Oil Price & Exchange Rate: A Comparative Study between Net Oil Exporting and Net Oil Importing Countries

MUKHRIZ IZRAF AZMAN AZIZ[1]

Lancaster University

August 2009

Abstract

The goal of this paper is to estimate the long run effects of real oil price and real interest rate differential on real exchange rate for a monthly panel of 8 countries from 1980 to 2008. The modelling exercise follows three steps. In the first step, the paper investigates the integrational properties of the data and finds them to be integrated of order one. In the second step, using several different panel cointegration tests, the paper finds evidence for cointegration among the three variables. In the third step, using pooled mean group estimator, the paper finds a positive and statistically significant impact of real oil price on real exchange rate for net oil importing countries, implying that increase in oil price leads to real exchange rate depreciation. In contrast, there is no evidence of long run relationship between real oil price and real exchange rate in a panel that consists of net oil exporting countries.

Keywords: Oil Price; Exchange Rate; Cointegration

JEL classification: F31, Q43

[1] Tel: 01524-94063; e-mail: m.azmanaziz@lancaster.ac.uk
The author would like to thank Dr. Kwok Tong Soo for valuable comments on earlier drafts.

1. Introduction

It has been widely accepted that oil price shocks contributed, at least in part, to the recession of the 1970s and 1980s. From the seminal work of Hamilton (1983), Burbidge and Harrison (1984) and Rotenberg and Woodford (1996) among others, these literatures had contributed to the understanding of the impacts of oil price shocks on macroeconomic variables. Although recent studies showed that the oil price-macroeconomy relationship has weakened following the collapse of oil prices in 1986[2], Hamilton (1996) and Hooker (1999) still show that oil prices play a significant role in explaining business cycles and unemployment. However, less attention has been paid to the relationship between the real exchange rates and the real price of oil. In 1973-1974, the US dollar appreciated in the wake of unexpected oil price hikes, but tended to depreciate in 1979 following news about oil price rises. In 1980 the pattern shifted once again, back to US dollar appreciation. The recent surge in oil prices till mid-2007 was followed by depreciation in the US dollar and other major currencies. The question is, is there a rational fundamental explanation for the behaviour of the foreign exchange market, or is it a matter of traders responding to what other traders arbitrarily think? It may be difficult to resolve this question, but some insight can be provided through an analytical examination of the relationship between oil price changes and exchange rates.

Since real exchange rates are computed with price indices, comprising different commodities with different weights, real exchange rates are relative prices. Moreover, as countries differ in the extent to which oil is an output included in the commodity price index, nonstationary oil price changes should be reflected in non-stationary real exchange rate changes (Chaudhuri and Daniel, 1998). The potential significance of the price of oil for exchange rate movements has been noted by, inter alia (Golub, 1983, Krugman, 1983a, Krugman, 1983b). There is a strong consensus among researchers[3] who examined the contribution of real oil price behaviour to the non-stationary behaviour of real exchange rates over the post-Bretton Woods period. Evidence showed that real exchange rate and real oil price are cointegrated and that oil prices may have been the dominant source of persistent shocks and the non-stationary behaviour of US Dollar real exchange rates over the post-Bretton Woods period.

Theoretically, it is well established that an oil-exporting country may experience exchange rate appreciation (fall in exchange rates) when oil prices rise and depreciation (increase in exchange rates) when they fall (see, e.g. Golub 1983; (Corden, 1984). In

[2] See for example Lee and Ni (1995), Hooker (1996)
[3] See Amano and Van Norden, 1988a,b and Chaudari and Daniel, 1988 for evidence.

comparing a country that is self-sufficient in oil with one which requires to import oil, the former, ceteris paribus, would exhibit an appreciation as the price of oil rose in terms of the other country. More generally, countries which have at least some oil resources could find their currencies appreciating relative to countries which do not have oil resources (MacDonald, 1998). Literature has generally found a negative relationship between oil price and exchange rate in oil-exporting countries. In other words, an increase in oil prices leads to an appreciation of the domestic currency. (Korhonen and Juurikkala, 2009) studied its link and found oil price negatively affect exchange rate for OPEC countries. (Koranchelian et al., 2005, Zalduendo, 2006) look at the effects of oil price on the real exchange rate in an oil-exporting country (Algeria and Venezuela, respectively). Koranchelian et al. (2005) finds that the long-run real exchange rate of Algeria is dependent on movements in relative productivity and real oil prices. Zalduendo (2006) using vector error correction model finds that increases in oil prices are associated with the appreciation pressures (and vice versa for price declines). There is also, however, a trend decline in the equilibrium rate that appears to be explained by depreciating pressures arising from the sharp decline in productivity differentials recorded by the Venezuelan economy, against the backdrop of a marked increase in economic volatility. (Olomola and Adejumo, 2006) use quarterly data over the period 1970–2003 to examine the relationship between real oil price shock and real effective exchange rates, among other macro variables, for Nigeria. Applying the variance decomposition technique, based on a VAR model, they find that real oil prices lead to an appreciation of the real exchange rate.

Studies of oil price-exchange rate relationship in oil importing countries clustered mainly among developed economies. (Chen and Chen, 2007) in a panel study of G7 countries showed that real oil prices may have been the dominant source of real exchange rate movements and there is a positive link between oil prices and real exchange rate. (Benassy-Quere et al., 2007) in the study of cointegration and causality between the real price of oil and the real price of the dollar over the 1974–2004 period found that, other things equal, a 10% rise in the oil price leads to a 4.3% appreciation of the dollar in real effective terms in the long run. (Amano and van Norden, 1998) found a stable linkage exists between oil price shocks and the US real effective exchange rate over the longer horizon. Their findings indicate that oil prices have been the dominant source of persistent shocks on real exchange rate. (Chaudhuri and Daniel, 1998) investigate 16 OECD countries and obtain similar results, asserting that the main source of US real exchange rate fluctuations comes from the real price of oil. (Camarero and Tamarit, 2002) use panel cointegration techniques to investigate the relationship between real oil prices and the Spanish peseta's real exchange rate. The inclusion of the real interest rate differential and real oil price seems to provide a reasonable model to explain the behaviour of the peseta bilateral real exchange rate vis-à-vis a group of EU countries.

Attempts to model long-run movements in real exchange rates have generally had mixed results. The simple purchasing power parity (PPP) hypothesis has proven to be a weak model of the long-run real exchange rate. Results from time series models that try to establish the link between real exchange rate behaviour and economic fundamentals have failed to find a robust relationship between the real exchange rate and its determinants. Early surveys on exchange rate model such as from (Meese, 1990) and (MacDonald et al., 1993) agreed that the existing exchange rate models are unsatisfactory. Monetary models that appeared to fit the data for the 1970s were rejected when the sample period was extended to the 1980s (see (Backus, 1984) for evidence). Meese and Rogoff (1988) and (Edison and Pauls, 1993) examine the link between real exchange rate and real interest rate differential but failed to find a long-run relationship between these two variables. However, MacDonald and Nagayasu (2000) tested this relationship using panel cointegration method, with data for a set industrialized countries and found evidence of statistically significant long-run relationships between real exchange rate and real interest rate differentials. MacDonald and Nagayasu (2000) conclude that the failure of previous researches may be due to the estimation method used rather than to any theoretical deficiency. In other related work by (Chortareas et al., 2001), they found evidence that there exists a valid long run relationship between the two variables. This is most evident when the results for a panel of small open economies are considered. In contrast, when only the G7 countries are included, the evidence for long run relationship breaks down.

In brief, there are several reasons to doubt the ability of traditional exchange rate models to explain exchange rate movements. (Zhou, 1995) investigated various sources of real shocks that explain real exchange rate movements. Among many sources of real disturbances, such as oil prices, fiscal policy, and productivity shocks, Zhou (1995) showed that oil price fluctuations play a major role in explaining real exchange rate movements. Bearing these considerations in mind, this paper complements the recent works by Karhonen (2009) and (Chen and Chen, 2007) on the study of oil price and exchange rate in two directions. First, unlike most of the existing literature which focuses on the net oil importing countries or net oil exporting countries separately, the paper combines both groups of countries under one study. This approach allows the paper to evaluate any significant differences in the oil price-exchange rate relationship between the two country groups. Second, the paper assesses the relation between oil prices and real exchange rate using several panel cointegration methods, which may improve the power of the tests (the ability to correctly reject the null hypothesis being investigated).

To achieve this, the paper uses a sample of 8 countries consisting of 5 net oil importing countries and 3 net oil exporting countries using monthly panel data from 1980:1 to 2008:11. The goal is achieved in three steps. In the first step, the paper ascertains the integrational properties of the data series. To achieve this, the paper applies the (Levin et al., 2002), (Breitung, 2000), (Im et al., 2003), (Maddala G. S. and Wu, 1999) and (Hadri, 2000) panel unit root tests. In the second step, the paper tests for panel cointegration relationships. This is achieved by using the Pedroni (1998), Kao (1999) and Maddala and Wu (1999) tests. In the third step, the paper sets out to estimate the long-run elasticities of the impact of oil price and interest rate differential on exchange rate. The paper achieves this by using the pooled mean group (PMG) estimator, mean group estimator (MG) and dynamic fixed effects estimator (DFE) proposed by (Pesaran et al., 1999a)

Following Amano and van Norden (1998) and Chaudhuri and Daniel (1998), this paper will apply the structural monetary model of Meese and Rogoff (1988) in a very simple fashion by considering the role of the real oil price as a determinant of the long-run equilibrium real exchange rate. The monetary model by (Meese and Rogoff, 1988) seems appropriate for this paper due to the inclusion of the real interest rate differential as the demand-side determinant of the real exchange rate. This variable should be able to capture the effects of the monetary policy strategy followed by central banks for the countries under study.

The balance of this paper is organised as follows. In the next section, the paper discusses the model and the theoretical framework. In section 3, the paper presents the econometric methodology. In section 4, the paper discusses the empirical results. In section 5, the paper concludes.

2. Theoretical Model

Meese and Rogoff (1988) examined the comovements of major currency real exchange rates and long-term real interest rates over the modern (post-March 1973) flexible exchange rate experience. The real exchange rate, q_t, can be defined as:

$$q_t \equiv e_t - p_t + p_t^* \tag{1}$$

where e_t is logarithm of nominal exchange rate (domestic currency per foreign currency unit) and p_t and p_t^* are the logarithms of domestic and foreign prices. Three assumptions are made: first, that when a shock occurs, the real exchange rate returns to its equilibrium value at a constant rate; second, that the long-run real exchange rate, $\hat{q}$, is a non-stationary variable; finally, that uncovered real interest rate parity (UIP) is fulfilled:

$$E_t\,(q_{t+k} - q_t) = R_t - R_t^* \tag{2}$$

where R_t^* and R_t are respectively, the real foreign and domestic interest rates for an asset of maturity k. Combining the three assumptions above, the real exchange rate can be expressed in the following form:

$$q_t = \delta(R_t - R_t^*) + \hat{q}_t \tag{3}$$

where δ is a positive parameter larger than unity. This leaves relatively open the question of which are the determinants of $\hat{q}_t$ that is non-stationary variable. Equation (3) is the second relationship investigated in this paper and represents a typical model of the relationship between the real interest rate differential and the real exchange rate explored in the literature. When shocks are primarily real this relationship is likely to outperform the relationship between nominal exchange rates and real interest rate differentials that can also be derived using international parity conditions (see Meese and Rogoff (1988)).

A number of studies discuss the determinants of equilibrium real exchange rates. The paper discusses two main determinants of exchange rate, namely the world oil price and interest rate differential.

World Real Price of Oil

The link between the price of oil and exchange rate has followed two main avenues. The first one focuses on oil as a major determinant of the terms of trade. Amano and van Norden (1998) propose a model with two sectors; tradable and non-tradable goods. Each sector uses both a tradable input (oil) and a non-tradable one (labour). Besides constant returns to scale technology, it assumes that inputs are mobile between the sectors and that both sectors do not make economic profits. The output price of the tradable sector is fixed internationally; hence the real exchange rate corresponds to the output price in the non-tradable sector. A rise in the oil price leads to a decrease in the labour price so as to meet the competitiveness requirement of the tradable sector. If the non-tradable sector is more energy intensive than the tradable one, its output price rises and real exchange rate appreciates. The opposite applies if the non-tradable sector is less energy intensive than the tradable one.

Accordingly, for oil importing country, a real oil price hike may increase the price of tradables relative to non-tradables by a bigger proportion than that of in the oil exporting country and thus cause a real depreciation of their currencies. For oil exporting country, a real oil price increase may lead to appreciation of the real exchange rate as prices of non-tradable goods increase relative to tradables. However, due to the small-country assumption, Amano and van Norden (1998)'s approach neglects the fact that tradable prices can rise worldwide following an oil price shock. Thus, allowing for this possibility (while keeping the law of one price in the tradable sector) allows one to conclude that real oil price effect on real exchange rate will depend on the oil intensity of both tradable and non-tradable sectors of the countries under review (Benassy-Quere et al., 2007).

A second strand of the literature (Krugman, 1983a,b, Golub, 1983) focuses on the balance of payments and international portfolio choices. Krugman (1983a,b) note that in a three-country world Europe, America and OPEC, higher oil prices will transfer wealth from the oil importers (America and Europe) to oil exporters (OPEC). The real exchange rate equilibrium in the long run will depend on the geographic distribution of OPEC imports, but no longer on OPEC portfolio choices. Assuming that oil-exporting countries have a strong preference for dollar-denominated assets but not for US goods, an oil price hike will cause the dollar to appreciate in the short run but not in the long run. In particular, Krugman (1983 a,b) posited that if America is a relatively small share of OPEC's export market but a large share of OPEC's import market, then the transfer of wealth from the industrial countries to OPEC would tend to improve the US trade balance. The introduction by Golub (1983) of a fourth country (the United Kingdom) and a third currency (the sterling) does not change the qualitative conclusions.

Interest Rate Differentials

A number of authors have posited that, despite the instability of nominal exchange rates, there is nevertheless a strong relationship between real exchange rates and real interest rates. One rationale for this view is that, if the poor performance of the nominal exchange rate regressions is primarily attributable to money demand disturbances, there can still be a close correlation between real interest differentials and real exchange rates (Meese and Rogoff, 1988). The theoretical ground of monetary influence on real exchange rate is based on the well-known overshooting model of (Dornbusch, 1976). According to the model, when the domestic money supply grows faster than the foreign money supply, the nominal exchange rate may deviate from the position corresponding to PPP (purchasing power parity) because of sluggish response of the price variables. The slow adjustment of the price variables increases the real money balance and therefore causes interest rates to fall below their equilibrium levels to raise the demand for money. As a consequence, the interest rate parity condition requires an overshooting exchange rate. An overshooting exchange rate together with a slow adjustment of price levels generates a change in the real exchange rate. The theory suggests that money could have only a temporary influence rather than long-term impact on the real exchange rate. When prices catch up after the disturbance occurs, the real exchange rate will move back to the original position.

In short, the paper describes the real exchange rate (Q) as a function of real price of oil (ROIL) and real interest rate differential (DRR). That is,

$$Q = F(\text{ROIL}, \text{DRR}) \tag{4}$$

One may argue that expression (4) suffers from the possibility of missing some other important variables. However, the purpose of this paper is to explore the long-term relationship between the real exchange rate and the relevant explanatory variables especially real oil price and its contribution to explaining the fluctuations of the real exchange rate based on that explored long-term relationship. If the paper can find the existence of a stable long-run relationship among the variables in the model, that could be viewed as an indication that there is no serious problem of missing important variables.

3. Data & Econometric Method

The paper uses monthly data of oil price, exchange rate and interest rate for panel of 8 countries from January 1980 to November 2008. Data are sourced from the International Financial Statistics (IFS), published by the International Monetary Fund (IMF). Real exchange rates are constructed by using domestic price level and price level in a foreign country. Real exchange rate is equal to Nominal Exchange Rate * (Foreign Price Level / Domestic Price Level). Real oil price are defined as the price of Dubai crude oil expressed in US dollars, deflated by domestic consumer price index. Real oil price and real exchange rate are expressed in natural logarithm form. Real interest rate differentials (DRR) is calculated as $DRR_{it} = r_{it} - r_t^*$, where r_{it} is the real interest rate of country i and r_t^* is the real foreign interest rate. Real interest rate is derived using Fisher equation. The real interest rate solved from the Fisher equation is (1 + Interest) / (1+Inflation) -1. US is chosen to be the numeraire country. Variable names and data codes are provided in Table 1. The model to estimate is given as:

$$q_{it} = \alpha_i + \beta_{1i} drr_{it} + \beta_{2i} roil_t \qquad (5)$$

where the exchange rate (q_{it}) is defined as the cost of a unit of foreign currency in terms of the domestic currency, drr_{it} is the real interest rate differential and $roilp_{it}$ is the real price of oil. According to the theoretical model, an increase in the real interest rate differential would appreciate the currency. The sign corresponding to the real price of oil would be positive for oil importing countries and negative for oil exporting countries. For example, an increase in the real price of oil will depreciate the oil importing currencies relative to oil exporters. Thus, in this case, we expect $\beta_{1i} < 0$ and $\beta_{2i} > 0$ for oil importing countries and $\beta_{1i} < 0$ and $\beta_{2i} < 0$ for oil exporting countries.

Table 1

Data

Variable	Source	Code
Nominal Exchange Rate	IFS	156..AEZF, 662..AEZF, 128..AEZF, 548..AEZF, 158..AEZF, 199..AEZF, 146..AEZF, 564..AEZF
Nominal Interest Rate	IFS	1560B..ZF, 6620B..ZF, 1280B..ZF, 5480B..ZF, 1580B..ZF, 1990B..ZF, 1460B..ZF, 5640B..ZF, 11160B..ZF
Consumer Price Index	IFS	1566F..ZF,66264..ZF,12864..ZF, 54864..ZF,15864..ZF, 56464..ZF, 19964..ZF, 14664..ZF, 11164..ZF
Inflation Rate	IFS	15664..XZF, 66264..XZF, 12864..XZF, 54864..XZF, 15864..XZF, 19964..XZF, 14664..XZF, 56464..XZF, 11164..XZF
Dubai Crude Oil Price	IFS	46676AAZZF

The paper divides the 8 countries into two panels. Each panel consists of 3 countries classified as net oil exporters and 5 net oil importers respectively. Table 2 provides the list of the 8 countries used in the paper.

Table 2

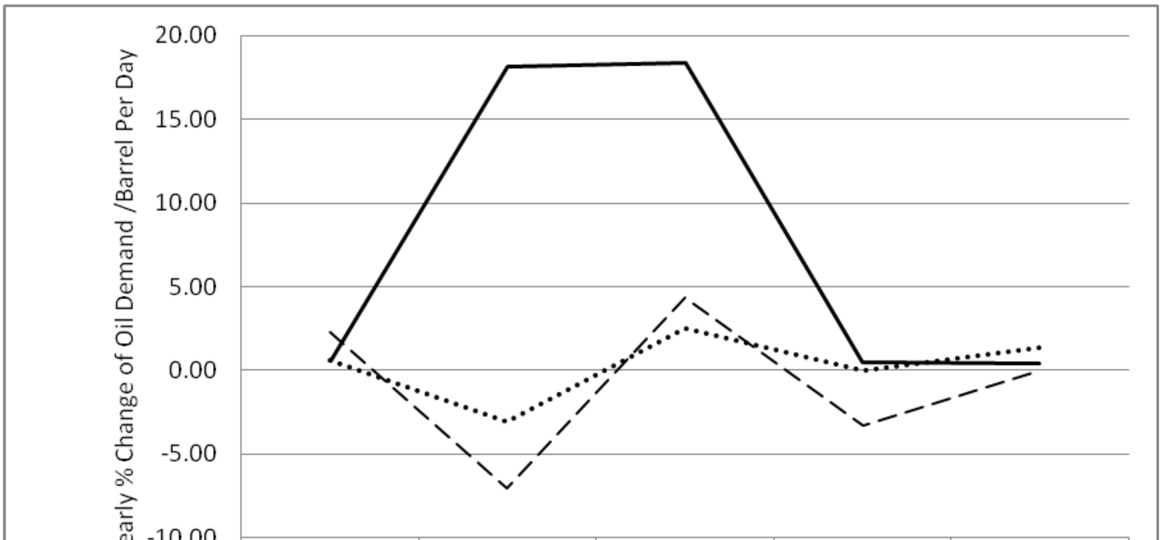
Country List

Net Oil Exporting Countries	Net Oil Importing Countries
Canada	Japan
Denmark	Pakistan
Malaysia	South Africa
	Switzerland
	Côte d'Ivoire

3.1 *Summary statistics of countries in regression*

Figure 1 and Figure 2 illustrate yearly percentage change in oil demand for net oil exporting and net oil importing countries from 1985-2005 respectively. For net oil exporters, oil demand grew between 1990-1995 and 2000-2005 periods. There was more volatility in oil demand for Malaysia than it was for Denmark and Canada between 1985-2005. As for net oil importers, there were significant fluctuations in oil demand especially for South Africa and Pakistan. As for Japan and Switzerland, there were fewer variations in oil demand growth from 1990 onwards. Both Figure 1 and Figure 2 show that most countries experienced large increase in oil demand during booming economic situations in mid’90s and 2005 but oil demand declined in 2000-2001 when economic condition was less favourable. Significant fluctuations in oil demand were also observed among developing countries (Malaysia, Côte d'Ivoire, Pakistan, South Africa) compared to developed countries (Japan, Switzerland, Canada, Denmark) from 1985-2005.

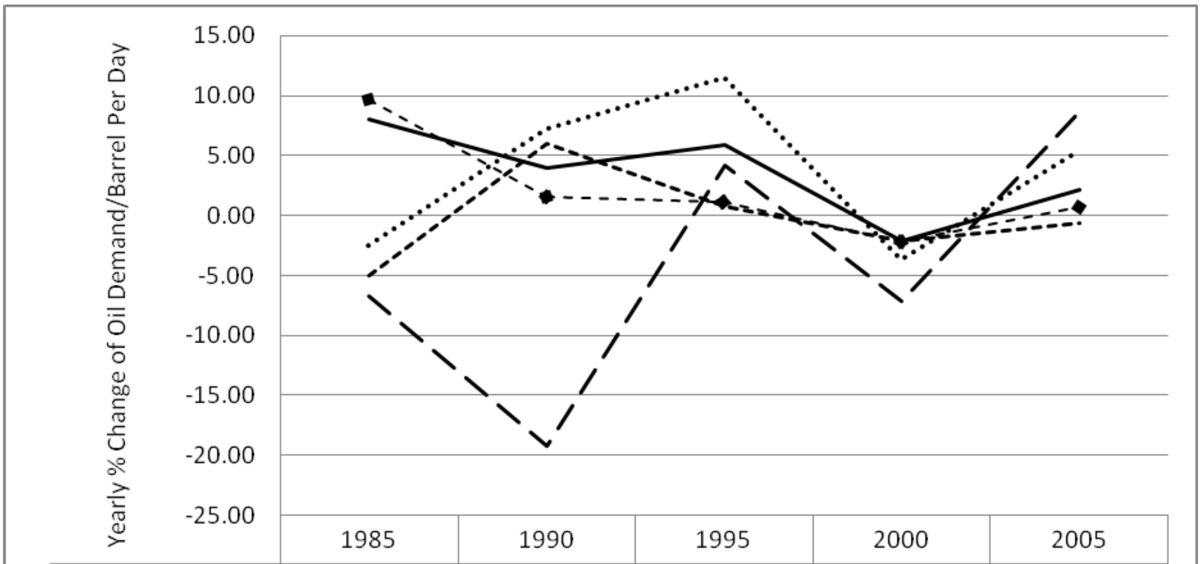
Figure 1: Yearly Percentage Change in Oil Demand: Net Oil Exporters



	1985	1990	1995	2000	2005
Canada	0.59	-3.06	2.51	0.00	1.40
Denmark	2.27	-7.04	4.35	-3.27	0.00
Malaysia	0.53	18.14	18.37	0.45	0.39

Source: International Financial Statistics

Figure 2: Yearly Percentage Change in Oil Demand: Net Oil Importers



	1985	1990	1995	2000	2005
Switzerland	9.68	1.53	1.15	-2.14	0.75
Japan	-4.97	6.03	0.77	-2.14	-0.64
South Africa	-2.56	7.23	11.51	-3.70	5.35
Pakistan	7.97	3.98	5.80	-2.11	2.13
Cote d'Ivoire	-6.67	-19.23	4.17	-7.14	8.70

Source: International Financial Statistics

Figure 3 and Figure 4 show the net import (or export) of oil percentage of GDP from 1980 to 2005. Overall, there were no significant changes of oil import for Japan and Switzerland since 1985 (see Figure 3). On the contrary, Pakistan and South Africa had increased their share of oil import between 1995-1999 before reducing the import in the following years. As for net oil exporting countries, Figure 4 shows that Malaysia's share of oil export is declining (negative values indicates oil import) while Canada and Denmark had increased their oil exports in recent years although the increment was marginal.

Figure 3: Net Oil Import/GDP

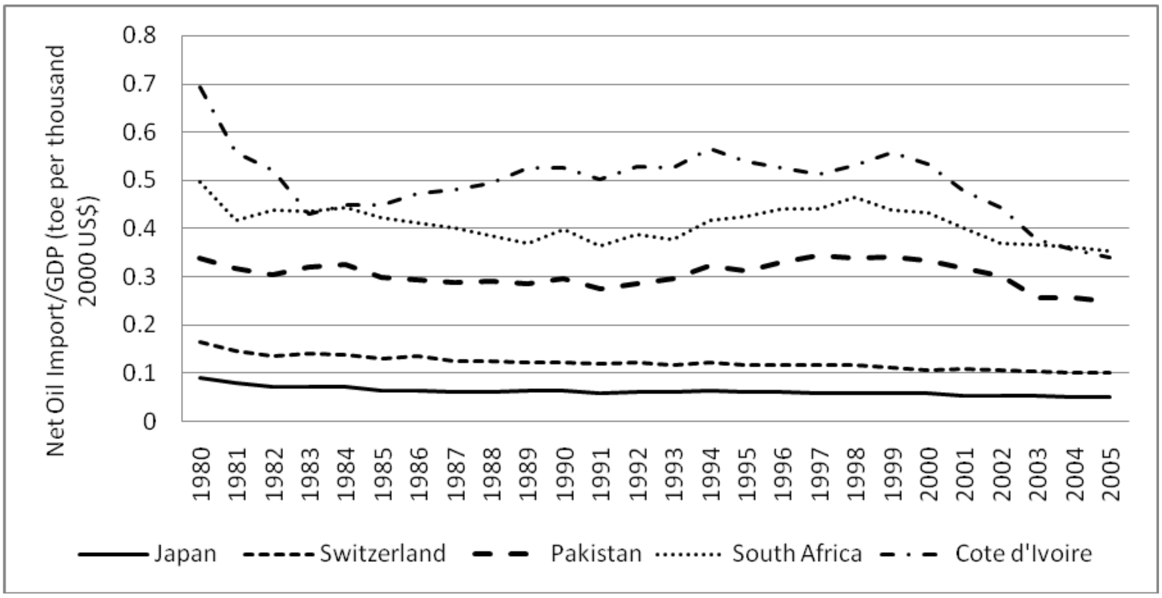
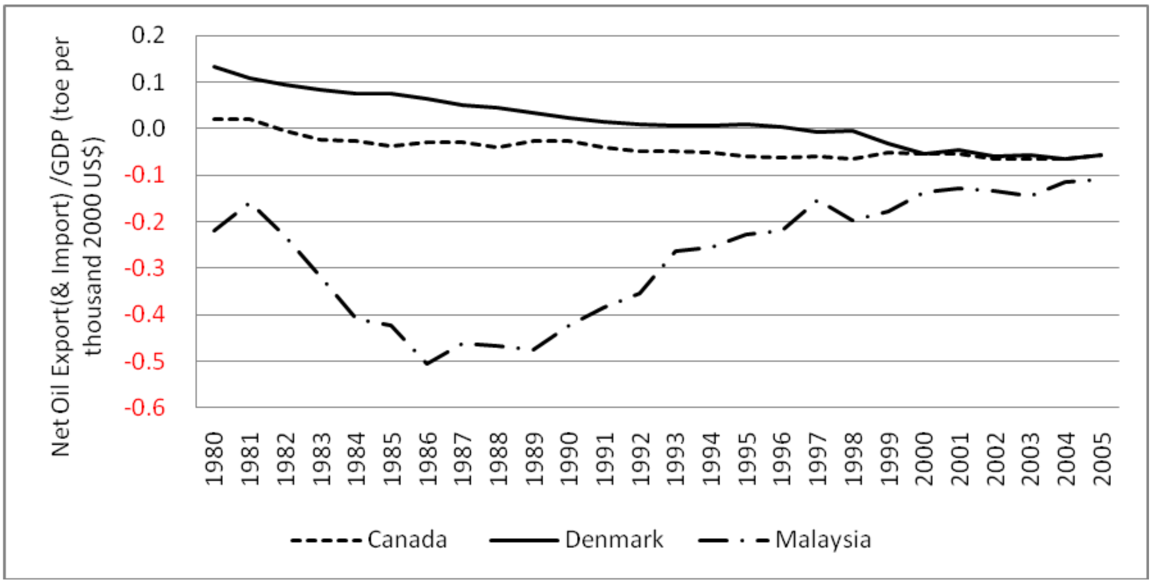


Figure 4: Net Oil Import (& Export)/GDP

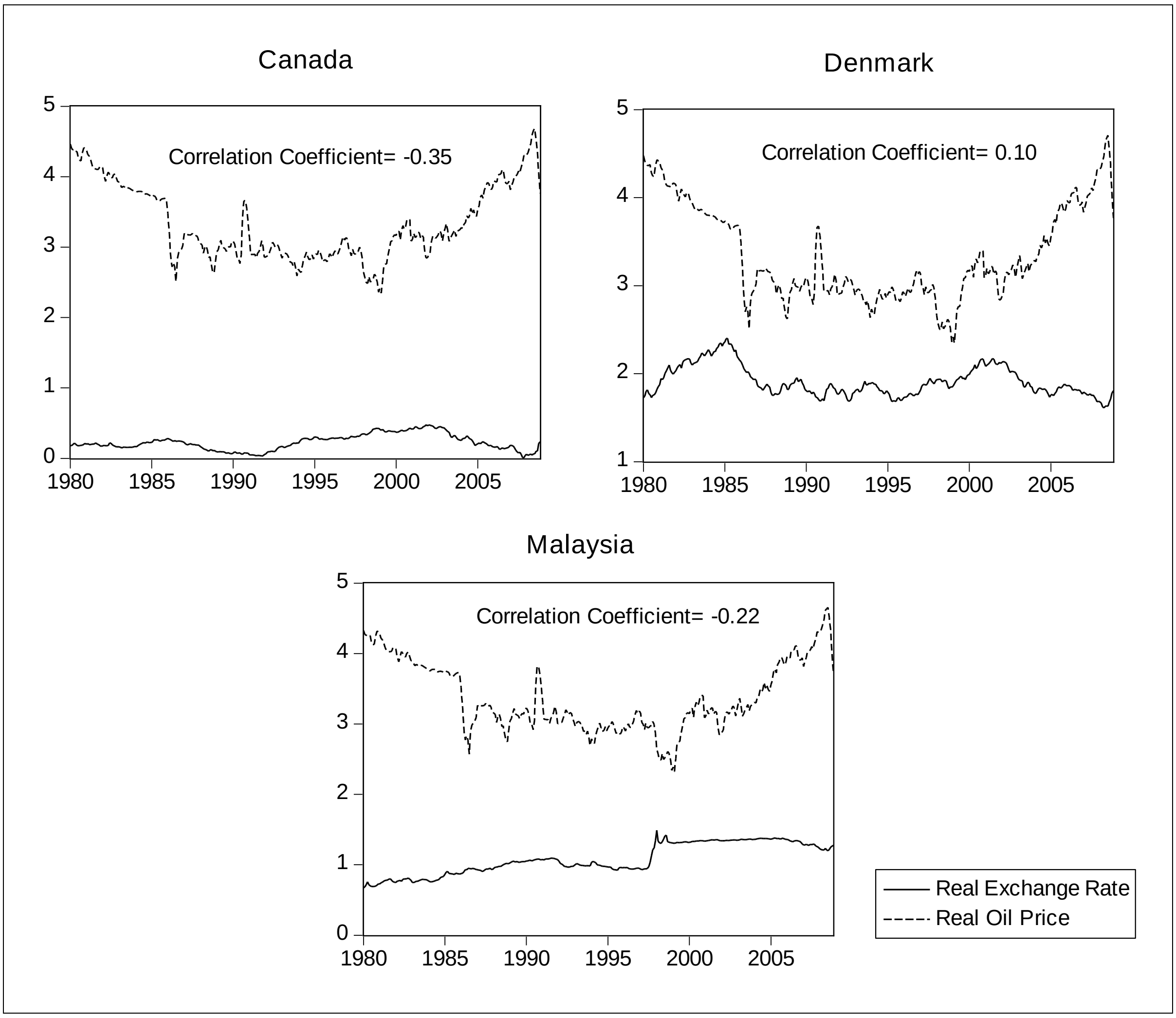


Source: International Financial Statistics

Note for Figure 4: Negative Percentage (%) values indicate Net Oil Export

Figure 5 shows that all net oil exporters except Denmark recorded negative correlation between real oil price and real exchange rates from 1980 to 2007. Surprisingly, two of four net oil importing countries (Pakistan and South Africa) recorded negative correlation between real oil price and real exchange rate (Figure 6). On the other hand, Japan and Switzerland recorded positive correlation between the two variables, in line with expectation from Eq. (5) as noted before.

Figure 5: Real Oil Price and Real Exchange Rate for Net Oil Exporting Countries



Source: International Financial Statistics

Figure 6: Real Oil Price and Real Exchange Rate for Net Oil Importing Countries

Source: International Financial Statistics

3.2 *Overview of Estimation Procedures*

Before estimating Equation (5), the paper needs to determine the order of integration of all three series involved in the panel. An integrated series needs to be differenced in order to achieve stationarity. A panel series Y_{it}, that requires no such differencing to obtain stationarity is denoted as $Y_{it} \sim I(0)$. Therefore, an integrated series such as $Y_{it} \sim I(1)$ is said to grow at a constant rate while $Y_{it} \sim I(0)$ series appear to be trendless. Thus, if two series Y_{it} and X_{it} are integrated of different order, say $Y_{it} \sim I(0)$ and $X_{it} \sim I(1)$ respectively, then they must be drifting apart over time. Therefore, a regression of Y_{it} on X_{it} would encounter a spurious regression problem, as the residual would also be $I(1)$ which violates the underlying assumptions of ordinary least squares (OLS). Thus, it is important to determine that the series of interest have the same order of integration before proceeding into further estimation.

After establishing the order of integration of the data, the paper would use panel cointegration approaches to test for a long run equilibrium relationship among variables. If two series Y_{it} and X_{it} are both $I(1)$ then it is normally the case that a linear combination between the two will also be $I(1)$ so that a regression of Y_{it} on X_{it} would produce spurious results. This is because the residual is also $I(1)$, which violates the assumptions of OLS. However, in a special case, a linear combination of two $I(1)$ variables will result in a variable (residual) which is $I(0)$. (Granger, 1981) has called such variables cointegrated. As shown by (Engle and Granger, 1987), there must be a vector error correction representation governing the comovements of these series over time. This leads to the intuitive interpretation of a cointegrated system as one that represents long-run steady state equilibrium.

Generally, if two or more variables are cointegrated, there is a long-term equilibrium relationship between them. To investigate the long-run relationship between the variables under study, the paper will adopt panel estimation method instead of standard OLS regression. With non-stationary variables, an OLS regression suffers from serial correlation. Moreover, since the cointegration literature does not assume exogenous regressors, estimation must account for potential endogenous feedback between X and Y (Funk, 2001). The advantage of panel estimators over standard time-series regressions is that each estimator is super-consistent. Asymptotically, the OLS estimator is normal with a nonzero mean, while panel estimators such as the PMG estimator proposed by Pesaran et al., (1999) are normal with zero means irrespective of whether the underlying regressors are $I(1)$ or $I(0)$.

3.3 *Panel unit root tests*

The methods applied to the estimation of the real exchange rate model are based on the combination of panel techniques and cointegration tests. The first step to take, as in the time series context, is to analyze the order of integration of the variables, as a pre-requisite. The paper employs several panel data unit root tests in order to exploit the extra power in the cross-sectional dimension of the data. Specifically, the paper utilizes the panel unit root tests proposed by (Levin et al., 2002), (Breitung, 2000), (Im et al., 2003), (G. S. Maddala, 1999) (1999) and (Hadri, 2000). Levin et al., (2002), Breitung (2000), and Hadri (2000) tests all assume that there is a common unit root process so that ρ_i is identical across cross-sections. The first two tests employ a null hypothesis of a unit root while the Hadri (2000) test uses a null of no unit root. Levin et al. (2002) and Breitung (2000) consider panel versions of the Augmented Dickey–Fuller (ADF) unit root test (with and without a trend). These tests restrict α to be identical across cross-sectional units, but allow the lag order for the first difference terms to vary across cross-sectional units, which in this study are countries.

$$\Delta y_{it} = \kappa_i + \alpha y_{it-1} + \sum_{j=1}^{\kappa} \psi_{ij} \Delta y_{it-j} + \epsilon_{it} \tag{6}$$

$$\Delta y_{it} = \kappa_i + \alpha y_{it-1} + \beta_i t + \sum_{j=1}^{\kappa} \psi_{ij} \Delta y_{it-j} + \epsilon_{it} \tag{7}$$

The subscript i=1,…,N indexes the countries. Equations (6) and (7) are estimated using pooled ordinary least squares (OLS). Levin et al. (2002) tabulate critical values for $t_{á}$ by performing Monte Carlo simulations for various combinations of N and T commonly employed in applied work. The null and the alternate hypotheses are: H_0: $\alpha=0$ and H_1: $\alpha<0$. Under the null hypothesis there is a unit root, while under the alternative hypothesis, there is no unit root. The difference between the Levin et al. (2002) test and the Breitung (2000) test is that while the former requires bias correction factors to correct for cross-sectionally heterogeneous variances to ensure efficient pooled OLS estimation, the Breitung (2000) test achieves the same result by appropriate variable transformations (Narayan et al., 2008).

One of the drawbacks of the Levin et al. (2002) and Breitung (2000) tests is that in Equations (6) and (7) α is restricted to be identical across countries under both the null and alternative hypotheses. The t-bar test proposed by Im et al. (2003) has the advantage over the

Levin et al. (2002) and Breitung (2000) tests that it does not assume that all countries converge towards the equilibrium value at the same speed under the alternative hypothesis and thus is less restrictive. (Karlsson and Löthgren, 2000) perform Monte Carlo simulations that show that in most cases the Im et al. (2003) test is superior to the Levin et al. (2002) test. There are two stages in constructing the t-bar test statistic. The first is to calculate the average of the individual ADF t-statistics for each of the countries in the sample. The second is to calculate the standardized t-bar statistic according to the following formula:

$$t - bar = \sqrt{N}\,(t_{\acute{a}} - \hat{e}_t) / \sqrt{v}_t \tag{8}$$

where N is the size of the panel, t_α is the average of the individual ADF t-statistics for each of the countries with and without a trend and κ_t and ν_t are, respectively, estimates of the mean and variance of each $t_{\alpha i}$. Im et al. (2003) provide Monte Carlo simulations of κ_t and ν_t and tabulate exact critical values for various combinations of *N* and *T*. A potential problem with the t-bar test is that when there is cross-sectional dependence in the disturbances, the test is no longer applicable. However Im et al. (2003) suggest that in the presence of cross-sectional dependence, the data can be adjusted by demeaning and that the standardized demeaned t-bar statistic converges to the standard normal in the limit.

Maddala and Wu (1999) criticize the Im et al. (2003) test such that cross correlations are unlikely to take the simple form proposed by Im et al. (2003) in many real world applications that can be effectively eliminated by demeaning the data. Maddala and Wu (1999) propose an alternative approach to panel unit root tests using Fisher's (1932) results to derive tests that combine the *p*-values from individual unit root tests. The test is non-parametric and has a chi-square distribution with *2N* degrees of freedom, where *N* is the number of cross-sectional units or countries. Using the additive property of the chi-squared variable, the following test statistic can be derived:

$$\lambda = -2 \sum_{i=1}^{N} \log_e \pi_i \tag{9}$$

Here, π_i is the *p*-value of the test statistic for unit *i*. An important advantage of this test is that it can be used regardless of whether the null is one of integration or stationarity. The paper also implemented the panel stationarity test suggested by Hadri (2000). The Hadri (2000) panel unit root test is similar to the (Kwiatkowski et al., 1992) unit root test, and has a null hypothesis of no unit root in any of the series in the panel. Like the Kwiatkowski et al. (1992) test, The Hadri (2000) test is based on the residuals from the individual OLS regressions from the following regression model:

$$y_{it} = \pi_i + \theta_i t + \mu_{it} \quad (10)$$

Given the residuals û from the individual regressions, the LM statistic is:

$$LM_1 = \frac{1}{N}\left(\sum_{i=1}^{N} \sum_{t} S_i(t)^2 / T^2 / \overline{f}_0\right) \quad (11)$$

where S_{it} are the cumulative sum of the residuals,

$$S_i(t) = \sum_{i=1}^{t} \hat{u}_{it} \quad (12)$$

$\bar{f}$ is the average of the individual estimators of the residual spectrum at frequency zero

$$\overline{f_0} = \frac{\sum_{i=1}^{N} f_{i0}}{N}$$

(13)

Hadri (2000) shows that under mild assumptions,

$$Z = \frac{\sqrt{N}\,(LM - \xi)}{\varphi} \rightarrow (0,1) \quad (14)$$

where $\xi = 1/6$ and $\xi = 1/45$ and φ=1/45, if the model only includes constants (η_i is set to 0 for all i), and $\xi = 1/15$ and $\varphi = 11/6300$, otherwise. It is worth noting that simulation evidence suggests that in various settings (for example, small T), Hadri's panel unit root test experiences significant size distortion in the presence of autocorrelation when there is no unit root. In particular, the Hadri (2000) test appears to over-reject the null of stationarity, and may yield results that directly contradict those obtained using alternative test statistics (see (Hlouskova and Wagner, 2006) for discussion and details).

3.4 *Panel unit root tests results*

Table 2 reports panel unit root tests for all countries while Table 3 and Table 4 report panel unit root tests for net oil exporting countries and net oil importing countries respectively. There are three different null hypotheses for the panel unit root tests. The first two are the Breitung (2000) and Levin et al. (2002) tests where the null hypothesis is the unit root (with the assumption that the cross-sectional units share a common unit root process). The second group includes two tests (Im et al. (2003), and Maddala and Wu (1999) Fisher type test with null of unit root assuming that the cross-sectional units have individual unit root process. The last test is the Hadri (2000) test, where the Z-stat has a null hypothesis of no unit root (but assumes a common unit root process for all cross-sectional units). All test results are based on the inclusion of an intercept and trend.

It is clear that real oil price and real exchange rates are $I(1)$ series for panel of eight countries and both country groups. For real oil price, each of the five tests suggest stationarity at first difference at 1% level of significance. As for real exchange rate, with the exception of Breitung (2000) test, all other four tests provide evidence of stationarity at 1% level of significance at first difference. For real interest rate differential, Hadri’s Z-stat rejects null of stationarity and Levin et. al. (2002) test rejects null of non-stationarity at 1% significance level in every case. The Im, Pesaran & Shin and ADF-Fisher Chi-square tests however suggest real interest rate differential is weakly non-stationary in level at 5% significance levels or lower for panel of eight countries and net oil exporting countries. For net oil importing countries, significant evidence of non-stationarity at levels for real interest rate differential is suggested by all tests at 1% level of significance. To sum up, the results indicates that there is stationarity in first differences and each of the three variables can be regarded as $I(1)$. In what follows, the paper will proceed on the assumption that all variables are $I(1)$ and differenced variables are $I(0)$. In this case cointegration methods would be preferable and appropriate.

Table 2

Panel Unit Root Tests for Panel of All Countries

	Null Hypothesis	Exchange Rate	Oil Price	Interest Rate Differential
Series in level				
Levin, Lin and Chu	Unit Root[a]	-0.46 (0.32)	1.15 (0.87)	2.89 (0.99)
Breitung t-stat	Unit Root[a]	0.17 (0.57)	3.33 (0.99)	-2.43 (0.00)
Im, Pesaran & Shin	Unit Root[b]	0.00 (0.50)	2.17 (0.98)	-1.95 (0.02)
ADF-Fisher Chi-square	Unit Root[b]	11.86 (0.75)	3.01 (0.99)	24.40(0.08)
Hadri Z-stat	Stationary[c]	10.05 (0.00)	29.24 (0.00)	4.86 (0.00)
Series in first differences				
Levin, Lin and Chu	Unit Root[a]	-4.40 (0.00)	-52.51(0.00)	-73.42 (0.00)
Breitung t-stat	Unit Root[a]	1.55 (0.93)	-9.71 (0.00)	-17.92 (0.00)
Im, Pesaran & Shin	Unit Root[b]	-8.68 (0.00)	-37.35 (0.00)	-49.52 (0.00)
ADF-Fisher Chi-square	Unit Root[b]	118.77 (0.00)	843.94 (0.00)	1038.81 (0.00)
Hadri Z-stat	Stationary[c]	0.07 (0.47)	-2.34 (0.99)	-1.59 (0.94)

Table 3

Panel Unit Root Tests for Net Oil Importing Countries

	Null Hypothesis	Exchange Rate	Oil Price	Interest Rate Differential
Series in level				
Levin, Lin and Chu	Unit Root[a]	-0.56(0.29)	1.01 (0.84)	3.28(0.99)
Breitung t-stat	Unit Root[a]	0.11 (0.54)	2.59(0.99)	-1.26(0.10)
Im, Pesaran & Shin	Unit Root[b]	-0.29 (0.38)	1.83 (0.97)	-1.26 (0.10)
ADF-Fisher Chi-square	Unit Root[b]	8.49 (0.58)	1.71(0.99)	13.60(0.19)
Hadri Z-stat	Stationary[c]	8.76(0.00)	23.23 (0.00)	3.20 (0.00)
Series in first differences				

Levin, Lin and Chu	Unit Root[a]	-2.57(0.00)	-41.62 (0.00)	-51.80 (0.00)
Breitung t-stat	Unit Root[a]	-1.25 (0.11)	-7.69 (0.00)	-15.81(0.00)
Im, Pesaran & Shin	Unit Root[b]	-7.19(0.00)	-29.56 (0.00)	-35.44(0.00)
ADF-Fisher Chi-square	Unit Root[b]	78.51 (0.00)	528.10 (0.00)	510.35 (0.00)
Hadri Z-stat	Stationary[c]	-0.22 (0.58)	-1.83 (0.96)	-1.20(0.89)

Table 4

Panel Unit Root Tests for Net Oil Exporting Countries

	Null Hypothesis	Exchange Rate	Oil Price	Interest Rate Differential
Series in level				
Levin, Lin and Chu	Unit Root[a]	-0.07(0.47)	0.61(0.73)	0.32 (0.62)
Breitung t-stat	Unit Root[a]	0.15(0.56)	2.09(0.98)	-2.71 (0.00)
Im, Pesaran & Shin	Unit Root[b]	0.40(0.65)	1.17(0.88)	-1.55 (0.06)
ADF-Fisher Chi-square	Unit Root[b]	3.37(0.76)	1.30(0.97)	10.81 (0.09)
Hadri Z-stat	Stationary[c]	4.17(0.00)	17.75(0.00)	4.49 (0.00)
Series in first differences				
Levin, Lin and Chu	Unit Root[a]	-3.80(0.00)	-32.01(0.00)	-53.14(0.00)
Breitung t-stat	Unit Root[a]	2.64(0.99)	-5.93(0.00)	-11.35(0.00)
Im, Pesaran & Shin	Unit Root[b]	-4.91(0.00)	-22.84(0.00)	-38.10(0.00)
ADF-Fisher Chi-square	Unit Root[b]	40.26(0.00)	315.85(0.00)	508.45(0.00)
Hadri Z-stat	Stationary[c]	0.82(0.21)	-1.47 (0.93)	-1.15(0.88)

Note for Table 2 to Table 4:
An intercept and trend are included in the test equation. The lag length was selected by using the Modified Akaike Information Criteria

[a] Signify that the null hypothesis is the unit root (with the assumption that the cross-sectional units share a common unit root process)

[b] Signify that the null hypothesis is the unit root assuming that the cross-sectional units have individual unit root process

[c] Signify that the null hypothesis of no unit root (but assumes a common unit root process for all cross-sectional units)

3.5 *Panel cointegration tests*

In the second step, the paper tests test for the presence of cointegration between real exchange rate, real oil price and real interest rate differential variables. The paper utilise panel cointegration tests due to Pedroni (1998), Kao (1999) and Maddala and Wu (1999). The tests proposed in (Pedroni, 1998) are residual-based tests which allow for heterogeneity among individual members of the panel, including heterogeneity in both the long-run cointegrating vectors and in the dynamics. Two classes of statistics are considered in the context of the Pedroni (1998) test. The panel tests are based on the within dimension approach (i.e. panel cointegration statistics) which includes four statistics: panel v-statistic, panel ρ-statistic, panel PP-statistic, and panel ADF-statistic. These statistics essentially pool the autoregressive coefficients across different countries for the unit root tests on the estimated residuals. These statistics take into account common time factors and heterogeneity across countries. The group tests are based on the between dimension approach (i.e. group mean panel cointegration statistics) which includes three statistics: group ρ-statistic, group PP-statistic, and group ADF-statistic. These statistics are based on averages of the individual autoregressive coefficients associated with the unit root tests of the residuals for each country in the panel. All seven tests are distributed asymptotically as standard normal. Of the seven tests, the panel v-statistic is a one-sided test where large positive values reject the null hypothesis of no cointegration whereas large negative values for the remaining test statistics reject the null hypothesis of no cointegration.

The (Kao, 1999) test follows the same basic approach as the Pedroni (1998) tests, but specifies cross-section specific intercepts and homogeneous coefficients on the first-stage regressors. In the null hypothesis, the residuals are nonstationary (i.e., there is no cointegration). In the alternative hypothesis, the residuals are stationary (i.e., there is a cointegrating relationship among the variables). The third test is the Johansen-type panel cointegration test developed by Maddala and Wu (1999). The test uses Fisher's result to propose an alternative approach to testing for cointegration in panel data by combining tests from individual cross-sections to obtain at test statistic for the full panel. The Maddala and Wu (1999) test results are based on *p*-values for Johansen's cointegration trace test and maximum eigenvalue test. Evidence of cointegration between real exchange rate and real oil price using the Maddala and Wu (1999) test is obtained if the null hypothesis of *none* ($r = 0$) cointegration variables is rejected and the null of *at most 1* ($r \leq 1$) cointegrating variables is accepted, suggesting the direction of causality is running from real oil price to real exchange rate. In other word, the paper would confirms the existence of a unique cointegration vector for the estimated model.

3.6 *Panel cointegration tests results*

Table 5 to Table 11 report the results for the three types of cointegration tests. The panel tests of Pedroni (1998) indicate no support for the hypothesis that real oil prices and real interest rate differential are cointegrated with real exchange rate for panel of eight countries and each country group. However, evidence of cointegrating relationship between the variables are obtained from Kao (1999) and Maddala & Wu (1999) tests. The null hypothesis of no cointegrating relationship is rejected at 10% level or lower for panel of eight countries, net oil exporting countries and net oil importing countries respectively when using Kao (1999) tests. Similarly, results from the Maddala & Wu (1999) panel cointegration test provide evidence of cointegration between the three variables. From the results in Table 9 to Table 11, the null hypothesis of no co-integration ($r = 0$) can be decisively rejected at 1% level of significance for all sampled countries. The null hypothesis of one cointegrating vector ($r \leq 1$) given that ($r \leq 0$ was rejected) cannot be rejected. Therefore, the paper has strong evidence in favour of the hypothesis of one cointegrating vector. In other words, for all country groupings the paper examines a unique cointegrating vector seems to be a reasonable hypothesis.

Although results from Pedroni (1998) test fail to reject the null hypothesis of no cointegration between variables, evidence from the other two tests seems to suggest there is a long run equilibrium relationship between real exchange rate, real oil price and real interest rate differential. The paper therefore continues with econometric technique which takes into account this long-run relationship between the variables.

Table 5

Pedroni (1998) panel cointegration tests for Panel of All Countries, 1980m01–2008m11

Within dimension		**Between dimension**	
Test statistics		Test statistics	
Panel v-Statistic	0.555794	Group rho-Statistic	0.988189
Panel rho-Statistic	0.037963	Group PP-Statistic	0.623754
Panel PP-Statistic	-0.043928	Group ADF-Statistic	0.667452
Panel ADF-Statistic	-0.054363		

Table 6

Pedroni (1998) panel cointegration tests for Net Oil Exporting Countries, 1980m01–2008m11

Within dimension		**Between dimension**	
Test statistics		Test statistics	
Panel v-Statistic	-0.40119	Group rho-Statistic	0.87646
Panel rho-Statistic	0.14973	Group PP-Statistic	0.48226
Panel PP-Statistic	-0.15128	Group ADF-Statistic	0.29329
Panel ADF-Statistic	-0.66729		

Table 7

Pedroni (1998) panel cointegration tests for Net Oil Importing Countries, 1980m01–2008m11

Within dimension		**Between dimension**	
Test statistics		Test statistics	
Panel v-Statistic	0.099429	Group rho-Statistic	0.415747
Panel rho-Statistic	0.105998	Group PP-Statistic	0.018748
Panel PP-Statistic	-0.085375	Group ADF-Statistic	0.030956
Panel ADF-Statistic	-0.286303		

Note for Table 5 to Table 7: The null hypothesis is that there is no cointegration. No trend is included in the test equation. An asterisk (*) indicates rejection at the 10% level or better

Table 8

Kao (1999) Residual Cointegration Tests

Null hypothesis: No Cointegration	**Statistics**	**Probability**
Panel of All Countries	-3.15	0.00*
Net Oil Exporting Countries	-1.28	0.09*
Net Oil Importing Countries	-2.88	0.00*

Table 9

Maddala & Wu (1999) Fisher Panel Cointegration Test for Panel of All Countries

Hypothesized No. of CE(s)	**Fisher Stat.* (from trace test)**	**Prob.**	**Fisher Stat.* (from max-eigen test)**	**Prob.**
None	38.93	0.00*	41.23	0.00*
At most 1	12.12	0.74	12.09	0.74

Table 10

Maddala & Wu (1999) Fisher Panel Cointegration Test for Net Oil Importing Countries

Hypothesized No. of CE(s)	**Fisher Stat.* (from trace test)**	**Prob.**	**Fisher Stat.* (from max-eigen test)**	**Prob.**
None	26.83	0.00*	24.16	0.00*
At most 1	9.78	0.45	9.73	0.46

Table 11

Maddala & Wu (1999) Fisher Panel Cointegration Test for Net Oil Exporting Countries

Hypothesized No. of CE(s)	**Fisher Stat.* (from trace test)**	**Prob.**	**Fisher Stat.* (from max-eigen test)**	**Prob.**
None	12.11	0.06*	17.08	0.00*
At most 1	2.33	0.89	2.36	0.88

Note for Table 8 to Table 11: The null hypothesis is that there is no cointegration. Linear deterministic trend is included in the test equation. An asterisk (*) indicates rejection at the 10% level or better

4. Long run estimation

In the third step, having found that a cointegrating relationship holds among real exchange rate, real oil price and real interest rate differential for the panel of eight countries and for each respective country group, the paper proceeds with the estimation of the long-run elasticities on the impact of real oil price and real interest rate differential on real exchange rate. The estimation of real exchange rate equilibrium model is based on pooled cross-country time series data. The main advantage of panel data for the analysis of real exchange rate equations is that the country-specific effects can be controlled for, for example by using dynamic fixed effect (DFE) estimator. However, such approach generally imposes homogeneity of all slope coefficients, allowing only the intercepts to vary across countries. (Pesaran and Smith, 1995) suggest that, under slope heterogeneity, this estimate is affected by a potentially serious heterogeneity bias, especially in small country samples.

Conversely, the mean group (MG) approach due to Pesaran and Smith (1995) allows all slope coefficients and error variances to differ across countries, having considerable heterogeneity. The MG approach applies an OLS method to estimate a separate regression for each country to obtain individual slope coefficients, and then averages the country-specific coefficients to derive a long-run parameter for the panel. For large T (the number of time periods) and N (the number of units), the MG estimator is consistent. With sufficiently high lag order, the MG estimates of long-run parameters are super-consistent even if the regressors are nonstationary (Pesaran et al., 1999). However, for small samples or short time series dimensions, the MG estimator is likely to be inefficient (Hsiao et al., 1999). For small T, the MG estimates of the coefficients for the speeds of adjustment are subject to a lagged dependent variable bias (Pesaran et al., 1999b).

Unlike the MG approach, which imposes no restriction on slope coefficients, the pooled mean group (PMG) estimators due to Pesaran et al. (1999a) allow short-run coefficients, speed of adjustment and error variances to differ across countries, but impose homogeneity only on long-run coefficients. This estimator is specially suited for panels with large T and N. It does not impose homogeneity of slopes in the short-run and it allows for dynamics. Therefore, under the null hypothesis of long-run homogeneity across coefficients, the paper estimates the long-run elasticities of the impact of real oil prices and real interest rate differential on real exchange rate equation on monthly data for 8 countries from 1980 to 2008 using the PMG procedure. In practice, the PMG procedure involves first estimating autoregressive distributed lag (ARDL) models separately for each country *i*.

$$q_{it} = \mu_i + \xi_{i,1} roil_{it} + \xi_{i,2} roil_{i,t-1} + \psi_{i,1} drr_{it} + \psi_{i,2} drr_{it-1} + \theta_i q_{it-1} + \epsilon_t \qquad (16)$$

In the equation subscript *i* refers to a country (i.e. a cross-sectional unit), whereas subscript *t* refers to a time period. The corresponding error correction equation can be written as

$$\Delta q_{it} = \varphi_i (q_{it-1} - \alpha_{i1} - \alpha_{i2} roil_{it} - \alpha_{i3} drr_{it}) - \xi_{i,1} \Delta roil_{it} - \psi_{i,1} \Delta drr_{it} + \nu_{it} \qquad (17)$$

where $\alpha_{i1} = \left(\frac{\mu_i}{1} - \theta_i\right)$, $\alpha_{i2} = \left(\xi_{i,1} + \frac{\xi_{i,2}}{1} - \theta_i\right)$, and $\alpha_{i3} = \left(\psi_{i,1} + \frac{\psi_{i,2}}{1} - \theta_i\right)$

In Eq. (17), φ_i is the coefficient that measures the speed of adjustment to short-run disequilibrium, $\alpha_{i2} roil_{it}$ and $\alpha_{i3} drr_{it}$ are the long run coefficients of real oil price and real interest rate differential respectively while $\xi_{i,1} \Delta roil_{it}$ and $\psi_{i,1} \Delta drr_{it}$ are the short run coefficients for real oil price and real interest rate differential respectively. For purpose of robustness check, the paper also utilizes the mean group (MG) estimator and dynamic fixed effect (DFE) estimator. The long-run slope homogeneity hypothesis of PMG is tested via the Hausman test. Under the null hypothesis, PMG estimators are consistent and more efficient than MG estimators, which impose no constraint on the regression (Pesaran et al., 1999). If the null is rejected, then there is evidence that the long run coefficients are not the same and the restriction imposed by PMG estimators is not valid. Hence MG estimators are preferred.

4.1 *Estimation results*

Table 12 to Table 14 examines whether real oil price and real interest rate differential affect real exchange rates, with the dependent variable being the real exchange rates in log. It reports three alternative pooled estimates of DFE, MG and PMG with and without a time trend. The paper expects the long-run effects of real oil price and real interest rate differential on real exchange rate to be homogenous across countries, although the short-run adjustments are more likely to differ across countries. Results vary significantly with respect to the estimation method, from MG (the least restrictive, but potentially not efficient) to PMG and to DFE that only allows intercepts to vary across countries. This analysis centres on the PMG estimates.

In the analysis for panel of eight countries, the Hausman test rejects the null hypothesis for homogeneity restriction at 1% significance level in both specifications (with and without time trend), suggesting that the MG are the preferred estimators to PMG. The coefficients corresponding to the speeds of convergence reported in Table 12 for MG estimators are significantly different from zero for two specifications, implying that Granger causality going from real oil price and real interest rate differential to real exchange rates exists in the cointegrated system. The MG approach however finds no evidence in support of a long-run effect of real oil price and real interest rate differential on real exchange rates. Moving from MG to PMG by imposing only long-run homogeneity reduces the standard errors and the speed of convergence but increases the size of the estimated long run parameters. The PMG estimates, which impose homogeneity only on the long-run coefficients, provide strong evidence in support of a positive effects of real oil price on real exchange rate (i.e. higher real oil price leads to depreciation of real exchange rates). Moving from the PMG to DFE estimates, the paper finds the DFE estimates suggest similar convergence speed in two specifications. Imposing homogeneity on all slope coefficients except for the intercept, the DFE estimates in two specifications however finds no evidence for the long-run effects of real oil price and real interest rate differential on real exchange rates.

Table 13 looks at the impact of real oil price and real interest rate differential on real exchange rate for net oil exporting countries. The long run restriction imposed by PMG estimators cannot be rejected at 1% level by the Hausman test statistics for both specifications. The PMG estimates however finds no evidence to suggest that real oil price has negative effect on real exchange rates but finds strong evidence for real interest differential at 1% level of significance. The MG and DFE estimates also fail to find evidence of long run relationship between the estimated variables. The coefficient on real oil price for MG estimates are negatively signed, although not significant, a result that is consistent with previous studies based on oil exporting countries[4]. Perhaps the lack of evidence to suggest that real oil price has positive effect on real exchange rate is due to the choice of sample countries included in the estimation. Of three net oil exporters in the sample, Denmark registered a positive correlation between real oil price and real exchange rate (when it should had been negative). Pooling these countries together may yield inconsistent slope coefficients among individual sample countries hence resulting in insignificant long run estimation results.

As for net oil importing countries, results of the Hausman test from Table 14 indicates that the restriction (equality of slopes for the long run coefficients) cannot be rejected at 1% significant level in both specifications (with and without time trend). Results from the PMG estimates suggest that higher real oil price leads to depreciation of real exchange rates among net oil importing countries. This finding is consistent with Chen and Chen (2007) study involving G7 countries from 1972 to 2005. They found real oil prices may have been the dominant source of real exchange rate movements and that higher real oil price leads to real exchange rates depreciation among the G7 countries. The PMG estimates also find strong evidence of negative relationship between real interest rate differential and real exchange rate among the net oil importers, extending the evidence recorded by (Macdonald and Nagayasu, 2000) on the significant long-run relationships between these two variables. The MG and DFE estimates however did not find any evidence to support this result.

Taking into account the whole set of regression results, this analysis on monthly data clearly shows a significant effects of real oil price and real interest rate differential on real exchange rate when using the PMG approach. This is true mainly for panel of eight countries and net oil importing countries respectively. The findings in general suggest that higher real oil price would results in depreciation in real exchange rate for net oil importing countries. On

[4] See Korhonen, I. & Juurikkala, T (2009) for evidence.

the impacts of real interest rate differential on real exchange rates, the PMG estimates provide evidence for negative long run relationship between the variables while the MG and DFE estimates do not support it.

Table 12: Panel of 8 Countries

Dependent Var: Log Real Oil Price	Without Time Trend. One lag (1,1,1) MG	PMG	Hausman	DFE	With Time Trend. One lag (1,1,1) MG	PMG	Hausman	DFE
Convergence Coeff	**-0.02***	**-0.01***		**-0.01***	**-0.02***	**-0.01***		**-0.01***
	(-4.98)	(-2.64)		(-4.60)	(-6.15)	(-2.56)		(-4.48)
Long Run Coeff.								
Log Oil Price	0.04	**0.18***	0.00	0.04	0.05	**0.21***	0.00	0.05
	(0.63)	(2.93)		(0.55)	(0.76)	(3.69)		(0.59)
Int.Rate Diff.	-1.596	**-5.41***		-0.30	-1.70	**-4.95***		-0.38
	(-0.82)	(-4.33)		(-0.25)	(-1.05)	(-4.15)		(-0.32)
Time Trend					0.00	-0.00*		0.00
					(0.43)	(-2.06)		(0.35)
Short Run Coeff.								
ΔLog Oil Price	**-0.01***	**-0.01***		**-0.01***	**-0.01***	**-0.01***		**-0.01***
	(-0.01)	(-2.17)		(-1.79)	(-2.13)	(-2.12)		(-1.82)
ΔInt. Rate Diff.	0.02	0.03		-0.00	0.02	0.03		-0.00
	(0.02)	(0.57)		(-0.11)	(0.58)	(0.58)		(-0.09)
No. of Countries	8	8		8	8	8		8
No. of obs.	2768	2768		2678	2768	2768		2768
Log likelihood		6282				6284		

Note: t-statistics calculated using heteroskedasticity consistent standard errors.
All equations include a constant country-specific term. T-statistics are in parentheses.
*Significant at 10% or better ; Significant coefficients in **bold** letters

Table 13: Panel of Net Oil Exporting Countries

Dependent Var: Log Real Oil Price	Without Time Trend. One lag (1,1,1) MG	PMG	Hausman	DFE	With Time Trend. One lag (1,1,1) MG	PMG	Hausman	DFE
Convergence Coeff	**-0.01***	-0.01		**-0.01***	**-0.02***	**-0.01***		**-0.01***
	(-3.08)	(-1.42)		(-2.48)	(-3.65)	(-1.26)		(-2.29)
Long Run Coeff.								
Log Oil Price	-0.02	0.17	0.03	0.06	-0.01	0.13	0.23	0.06
	(-0.15)	(1.43)		(0.45)	(-0.14)	(1.42)		(0.45)
Int.Rate Diff.	-1.35	**-4.07***		-2.95	-1.64	**-3.83***		-2.96
	(-0.83)	(-2.04)		(-1.08)	(-1.37)	(-2.15)		(-1.06)
Time Trend					0.00	-0.00*		-0.00
					(-0.14)	(-2.15)		(-0.16)

Short Run Coeff.								
ΔLog Oil Price	**-0.03***	**-0.03***		**-0.02***	**-0.02***	**-0.03***		**-0.02***
	(-3.22)	(-3.53)		(-3.19)	(-3.33)	(-3.70)		(-3.16)
ΔInt. Rate Diff.	-0.05	-0.04		-0.06	-0.04	-0.04		-0.06
	(-0.55)	(-0.48)		(-1.20)	(-0.47)	(-0.46)		(-1.21)
No. of Countries	3	3		3	3	3		3
No. of obs.	1038	1038		1038	1038	1038		1038
Log likelihood		2620				2622		

Note: t-statistics calculated using heteroskedasticity consistent standard errors.
All equations include a constant country-specific term. T-statistics are in parentheses.
*Significant at 10% or better; Significant coefficients in **bold** letters

Table 14: Panel of Net Oil Importing Countries

Dependent Var:	Without Time Trend. One lag (1,1,1)				With Time Trend. One lag (1,1,1)			
Log Real Oil Price	MG	PMG	Hausman	DFE	MG	PMG	Hausman	DFE
Convergence Coeff	**-0.02***	**-0.02***		**-0.01***	**-0.03***	**-0.02***		**-0.01***
	(-4.49)	(-2.10)		(-3.81)	(-4.67)	(-2.04)		(-3.77)
Long Run Coeff.								
Log Oil Price	0.08	**0.18***	0.022	0.03	0.08	**0.22***	0.013	0.04
	(0.96)	(2.53)		(0.34)	(0.94)	(3.22)		(0.41)
Int.Rate Diff.	-1.74	**-6.20***		0.15	-1.75	**-5.90***		0.00
	(-0.56)	(-3.74)		(0.11)	(-0.66)	(-3.46)		(0.00)
Time Trend					0.00	-0.00		0.00
					(0.18)	(-1.10)		(0.42)
Short Run Coeff.								
ΔLog Oil Price	-0.01	-0.01		-0.00	-0.01	-0.01		-0.00
	(-0.81)	(-0.80)		(-0.48)	(-0.82)	(-0.79)		(-0.51)
ΔInt. Rate Diff.	0.06	0.08		0.01	0.07	0.08		0.02
	(1.22)	(1.15)		(0.29)	(1.34)	(1.17)		(0.32)
No. of Countries	4	4		4	4	4		4
No. of obs.	1730	1730		1730	1730	1730		1730
Log likelihood		3663				3663		

Note: t-statistics calculated using heteroskedasticity consistent standard errors.
All equations include a constant country-specific term. T-statistics are in parentheses.
*Significant at 10% or better; Significant coefficients in **bold** letters.

5 Summary and Conclusion

The paper has explored whether a link exists between the price of oil and real exchange rate for five oil-importing countries and three oil-exporting countries. The paper has applied very recent tests for unit root and cointegration in panel data based on the simple model of Meese and Rogoff (1988) to unravel evidence for any long run relationship among real exchange rate, real interest rate differential and real oil price for the period 1980:1 to 2008:11. The use of these methods, quite recent in the applied literature, avoids the problems found in panel data analysis when the variables are non-stationary, and adds the cross-country dimension to the traditional time series analysis. The inclusion of the real interest rate differential and real oil price as the determinant of the equilibrium real exchange rate seems to provide a reasonable model to explain the behaviour of the real exchange rate among net oil importing countries in particular.

First, the paper has found evidence of non-stationarity for the three series for all groups of countries. For real oil price and real exchange rate, the series contain unit root as all panel unit root tests fail to reject the null hypothesis of unit root at 1% significance level. For real interest rate differential, it appears to be weakly non-stationary especially for oil exporting countries and panel of eight countries as the null hypothesis of unit root can only be rejected at 10% significance level for most unit root tests. Second, the paper has shown evidence of a long-term relation (i.e. cointegration relation) between the three series, and of a causality running from real oil price to the real exchange rate. While the Pedroni (1999) test failed to find evidence of cointegration, Maddala and Wu (1999) and Kao (1999) tests provide significant evidence of cointegration among the variables for all groups of countries.

Finally, to investigate the impacts of real oil price on real exchange rate, the paper conducted a dynamic panel data study allowing for considerable heterogeneity across countries for 8 countries over 1980-2008. It mainly focuses on the pooled mean group (PMG) procedure which allows for heterogeneous dynamic adjustments towards a common long-run equilibrium. This research in general provides strong evidence in support of a significant positive impact of real oil price and real interest rate differential on real exchange rate, indicating any future oil price shocks would cause real depreciation of exchange rate in the long run especially among net oil importing countries. The paper however did not find evidence to suggest that higher real oil prices lead to real appreciation of exchange rate among net oil exporting countries. This is nevertheless not surprising because previous literatures which attempted to link the effect of real oil price on real exchange rate for oil exporting countries were based on OPEC countries where oil accounts for at least three-quarters of total export earnings. Notwithstanding, strong evidence is obtained to link between real interest rate differential and real exchange rate for each type of country grouping. The sign of real interest rate differential coefficient is negative and is consistent with the theory.

References

AMANO, R. A. & VAN NORDEN, S. (1998) Oil prices and the rise and fall of the US real exchange rate. *Journal of International Money and Finance,* 17**,** 299-316.

BACKUS, D. (1984) Empirical models of the exchange rate: separating the wheat from the chaff. *Canadian Journal of Economics,* 17**,** 824-846.

BENASSY-QUERE, A., MIGNON, V. & PENOT, A. (2007) China and the relationship between the oil price and the dollar. *Energy Policy,* 35**,** 5795-5805.

BREITUNG, J. (2000) The local power of some unit root tests for panel data. IN BALTAGI, B. H. (Ed.) *Nonstationary Panels, Panel Cointegration, and Dynamic Panels.* Amsterdam, Elsevier.

CAMARERO, M. & TAMARIT, C. (2002) Oil prices and Spanish competitiveness: A cointegrated panel analysis. *Journal of Policy Modeling,* 24**,** 591-605.

CHAUDHURI, K. & DANIEL, B. C. (1998) Long-run equilibrium real exchange rates and oil prices. *Economics Letters,* 58**,** 231-238.

CHEN, S.-S. & CHEN, H.-C. (2007) Oil prices and real exchange rates. *Energy Economics,* 29**,** 390-404.

CHORTAREAS, G. E., DRIVER, R. L., PARK, W. & STREET, T. (2001) PPP and the real exchange rate-real interest rate differential puzzle revisited: evidence from non-stationary panel data. *Working Papers.* Bank of England.

CORDEN, W. M. (1984) Booming Sector and Dutch Disease Economics: Survey and Consolidation. *Oxford Economic Papers,* 36**,** 359-380.

EDISON, H. J. & PAULS, B. D. (1993) A re-assessment of the relationship between real exchange rates and real interest rates: 1974-1990. *Journal of Monetary Economics,* 31**,** 165-187.

ENGLE, R., F & GRANGER, C. W. J. (1987) Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica (1986-1998),* 55**,** 251.

FISHER, R. A. (1932) *Statistical Methods for Research Workers,* Edinburgh, Oliver & Boyd.

FUNK, M. F. (2001) International R&D Spillovers and Convergence Among OECD Countries. *Journal of Economic Integration* 16**,** 48 - 65

G. S. MADDALA, S. W. (1999) A Comparative Study of Unit Root Tests with Panel Data and a New Simple Test. *Oxford Bulletin of Economics and Statistics,* 61**,** 631-652.

GOLUB, S. S. (1983) Oil Prices and Exchange Rates. *The Economic Journal,* 93**,** 576-593.

GRANGER, C. W. J. (1981) Some properties of time series data and their use in econometric model specification. *Journal of Econometrics,* 16**,** 121-130.

HADRI, K. (2000) Testing for stationarity in heterogeneous panel data. *Econometrics Journal,* 3**,** 148.

HLOUSKOVA, J. & WAGNER, M. (2006) The Performance of Panel Unit Root and Stationarity Tests: Results from a Large Scale Simulation Study. *Econometric Reviews,* 25**,** 85-116.

HSIAO, C., PESARAN, M. H. & TAHMISCIOGLU, A. K. (1999) Bayes Estimation of Short-run Coefficients in Dynamic Panel Data Models. IN HSIAO, C., K. LAHIRI, L.-F. L. & PESARAN, M. H. (Eds.) *Analysis of Panels and Limited Dependent Variables: A Volume in Honour of G S Maddala.* Faculty of Economics, University of Cambridge.

IM, K. S., PESARAN, M. H. & SHIN, Y. (2003) Testing for unit roots in heterogeneous panels. *Journal of Econometrics,* 115**,** 53-74.

KAO, C. (1999) Spurious regression and residual-based tests for cointegration in panel data. *Journal of Econometrics,* 90**,** 1-44.

KARLSSON, S. & LÖTHGREN, M. (2000) On the power and interpretation of panel unit root tests. *Economics Letters,* 66**,** 249-255.

KORANCHELIAN, T., SPATAFORA, N. & STAVREV, E. (2005) The Equilibrium Real Exchange Rate in a Commodity Exporting Country: Algerias Experience. *Working paper 05/135.* Washington D.C, International Monetary Fund.

KORHONEN, I. & JUURIKKALA, T. (2009) Equilibrium exchange rates in oil-exporting countries. *Journal of Economics & Finance,* 33**,** 71-79.

KRUGMAN, P. (1983a) Oil and the Dollar. IN BAHANDARI, J. S. & PUTNAM, B. H. (Eds.) *Economic Interdependence and Flexible Exchange Rates.* Cambridge, MA, MIT Press.

KRUGMAN, P. (1983b) Oil shocks and exchange rate dynamics. IN FRENKEL, J. A. (Ed.) *Exchange Rates and International Macroeconomics.* Chicago, University of Chicago Press.

KWIATKOWSKI, D., PHILLIPS, P. C. B., SCHMIDT, P. & SHIN, Y. (1992) Testing the null hypothesis of stationarity against the alternative of a unit root. *Journal of econometrics,* 54**,** 159-178.

LEVIN, A., LIN, C.-F. & JAMES CHU, C.-S. (2002) Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of Econometrics,* 108**,** 1-24.
MACDONALD, R. (1998) What determines real exchange rates?: The long and the short of it. *Journal of International Financial Markets, Institutions and Money,* 8**,** 117-153.
MACDONALD, R. & NAGAYASU, J. U. N. (2000) The Long-Run Relationship Between Real Exchange Rates and Real Interest Rate Differentials: A Panel Study. *IMF Staff Papers,* 47**,** 116-128.
MACDONALD, R., TAYLOR, M. P. & DOOLEY, M. P. (1993) Exchange Rate Economics: A Survey. *IMF Working Paper No. 91/62*
MADDALA G. S. & WU, S. (1999) A Comparative Study of Unit Root Tests with Panel Data and a New Simple Test. *Oxford Bulletin of Economics and Statistics,* 61**,** 631-652.
MEESE, R. (1990) Currency Fluctuations in the Post-Bretton Woods Era. *Journal of Economic Perspectives,* 4**,** 117-134.
MEESE, R. & ROGOFF, K. (1988) Was it Real? The Exchange Rate-Interest Differential Relation Over the Modern Floating-Rate Period. *The Journal of Finance,* 43**,** 933-948.
NARAYAN, P. K., NARAYAN, S. & SMYTH, R. (2008) Are oil shocks permanent or temporary? Panel data evidence from crude oil and NGL production in 60 countries. *Energy Economics,* 30**,** 919-936.
OLOMOLA, P. A. & ADEJUMO, A. V. (2006) Oil Price Shock and Macroeconomic Activities in Nigeria. *International Research Journal of Finance and Economics*.
PEDRONI, P. (1998) Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors. *Oxford Bulletin of Economics and Statistics,* 61**,** 653-670.
PESARAN, M. H., SHIN, Y. & SMITH, R. P. (1999a) Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. *Journal of the American Statistical Association***,** 621-634.
PESARAN, M. H. & SMITH, R. (1995) Estimating long-run relationships from dynamic heterogeneous panels. *Journal of Econometrics,* 68**,** 79-113.
PESARAN, M. H., ZHAO, Z. & UNIVERSITY OF CAMBRIDGE. DEPT. OF APPLIED, E. (1999b) Bias reduction in estimating long-run relationships from dynamics heterogeneous panels. IN HSIAO, C., LAHIRI, K., LEE, L.-F. & PESARAN, M. H. (Eds.) *Analysis of Panels and Limited Dependent Variables: A Volume in Honour of G S Maddala.* Department of Applied Economics, University of Cambridge.
WESTERLUND, J. (2007) Testing for Error Correction in Panel Data. *Oxford Bulletin of Economics & Statistics,* 69**,** 709-748.
ZALDUENDO, J. (2006) Determinants of Venezuela's Equilibrium Real Exchange Rate. *IMF Working Papers,* 6074**,** 1-17.
ZHOU, S. (1995) The response of real exchange rates to various economic shocks. *Southern Economic Journal,* 61**,** 936.