic uncertainty in the US for both sample periods. These results are available on request from the authors.

level after a period of more than one year. The Italian and the UK results are also very similar to the French result, while the Spanish business cycle takes almost twenty months to reach the pre-shock level. The lowest value for the Irish business cycle is less than -4% after five months, but the pre-shock level is reached relatively quickly after eight months. The Danish result is similar to the Irish result but with much smaller change. For the remaining countries the initial reaction is a jump in the business cycles and then a decline afterwards; for example, in Finland, after a 2% jump within two months, there is a decline to -3% after four months. The climb to the pre-shock level is reached after twelve months. The Greek result is similar to the Finnish result, while results from Austria, Belgium, Germany and Netherlands are very similar. After an initial jump, the lowest level is reached after four months but within seven months recovery is observed and the climb to the pre-shock level takes more than eighteen months. A comparison with the pre-crisis results (figure 4) shows a less responsiveness of the business cycles to the one-standard deviation to the US uncertainty. The average time for the business cycles to return to the pre-shock level is faster during the pre-crisis period. This is especially true in the cases of Belgium, Germany, Greece, Ireland, Italy, Netherlands, Spain and the UK. Impulse response results confirm and back the results of the causality tests that adding the crisis years to the analysis clearly shows the increase in the impact and importance of the US economic uncertainty on the business cycles of the EU countries. [14]

4. Robustness Check

This section builds upon the causality results reported above and aims to empirically test the role of the US economic uncertainty as a short-term predictor of the changes in the business cycles of the twelve European countries. This section compliments and strengthens the evidence of Granger linear and nonlinear causality as well as a significant robustness check. These tests are only conducted for the total period. For this purpose, initially focus on the linear forecasting regression:

$$y_{t+h} = a + \beta x_t + \sum_{i=0}^{\gamma} \gamma_i y_{t-i} + \epsilon_{t+h} \qquad (9)$$

Where y_{t+h} refers to the changes in the business cycles (i.e. the industrial production growth), $y_{t+h} = \frac{1200}{h+1} ln\left(\frac{Y_{t+h}}{Y_t}\right)$, h>0 is the forecast horizon, and x represents the changes in the US economic uncertainty. The null hypothesis of $\beta = 0$ is tested here to observe the predictability of changes in the business cycle using the US economic uncertainty. The corresponding results for h=1 are presented in table 3.

[Insert Table 3 around here]

We report that the US economic uncertainty is a significant short-term predictor of the business cycle of most of the EU countries in sample, with the exception of Denmark, Greece and Ireland. These forecasting results reaffirm and strengthen the evidence of spill over effect of the US economic uncertainty on the major EU countries.

[14] Further investigation is conducted by means of the variance decomposition of the forecast errors. The variance decomposition highlights the contribution of the US uncertainty in explaining the short-run fluctuations in the EU business cycles Using the total period, at six months, the US uncertainty shocks explains more than 5% of the variation in the business cycles of Austria, France, Italy, Spain and the UK. At twelve months and later, and only in the cases of Denmark, Greece, and Ireland, the US uncertainty shock explains less than 5% of the variation. US economic uncertainty in the pre-crisis period explains relative lesser variation in the business cycles of the EU countries as compared to the full sample period. At six months, less than 1% variation in the business cycle of all the selected EU countries may be attributed to the US uncertainty shocks. These results are available on request from the authors.

We further extend the forecasting approach presented above and report evidence based on nonlinear forecasting models, which allows us to further enhance our understanding of the underlying relationship between the US economic uncertainty and EU countries' business cycles. In this context, smooth-transition threshold (STR) models are employed for nonlinear forecasting (see, *inter alia*, Chan and Tong, 1986; Teräsvirta and Anderson, 1992; Granger and Teräsvirta, 1993; Teräsvirta, 1994; McMillan, 2003). In contrast to simple threshold models which limit abrupt change in parameter values, STR models allow for smooth variations between different regimes. The threshold model is presented as follows:

$$y_{t+h} = \alpha + \beta x_t + \sum_{i=0}^{p} \gamma_i y_{t-i} + \left(\varphi_0 + \varphi_1 x_t + \sum_{i=0}^{p} \theta_i y_{t-i} \right) F(y_{t-d}) + \varepsilon_{t+h} \quad (10)$$

where all variables are defined as in equation (9) while $F(y_{t-d})$ is the transition function and y_{t-d} is the transition variable. Following the literature, the first form of transition function we consider is the logistic function which is shown in equation (11) (see also, Chang and Tong, 1986; Teräsvirta and Anderson, 1992; Teräsvirta, 1994; McMillan, 2003). In this case, the full model is referred to as a logistic STR (LSTR) model.

$$F(y_{t-d}) = (1+\exp(-\lambda(y_{t-d}-c)))^{-1},\ \lambda > 0 \quad (11)$$

where*d* is the delay parameter, λ is the smoothing parameter, and *c* is the transition parameter. This function is monotonically increasing in y_{t-d}. Note that when $\lambda \to +\infty$, $F(y_{t-d})$ becomes a Heaviside function: $F(y_{t-d}) = 0$ when $y_{t-d} \le c$ and $F(y_{t-d}) = 1$ when $y_{t-d} > c$.

However, monotonic transition might not always be successful in empirical applications. Therefore, the second form of transition function we consider is the exponential function with the relevant model in this case being referred to as an exponential STR (ESTR) model (see, Teräsvirta and Anderson, 1992; Teräsvirta, 1994; McMillan, 2003):

$$F(y_{t-d}) = 1-\exp(-\lambda(y_{t-d}-c)^2),\ \lambda > 0 \quad (12)$$

In this case, the transition function is symmetric around *c*. The ESTR model implies that contraction and expansion have similar dynamic structures while the dynamics of the middle ground differ (Teräsvirta and Anderson, 1992). As there might be some issues in the STR models related to the estimation of the smoothing parameter λ which can be problematic, we follow the literature and scale λ by the standard deviation of the transition variable in the LSTR model and by the variance of the transition variable in the ESTR model (see, Teräsvirta and Anderson, 1992; Teräsvirta, 1994). Hence, we have the following versions of transition functions, respectively:

$$F(y_{t-d}) = (1+\exp(-\lambda(y_{t-d}-c)/\sigma(y_{t-d})))^{-1},\ \lambda > 0 \quad (13)$$

$$F(y_{t-d}) = 1-\exp(-\lambda(y_{t-d}-c)^2/\sigma^2(y_{t-d})),\ \lambda > 0 \quad (14)$$

Table 4 presents the results of the LSTR and the ESTR models. In the LSTR model results, the estimated transition parameter *c*, which marks the half-way point between the two regimes, is significantly different from zero in most of the EU countries, except for Denmark, France, Greece and Ireland. Moreover, we observe that in most of the estimated betas are negative and significant (at 1% and 5% levels, depending on the case) suggesting that high US economic uncertainty forecasts a lower industrial production growth rate in the following month. Further the estimates of φ_1,in the upper regime significance is found in six out of ten EU countries revealing the importance of US economic uncertainty as an explanatory variable of industrial production growth rate in both regimes for these countries. Insignificant results are found for Denmark, France, Greece and Ireland. Finally, the estimated parameter λ indicates that the

fastest speed of transition occurs in Finland, while the slowest are observed in Austria, Germany, Netherlands and the UK. Once again the speed coefficient is insignificant for the same four countries.

Results for the estimated ESTR models are very similar to the LSTR results. This reaffirms the significance of the US economic uncertainty as a short-term predictor of future changes in the business cycles of the EU countries in a nonlinear context and compliments the previously reported results under the linear framework. These results reinforce the idea that the US is often seen as "the engine" of the world economy (Dees and Saint-Guilhem, 2011), any sign of slowdown or rise in the uncertainty raises concerns about adverse spill over effects to other economies.

5. Conclusion

An increase in economic uncertainty can affect an economy by reducing employment, investment and output. During periods of financial crisis, uncertainty arises because of negative news, which lowers expectations of future economic activity. Any significant shock that affects a leading economy, such as the US can potentially have a spill-over effect on the macroeconomics variables and financial markets of other countries. This potential causal relationship can be explained in terms of interdependence and integration between the US economy and the EU economy. However, empirical evidence on this spill-over effect of the US economic uncertainty shocks on the economies of the other countries is very limited and the evidence on the effect of the financial crisis on this spill-over is non-existent. This paper attempts to fill these gaps in the literature. This paper studies the impact of the US economic uncertainty during pre-crisis and crisis periods on the business cycles of twelve major EU countries using the linear and nonlinear causality, impulse response function and variance decomposition. We apply monthly data ranging from January 1991 to December 2015 from Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Spain and the UK. Tests are first conducted for the pre-crisis period (January 1991 to June 2007) and then for the total sample which includes the crisis period. In this manner, the impact of the financial crisis on the spill-over effect of the US uncertainty on EU business cycles may be investigated. Business cycles are measured as the monthly changes in the industrial production and US economic uncertainty are adopted from Jurado et al. (2015). Uncertainty here is defined as the conditional volatility of a disturbance that is unpredictable from the perspective of economic agents. Jurado's index exploit a data-rich environment to provide direct econometric estimates of time-varying US macroeconomic uncertainty.

Results provide ample evidence of linear and nonlinear causality from the US economic uncertainty to the EU business cycles when the crisis period is included in the study. . There is very little evidence of causality during the pre-crisis period. Only in the cases of Austria and Germany there is evidence of causality. This result clearly indicates the increase in the importance of the US economic uncertainty during the crisis period. This result has implications for EU policy makers and businesses. Impulse response shows that innovations in the uncertainty trigger significant changes in the business cycles. These significant changes are more prominent when the crisis period is included in the sample. Variance decomposition results show that the US uncertainty shocks explains a decent share of variance of the forecast errors of the EU countries' business cycles. For robustness check, we test the role of the US economic uncertainty as a short term predictor of the changes in the business cycles. For this purpose, we apply both the linear and non-linear forecasting methods. Both tests indicate that US uncertainty is a significant short term predictor of the business cycles of most of the EU countries.

Overall, the findings in this paper suggest that policies associated with EU countries economic activity should take into consideration the spill-over effect of the US economic uncertainty and the nonlinear features of the relationship between the business cycles and the US uncertainty. This is particularly important in periods of heightened economic uncertainty such as the recent global financial crisis.

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Figure 1: Industrial Production Growth Rates

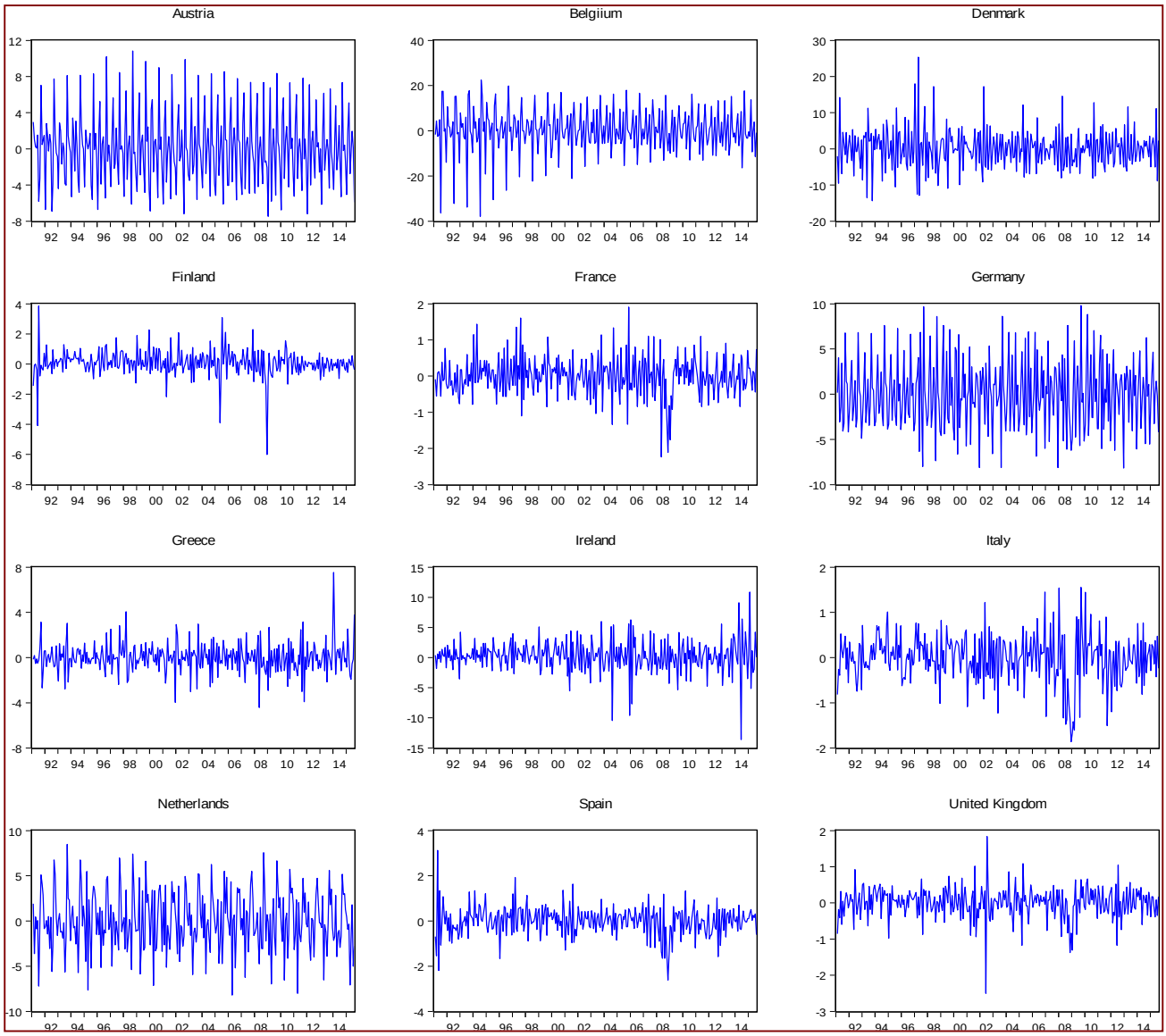

Figure 2: US Economic Uncertainty in levels

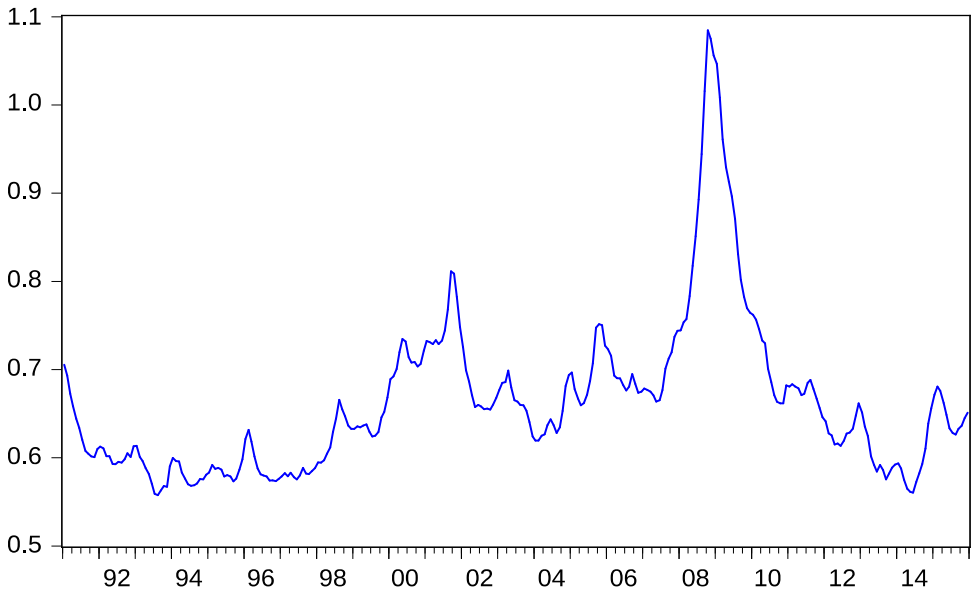

Figure 3: First Difference of US Economic Uncertainty

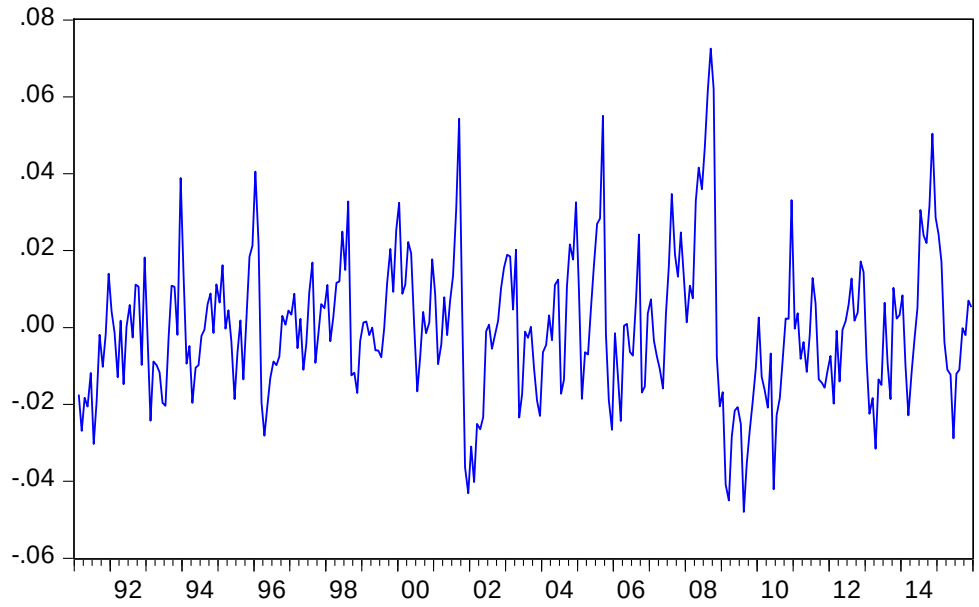

Figure 4 :Impulse Response Functions – Before Financial Crisis

(Response of BC to Cholesky One S.D. Innovations in US Eco Uncertainty)

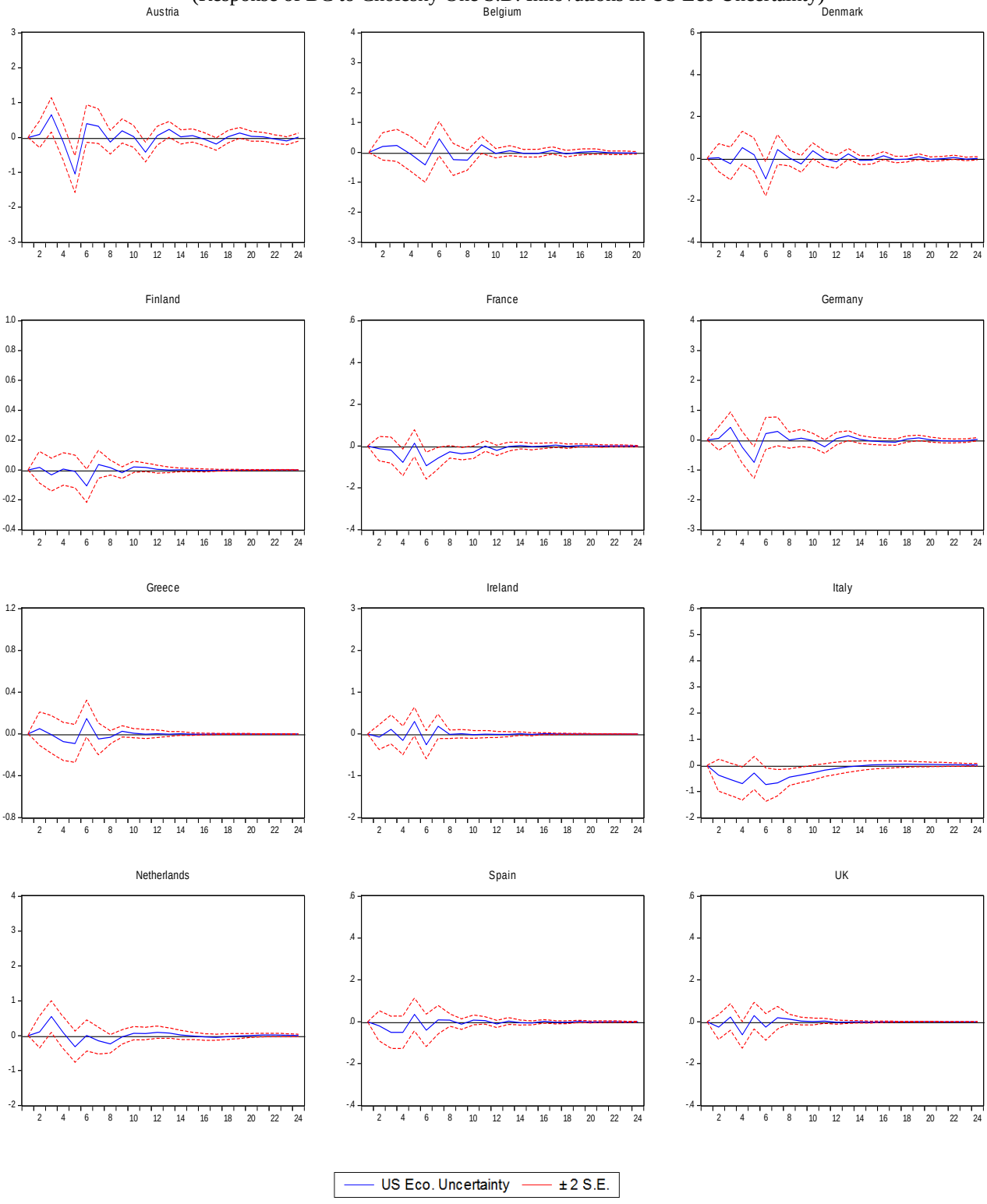

Figure 5: Impulse Response Functions – Total Period

(Response of BC to Cholesky One S.D. Innovations in US Eco Uncertainty)

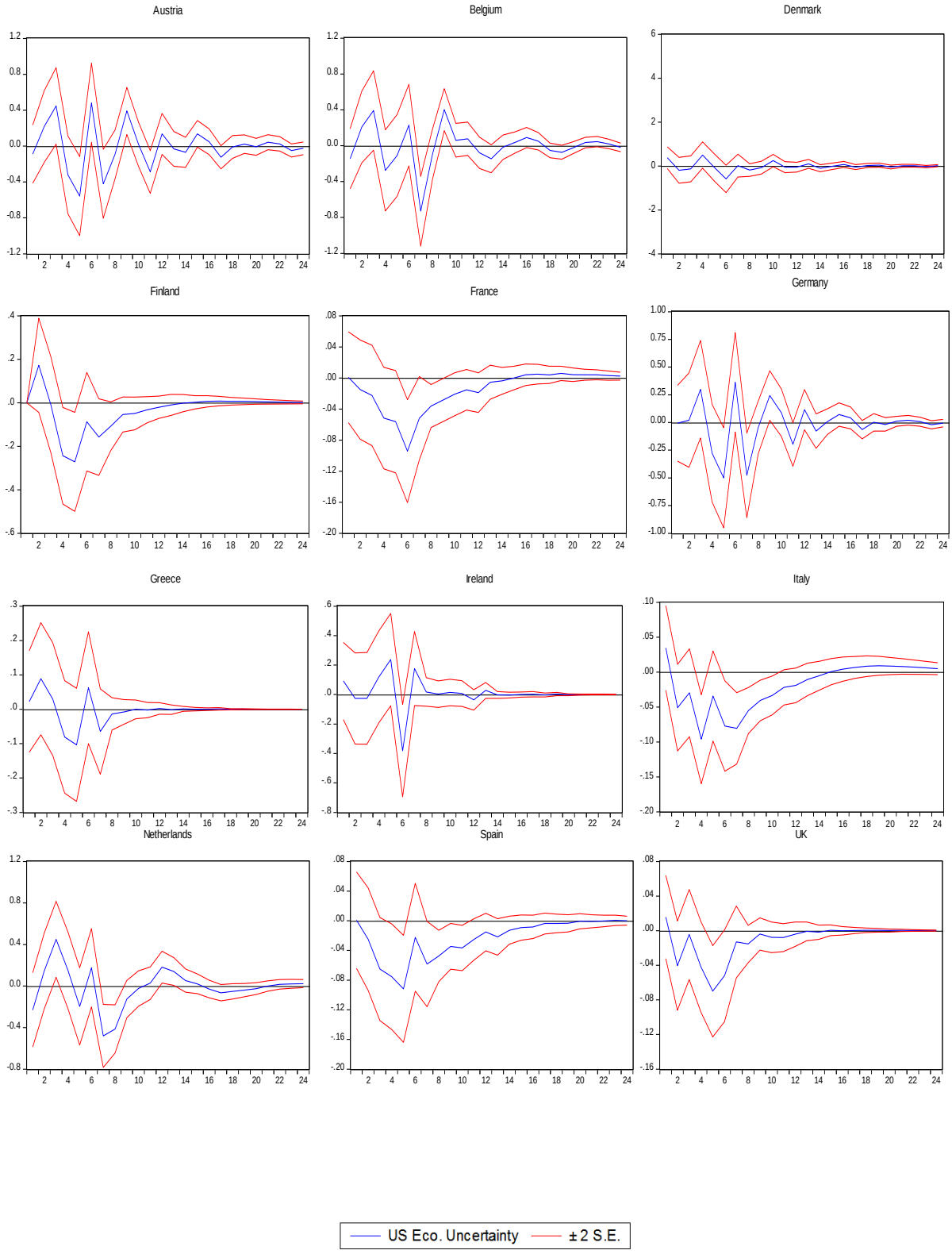

Table 1: Linear Causality Results

Table 1 presents the results of the bivariate linear causality tests, described in Section 3.1, between the US economic uncertainty index proposed by Jurado et al. (2015) and the business cycle (represented by the industrial production growth rate) for selected European countries. Results are shown with respect to the pre-crisis and full sample periods to assess the impact of the recent financial crisis. Asterisks ***, ** and * denote significance at the 1%, 5% and 10% conventional levels respectively. Standard diagnostic tests such as Ramsey's Specification Test (RESET), White's Heteroskedasticity Test; LB: Ljung-Box (1978) test for autocorrelation up to 12 lags; and Jarque-Bera normality of residuals test have been applied.

Countries	US Eco. Uncertainty → BC	
	Before Financial Crisis	After Financial Crisis
Austria	25.95***	29.24***
Belgium	10.2	27.46***
Denmark	7.69	11.51*
Finland	4.66	22.54**
France	6.76	34.92***
Germany	14.76**	34.95***
Greece	4.56	20.13**
Ireland	4.46	22.71**
Italy	3.51	30.34***
Netherlands	8.98	18.11***
Spain	8.47	28.66***
United Kingdom	6.09	27.12***

Table 2: Nonlinear Causality Results from Uncertainty to Business Cycles

This table presents the results of the Hiemstra and Jones (1994) test statistic (HJ) described in Section 3.2 which tests for nonlinear causality between the US economic uncertainty index proposed by Jurado et al. (2015) and the business cycle (represented by the industrial production growth rate) for selected European countries. Results are shown with respect to the pre-crisis and full sample periods to assess the impact of the recent financial crisis. Asterisks ***, ** and * denote significance at the 1%, 5% and 10% conventional levels respectively

Countries	US Eco. Uncertainty → BC	
	Before Financial Crisis	After Financial Crisis
Austria	1.85**	1.50*
Belgium	0.89	5.80***
Denmark	0.55	2.01**
Finland	0.65	1.930**
France	0.75	0.27
Germany	2.99***	0.024
Greece	1.01	1.37
Ireland	1.07	1.73**
Italy	0.91	1.81**
The Netherlands	0.73	2.17**
Spain	0.97	2.49***
United Kingdom	1.05	2.34***

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Table 3: Linear Forecasting Results

This table presents the results from the linear forecasting regressions described in Section 5 (equation (9)) during the full sample period (i.e. Jan-1991 to Dec-2015) and when the forecast horizon is 1. For each country, the dependent variable is the change in its economic activity (i.e. the log-change in the total industrial production index, which is our business cycle indicator, BC). The main predictive variable is the change in the US economic uncertainty index proposed by Jurado et al. (2015). For each regression, the estimated coefficients are given in the first row while the corresponding *t*-statistics are reported in parentheses below. Asterisks *** and ** denote significance at the 1%, and 5% levels, respectively.

Country	JEU	Adj. R^2
Austria	6.49**	0.52
	(2.23)	
Belgium	5.94**	0.48
	(2.03)	
Denmark	1.50	0.42
	(0.79)	
Finland	-0.43*	0.056
	(1.92)	
France	-1.019**	0.164
	(1.97)	
Germany	-1.88**	0.41
	(2.41)	
Greece	0.479	0.12
	(0.37)	
Ireland	1.89	0.26
	(0.82)	
Italy	-1.57**	0.14
	(2.95)	
Netherlands	4.15**	0.27
	(2.44)	
Spain	-1.96***	0.19
	(3.46)	
United Kingdom	-1.25***	0.13
	(3.03)	

Table 4: Nonlinear Forecasting Results

This table presents the results of the smooth-transition threshold (STR) models which were described in Section 5. LSTR refers to the case where the transition function is the logistic function while ESTR employs an exponential function instead. Results are reported for all countries under consideration during the full sample period (i.e. Jan-1991 to Dec-2015). Asterisks ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Panel – I: Exponential Smooth Transition Threshold Model (ESTR)

Country	α	ß	φ_0	φ_1	λ	c	Adj. R^2
Austria	-52.04***	10.49***	56.99***	-5.33***	0.055**	-17.29***	0.69
Belgium	19.80**	-1.14**	-79.13***	17.64***	1.18	19.49***	0.64
Denmark	38.60	-41.15	-27.57	41.56	0.0016	-15.93	0.38
Finland	13.31***	-19.69***	-11.49***	18.83***	9.71***	-19.71***	0.27
France	-4.63	-3.51*	5.09	2.45	0.089	-9.28***	0.25
Germany	-51.21**	-8.6**	57.34**	8.26*	0.046**	-49.28	0.54
Greece	-0.04	-0.99	11.45	0.05	0.006	44.63	0.14
Ireland	11.93	-5.09	-3.75	11.73	4.70	-6.74	0.22
Italy	-40.84	-55.72***	40.72***	55.54***	0.10***	-60.74**	0.28
Netherlands	-7.31	5.30**	-25.71**	-5.41**	0.035**	13.06**	0.53
Spain	22.55	-16.37**	-22.22	15.14**	0.144**	-20.34	0.23
UK	-5.67	-4.21***	6.52	3.77**	0.068**	-7.30**	0.18

Panel – II: Logistic Smooth Transition Threshold Model (LSTR)

Country	α	ß	φ_0	φ_1	λ	c	Adj. R^2
Austria	-7.67**	2.04***	12.03*	2.24**	0.091**	2.38**	0.74
Belgium	31.27***	11.97**	-25.35***	-16.52	0.012***	23.52***	0.69
Denmark	23.82	29.45	23.71	28.01	0.568	-3.775	0.37
Finland	1.96***	0.42***	-11.5***	-6.07***	0.03***	3.73***	0.19
France	0.84	-0.46	-2.19	-2.67	0.049	15.47***	0.24
Germany	3.33**	-4.53**	0.37	6.93*	0.048**	1.94**	0.44
Greece	3.36	-5.46	-2.79	5.14	0.013	-1.009	0.12
Ireland	-14.74	-33.8	14.81	35.08	0.063	19.05**	0.31
Italy	5.66	2.75**	-6.02	-5.14**	0.064**	1.66***	0.20
Netherlands	-17.56***	5.01**	16.97*	-4.27**	0.015***	-42.33***	0.52
Spain	0.56	-2.17**	-1.61	-6.43***	0.003*	-1.61**	0.26
UK	1.02**	-1.53**	-1.22	0.31***	0.013***	39.89**	0.19

How Does Microfinance Prosper? An Analysis of ESG Context

Tauhidul Islam Tanin[1]*, Mohammad Ashraful Mobin[2], Adam Ng[3] & Ginanjar Dewandaru[4]

[1] *Graduate Student, INCEIF, The Global University of Islamic Finance, Kuala Lumpur 59100, Malaysia.*
[2]*PhD Candidate, INCEIF, The Global University of Islamic Finance, Kuala Lumpur 59100, Malaysia.*
[3]*Assistant Professor, Islamic Finance & Banking, INCEIF, The Global University of Islamic Finance, Kuala Lumpur 59100, Malaysia and Fellow, Royal Society of Arts, London, WC2N 6EZ, UK.*
[4]*Assistant Professor, Econometrics & Economic Modelleling, INCEIF, The Global University of Islamic Finance, Kuala Lumpur 59100, Malaysia*

**Corresponding Author: tanin0206@gmail.com*

Abstract

The linkage between the financial performance of microfinance institutions (MFIs) and comprehensive ESG (Environmental, Social and Governance) performance has been ignored by researchers till date albeit this tie may serve as a primary objective for MFIs. This paper investigated whether ESG performance influences MFIs' financial performance based on an annual dataset covering 5 years, 34 countries and 62 MFIs. The empirical findings of panel data analysis reveal that ESG performance positively affects financial performance for the periods under review yet sub-models (of ESG) documented mixed results. In particular, environmental performance contributes positively to financial performance while governance performance does so oppositely. For social-financial performance nexus, depth of outreach appears to be positive, but women empowerment seems deteriorative. This study may help regulators in creating a comprehensive framework; investors in getting relatively higher return focusing more on ESG; and MFIs in engaging further in ESG activities.

Keywords: Financial Performance, ESG Performance, Environmental Performance, Social Performance, Governance Performance, Microfinance.

1. Introduction

Microfinance institutions (MFIs) came into its existence, five decades ago in Bangladesh following the financial empowerment of the poor through microloan. Since then, MFIs offering diverse financial products and services in many regions to fulfil the key objectives of eradicating poverty and enhancing social development. Specifically, MFIs have started offering non-financial amenities to their clienteles with the passes of time. These include, but not limited to technical aid, agricultural education, children's schooling, healthcare services and specialised training for both self-development and improving environmental practices or mitigate environmental risk.

Although these facilities belong to the notion of Environmental, Social[1] and Governance (ESG) performance, one might wonder how ESG performance drives MFIs' financial Performance[2]. The feasible answer is, after the addition of ESG features; an individual can get an extended sustainable business environment with no less than today's good returns or possibly even higher (Nielsen & Noergaard, 2011). That means, with the addition of ESG contribution, a business enterprise may get a better financial performance. In addition, the firms that showed competency in handling their environmental, social and corporate governance would carry lower risks compared to other firms (Artiach, Lee, Nelson, & Walker, 2010; Oikonomou, Brooks, & Pavelin, 2012).

As empirical evidence, the research papers related to firms, SMEs and stock markets argued that ESG performance lead to better financial performance. For instance, the study of Friede et al. (2015) combines the findings of around 2200 individual studies which indicates a significant impact of ESG performance on financial performance. About 90% extracted studies disclose a non-negative relationship of ESG-financial performance nexus where the majority (62.6% in meta-analyses and 47.9% in vote-count studies) revealed positive findings over time. This study also reports a stable positive association between ESG and financial performance.

For MFIs, the earlier findings experienced by this paper exhibits inconclusive results. Some discrete studies tried to establish a relationship between MFIs' environmental and financial performance, social and financial performance, and governance and financial performance. Interestingly, the results coming from those studies remain inconclusive. On the one hand, the relationship between environmental and financial performance yet to be conclusive by the earlier studies. Suggested results include a positive (Lankoski, 2000; M. Wagner, 2001), a moderate positive (M. Wagner, 2001) and a no significant (Allet & Hudon, 2015) relationship. These sorts of diverse result might be result in usage of inappropriate econometric techniques(s) or limited data points or incomparable countries/regions. On the other hand, many studies regarding MFIs suggest that the relationship between social and financial performance is negative (Hermes et al., 2011; Mersland & Strøm, 2010; Morduch, 2000; Otero & Rhyne, 1994; Von Pischke, 1996; Woller, 2002). The study of Gutiérrez-Nieto et al. (2009) finds a little positive relationship between them. For governance component, the results of previous studies regarding the relationship between governance and financial performance show a diverse feature which includes a slight influence (Mersland & Strøm, 2009), no significance relationship (Hartarska & Nadolnyak, 2007), and a positive connection (Thrikawala, Locke, & Reddy, 2013).

[1] "The effective translation of an organization's social mission into practice. Social performance is not just about measuring the outcomes, but also about the actions and corrective measures that are being taken to bring about those outcomes." (MicrofinanceGateway, 2017). Another way, social performance refers to the developmental objective of MFIs, or the impact of providing access to financial services (microfinance) for the poor (Hossain & Knight, 2008; Littlefield & Kneiding, 2009; Rosenberg, 2009).

[2] Financial performance refers to the ability to cover all administrative costs, loan losses, and financing costs from operating income (Rosenberg, 2009).

All in all, this paper witnessed some unsolved issues with this study topic which are following. Firstly, the prior studies are inconclusive concerning the relationship between discrete environmental, social and governance performance with regards to financial performance. Secondly, we failed to find a single/comprehensive empirical study which talks about whether all three aspects of ESG jointly makes any difference to MFIs' financial performance[3]. It seems indispensable to examine whether MFIs' financial performance depends on ESG performance following the empirical gap to date. Hence, this paper aimed at studying whether ESG performance influences MFIs' financial performance.

This paper has three main research objectives. The first is to identify whether financial performance is affected by ESG performance of microfinance institutions. The second is to address the following research question in accord with the objective above of the study. The third is to investigate as to how ESG performance contribute unto MFIs' financial performance for the periods under review. As such, this study aims at using a blended data of Mixmarket and International Financial Statistics (IFS)[4] with a panel data analysis to answer this issue meaningfully. The findings will have manifold implications for both the active practitioners and legislators such as NGOs[5], donors, governments; and the same to poor people. With a unique dataset covering five years' annual data[6] coming from 34 countries and 82 MFIs, the paper aimed to add some contribution up in the avenue of microfinance.

To talk about econometric evidence of comprehensive ESG models, this study might be the first in its kind in offering an empirical evidence that environmental performance contributes financial performance positively. For social performance, the first aspect - women empowerment appears to have no impact on financial performance which somewhat validates the study of Boehe & Barin Cruz (2013) while the depth of outreach, the second aspect confirms Cull et al. (2015) that it contributes financial performance positively. The findings of governance performance support the study of Strom et al. (2014) that female CEOs seem to escalate financial performance better but our finding opposes the study of Allen & Gale (2000) and Mersland & Strøm (2009).

For discrete[7] ESG models, we witness no significant impact of governance performance on financial performance which is in line with Hartarska & Nadolnyak (2007) while women empowerment (one proxy for social performance) tend to contribute financial performance negatively. Hermes et al. (2011) note that MFIs who have more female borrowers appear to be less efficient whereas Boehe & Barin Cruz (2013) documented that whether a higher number of women borrowers advance MFI's performance is subject to institutional characteristics. Other findings remain the same alike comprehensive ESG model. The policy implications and the significance of the study are discussed in later section. However, it worth to mention that we made a humble attempt for the first time to our best knowledge in studying MFIs' financial performance and comprehensive ESG nexus, empirically. The rest of the paper is structured as follows. Chapter 2 presents the aspects of ESG in microfinance institutions. Chapter 3 outlines the conceptual framework and empirical literature concerning EGS and financial performance. Chapter 4 dedicated to the dataset, methodology and variables used, and Chapter 5 presents the descriptive and empirical results obtained. Finally, Chapter 6 discusses a coherent conclusion and policy implications bundled with the limitations and the areas of potential future study.

2. Aspects of ESG in MFIs

[3] Moreover, this study expects that ESG performance might have a positive impact on financial performance regardless of the diverse results of prior studies and the findings of Friede et al. (2015) for firms and other organisations.
[4] An initiative of International Monetary Fund (IMF).
[5] Non-Governance Organizations (NGOs).
[6] Due to availability of the MFIs' ESG data.
[7] Discrete ESG models means the models what studied Environmental, Social and Governance Performance individually.

The earlier MFIs were concerned about the "Double Bottom Line[8]" which signifies financial advancement and social performance (Morduch, 1999). With an addition of environmental performance, this outlook has been extended further to "Third Bottom Line" (Huybrechs, Bastiaensen, & Forcella, 2015) or "Triple Bottom Line"[9] (Allet, 2012; Allet & Hudon, 2015; Gutierrez-Nieto & Serrano-cinca, 2007; Mersland, D'Espallier, & Supphellen, 2013). Keeping governance performance aside, recent ESG model[10] appears quite akin to "Triple Bottom Line". Over the time, this concept became a likely goal for MFIs (Allet, 2014; Glavas & Mish, 2015)[11].

In recent years, the environment, social and governance (ESG) trends have been gaining traction in the financial sector, including microfinance services. The ***environmental performance,*** the first aspect of ESG, were originally followed by businesses as a means of corporate social responsibility (CSR) strategy (Carroll, 2008). For environmental sustainability and promotion of environmentally friendly activities and technologies, some MFIs redesigned their strategies and products significantly. MFIs started adding clauses in loan their contracts that require clients to improve practices or mitigate environmental risk. Genesis (Guatemala), for example, disbursed 4,000 microcredits with subsidised rates in early 2012 to support small coffee and cocoa farmers using environmentally friendly production techniques such as organic fertilisers, soil conservation, and agroforestry (Allet & Hudon, 2015).

However, the development environment where MFIs play around might trigger the development of the MFIs' itself. That means, once the neighbouring environment developed due to environmental policies and initiatives of MFIs, the MFIs would be able to offer financial and social services better. This state might come at end grabbing the attention of further clients and investors towards MFIs' helping them financially more viable. Hence, it assumed that the development of environmental aspects would escalate the growth of the MFIs' financial performance. The validity of this argument has been witnessed by Arafat et al. (2012) analysing 33 listed Indonesian manufacturing firms that were reported their environmental performance assessment to the Ministry of Environment in Indonesia.

Whereby the second aspect of ESG talks about the ***social performance*** which is the fundamental aim for the MFIs. Achieving this social performance, MFIs design, develop and implement their financial and non-financial products and services on a timely basis so that they can reach a large number of poor people. This view is called outreach of MFIs. Similarly, they try to keep active their clients in an attempt of the liveliness of the MFIs' performance and the individual development of the client. To be fair and prudent, MFIs tend to be transparent calculating interest rate and performing better regarding client protection (Cull et al., 2015). Furthermore, as a means of outreach, MFIs are also coming forward with various products and services like village banking to the micro and small enterprises.

As such, they are inclined to contribute unto overall development of the society leading attainment of the poverty outreach goal and bringing the people up above the poverty line. Moreover, similar to Sub-Sahara African MFIs, many MFIs might be committed to establishing a deep retail banking presence as a means of financial inclusion (Cull, Harten, Nishida, Rusu, & Bull, 2015). As such, the global MFIs who are following the same are also expected to have substantial implications for both the financial and operating performance like African MFIs.

[8] Boosting financial performance of an organization while taking care of the issue of social performance simultaneously.
[9] Triple Bottom Line comprises of financial, social and environmental performance within a business entity.
[10] ESG model talks about the performance of environmental, social and governance performance of an organization.
[11] The stakeholders and investors of MFIs might think of how MFIs contribute toward ESG performance. The answer of Nielsen & Noergaard (2011) might be applicable for MFIs as well. Thus, it seems crucial to study the relationship between financial and ESG performance for MFIs.

However, women empowerment usually considered as an indicator of social performance (Copestake, 2007). Women empowerment denotes the percentage of women borrowers in the total loan portfolio of MFI. Higher values of women empowerment indicate more depth of outreach as lending to women linked with lending to poor borrowers (Hermes, Lensink, & Meesters, 2011). Also, poverty appears intense among women hence lending to them, MFIs are actually helping in attaining social capital creation, poverty reduction and eventually bringing social performance. Furthermore, ''Access to finance enables poor women to become economic agents of change by increasing their income and productivity, their access to markets and information, and their decision-making power'' (Roodman, 2009).

According to World Bank (2007), numerous studies endorse that a dollar loaned to a woman has a better advancement effect than a dollar loaned to a man. The presence of women enhances social performance or outreach (Gudjonsson, 2015) when it comes to the issue of sustainability. The women focus generally credited to two reasons – (1) they are more trustworthy (Armendáriz & Morduch, 2005) and (2) the loans to women leads to better social impact (Croson & Buchan, 1999; Maclean, 2010). Moreover, women borrowers have a more likely tendency to pay back uncollateralized microloans (D'Espallier, Guerin, & Mersland, 2011). Aggarwal et al. (2015) note that Grameen Bank and other MFIs that women borrowers have a more likely tendency to pay back uncollateralized microloans. Therefore, targeting them might translate into a better financial performance.

Nevertheless, mechanisms above will work once the final aspect of the ESG, the ***governance performance*** is in place. The prior studies commonly use female leadership or female members on board as a proxy for governance. Strøm et al. (2014) find that female leadership seems to meaningfully link with younger firms, a non-commercial legal status, larger boards, and more female clients. The female chief executive officer (CEO) and female chairman of the board positively associated with MFI's financial performance, but this result is not due from enhanced governance, they added. Studying non-profits organisations, O'Regan & Oster (2005) documented that women directors employ additional time on monitoring activities albeit the organisations which perform better do not have proportionately more women but minorities on the boards.

Since many studies suggest that most of the clients of MFI are women thus the female members on board might be in better sides to employ internal governance policies better serving increased number of female clients. Eventually, it would have enhanced governance performance of MFI and thus financial performance for them. Therefore, it may be a good idea to appoint women in the management position to reach out more number of female borrowers, especially those are poor, improving social welfare and not sacrificing financial performance of MFIs. For Europe and Central Asia, Hartarska (2005) note a positive link between women on the board and MFIs' performance.

3. Empirical Literature

The results inherited from earlier studies demonstrate a diverse and mixed picture for the distinct studies regarding the influence of environmental, social and governance aspects over MFIs' financial performance. Until now, there is a controversy prevails concerning these nexuses.

3.1 Environmental and Financial Performance

We managed to find only one study which attempted at examining the relationship between environmental and financial performance for MFIs. However, there are other areas that discussed about the environmental and financial performance nexus, especially as to how environmental performance/regulation affect financial performance (Horváthová, 2016). Konar & Cohen (2001) and M. Wagner (2001) note that it is three decades for theoretical and empirical research and it seems that findings regarding environmental and financial performance yet to be inconclusive. The typical

neoclassical theory claims that improved environmental performance usually increases the operational costs of the firm (Palmer, Oates, & Portney, 1995; Walley & Whitehead, 1994) as the theory says, pollution reduction and environmental developments lessen marginal net benefits.

Porter (1991) argues that environmental performance can attain win–win situations in both social welfare and improved private benefits of firms. Likewise, Porter & Van der Linde (1995) claim that rightly designed environmental regulation may beget innovations, which can partially or entirely compensate the cost of environmental law compliance. However, these negative "traditionalist" and positive "revisionist" views regarding environmental and financial performance challenged by a new line of thought saying an inverse U-shaped relationship (Lankoski, 2000; M. Wagner, 2001). The current view (U-shaped relationship) assumes a positive connection between environmental and financial performance would be up to a level of environmental performance where financial benefits maximised.

Studying determinants of the environmental performance of SMEs[12], Lefebvre et al. (2003) note that SMEs are more likely to have a better environmental performance as they have an opportunity to benefit from scale economies as a means of going green efforts. In the case of Australian listed companies, Elijido-Ten (2007) note that less profitable organisations will predominantly focus on stakeholders' economic demands and leave social and environmental initiatives behind due to lack of financial capacity to undertake those programs. Conversely, better environmental performance would lead to a better financial performance what would come from attracted numerous stakeholders' groups who are environmentally concerned. This view is somewhat supported by Al-Tuwaijri et al. (2004) and Russo & Fouts (1997).

For firms, prior studies regarding environmental and financial performance failed to get a unified result. For example, King & Lenox (2001), Konar & Cohen (2001) and Russo & Fouts (1997) documented that environmental performance contributes positively to the financial performance. In contrast, Cordeiro & Sarkis (1997), Jaggi & Freedman (1992) and Stanwick & Stanwick (1998) observe the opposite result. While the studies of Cohen et al. (1995), Earnhart & Lízal (2007) and M. Wagner (2005) could not find a clear conclusion, Porter (1991) documented that both social welfare and private benefits of a firm could increase due to win–win situations of the environmental regulation. However, Lankoski (2000) and M. Wagner (2001) finds a positive relationship between environmental and financial performance up to the level of environmental performance where economic prosperities maximised.

Moving forward with MFI related empirical finding. Allet & Hudon (2015) illustrates that MFIs' financial performance has no significant relation with environmental performance, signifying that 'green' MFIs are indifferent regarding profitability as compared to other MFIs. Following the studies presented above, we may argue that better environmental performance could be a predictor of better financial performance in the arena of microfinance.

3.2 Social and Financial Performance

As for the case of general business firms, there are so many intervening variables between social and financial performance that there is no reason to expect a relationship to exist, except possibly by chance (Ullmann, 1985). However, McWilliams & Siegel (2001) claimed for a neutral relationship among social and financial performance for firms. Because, firms with no investment in social accountability will lead to comparatively lower costs and regular prices, while firm with social investment will make higher costs but will avail clients keen to offer higher prices. Albeit Cordeiro

[12] Small and medium-sized enterprises (SMEs).

& Sarkis (1997) documented that prior studies tend to obtain a short-term negative connection whereas long-term influences seem to be much promising.

Despite this, M. Wagner (2001) notes that earlier literature indicates a moderate positive relationship between financial and social performance. Horváthová (2010) note that the positive link is found more often in common law countries compared to civil law countries regarding social and financial performance. Di Vita (2009) validated this statement with a finding that usually developed countries are under common law systems which have a lower level of pollution than in civil law countries. However, the meta-regression analysis conducted by Horváthová (2010) observed that if the primary study uses qualitative measures of environmental performance, it is a more likely to witness a positive influence on environmental performance on financial performance.

For MFIs, one could say that the relationship between social and financial performance would negative. The probable argument of having a negative relationship between MFIs financial and social performance is because MFIs that engage actively in socially responsible activities might be in a position of competitive disadvantage. Because these MFIs would highly be exposed to incur more costs than that of other MFIs and this state otherwise could be avoided or minimised. This view might be in line with the view of Friedman (2007) and some other neoclassical economists' who claims of a few measurable financial benefits to social performance while it leads to numerous costs (Waddock & Graves, 1997). By this argument, the costs directly hit the bottom line minimising financial performance and thus sustainability of the MFIs. Therefore, MFIs might expect a negative relationship between social and financial performance.

To put forward a complement against this argument, one could say, when the financial sector developed enough, MFIs might face a direct competition with the mainstream banks leading a pressurised state to increase the loan size to retain their clients. It would increase MFIs' risk and likely repayment problems (Vanroose & D'Espallier, 2013). In contrast, MFIs may be hard-pressed to shift their market focus to an unbanked population or poorer class which would negatively influence the financial performance using lowering MFIs' average loan sizes, but increasing their costs. Moreover, MFIs may also be pushed to lower the interest rates, making it more difficult to cover their costs and affecting financial performance negatively.

On the other hand, another school might say that the MFIs that manage their social performance actively, usually earn greater financial proceeds than otherwise. "Doing social performance management, apparently, yields a variety of benefits that translate into higher financial returns, such as improved stakeholder relations, greater management capacity, improved internal capacities, better inter-firm communication, improved employee relations, and enhanced reputation (Woller, 2007)". Therefore, one can reasonably believe that MFIs can make a good financial performance even though they focus on poorer or harder-to-reach clients to serve. It may not be true for all market segments which is quite understandable, but there is a plenty room available for the MFIs to get a good return targeting different market segments and clients.

While talking about MFIs specific social and financial performance, many studies suggest a negative relation. For example, Otero & Rhyne (1994), Von Pischke (1996), Morduch (2000), Woller (2002) and Hermes et al. (2011) note that there could exist a trade-off between financial and social performance. Nonetheless, Bartle (2010) and Roodman (2009) demonstrates that global researchers have examined the social impact widely and the ensuing studies exemplify that microfinance does have significantly positive influences on the poor in obvious situations. However, Gutiérrez-Nieto et al. (2009) find a little positive relationship among social and financial efficiency with a result which showed that compared to other MFIs, the social efficiency of NGOs is higher.

Considering an augmented focus on social performance, Social Performance Task Force (SPTF) has dedicated, since 2005, on developing Social Performance Indicators for the MFIs (SPTF, 2016). However, keeping above discussion in mind, one can say that the relationship between social and financial performance is yet to resolve. Therefore, it seems necessary to conduct a study regarding this relationship.

3.3 Governance and Financial Performance

For general firms, Shailer (2004) notes corporate governance as the mechanisms, processes and relations by which means the corporations are controlled and directed. Governance helps the decision-making process and gives people accountability (Klazema, 2017). One of the main goals clearly described to the board, the stakeholders, and the shareholders what their duties and responsibilities are within the organisation. Governance plays an important role in mitigating or reducing the amount of risk involved. On top of that, properly recognising what the roles in the firms allow decisions to make that will not have a negative effect on the overall organisation. By the help of governance, everyone held to a specific standard and communication made easier due to the being an established hierarchy and role that everyone involved in the institution acts (Klazema, 2017).

It can be problematic for a firm to become successful just by having a high level of profit, with the way that social businesses are run today because as a corporation is also evaluated based on its image and governance structure is established to help ensure that the image remains clean. All in all, if the governance mechanism goes well what it should be then, the firm might get a better financial performance. In contrast, Microfinance practitioners state that decent governance is vital to have a profitable MFI (Campion, 1998; Helms, 2006; Labie, 2001; Rock, Otero, & Saltzman, 1998) and it now tends to rise in significance, especially amongst donors, is the prerequisite that MFIs attain financial sustainability. For MFIs, governance means the mechanisms by which equity investors, donors, and fund providers safeguard themselves that their funds will be employed as par envisioned purposes[13] (Hartarska, 2005). "The changing of microfinance environment has shown a move towards sustainability ultimately leading to governance issues as donor funds shrink and equity inflows increase in the microfinance sector. MFIs have therefore embraced boards and adopted principles of corporate governance to ensure their survival" (Bassem, 2009)

Strøm et al. (2014) witnessed that this female leadership, one measure of (MFIs) governance is negatively related to governance indicators as the internal audits, the number of board meetings, and the separation of the chairman's and CEO's roles. Then they illustrate that the quality of an MFI's chair and CEO appears to be more vital for the MFI's achievement compared to general corporate governance. However, the female CEO and female chairman of the board positively associated with MFI's financial performance, but this result is not due from enhanced governance (Strøm et al., 2014). This finding contradicts what Adams and Ferreira (2007) documented for female directors thus this study assume that female members on board may be significantly positive for MFI's financial performance what driven by enhanced governance.

In contrast, Mersland & Strøm (2009) illustrates that most of the corporate governance structures have a little influence on MFIs outreach and financial performance. They also find that financial performance elevates when MFIs has local directors, women CEO and an internal board auditor. Hartarska (2005) find that not all recognised governance measures affect performance, but different mechanisms drive outreach and sustainability differently. For Sri Lankan MFIs, Thrikawala et al. (2013) note that financial performance improves with some governance aspects like a female chair, female CEO, CEO/chairman duality, client representation on the board and independent directors. However, the discussed enactment may turn opposite if female director's representation is higher.

[13] The definition is spirited by Shleifer & Vishny (1997) where they illustrate corporate governance as the mechanism by which shareholders make secure themselves that they will earn maximum yields on their investments.

They also find no significant relationship between MFIs' firm performance, internal audit, and international directors on the board.

Besides, Hartarska & Nadolnyak (2007) failed to find a direct influence of regulation on both financial performance and outreach. The findings of prior studies related to governance-financial performance nexus seem to inclusive alike environmental and social performance.
Summing up all, the discussion suggests that the result coming from all three discrete aspects of ESG by earlier studies does offer a diverse result but left in a questioned position. Hence, it is imminent that fresh and an aggregate study should carry forward regarding ESG performance vis-à-vis MFIs' financial performance to get a convincible answer.

4. Data, Methodology, and Variables

The study employed a set of data from Mixmarket and International Financial Statistics (IMF) following relevancy among them while employed three econometric techniques excluding robustness check. The details about data, methodology and variables will be presented in the following.

4.1 Variables Selection and Rationale

4.1.1 Dependent Variable

ROA appears to be the most commonly used indicator for financial performance for many sectors like banks, insurance and MFIs. In line with the Mersland & Strøm (2009, 2014), Mersland (2011), Vanroose & D'Espallier (2013) and Hartarska (2005), this study uses ***Return on Assets (ROA)*** as a means of financial performance measurement. ROA by way of conventional financial or accounting performance metric (Aebi, Sabato, & Schmid, 2012; Fahlenbrach & Stulz, 2011). We also can say, it is the attitude of MFIs to employ its total assets generating returns (CGAP, 2003) or how efficiently MFIs' management generate proceeds from its investments. Higher ROA translated as less the likelihood of being defaulted. A stable financial performance is very important for MFIs as this performance offers a key "social" sign of whether the MFI will be able to continue to serve the customers over time (Schreiner, 2002).

4.1.2 Explanatory Variables

4.1.2.1 Environmental Performance of MFIs

In our best knowledge, no study has been conducted yet dedicating the relationship between the environmental and financial performance concerning MFIs, therefore, it was a challenge for us taking a proxy to define environmental performance better. However, Allet & Hudon (2015) developed a Microfinance Environmental Performance Index (MEPI) where one aspect is Green Microcredit and is proxied by RE&EE loans[14] and Green IGAs loans[15]. Moreover, studying a relationship between corporate environmental policy and abnormal stock price returns, Thomas (2001) used a variable namely "adoption of an environmental policy defining environmental performance". Following their studies and considering the availability of the mixmarket data, this study aims to use Environmental Policies and Initiatives[16] as a proxy for environmental performance.

4.1.2.2 Social Performance of MFIs

Social performance denotes to the developmental objective of MFIs, or the MFI's impact of offering access to financial services for the poor (Hossain & Knight, 2008; Littlefield & Kneiding, 2009;

[14] Provision of credits to promote access to renewable energy or energy efficient technologies (RE&EE).
[15] Provision of loans with reduced interest rates to promote the development of environmentally friendly activities.
[16] Environmental Policies and Initiatives denotes the institution includes clauses in loan contracts that require clients to improve environmental practices/ mitigate environmental risk.

Rosenberg, 2009). This performance belongs to one of the main goals of MFIs, the financial inclusion. The social performance commonly measured by two notable variables namely depth of outreach and women empowerment.

Studying a linkage between social performance management and mission drift, Copestake (2007) mentioned ***women empowerment*** as a social performance variable. Moreover, Microfinance not only has a positive impact on micro-enterprise development but also on the women borrowers. Taking microloan, women can do manifold productive activities and expand their income sources more than that of men. Pitt & Khander (1998) documented that women play a substantial role in economic development, especially in the development of the very poor class. As many studies (Hartarska, Shen, & Mersland, 2013; Hermes & Lensink, 2011; Hermes et al., 2011; Périlleuxa & Szafarzb, 2015) use a percentage of female borrowers[17] as a proxy of social performance, this study aims to follow them. Average Loan Balance per Borrower[18] (ALB) is the indicator of social performance or outreach (Ngo, 2015) or poverty outreach (Sheremenko, Escalante, & Florkowski, 2016). Hermes et al. (2011) note that higher ALB shows less depth of outreach as this case might lead MFI to offer fewer loans to the poor borrowers. Studying the factors explaining the rating of MFIs, Gutierrez-Nieto & Serrano-cinca (2007) employed Average Loan Balance per Borrower/GNI Per Capita (ALBGNI) as one of the indicators of social performance. Cull et al. (2015) also considered ALBGNI as a proxy of financial inclusion (social performance).

Notwithstanding Quayes (2012), Bassem (2012) and others divide ALB by Gross National Income (GNI) per capita, Mersland & Strøm (2010) do not follow the same instead uses the direct value of ALB. We assume that ALB scaled by GNI would be more relevant variable capturing financial inclusion better as it can compensate for variances in monetary units. Therefore, this paper chooses Average Loan Balance per Borrower/GNI Per Capita (ALBGNI) in defining the ***depth of outreach,*** following literature (Aggarwal et al., 2015; Al-Azzam & Mimouni, 2016; Barry & Tacneng, 2014; Bos & Millone, 2015; Cull & Morduch, 2007; Louis, Seret, & Baesens, 2013; Quayes, 2012). The lowest ALBGNI means the most an MFI is moving towards the class of very poor (Bassem, 2012).

4.1.2.3 Governance Performance of MFIs

The leadership shapes any companies, communities, and societies. A gender-diverse board, another aspect of governance (Hartarska, Mersland, Nadolnyak, Hall, & Christopher, 2013), and its leadership might help corporations to lead and manage sustainable and effective business strategies. MFIs habitually focus on female customers (Armendáriz & Morduch, 2010) hence female borrowers tends to be large compared to men. Hartarska et al. (2013) note that "a female CEO may be better at obtaining information from predominantly female customers compared to a male CEO".

O'Regan & Oster (2005) note that women directors employ additional time on monitoring activities. Therefore, we assume that if senior female members are the part of the board of directors, then they might formulate the governance policy better. Moreover, Hartarska (2005) experienced the positive connection between women on the board and MFIs' performance for MFIs for Europe and Central Asia. As such, we aim to choose women on the board as a proxy defining the performance of internal governance better. We may assume that once the internal governance policies are sound enough, it could be one of the leading indicators of superior governance performance and so will help in getting better financial performance.

4.1.2.4 Microfinance Specific Control Variables

[17] Number of Active Borrowers who are women / Number of Active Borrowers
[18] Calculated as Average Gross Loan Portfolio divided by Number of Active Borrowers.

The size of the MFI may have a close relationship with the financial performance. If MFIs are large enough regarding size, then it may have led them to invest and circulate the fund, increase loan portfolio, and take further initiatives enriching their financial performance. ***Total assets*** are the size indicators of the MFIs (Hartarska, 2005; Lankoski, 2000). Many earlier studies (for example, Mersland and Strøm, 2009, Hartarska et al. 2013, Mersland et al. 2013, Vanroose and D'Espallier 2013) also use the total asset as an independent variable in their study. In reducing the influence of the deviation of companies with extreme sizes (Wang & Sarkis, 2013), this paper uses the natural logarithm of total assets.

Cost per borrower (CPB) is a measure of efficiency (Lafourcade, Isern, Mwangi, & Brown, 2005) specifying the operation expenses of MFIs (Wijesiri, Viganò, & Meoli, 2015). It is calculated by operating expense/average number of active borrowers (Sanfeliu, Royo, & Clemente, 2013) and has employed in various prior studies (Haq, Skully, & Pathan, 2010; Qayyum & Ahmad, 2006; Segun & Anjugam, 2013) as an input variable. Woller et al. (1999), acknowledged that the cost per borrower measures the value of total financial and in-kind inputs that is essential in producing a given level of output, as determined by borrowers.

In the micro banking bulletin highlights, Christen & McDonald (1998) states that ***administrative expense ratio*** is a noteworthy determinant of financial self-sufficiency[19]. Financial self-sufficiency (financial performance) is required (Sanderatne, 2003) to attain a financial viability or stability. Woller et al. (1999) and Stauffenberg et al. (2003) note that the operating expense ratio is a determinant of institutional effectiveness. An increase in administrative expense ratio[20] is hypnotised to relate to a reduction in financial self-sufficiency and vice versa (Woller et al., 1999). The ratio calculated by the amount of Administrative Expense plus Depreciation divided by Average Assets.
Instead of real interest rate, the ***yield on gross portfolio (real) or real portfolio yield*** commonly used by literature for the proxy of MFIs' interest rate. The reason is, the yield on gross loan portfolio (real) offers an accurate picture of the portfolio quality in generating the financial revenues (Janda & Zetek, 2014). The Yield on gross portfolio (real) can be found using the formula of 'Yield on Gross Portfolio (nominal)[21] – Inflation Rate) divided by (1 + Inflation Rate)'. A higher value of real yield indicates that MFIs increased focus more on lending about total available assets. Real yield, unlike the margin, usually represents only the revenues coming from credit products afterwards adjusted for inflation. If any change in some variables either macroeconomic or internal, the final influence will then be linked only to the MFI's revenues (Janda & Zetek, 2014). Following Louis et al. (2013), Cull et al. (2009) and D'Espallier et al. (2016), we aim to use real portfolio yield as a proxy for the interest rate.

4.1.2.5 Macroeconomic Specific Control Variables
Following the study of Kutan et al. (2012) regarding determinants of bank performance, we have used macroeconomic specific variables. Namely, GDP growth and Inflation that signifies the growth of the economy measured as the percentage change in real GDP and, inflation, accordingly.

Theory of Economic Development by Schumpeter (2003) states that banks are the key towards economic development as they route savings of the society to entrepreneurs who innovate. Thus, the financial system development stimulates economic growth as the level of financial development is intensely associated with both the rate of physical capital accumulation and real ***GDP growth*** (R. G. King & Levine, 1993). Particularly in developing economies, long-term economic growth and a healthy financial system are intensely linked as economic growth upsurges the demand for financial

[19] There are two kinds of sustainability can witness in assessing MFIs performances- operational self-sufficiency and self-sufficiency (Meyer, 2002). Operational self-sufficiency is when operating income is enough to cover operational costs like salaries, suppliers, loan losses, and other administrative costs, further he added.
[20] Generally, administrative Expense Ratio is synonymous to operating expense ratio.
[21] Calculated by Interest and Fees on Loan Portfolio / Gross Loan Portfolio, Average.

services, which eventually leads to a financial development (Hassan, Sanchez, & Yu, 2011; Inoue & Hamori, 2012). The MFIs can be considered as 'Bank to the Poor' as they are financing poor clients. Therefore, we may expect that there might have some connection between GDP growth rate and MFIs' financial performance. Barry & Tacneng (2014) note that real GDP growth is the viable measure what would control for changes in MFIs' performance that can credit with economic growth. Hence, we choose GDP growth rate[22] as one of our control variables.

Following the Ahlin (2011), M. Wagner (2013) and Vanroose & D'Espallier (2013), ***Inflation*** also is taken into consideration for the study as it might affect MFIs growth greatly. We assume that there might be a significantly negative association between inflation and the financial performance of MFIs. Boyd (2001) find that rising inflation diminishes the marginal impact on banking lending activity rapidly. That study also suggests that if inflation rates exceed 15 percent, a distinct drop in financial sector performance might experiences. Microfinance sector is no less than a banking sector (Aggarwal et al., 2015). Therefore, we may anticipate the same relationship (as like banking) between inflation and financial performance of MFI. The inflation rate, defined as consumer price index (CPI)[23] is attainable from International Financial Statistics (IFS), IMF[24].

4.1.2.6 Dummy Variable

We have introduced a dummy variable namely ***OIC Dummy*** (dOIC) to know whether the relationship between ESG performance and financial performance has any significance for the OIC[25] countries. The OIC countries refer to the countries where the number of Muslim inhabitants is higher.

4.2 Data and Sources

The study aims to use secondary data sources. The expected sample of microfinance-specific variables would be composed of default, non-adjusted and median data derived from "Microfinance Information Exchange (MIX or www.themix.org/mixmarket)" for the period of 2010 to 2014 as only five years' data is available defining ESG performance. This study is limited to a dataset of 62 MFIs due to ESG data availability while these MFIs are from 34 developing countries (Appendix: A3). Understanding the context of this study, one can expect that macroeconomic data might have a significant link with MFIs' performance. As such, relevant macroeconomic specific control variables sourced from International Financial Statistics (IFS) what is the principal statistical publication of International Monetary Fund (IMF).

4.3 Method and Model Specification

We have initially employed two (2) panel data estimation models, precisely, fixed effects[26] and random effects[27] which can handle a model without endogeneity issue. In panel regression, endogeneity problem arises when the correlation between some variables of the model are with the error term (Kipesha & Zhang, 2013). It may be due to the autocorrelation of error terms, measurement error, simultaneity or omission of the variable that have a noteworthy impact on the dependent variable (Greene, 2008; Gujarati, 2009).

[22] Defines how fast the country's economy is growing, annually.
[23] Consumer Prices Index (CPI) are the most commonly used indicators of inflation which exhibits the changes in the cost of acquiring a fixed basket of goods and services by the average consumer. The percentage changes are calculated from the index number series. Preference is given to series having wider geographical coverage and relating to all income groups, provided they are no less current than more narrowly defined series. The weights are usually derived from household expenditure surveys while the Laspeyres index formula is the most frequently used to calculate the changes in consumer prices.
[24] International Monetary Fund (IMF).
[25] Organisation of Islamic Cooperation
[26] Also, known as the within estimator.
[27] Also, called a variance components model.

"The fixed-effects model controls for all time-invariant differences between the individuals, so the estimated coefficients of the fixed-effects models cannot be biased because of omitted time-invariant characteristics[28]. However, one side effect of the features of fixed-effects models is that they cannot be used to investigate time-invariant causes of the dependent variables. Substantively, fixed-effects models are designed to study the causes of changes within a person (or entity)" (Kohler & Kreuter, 2009, p. 245).

The rationale behind random effects model is that, unlike the fixed effects model, the variation across entities is assumed to be random and uncorrelated with the predictor or independent variables included in the model (Torres-Reyna, 2007). "The crucial distinction between fixed and random effects is whether the unobserved individual effect embodies elements that are correlated with the regressors in the model, not whether these effects are stochastic or not" (Greene, 2008, p. 183).

The general equations for two static models, fixed and random effects are as follows-
Fixed Effects: $y_{it} = X'_{it}\beta + \alpha_i + \varepsilon_i$ (1)
Where, y_{it} is the dependent variable; X'_{it} signifies the vector of independent variables, α_i is the mean of unobserved heterogeneity; βs are the coefficients and ε_{it} is the error term.
Random Effect: $y_{it} = X'_{it}\beta + (\alpha_i + \mu_i) + \varepsilon_i$ (2)
Where μ_i signifies heterogeneity specific to firm i while ε_{it} is the remaining firm year heterogeneity. In line with Mersland & Strøm (2009), we could say that the constant term (α_i) in the regression essentially be interpreted as the average firm year heterogeneity. The random effects technique converts the original data to present a robust result.

The fixed effects model is robust to the omission of any relevant time-invariant regressors (Jack & DiNardo, 1997) but cannot include time-invariant explanatory variables (Unite & Sullivan, 2003). In contrast, the random effects model takes into account the association between these time-invariant variables and the dependent variable (Ganioğlu & US, 2014) such as regulatory status, MFI type, and lending technology.

Hausman (1978) test indicates that which estimator, fixed effects or random effects would be the efficient one better explaining models. "If the error terms are correlated, then fixed effects is no suitable since inferences may not be correct and you need to model that relationship (probably using random-effects), this is the main rationale for the Hausman test" (Torres-Reyna, 2007). Thus, Hausman test usually used in defining focused estimator/models interpreting obtained statistical results.

The following equation would be our base equation as suggested by random effects.
$FinPer_{it} = \alpha + \beta_1 MFI.ESG_{it} + \beta_2 MFI.CV_{it} + \beta_3 MAC.CV_{it} + \varepsilon_{it}$ (3)
Where, $FinPer_{it}$ represents the Financial Performance of ith MFIs for a particular period, t. The α is a constant, β_i are the coefficients and $MFI.ESG_{it}$ represents MFIs' ESG performance. We have employed a mixture of existing and new variables to express MFIs' ESG performance. Some variables are suggested by previous literature while others extracted from Social Performance Indicators as suggested by Krell & Pierantozzi (2014) and Social Performance Task Force (SPTF, 2011). The model also decorated by both the MFI-specific control variables, $MFI.CV_{it}$ and macroeconomic specific control variables, $MAC.CV_{it}$ (Table 1). Finally, ε_{it} signifies an error term for the period of t.

[Insert Table 1 around here]

[28] Like culture, religion, gender, race etc.

5. Empirical Findings

The findings of the study divided into two main parts - descriptive results and empirical results. The former dedicated to preliminary analysis and the latter is about the post regression investigation alongside probable justification and literature support if any.

5.1 Descriptive Results

The descriptive statistics tell us the location of information on individual variables. The values of the variables can interpret as the percentage form (Mersland & Strøm, 2009). For example, the average (mean) financial performance (Return on Assets) of MFIs is 2.9%, which is quite low compared to our expectation and might not be a good sign for a long-run sustainability. The standard deviation here is 5.6%, which indicates that the financial performance of the sampled MFIs does not vary that much. The average performance of environmental policies and initiatives is 30.5% while in the case of governance, it is 37.5%. That means, MFIs in current days, are moderately concerned about environmental and governance performance.

[Insert Table 2 and 3 around here]

The study aims to see the strengths of relationships between variables using a Pearson's correlation[29] matrix. Kennedy (2008, p. 196), however, documented that correlations need to be within 0.8 – 0.9 to note collinearity among two variables. Our dataset suggests that none of the correlation coefficients falls in this range thus the data are free from multicollinearity.

The correlation matrix exhibits that the relationship between financial inclusion (ALBGNI) and financial performance is positively significant. The administrative expense ratio is seen as a significantly negative for return on assets (ROA). Therefore, before running the data, we may expect that the relationship between our dependent variable (ROA) and focus variable (ALBGNI) may give us significantly positive results while control variable (AEXR) could appear to be negative. We also observe that cost per borrower (CPB) has a significantly positive connection with the environment (ENV), ALBGNI and l_ASST (total assets) while it is just opposite to WOEM (a proxy for social performance) and INF (inflation). Nevertheless, total assets and governance have a significantly negative impact on each other. The same is true for the relationship of YGP (Yield on the gross portfolio, real) and INF.

5.2 Empirical Results

Due to a limited number of observations, unbalanced panels, lower number of "T" and lack of variations among observations, this paper resort to static panel models. This paper aimed at choosing either Fixed or Random Effects as they are ideal when data are static, homogeneous, and have no dynamics and endogeneity/simultaneity. Yet we may not discard the possibility of having Pooled OLS as a better estimator to answer to the critics. Thus, we wish to follow Hausman and LM tests in selecting most efficient estimator.

We initially have employed two (2) panel techniques, fixed and random effects (Appendix: A1). However, concerning a robust result, we need to identify which technique would be the most suitable for our study. The fixed effects technique is suitable when controlling for variables that are consistent over time, however, if they differ between cases; the random effects is suitable as it can control the

[29] "The Pearson product-moment correlation coefficient, often shortened to Pearson correlation or Pearson's correlation, is a measure of the strength and direction of association that exists between two continuous variables. A Pearson's correlation attempts to draw a line of best fit through the data of two variables, and the Pearson correlation coefficient, r, indicates how far away all these data points are to this line of best fit (i.e., how well the data points fit this new model/line of best fit). Its value can range from -1 for a perfect negative linear relationship to +1 for a perfect positive linear relationship. A value of 0 (zero) indicates no relationship between two variables" (Laerd Statistics, 2017).

variables that vary across time and cases (Brooks, 2014). After running Hausman test, if we get p-value > 5%, then we need to resort to random effects (RE) and otherwise (Greene, 2008). In our case, the p-values coming from Hausman tests are more than 5% for all the models. Therefore, we may then conclude that the random effects would be the better/efficient estimator for our study.

However, we then run Pooled OLS estimator (POLS) and Random Effect (RE) (Appendix: A2), to make sure that our finding is further viable. The LM test used to distinguish between POLS and Random Effects where the null hypothesis is, "no significant difference across units" that means no panel effect. The LM test helps in deciding between a random effects regression and a Pooled OLS regression (Torres-Reyna, 2007). If p-value of LM test is less than 5%, then we need to resort to Random Effects and otherwise. Similar to Hausman tests, LM test confirms for Random Effects for all the models (discarding RE 10). Therefore, the remainder of the study will be talking about only the findings of RE. We have extended our models further in Table 4 using our focused estimator, Random Effects to find the best-fitted model(s). The table classified into five sections – without ESG performance (W/ ESG), comprehensive ESG performance (ESG), and discrete performance of environmental (E), social (S) and Governance (G).
Defining the best-fitted model among all the estimation models, we aim to resort to Wald chi^2 (χ^2) and R^2. The Wald chi^2 (χ^2) serving as an omnibus indicator of the goodness of fit of the overall model similar to F test. If the p-value of the Wald χ^2 is statistically significant, the coefficients in the model are assumed to be statistically significant. In contrast, R^2 is also an indicator of the goodness of fit of the comprehensive model while higher the R^2 denotes better the model if it remains within 80%.

[Insert Table 4 around here]

The model without ESG performance (RE 1) does not give much information following the aim of the study as we ran this model without ESG variables/indicators (of MFI). However, the administrative ratio (AEXR), the yield on the portfolio, real (YGP) and inflation (INF) found to be positively significant like other models. The details about these findings will be highlighted in the later stages.

5.2.1 ESG and Financial Performance
The model RE 2 to 5 (Table 4), presents estimations for ***comprehensive ESG performance*** with all the proxies of along with the microfinance-specific and macroeconomic-specific control variables. In the regression, model RE 2 shows relatively higher Wald χ^2 and R^2 (134.16 and 0.667 respectively) compared to other models. Thus, RE 2 model might be the most suitable one exhibiting comprehensive ESG performance. The model RE 2 (comprehensive ESG model) demonstrates that environment (ENV) and social (ALBGNI) and governance performance (FeBM) has a significantly positive impact on the financial performance (ROA). The significance level for ALBGNI is 1%, ENV 5%, and FeBM is 10%.

As a part of the objective of "Triple Bottom Line", MFIs tend to enhance environmental performance hence they might be enjoining a better financial performance. Furthermore, both the social welfare and private benefits of a firm could increase due to win–win situations of the environmental regulation as suggested by Porter (1991). Therefore, we might be observing this result.The result of the depth of outreach (ALBGNI) - the first aspect of social performance validates the study of Cull et al. (2015) while opposes the finding of Hermes et al. (2011). As such, we may argue that once MFIs entitled to a better depth of outreach, MFIs might get a better financial performance due to their social performance. However, the second aspect of social performance, women empowerment (WOEM) appears to be negatively significant for MFIs' financial performance.

Although it expected that women empowerment would bring financial performance, Hermes et al. (2011) documented that MFIs who have more female borrowers appear to be less efficient. One probable justification is that serving women might be costly as compared to the men. Hence MFIs are entitled to higher total costs, in turn, reducing their financial performance. Besides, the MFIs might be inefficient in serving women due to their technical and allocative efficiency thus they might get failed to attain a better financial performance from an augmented women empowerment.

The findings of governance performance (positive impact on financial performance) support the study of Strom et al. (2014) that female CEOs seem to escalate financial performance better. This result is not in line with the findings of Allen & Gale (2000) and Mersland & Strøm (2009) as they documented that governance has little importance for the financial performance of MFIs. Following our econometric evidence of comprehensive ESG model (RE 2), we may say that governance has a significant influence on MFI's financial performance when we consider all three aspects of ESG together.

Summing up all, we might say that ***comprehensive ESG performance*** has a significantly positive impact on financial performance. Noteworthy to says, this study might be the first study in examining comprehensive ESG performance for MFIs complementing existing literature.

5.2.2 Environmental and Financial Performance

Both the Wald test and R^2 supporting RE 6 model (Table 4) to be the most fitted model with regards to environmental performance. The Wald χ^2 value is 95.42 with a p-value of 00.00%, illustrating that the model as a whole is fit for the study. Wald test also suggest that the variables we have studied here have a strong explanatory power defining our dependent variable. Moreover, the R^2 offers a value of 0.561 which is also good enough in indicating that the same result as Wald test presented; the model is fit for study. The RE 6 model also suggests that environment has a positive impact on MFI's financial performance with a 5% significance level.

The following explanations may justify this positive affiliation amongst ***discrete environmental and financial performance***. The clients are getting concerned about the environmental performance in these days. Therefore, they might be helping MFIs in assisting green credits to have better proceeds. Moreover, as a part of the "Triple Bottom Line", MFIs aim to enhance environmental performance. As such, they might be enjoining a better financial performance. Porter (1991) also support this statement by stating, both the social welfare and private benefits of a firm could increase due to win–win situations of the environmental regulation. We may be experiencing the same sorts of chemistry here in the case of MFIs. Nevertheless, governments and regulatory boards in these days working on Sustainable Development Goals (SDGs) which may boost the MFIs' financial performance up, eventually. Another explanation would be, as MFIs are getting dedicated on social performance with regards to a sustainable standing and exposure in the market, government and regulatory bodies might be helping them to gain financially further.

5.2.3 Social and Financial Performance

For the case of ***distinctive social performance***, we aim to select RE 10 model (Table 4) as it is suggested by both the Wald χ^2 and R^2 with higher values of 117.86 and 0.672 respectively. We have used two common proxies of social performance to experience the influence of each one over financial performance. We can witness that the both the women empowerment (WOEM) and depth of outreach (ALBGNI) has a significant impact on financial performance. However, women empowerment seems to affect negatively whereas financial inclusion does so positively. The significance level for the women empowerment is 5% while it is 1% for depth of outreach.

This paper finds a negative connection between women empowerment and financial performance. Rosenberg et al. (2009) illustrate that MFIs may particularly target women have been very successful

in serving them, particularly in some countries. Nevertheless, Hermes et al. (2011) note that MFIs who have more female borrowers appear to be less efficient. However, Boehe & Barin Cruz (2013) documented that whether a higher number of women borrowers advance MFI's performance is subject to institutional characteristics. That means, increased number of women borrowers does not necessarily bring financial performance to the MFI. Nevertheless, this finding contradicts Ghatak (2000) that the risk-aversion nature of female borrowers and sharing the same gender traits matched them to be grouped together which eventually bring better performance for MFIs.

The depth of outreach (ALBGNI), on the other hand, appears to have a positive and significant impact on MFIs' financial performance as indicated by RE 10 model. This finding validates the study of Cull et al. (2015) where they found that the significant amount of greenfield MFIs in Sub-Saharan Africa are quite committed to establishing a deep retail banking presence as well as the formation of widespread branch networks as a means of financial inclusion. As such, they are getting substantial implications for both the financial and operating performance about other MFIs performing in the same African markets. However, this result contradicts the finding of Hermes et al. (2011) where they witnessed that outreach is negatively correlated to the efficiency of MFIs thus MFIs those have lower average loan balance (ALB) are less efficient.

With that, we may then conclude that social performance does have a noteworthy impact on MFIs' financial performance considering our econometric findings.

5.2.4 Governance and Financial Performance

For the case of governance performance, the Wald χ^2 and R^2 are contradicting each other determining the most fitted model. While Wald χ^2 is suggesting RE 18 as a fitted model, R^2 directing us towards RE 16. Considering Wald χ^2 as a most acceptable indicator stating the goodness of fit of the overall model, we tend to choose RE 18 as our focused model. By selecting this model, we are saying that total assets (l_ASST) and cost per borrowers (CPB) might not directly connect to the performance of governance and so to the financial performance. However, total assets and cost per borrower expected to influence governance performance indirectly through other variables.

The result states that ***governance performance*** individually has no impact on financial performance as suggested by RE 18 model (Table 4). This study somewhat validates the finding of Hartarska & Nadolnyak (2007) while they failed to find a direct influence of regulation, an aspect of governance on financial performance. In contrast, Strom et al. (2014) illustrate that female CEOs seems to escalate financial performance better, but Allen & Gale (2000) documented that governance has little importance for the financial performance of MFIs. However, Mersland & Strøm (2009) also illustrates that most of the corporate governance structures have a slight influence on financial performance.

Moreover, the justification for this finding could extend in the following. Firstly, we have employed only one proxy of women on the board defining governance performance. That is why we might be having an insignificant result. Secondly, our sample is from developing countries where the acknowledgement or appreciation to women empowerment might be less to allow them to take decision freely. Thirdly, there might have some unique characteristics for those sample countries which may not help us in achieving governance performance; thus, statistically significant financial performance.

5.2.5 Microfinance Specific Variables and Financial Performance

For comprehensive ESG model and social performance' model, cost per borrower (l_CPB) appearing to have a negative impact on financial performance of MFI while it is insignificant for environment and governance performance model. For both the cases, the significant level is 1%.

Woller et al. (1999) documented that the cost per borrower assumed to inversely related with financial self-sufficiency. "Reduction of cost per borrower which improves profitability result into declining outreach as well as focusing on other profitable investments apart from loan portfolio results into declined outreach" (Kipesha & Zhang, 2013). It is expected that cost per borrower to increase with outreach (social performance) to the poor. MFIs which seek to lessen operating costs incline to offer larger loan size with a long-term maturity, which is not preferred by most of the poor clients (Kipesha & Zhang, 2013).

Lebovics et al. (2016) documented that cost per borrower positively linked with financial efficiency. It may be assumed as costs per borrower give rise with the average loan sizes which are associated with financially efficient MFIs more. However, it is negatively allied with social efficiency. Lebovics et al. (2016) note that it is to be anticipated as the costs per borrower rises with average loan size, and social efficiency is linked with lower loan sizes. It may not true for socially efficient MFIs to have a better financial performance and to attain a better experience in reaching out to the poor.

It is known that larger the asset size better the financial performance would be. As such, we assumed that the size of MFIs (total assets or l_ASST)[30] (Cull & Spreng, 2011) would have a positive impact on financial performance, this study suggests in having no significant connection among them, and this finding is true for comprehensive ESG model and the models of social and environmental performance. Here, the significance level is 1% what is true for all models whether main model or sub-models. It is the nature of MFIs to employ its total assets in generating returns (Jansson et al., 2003). That means total assets by nature should help MFIs to generate good proceeds from its investments once the MFIs' management would use it efficiently. As our findings contradict, we discard the result favouring the intrinsic nature of total assets.

Following the finding of this paper, we may argue that the management of these MFIs might not that much efficient to utilise total assets as a significant cause of financial performance. Another justification would be that although, it seems that the total assets are not directly linked with the MFIs financial performance but it may affect financial performance indirectly through other variables.
However, administrative expense ratio (AEXR) and real yield on gross portfolio (YGP) appear to contribute significantly and positively to MFI's financial performance. We may observe this result for main model and sub-models. We observe the significance level for AEXR and YGP are 1% what is valid for all models whether main model or sub-models.

Christen & McDonald (1998) states that administrative expense ratio is a noteworthy determinant of financial self-sufficiency. Financial self-sufficiency or performance is required (Sanderatne, 2003) to attain a financial viability or stability. Operating expense ratio is a determinant of institutional effectiveness (Jansson et al., 2003; Woller et al., 1999). Woller et al. (1999) further mentioned that an increase in administrative expense ratio translated into a reduction in financial self-sufficiency and vice versa. This paper suggests the opposite of what Woller et al. (1999) suggested. As such, we may argue that the MFIs may be successful to have a better financial performance yet they are having an increase in the administrative expense ratio. If it is true, then the credit goes to the management of those MFIs.

The real yield on gross portfolio illustrates that how much fees, interest, and commissions an MFI gets from its average gross loan portfolio (SEEP Network, 2010). Self-dependent MFIs are alleged to impose high-interest rates (Morduch, 2000). Any business required to set their policy so that they can continue their operation, not in the short-run but the long-run. "Subsidised MFIs were often

[30] Total Assets is commonly used as a proxy for bank size while microfinance institutions are considered as micro banks.

requested to enforce an interest rate ceiling, which was usually set at a level less than that required to cover its costs" (Louis et al., 2013).

This paper finds that (in summary statistics presented in Table 2) the average real yield is 26.3% which is lower than the number reported by Cull & Morduch (2007) (35.4%). One probable justification for this finding would be of MFIs has decreased their average yield taking into account the fact of increased number of competition within this industry (Louis et al., 2013). However, this might not true for all we have identified a minimum of 2.4% while the maximum of 71.6% is indicating a combination of subsidised and self-reliant MFIs accordingly.

5.2.6 Macroeconomic Specific Variables and Financial Performance

Talking about the macroeconomic-specific variable, we find that ***inflation*** positively correlated with MFIs' financial performance and this is true for all focused models (RE 2, 6, 10 and 16) where the significance level is 1%.

Although the nature of inflation is negative for financial performance, the interaction is a bit different for MFIs. Hartarska (2005) argues that yet inflation level negatively distresses sustainability, but MFIs in greater inflationary surroundings appear to reach greater borrowers. As such, MFIs may expect better financial performance is coming from a larger number of borrowers while there is an inflationary environment. However, this statement contradicts the finding of Vanroose & D'Espallier (2013) as they found that "MFIs perform better in countries that are not heavily affected by high inflation". Boyd et al. (2001) documented that the banking activities tend to be lower in regions that affected by heavy inflation. Therefore, our evidence also opposes the finding of Vanroose & D'Espallier (2013) and Boyd et al. (2001).

Secondly, our econometric results indicate that ***GDP growth*** negatively affects financial performance for the case of comprehensive ESG model (RE 2) with a significance level of 10%. However, the sub-models for discrete environmental, social and governance performance suggested in having an insignificant result. This finding opposes the study of Vanroose & D'Espallier (2013) where they note that a rising economy positively influences MFIs' performance and helps them to cover costs without difficulty and triggers demand for micro-loans. Moreover, Hassan et al. (2011) and Inoue & Hamori (2012) note that especially in developing economies, long-term economic growth and a healthy financial system are intensely linked as economic growth upsurges the demand for financial services, which eventually leads to financial performance.

The probable explanation of having a negative result for our case(s) is, the countries what belongs to our dataset might be unique compared to other developing countries. Secondly, this study finds a positive association with inflation and financial performance. Thus, that result might help those countries (what studied here) to have a negative GDP growth as opposed to other developing countries.

5.2.7 Dummy Variable

For OIC dummy, the result appears to be insignificant for main model and sub-models. That means, being established in an OIC country might not help MFI to be significantly different from other countries regarding performance. As such, the performance of ESG might contribute towards MFIs' financial performance in the same fashion no matter where MFIs are offering their products and services. However, Ashraf et al. (2014) witnessed that on average, MFIs are more likely to generate higher real yields on their gross portfolio in countries with deferred OIC membership. The also experienced that the determinants of MFI performance indicators differ between the non-OIC and OIC countries. Because, "The religious inclination variable may capture some unobservable features, such as a country's commitment toward Islamic principles and the overall religious conscience of the

country" (Ashraf et al., 2014). Since this study did not capture those unobservable features of religious inclination, the paper might be having an insignificant result for OIC dummy.

Furthermore, using 12 Islamic economic principles embodied by 113 economic proxies, Rehman & Askari (2010) tentatively studied 208 countries for Economic Islamicity Index (EI2). All twelve Islamic economic principles actually promote good economic and social policies alongside good governance. They found that Islamic countries (56 OIC countries) are not as Islamic, at least in the dominion of economics, compared to most developed countries. This study experimentally surmises that the poor economic development can be credited to age-old problems of developing countries such as bad economic policies, inefficient institutions, corruption, and other outdated developing country diseases. It is due to the shortcoming of the governments, not the religion Islam, that attributable to the miserable economic development in the Middle East. These finding may justify the finding of the OIC dummy.

5.3 Robustness Check

The paper initially has employed three econometric techniques – Fixed Effects, Random Effects and Pooled OLS to find out the best one for our study. This study tends to select Random Effects Estimator, having confirmed by Hausman and LM test. However, the author aimed at checking the robustness of the findings using robust Random Effects estimator[31] as presented in Table 5.

[Insert Table 5 around here]

It is normal to depend on "robust" standard errors to make sure valid statistical inference once some of the fundamental regression model's assumptions violated (Hoechle, 2007). Perhaps the most common of these substitute covariance matrix estimators has been developed by Huber (1967) and White (1980). "Heteroscedasticity-consistent or "White" standard errors are obtained by choosing option vce(robust)" (Hoechle, 2007). The robust Random Effects offer a heteroskedasticity-robust standard errors which is also known as Huber/White or sandwich estimators (Torres-Reyna, 2007). That is why this paper followed robust Random Effects as a robustness test.

The robust Random Effects indicate that women empowerment (WOEM) (a proxy for social performance) has no impact on MFI financial performance for the case comprehensive ESG model (RE_r 2). This result contradicts our earlier finding that women empowerment negative affect financial performance. Considering robust Random Effects is superior compared to original Random Effects, we tend to follow the findings of robustness check discarding earlier one. However, for the case of discrete social performance model (RE_r 10), women empowerment appears to be negatively significant (at 10% significance level) which is in line with the prior finding of this study. For Hermes et al. (2011), the negatively significant result of women empowerment remained robustly significant after adding further control variables. Therefore, we may argue that women empowerment negatively affects financial performance while we consider only social performance, not all three aspects together. We also may say that women empowerment may deteriorate financial performance when MFI consider only social performance is keeping environmental and governance performance aside. However, the robust Random Effects suggest that GDP growth might affect MFIs' financial performance negatively for the comprehensive ESG model and environmental and social model while it would not have any connection with distinctive governance model. This result opposes the finding of Vanroose & D'Espallier (2013). These also result contradicts the earlier finding (found in Table 4) that GDP growth to be negative for comprehensive ESG model only. Although we supposed to follow the latest findings of robust Random Effects rejecting the earlier one, we discard this result

[31] Using "xtreg $Y $X, re vce(robust)" command

favouring the finding of Vanroose & D'Espallier (2013). Because this paper also believes that GDP growth supposed to contribute financial performance positively.

We further observed an interesting finding from robustness check, is that when we include total assets (l_ASST), cost per borrowers (l_CPB) and administrative expense ratio (AEXR) in the model, we find a notable influence of both the environmental (ENV) and governance performance (FeBM) over financial performance. We know that higher the total assets better the health of the organisation is (say, MFIs) while the lower level of cost per borrower (l_CPB) and administrative expense ratio result in better financial performance. With that, we may argue that if the financial health is sound enough for MFIs, it might translate into a better environmental and governance performance what we have witnessed here. The robustness check confirms most of the earlier findings. Thus, this study might be a reliable source to rely upon and formulate further policies based on it.

6.0 Conclusion

6.1 Summary of the Findings

This study made a humble attempt in detecting whether ESG performance has any contribution to MFIs' financial performance which may support MFIs in having a sustainable development to serve the poor better. As such, MFIs may sustain in the market for a long period to offer diverse products and services based on microloan attaining societal development, reduction in poverty, enriching human lives and upgrading the lifestyle of the poor.

The model with all the ESG variables and the models with discrete environmental, social and governance variables offers almost same results regarding ESG and financial performance nexus. Econometric evidence suggests that environmental performance has a significantly positive impact on financial performance. It may be because MFIs aim to enhance the performance of environment as a part of their "Triple Bottom Line" objective hence they might be enjoining a better financial performance.

The first proxy for social performance - women empowerment appears to have no impact on financial performance in case of comprehensive ESG performance as suggested by robust Random Effects. This result somewhat supported by earlier literature that increased number of women borrowers does not necessarily bring financial performance to the MFI. However, women empowerment also found deteriorative to financial performance for the case of discrete social performance.

The depth of outreach, the second aspect of financial performance tend to have a significantly positive impact on MFIs' financial performance. This finding confirms one prior study that a deep retail banking presence, as well as the formation of widespread branch networks of MFI, helps them in getting substantial implications for both the financial and operating performance. With this, we may then conclude that social performance does have a noteworthy impact on MFIs' financial performance considering our econometric findings.

Governance performance seems to have a significantly positive effect on financial performance for comprehensive ESG performance. However, we witness no significant impact of governance performance on financial performance when we study governance performance individually. This result somewhat validates the finding of one former study what failed to find a direct influence on governance over financial performance.

The macroeconomic-specific variable, inflation is found to be positively correlated with MFIs' financial performance which is quite interesting. Hartarska (2005) argued that MFIs in greater inflationary surroundings appear to reach greater borrowers. Thus they may expect better financial

performance. The OIC dummy appears to be insignificant for main model and sub-models, and these results remained valid for robustness test as well. We may argue that the ESG performance might contribute MFIs' financial performance in the same fashion no matter where MFIs are offering their products and services.

Finally, we may conclude that the ESG performance has a significantly positive impact on MFIs' financial performance keeping the findings of discrete governance and women empowerment aside. With that, the findings of this paper answers that ESG performance contribute unto MFIs' financial performance for the periods under investigation.

6.2 Policy Implications and Significance

The findings will have manifold implications for diverse classes of stakeholders like governments, donors, NGOs and others. The probable policy implications would be of the following. (1) the regulators should create a comprehensive framework to encourage MFI's to be more engaged in environmental and other aspects of ESG which impacts financial performance positively. (2) the investors may get a relatively higher return by focusing on those MFIs' which are more engaged in ESG. (3) MFIs' should engage more in ESG especially environmental contribution to signal the market about their social responsibilities.

For significance, the study might attract more potential investors so that they can engage with MFIs fruitfully getting an optimum financial performance throughs better ESG performance. In a nutshell, the viable results aim to lead unto a fruitful attempt to poverty alleviation, enriching living standards, social welfare and environmental development. It will be true following more investments coming from active investors helping the poor clients further. The paper does believe, as this study might be a new addition to its kind, would be able to leave an impactful contribution to the research and practices yet to come.

6.3 Limitations of the Study and Future Research

We acknowledge that the limitations of this study are manifold. Firstly, this study suffers from a lack of observations as the MIX has a limited number of ESG data. Secondly, this is a cross-country study but covers only 34 countries and 62 MFIs of the world. Thirdly, the study could have been more robust if we have had a higher frequency of data, for example, quarterly data. Taking these limitations into consideration, one can extend the scope of this study further. However, the study could also be expanded, making a comparison between additional countries, MFIs and regions. Nevertheless, with a large sample size and advanced econometrics techniques such as GMM (Generalised Method of Moments) or other variables, one may find better results.

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Table 1: Definition and Sources of the Variables

	Code	Variable Name	Explanations/Proxies	Source
Dependent Variable	**Financial Performance**			
	ROA	Return on Assets (%)	Net Operating Income After Taxes / Average Total Assets	Mixmarket
Independent Variables	**Environment Performance**			
	ENV	Environmental Policies & Initiatives (0/1)	The institution includes clauses in loan contracts that require clients to improve practices/mitigate environmental risk.	Mixmarket
	Social Performance			
	WOEM	Women Empowerment (%)	Percentage of Female Borrowers	Mixmarket
	ALBGNI	Depth of Outreach (%)	Average Loan Balance Per Borrower / GNI per capita	Mixmarket/ IFS (IMF)
	Governance Performance			
	FeBM	Governance (%)	Percent of Female Board Members	Mixmarket
	MFI Specific Control Variables			
	ASST	Total Assets (US$)	Total of All Net Asset Accounts *(Logged)*	Mixmarket
	CPB	Cost Per Borrower (US$)	Operating Expense / Number of Active Borrowers, Average *(Logged)*	Mixmarket
	AEXR	Administrative Expense Ratio (%)	(Administrative Expense + Depreciation) / Assets, Average	Mixmarket
	YGP	Yield on Gross Portfolio (Real) (%)	(Yield on Gross Portfolio (Nominal) - Inflation Rate) / (1 + Inflation Rate)	Mixmarket, IFS (IMF)
	Macroeconomic Specific Control Variables			
	GDPG	GDP Growth Rate (%)	Percent Increase in the GDP from Year to Year	IFS (IMF)
	INF	Inflation (CPI) (Scale)	Consumer Price Index	IFS (IMF)
	Dummy Variable			
	dOIC	OIC Dummy (0/1)	Dummy for OIC Countries	Own Calc.

Table 2: Summary Statistics

Variable	Code	Obs.	Mean	Std. Dev.	Min	Max
Return on Assets	ROA	79	0.029	0.056	-0.232	0.188
Environmental Policies & Initiatives	ENV	82	0.305	0.463	0.000	1.000
Women Empowerment	WOEM	74	0.714	0.233	0.28	1.000
Depth of Outreach	ALBGNI	82	0.579	1.485	0.023	10.519
Governance	FeBM	72	0.375	0.243	0.000	1.000
Total Assets	l_ASST	74	17.092	1.621	12.175	21.174
Cost per Borrowers	l_CPB	79	4.686	1.046	2.591	7.367
Administrative Expense Ratio	AEXR	79	0.074	0.056	0.01	0.421
Real Yield	YGP	80	0.263	0.135	0.024	0.716
GDP Growth	GDPG	82	5.391	3.906	-15.09	17.29
Inflation	INF	82	6.14	4.722	-0.94	22.77

(1) Total Assets and Cost per Borrowers are in natural logged form; (2) "l_" stand for the log.

The summary statistics also suggests that the deviation of inflation and GDP growth does vary quite significantly. While the min of the variables varies from -15.09 to 12.175, the max of the variables as seen by -0.188 to 22.77.

Table 3: Pearson Correlation Matrix

	ROA	ENV	WOEM	ALBGNI	FeBM	l_ASST	l_CPB	AEXR	YGP	GDPG	INF
ROA	1										
ENV	-0.0826	1									
WOEM	-0.1667	-0.206	1								
ALBGNI	0.2904*	-0.0453	-0.3413*	1							
FeBM	-0.0187	-0.1798	0.3415*	-0.0624	1						
l_ASST	0.1707	0.0569	-0.4102*	0.0977	-0.3213*	1					
l_CPB	0.0373	0.2261*	-0.7905*	0.4418*	-0.182	0.2846*	1				
AEXR	-0.5392*	0.1436	0.3358*	-0.192	0.0466	-0.3815*	-0.126	1			
YGP	-0.1562	0.0569	0.3218*	-0.1111	0.112	-0.3978*	-0.012	0.7759*	1		
GDPG	0.0479	-0.093	0.2730*	0.1149	0.1404	-0.0528	-0.1812	-0.0212	0.0749	1	

INF	-0.0751	-0.092	0.1504	0.1682	-0.1319	-0.0222	-0.3293*	0.1212	-0.2314*	0.0154	1

(1) * $p < 0.05$; (2) "l_" stand for log; (3) TA and CPB are in naturally logged form.

Table 4: Econometric Evidence using Random Effects (RE)

	W/ ESG	ESG				Environmental Performance (E)				Social Performance (S)						Governance Performance (G)			
	(RE 1)	(RE 2)	(RE 3)	(RE 4)	(RE 5)	(RE 6)	(RE 7)	(Re 8)	(RE 9)	(RE 10)	(RE 11)	(RE 12)	(RE 13)	(RE 14)	(RE 15)	(RE 16)	(RE 17)	(RE 18)	(RE 19)
Variable	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA
ENV		0.021**	0.021**	0.021**	0.007	0.018**	0.019**	0.018**	0.001										
		[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]										
WOEM		-0.090**	-0.094**	0.001	0.016					-0.088**	-0.076		-0.093**	-0.000	0.017				
		[0.04]	[0.05]	[0.03]	[0.04]					[0.04]	[0.05]		[0.04]	[0.03]	[0.04]				
ALBGNI		0.014***	0.012***	0.008**	0.016**					0.013***		0.012***	0.012***	0.008*	0.016**				
		[0.00]	[0.00]	[0.00]	[0.01]					[0.00]		[0.00]	[0.00]	[0.00]	[0.01]				
FeBM		0.037*	0.031*	0.030	0.018											0.016	0.013	0.011	0.011
		[0.02]	[0.02]	[0.02]	[0.03]											[0.02]	[0.02]	[0.02]	[0.03]
l_ASST	0.001	0.005				0.002				0.003	0.001	0.004				0.002			
	[0.00]	[0.00]				[0.00]				[0.00]	[0.00]	[0.00]				[0.00]			
l_CPB	-0.000	-0.027***	-0.024**			-0.002	0.000			-0.026***	-0.013	-0.011*	-0.024**			0.000	0.001		
	[0.01]	[0.01]	[0.01]			[0.01]	[0.00]			[0.01]	[0.01]	[0.01]	[0.01]			[0.01]	[0.01]		
AEXR	-1.294***	-1.323***	-1.336***	-1.317***		-1.363***	-1.337***	-1.335***		-1.250***	-1.321***	-1.215***	-1.263***	-1.238***		-1.295***	-1.298***	-1.312***	
	[0.14]	[0.14]	[0.14]	[0.14]		[0.15]	[0.14]	[0.14]		[0.14]	[0.14]	[0.14]	[0.14]	[0.14]		[0.15]	[0.15]	[0.14]	
YGP	0.386***	0.455***	0.437***	0.378***	-0.077	0.406***	0.388***	0.385***	-0.071	0.434***	0.432***	0.378***	0.425***	0.365***	-0.069	0.385***	0.376***	0.380***	-0.081
	[0.06]	[0.07]	[0.07]	[0.06]	[0.06]	[0.06]	[0.06]	[0.06]	[0.05]	[0.07]	[0.07]	[0.06]	[0.07]	[0.06]	[0.06]	[0.07]	[0.06]	[0.06]	[0.06]
GDPG	-0.001	-0.002*	-0.002*	-0.001	-0.001	-0.001	-0.001	-0.001	-0.000	-0.001	-0.001	-0.002	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.000
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
INF	0.004***	0.003***	0.003***	0.004***	-0.001	0.004***	0.003***	0.003***	-0.001	0.003***	0.004***	0.003***	0.003***	0.003***	-0.001	0.004***	0.004***	0.004***	-0.001
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
dOIC	0.004	-0.005	-0.005	0.006	0.018	0.001	-0.001	-0.001	0.013	-0.005	-0.003	0.003	-0.006	0.005	0.017	0.004	0.004	0.004	0.014
	[0.01]	[0.01]	[0.01]	[0.01]	[0.02]	[0.01]	[0.01]	[0.01]	[0.02]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.02]	[0.01]	[0.01]	[0.01]	[0.02]
Wald χ2	89.61***	**134.16*****	127.22***	110.27***	9.91	**95.42*****	91.43***	93.54***	2.53	**117.86*****	92.10***	110.95***	116.97***	100.33***	9.51	88.31***	88.74***	**93.82*****	2.85
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
R^2	0.565	**0.667**	0.648	0.571	0.128	**0.561**	0.519	0.521	0.045	**0.672**	0.606	0.625	0.660	0.581	0.138	**0.562**	0.555	0.559	0.050

N	73	70	70	70	70	73	79	79	79	72	72	73	72	72	72	71	71	71	71

(1) Standard errors in brackets, [.]; (2) *p*-values in parentheses, (.); (3) * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; (4) RE = Random Effects; (5) "l_" = Natural Log; (6) RE follow Wald Test.

Table 5: Robustness Test using Robust Random Effects (RE_r)

	W/ ESG	ESG				Environmental Performance (E)				Social Performance (S)						Governance Performance (G)			
Variable	RE_r 1 ROA	RE_r 2 ROA	RE_r 3 ROA	RE_r 4 ROA	RE_r 5 ROA	RE_r 6 ROA	RE_r 7 ROA	RE_r 8 ROA	RE_r 9 ROA	RE_r 10 ROA	RE_r 11 ROA	RE_r 12 ROA	RE_r 13 ROA	RE_r 14 ROA	RE_r 15 ROA	RE_r 16 ROA	RE_r 17 ROA	RE_r 18 ROA	RE_r 19 ROA
ENV		0.021**	0.021**	0.021**	0.007	0.018*	0.019**	0.018**	0.001										
		[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]										
WOEM		-0.090	-0.094	0.001	0.016					-0.088*	-0.076		-0.093*	-0.000	0.017				
		[0.06]	[0.06]	[0.03]	[0.04]					[0.05]	[0.05]		[0.05]	[0.03]	[0.04]				
ALBGNI		0.014***	0.012***	0.008***	0.016***					0.013***		0.012***	0.012***	0.008***	0.016***				
		[0.00]	[0.00]	[0.00]	[0.00]					[0.00]		[0.00]	[0.00]	[0.00]	[0.00]				
FeBM		0.037**	0.031*	0.030**	0.018											0.016	0.013	0.011	0.011
		[0.02]	[0.02]	[0.01]	[0.02]											[0.01]	[0.01]	[0.01]	[0.02]
l_ASST	0.001	0.005*				0.002				0.003	0.001	0.004				0.002			
	[0.00]	[0.00]				[0.00]				[0.00]	[0.00]	[0.00]				[0.00]			
l_CPB	-0.000	-0.027**	-0.024**			-0.002	0.000			-0.026**	-0.013	-0.011	-0.024**			0.000	0.001		
	[0.01]	[0.01]	[0.01]			[0.01]	[0.01]			[0.01]	[0.01]	[0.01]	[0.01]			[0.01]	[0.01]		
AEXR	-1.294***	-1.323***	-1.336***	-1.317***		-1.363***	-1.337***	-1.335***		-1.250***	-1.321***	-1.215***	-1.263***	-1.238***		-1.295***	-1.298***	-1.312***	
	[0.17]	[0.15]	[0.14]	[0.15]		[0.17]	[0.17]	[0.17]		[0.16]	[0.17]	[0.15]	[0.15]	[0.16]		[0.16]	[0.16]	[0.16]	
YGP	0.386***	0.455***	0.437***	0.378***	-0.077	0.406***	0.388***	0.385***	-0.071	0.434***	0.432***	0.378***	0.425***	0.365***	-0.069	0.385***	0.376***	0.380***	-0.081
	[0.07]	[0.07]	[0.07]	[0.07]	[0.13]	[0.07]	[0.07]	[0.07]	[0.11]	[0.07]	[0.08]	[0.06]	[0.07]	[0.07]	[0.13]	[0.06]	[0.07]	[0.06]	[0.12]
GDPG	-0.001	-0.002***	-0.002***	-0.001**	-0.001	-0.001*	-0.001*	-0.001*	-0.000	-0.001**	-0.001	-0.002**	-0.001**	-0.001	-0.001	-0.001	-0.001	-0.001	-0.000
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
INF	0.004***	0.003***	0.003***	0.004***	-0.001	0.004***	0.003***	0.003***	-0.001	0.003***	0.004***	0.003***	0.003***	0.003***	-0.001	0.004***	0.004***	0.004***	-0.001
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
dOIC	0.004	-0.005	-0.005	0.006	0.018	0.001	-0.001	-0.001	0.013	-0.005	-0.003	0.003	-0.006	0.005	0.017	0.004	0.004	0.004	0.014
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
R^2	0.565	**0.667**	0.571	0.57	0.128	**0.561**	0.519	0.521	0.044	**0.672**	0.606	0.625	0.660	0.581	0.138	**0.562**	0.555	0.559	0.050

Wald $\chi 2$	74.82***	**689.14***	585.76***	277.71***	28.42***	**88.12***	83.19***	76.20***	1.08	**560.79***	80.13***	461.57***	529.56***	233.04***	29.12***	84.12***	87.29***	**89.91***	1.66
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.96]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.89]
N	73	70	70	70	70	73	79	79	79	72	72	73	72	72	72	71	71	71	71

(1) Standard errors in brackets, [.]; (2) *p*-values in parentheses, (.); (3) * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; (4) RE_r = Robust Random Effects; (6) "l_" = Natural Log; (7) RE follow Wald Test.

A1: Fixed Effects (FE) VS Random Effects (RE)

	W/ ESG		ESG				Environmental Performance (E)				Social Performance (S)						Governance Performance (G)			
	(FE 1)	(RE 1)	(FE 2)	(RE 2)	(FE 3)	(RE 3)	(FE 4)	(RE 4)	(FE 5)	(RE 5)	(FE 6)	(RE 6)	(FE 7)	(RE 7)	(FE 8)	(RE 8)	(FE 9)	(RE 9)	(FE 10)	(RE 10)
Variable	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA
ENV			0.028	0.021**	0.030	0.021**	0.025*	0.018**	0.026**	0.019**										
			[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]										
WOEM			-0.011	-0.090**	0.030	-0.094**					-0.408	-0.088**	-0.409	-0.076						
			[0.47]	[0.04]	[0.37]	[0.05]					[0.28]	[0.04]	[0.27]	[0.05]						
ALBGNI			-0.010	0.014***	-0.015	0.012***					-0.009	0.013***			-0.013	0.012***				
			[0.09]	[0.00]	[0.08]	[0.00]					[0.08]	[0.00]			[0.08]	[0.00]				
FeBM			0.017	0.037*	0.018	0.031*											-0.012	0.016	-0.007	0.013
			[0.04]	[0.02]	[0.04]	[0.02]											[0.04]	[0.02]	[0.03]	[0.02]
l_ASST	-0.013	0.001	-0.003	0.005			-0.006	0.002			-0.017	0.003	-0.018	0.001	-0.012	0.004	-0.014	0.002		
	[0.01]	[0.00]	[0.02]	[0.00]			[0.01]	[0.00]			[0.02]	[0.00]	[0.01]	[0.00]	[0.02]	[0.00]	[0.02]	[0.00]		
l_CPB	0.117**	-0.000	0.073	-0.027***	0.073	-0.024**	0.080*	-0.002	0.073*	0.000	0.077	-0.026***	0.076	-0.013	0.118**	-0.011*	0.118**	0.000	0.104**	0.001
	[0.04]	[0.01]	[0.06]	[0.01]	[0.05]	[0.01]	[0.04]	[0.01]	[0.04]	[0.00]	[0.05]	[0.01]	[0.05]	[0.01]	[0.05]	[0.01]	[0.05]	[0.01]	[0.04]	[0.01]
AEXR	-1.957***	-1.294***	-1.821**	-1.323***	-1.804**	-1.336***	-1.862***	-1.363***	-1.722***	-1.337***	-1.556**	-1.250***	-1.564**	-1.321***	-1.943**	-1.215***	-1.964**	-1.295***	-1.631***	-1.298***
	[0.63]	[0.14]	[0.75]	[0.14]	[0.71]	[0.14]	[0.56]	[0.15]	[0.45]	[0.14]	[0.69]	[0.14]	[0.66]	[0.14]	[0.66]	[0.14]	[0.65]	[0.15]	[0.53]	[0.15]
YGP	0.502**	0.386***	0.552**	0.455***	0.547**	0.437***	0.569***	0.406***	0.541***	0.388***	0.474**	0.434***	0.479**	0.432***	0.496**	0.378***	0.516**	0.385***	0.432**	0.376***
	[0.20]	[0.06]	[0.22]	[0.07]	[0.21]	[0.07]	[0.18]	[0.06]	[0.16]	[0.06]	[0.20]	[0.07]	[0.19]	[0.07]	[0.21]	[0.06]	[0.21]	[0.07]	[0.19]	[0.06]
GDPG	-0.001	-0.001	-0.002	-0.002*	-0.002	-0.002*	-0.002	-0.001	-0.002	-0.001	-0.002	-0.001	-0.002	-0.001	-0.001	-0.002	-0.001	-0.001	-0.001	-0.001
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
INF	0.005**	0.004***	0.005*	0.003***	0.005**	0.003***	0.005**	0.004***	0.005**	0.003***	0.004*	0.003***	0.004*	0.004***	0.005**	0.003***	0.005**	0.004***	0.005**	0.004***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]

dOIC		0.004		-0.005		-0.005		0.001		-0.001		-0.005		-0.003		0.003		0.004		0.004
		[0.01]		[0.01]		[0.01]		[0.01]		[0.01]		[0.01]		[0.01]		[0.01]		[0.01]		[0.01]
Hausman	9.16		8.97		9.29		10.52		9.90		12.68		13.31		9.15		8.56		7.91	
Test	(0.17)		(0.54)		(0.41)		(0.16)		(0.13)		(0.12)		(0.07)		(0.24)		(0.29)		(0.25)	
Wald χ2	-	89.61***	-	134.16***	-	127.22***	-	95.42***	-	91.43***	-	117.86***	-	92.10***	-	110.95***	-	88.31***	-	88.74***
		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		[0.00]
R^2	**0.588**	0.565	**0.705**	0.667	0.704	0.648	**0.697**	0.561	0.692	0.519	**0.654**	0.672	0.653	0.606	0.589	0.625	**0.592**	0.562	0.566	0.555
F	3.093	-	2.149	-	2.643	-	3.939	-	4.871	-	2.597	-	3.232	-	2.456	-	2.490	-	2.821	-
N	73	73	70	70	70	70	73	73	79	79	72	72	72	72	73	73	71	71	71	71

(1) Standard errors in brackets, [.]; (2) *p*-values in parentheses, (.); (3) * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ (4) FE = Fixed Effects & RE = Random Effects (6) "l_" = Natural Log (7) RE follow Wald Test while FE take F Test

A2: Pooled OLS (POLS) VS Random Effects (RE)

	W/ ESG		ESG				Environmental Performance (E)				Social Performance (S)						Governance Performance (G)			
	(POLS 1)	(RE 1)	(POLS 2)	(RE 2)	(POLS 3)	(RE 3)	(POLS 4)	(RE 4)	(POLS 5)	(RE 5)	(POLS 6)	(RE 6)	(POLS 7)	(RE 7)	(POLS 8)	(RE 8)	(POLS 9)	(RE 9)	(POLS 10)	(RE 10)
Variable	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA
ENV			0.008	0.021**	0.007	0.021**	0.008	0.018**	0.010	0.019**										
			[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]										
WOEM			-0.128***	-0.090**	-0.132***	-0.094**					-0.124***	-0.088**	-0.123***	-0.076						
			[0.04]	[0.04]	[0.04]	[0.05]					[0.04]	[0.04]	[0.04]	[0.05]						
ALBGNI			0.014***	0.014***	0.013***	0.012***					0.014***	0.013***			0.014***	0.012***				
			[0.00]	[0.00]	[0.00]	[0.00]					[0.00]	[0.00]			[0.00]	[0.00]				
FeBM			0.020	0.037*	0.011	0.031*											-0.000	0.016	-0.006	0.013
			[0.02]	[0.02]	[0.02]	[0.02]											[0.02]	[0.02]	[0.02]	[0.02]
l_ASST	0.003	0.001	0.006*	0.005			0.003	0.002			0.005	0.003	0.002	0.001	0.006*	0.004	0.004	0.002		
	[0.00]	[0.00]	[0.00]	[0.00]			[0.00]	[0.00]			[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]		
l_CPB	-0.005	-0.000	-0.037***	-0.027***	-0.035***	-0.024**	-0.006	-0.002	-0.003	0.000	-0.037***	-0.026***	-0.026***	-0.013	-0.015***	-0.011*	-0.005	0.000	-0.003	0.001
	[0.00]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]	[0.00]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]	[0.01]
AEXR	-1.348***	-1.294***	-1.339***	-1.323***	-1.354***	-1.336***	-1.375***	-1.363***	-1.330***	-1.337***	-1.320***	-1.250***	-1.405***	-1.321***	-1.263***	-1.215***	-1.350***	-1.295***	-1.352***	-1.298***
	[0.16]	[0.14]	[0.15]	[0.14]	[0.15]	[0.14]	[0.16]	[0.15]	[0.16]	[0.14]	[0.14]	[0.14]	[0.15]	[0.14]	[0.15]	[0.14]	[0.16]	[0.15]	[0.16]	[0.15]
YGP	0.422***	0.386***	0.509***	0.455***	0.488***	0.437***	0.429***	0.406***	0.390***	0.388***	0.501***	0.434***	0.508***	0.432***	0.415***	0.378***	0.422***	0.385***	0.406***	0.376***
	[0.07]	[0.06]	[0.07]	[0.07]	[0.07]	[0.07]	[0.07]	[0.06]	[0.07]	[0.06]	[0.07]	[0.07]	[0.07]	[0.07]	[0.06]	[0.06]	[0.07]	[0.07]	[0.07]	[0.06]
GDPG	-0.001	-0.001	-0.002	-0.002*	-0.001	-0.002*	-0.001	-0.001	-0.001	-0.001	-0.002	-0.001	-0.000	-0.001	-0.002*	-0.002	-0.001	-0.001	-0.001	-0.001
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
INF	0.004***	0.004***	0.004***	0.003***	0.003***	0.003***	0.004***	0.004***	0.004***	0.003***	0.003***	0.003***	0.004***	0.004***	0.003**	0.003***	0.004***	0.004***	0.004***	0.004***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
dOIC	-0.002	0.004	-0.013	-0.005	-0.014	-0.005	-0.002	0.001	-0.004	-0.001	-0.014	-0.005	-0.014	-0.003	-0.002	0.003	-0.002	0.004	-0.002	0.004
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
LM Test	24.70***		18.58***		20.31***		26.75***		28.66***		13.29***		14.15***		25.38***		23.78***		7.91	
	(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.25)	
Wald χ2	-	89.61***	-	134.16***	-	127.22***	-	95.42***	-	91.43***	-	117.86***	-	92.10***	-	110.95***	-	88.31***	-	88.74***
		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)
R^2	**0.573**	0.565	**0.690**	0.667	0.674	0.648	**0.577**	0.561	0.532	0.519	**0.683**	0.672	0.625	0.606	0.630	0.625	**0.575**	0.562	0.568	0.555
F	12.47	-	11.75	-	12.18	-	10.91	-	11.53	-	14.84	-	13.11	-	13.65	-	10.47	-	11.82	-
N	73	73	70	70	70	70	73	73	79	79	72	72	72	72	73	73	71	71	71	71

(1) Standard errors in brackets, [.]; (2) *p*-values in parentheses, (.); (3) * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ (4) POLS = Pooled OLS & RE = Random Effects (6) "l_" = Log (7) RE follow Wald Tes1t while POLS take F Test

A3: List of MFIs that used for the Study

#	MFI Name	Country	Region
1	SEF-ARM	Armenia	Eastern Europe and Central Asia
2	Azercredit	Azerbaijan	Eastern Europe and Central Asia
3	SSS	Bangladesh	South Asia
4	CTS	Bangladesh	South Asia
5	Vital Finance	Benin	Africa
6	Banco FIE	Bolivia	Latin America and The Caribbean
7	CRECER	Bolivia	Latin America and The Caribbean
8	Emprender	Bolivia	Latin America and The Caribbean
9	LIDER	Bosnia and Herzegovina	Eastern Europe and Central Asia
10	Partner	Bosnia and Herzegovina	Eastern Europe and Central Asia
11	EKI	Bosnia and Herzegovina	Eastern Europe and Central Asia
12	PRIZMA	Bosnia and Herzegovina	Eastern Europe and Central Asia
13	VisionFund Cambodia	Cambodia	East Asia and the Pacific
14	Chamroeun	Cambodia	East Asia and the Pacific
15	Fundaci¢n Amanecer	Colombia	Latin America and The Caribbean
16	Confiar	Colombia	Latin America and The Caribbean
17	ADRI	Costa Rica	Latin America and The Caribbean
18	Banco ADEMI	Dominican Republic	Latin America and The Caribbean
19	Moris Rasik	East Timor	East Asia and the Pacific
20	VISIONFUND ECUADOR-FODEMI	Ecuador	Latin America and The Caribbean
21	FACES	Ecuador	Latin America and The Caribbean
22	CACMU	Ecuador	Latin America and The Caribbean
23	VF Ethiopia	Ethiopia	Africa
24	Crystal	Georgia	Eastern Europe and Central Asia
25	Friendship Bridge	Guatemala	Latin America and The Caribbean
26	ODEF Financiera	Honduras	Latin America and The Caribbean
27	Grameen Koota	India	South Asia
28	BISWA	India	South Asia
29	ESAF	India	South Asia
30	Arohan	India	South Asia
31	Belghoria	India	South Asia
32	MCM	India	South Asia
33	MBK Ventura	Indonesia	East Asia and the Pacific
34	Amartha Microfinance	Indonesia	East Asia and the Pacific
35	DEF	Jordan	Middle East and North Africa
36	NKCF LLC	Kazakhstan	Eastern Europe and Central Asia
37	KMF	Kazakhstan	Eastern Europe and Central Asia
38	KosInvest	Kosovo	Eastern Europe and Central Asia
39	WFDF	Laos	East Asia and the Pacific
40	MLF MWI	Malawi	Africa
41	XacBank	Mongolia	Eastern Europe and Central Asia
42	Ochir-Undraa OMZ	Mongolia	Eastern Europe and Central Asia
43	Asasah	Pakistan	South Asia
44	Fundación Paraguaya	Paraguay	Latin America and The Caribbean
45	FINCA - PER	Peru	Latin America and The Caribbean
46	MiBanco	Peru	Latin America and The Caribbean
47	ADRA Peru	Peru	Latin America and The Caribbean
48	Manuela Ramos	Peru	Latin America and The Caribbean
49	Microfinanzas PRISMA	Peru	Latin America and The Caribbean
50	EDPYME Raiz	Peru	Latin America and The Caribbean
51	ASKI	Philippines	East Asia and the Pacific
52	NWTF	Philippines	East Asia and the Pacific
53	CEVI	Philippines	East Asia and the Pacific
54	ASA Philippines	Philippines	East Asia and the Pacific
55	OBS	Serbia	Eastern Europe and Central Asia
56	FMFB - TJK	Tajikistan	Eastern Europe and Central Asia
57	MDO Arvand	Tajikistan	Eastern Europe and Central Asia
58	IMON INTERNATIONAL	Tajikistan	Eastern Europe and Central Asia
59	PRIDE - TZA	Tanzania	Africa
60	Enda	Tunisia	Middle East and North Africa
61	CEP	Vietnam	East Asia and the Pacific
62	Al Amal Bank	Yemen	Middle East and North Africa