

NHH



# The relationship between oil prices and exchange rates

*Evidences from Norway, Canada and Mexico*

**My Nguyen**

**Supervisor: Øivind Anti Nilsen**

MSc in Economics and Business Administration,  
International Business

NORWEGIAN SCHOOL OF ECONOMICS

This thesis was written as a part of the Master of Science in Economics and Business Administration at NHH. Please note that neither the institution nor the examiners are responsible – through the approval of this thesis – for the theories and methods used, or results and conclusions drawn in this work.

## FOREWORD

This Master thesis is written as part of the Master of Science in Economics and Business Administration program at the Norwegian School of Economics (NHH), with a main profile of International Business.

The process of writing this thesis has undeniably been challenging to me due to my bad health condition and time pressure. For the last couple of years, chronic diseases have hindered my studies and delayed my graduation. To add to its worse, the absence of important data combined with its irrelevance to my future studies forces me to change topic around the end of September. Sincerely sharing, I was suffering from a high level of stress at that point and was afraid that I would fail to catch up with submission deadline.

I would like to take this opportunity to express deepest gratitude to my advisor, Professor Øivind Anti Nilsen. Without his great help, I would never graduate on time. Upon recognizing my difficulty in seeking for supervisor, he was very willing to help me out and agreed on supervising my master thesis despite of his relatively heavy teaching load. Later on, his remarkable guidance, detailed comments and interesting discussions are extremely helpful to me.

I am also grateful to examination office, especially Hilde Karen Hilde Methlie Strømme, for always assisting students to the fullest, more notably accepting and processing my extremely late application for supervisor change.

Last but not least, my special thanks go to my beloved parents for their encouragement and continuous support during the research.

Bergen, 20<sup>th</sup> December, 2015.

## ABSTRACT

In this research, we attempt to explore the short and long run relationship between real crude oil prices and currencies of the world's major oil exporting countries from 2000 to 2015. More specifically, exchange rates of Canadian Dollar (CAD), Mexican peso(MXN), Norwegian Krone (NOR) measured against United States Dollar (USD) are placed under scrutiny. We find bidirectional causality in the case of CAD/USD and West Texas Intermediate crude oil (WTI) prices regardless of diverse frequency, yet only unidirectional effect running from NOK/USD to Brent price at weekly and daily data. Unfortunately, from our out-of sample forecast experiment, either crude oil price or exchange rate cannot serve as efficient predictor for the other. For Mexico, the indication in favour of the linkage fails to present at all. More interestingly, we uncover a strong and robust evidence that the positive response of CAD/ USD to WTI and connection between NOK/USD and Brent are of more robust in daily data than in weekly data and such a pronounced influence wipes out in monthly observations. The plausible explanation is that market participants tend to assess constantly economic news and development, so the short-lived effect spreads over time and vanishes at lower frequency. We indeed acknowledge that the base currency is crucial to our findings. We also extend another avenue of our approach to assess dollar effect by switching the denominator of exchange rates to Euro and thereafter another surprising findings show up that Canadian dollar-Euro exchange rates and Norwegian Krone-Euro exchange rates no longer form stable and long run linkage with their corresponding oil price indices .The role of US dollar in the oil-currency relationship is found to be obvious in the case of Canada.

---

## TABLE OF CONTENTS

<b>1. Introduction.....</b>	<b>10</b>
1.1 Motivation for the choice of research topic.....	10
1.2 Objectives.....	13
1.3 Research questions.....	14
1.4 Structure of paper.....	15
<b>2. Theoretical framework .....</b>	<b>16</b>
2.1 The effect of crude oil prices on us dollar.....	16
2.2 The effect of crude oil prices on currency values of oil exporting countries	16
2.2.1 Dutch disease.....	17
2.2.2 Trade theory .....	18
2.3 The ability of currency value of major oil exporting countries to explain the movement of crude oil prices.....	18
2.4 The effect of us dollar on crude oil prices.....	21
2.4.1 Demand side:.....	21
2.4.2 Supply side:.....	22
2.5 Literature review.....	23
<b>3. Data description and graphs.....</b>	<b>26</b>
3.1 Data description.....	26
3.2 Graphs .....	28
3.3 Contemporaneous correlation.....	30
<b>4. Methodology .....</b>	<b>32</b>
4.1 Error correction model.....	32
4.2 Vector Autoregressions model (VAR) and Granger causality test.....	33
<b>5. Empirical analysis .....</b>	<b>35</b>

---

5.1	Unit root test ( 4 of jan 2000- 14 of september 2015).....	35
5.2	Engle Granger residual-based approach for cointegration .....	36
5.3	Error correction model .....	37
5.4	Johansen -Juselius cointegration test .....	39
5.5	Vector autoregression model (VAR) and Granger causality test .....	41
5.6	Gregory and Hansen cointegration test with structural break .....	45
<b>6.</b>	<b>Discussions.....</b>	<b>48</b>
6.1	Is there any long run relationship between oil prices and currency exchange rates of the world's major oil exporting countries? .....	48
6.2	Can crude oil prices impact on exchange rates of these given countries in a long and short run? .....	50
6.3	Can the movement of chosen exchange rates contribute to explaining the fluctuation of crude oil prices? .....	54
6.4	Compare the predictive power of var model with random walk model in out of sample dynamic forecast.....	55
6.5	Are the results sensitive to the choice of frequency?.....	58
6.6	Does dollar effect play any role in the relationship? .....	61
<b>7.</b>	<b>Limitation , conclusion and suggestion.....</b>	<b>68</b>
7.1	Limitation .....	68
7.2	Conclusion.....	68
7.3	Further research.....	70
	<b>REFERENCES.....</b>	<b>71</b>
	<b>APPENDIX TABLES .....</b>	<b>77</b>
	<b>APPENDIX FIGURES.....</b>	<b>82</b>

---

## LIST OF TABLES

Table 1. General information about Canada,Norway and Mexico .....	14
Table 2. Contemporaneous correlation matrices between the weekly returns of exchange rates and crude oil prices .....	30
Table 3. Stationarity Test for all series (weekly data , 4 of Jan 2000 -14 of Sept 2015) .....	35
Table 4. Engle Granger residual –based test for cointegration(weekly data).....	37
Table 5. Johansen Cointegration test for each pair (weekly data) .....	40
Table 6. Granger Causality Test of L <sub>CAN</sub> and L <sub>WTI</sub> equation (weekly data).....	42
Table 7. Granger Causality Test of L <sub>NOR</sub> and L <sub>BRENT</sub> equation (weekly data) .....	42
Table 8. Gregory and Hasen test for cointegration with structural break (weekly data).....	46
Table 9. RMSFE statistics for 2 models in weekly out of sample dynamic forecasts .....	56
Table 10. Johansen and Juselius test for cointegration as Euro is used in the common denomination (weekly data).....	63
Table 11. Granger Causality Test of L <sub>USD/EUR</sub> and L <sub>WTI</sub> (weekly data).....	64
Table A. 1. Engle Granger test on monthly and daily data.....	77
Table A. 2. Johansen test on monthly and daily data .....	77
Table A. 3. VAR model and Granger causality test on monthly and daily data.....	77
Table A. 4. Lag exclusion test of VAR model (weekly data).....	78
Table A. 5. Lagrange-multiplier test for serial correlation in VAR model. ....	78
Table A. 6. Normality test of Var Model (L <sub>NOR</sub> -L <sub>BRENT</sub> ) Jarque-Bera test.....	79
Table A. 7. Tabulated Impulse response function of VAR model (weekly data).....	80
Table A. 8. Breusch-Godfrey LM test for autocorrelation of VAR model (weekly data) ....	80
Table A. 9. LM test for autoregressive conditional heteroskedasticity (ARCH) of VAR model (weekly data) .....	80
Table A. 10. Engle Granger test for cointegration as the base currency is switched to Euro (weekly data) .....	81
Table A. 11. Gregory and Hasen test for cointegration with structural break as the base currency is switched to Euro ( weekly data).....	81

---

## LIST OF FIGURES

Figure 1. The effect of USD dollar value on crude oil prices in international market .....	22
Figure 2. The development of Crude oil prices(Brent and WTI) and exchange rates (CAN/USD; NOK/USD; MXN /USD).....	28
Figure 3. Impulse response function of VAR model .Impulse:LCAN, Response: LWTI (weekly data).....	44
Figure 4. Impulse response function of VAR model .Impulse:LWTI, Response: LCAN (weekly data).....	44
Figure 5. Impulse response function of VAR model ,Impulse:LBRENT, Response: LNOR (weekly data).....	45
Figure 6. The impulse response function ,impulse :LUSD/EUR, response : LWTI (weekly data) .....	65
Figure A. 1 Out of sample dynamic forecast of VAR model (weekly data) .....	82
Figure A. 2. Inverse roots of the characteristic polynomial in VAR model(weekly data) .....	83
Figure A. 3. Impulse response function of VAR model (weekly data) .....	84

---

## LIST OF ABBREVIATIONS AND ACRONYMNS

ABBR	DESCRIPTION
ADF	Augmented Dickey Fuller
ADL	Autoregressive Distributed Lag
ARCH	Autoregressive Conditional Heteroskedasticity
BRENT	North Sea Brent crude oil prices
CAD/USD	Canadian Dollar against United State Dollar
ECM	Error Correction Model
EIA	USA Energy Information Administration
IRF	Impulse Response Function
GDP	Gross Domestic Product
GPF	Government Pension Fund in Norway
MXN/USD	Mexico Peso against United State Dollar
NOK/USD	Norwegian Krone against United State Dollar
OPEC	Organization of the Petroleum Exporting Countries
WTI	West Texas Intermediate crude oil prices
LBRENT	The logarithm form of Brent or North Sea crude oil prices
LCAN	The logarithm form of CAD/USD
LCAN/EUR	The logarithm form of CAD/EUR
LM	Lagrange-Multiplier test
LMEX	The logarithm form of West Texas Intermediate crude oil prices
LNOR	The logarithm form of NOK/USD
LNOR/EUR	The logarithm form of NOK/EUR
LWTI	The logarithm form of MXN/USD
LUSD/EUR	The logarithm form of USD/EU
PP	Phillips-Perron
RMSE	The root mean squared error for forecast
UK	United Kingdom
US	United States
USD	United States Dollar
USD/EU	United States Dollar against Euro
VAR	Vector Autoregressions Model



---

VECM	Vector Error Correction Model
$\Delta$	The first difference

# 1. INTRODUCTION

## 1.1 Motivation for the choice of research topic

Crude oil is singled out as one of the most dominant energy natural resources and prominently serves as lifeblood of the world economy. Interestingly, in 2014, oil reportedly makes up of approximately 38 % of global energy mix. According to USA Energy Information Administration (EIA), for the first half of 2015, on average the world demand reaches roughly 93 million barrels of oil and liquid fuels per day. An unprecedented explosion of oil consumption is in conjunction with enormous economic progress in the early 21st century .Meanwhile, a steep plummet of oil prices is in parallel with the global financial crisis during the period from 2008 to 2009.The unique combination of characteristics enables oil to be designated as the king of commodity. A sudden disappearance of oil would make the majority of industries, especially transport sector, come to screeching halt and human's daily lives become stagnant.

Hamilton (1983) observes that seven of the eight major recessions since World War II in the United States are preceded by a drastic surge in the oil prices. From empirical perspective, he claims that oil shock might at least responsible partly for some of the downturns prior to 1972. Consistent with Hamilton's work, Guo and Kliesen(2005) document that oil prices' volatility over the period from 1984 to 2004,is significantly detrimental to US future gross domestic product (GDP) growth ,notably in terms of various measures of US macroeconomics such as fixed investment, consumption, employment and the unemployment rate. In contrast, Eikaa and Magnussen (2000) reveal that a windfall gain yielded from oil price's spike contributes considerably to raising Norway's private and public consumption, lowering unemployment and more prominently boosting welfare. Hence, the global rapid growth combined with a strong tie of many economies to crude oil has been making it the most-frequently traded and highly competitive commodity in the centralized international exchange markets.

As a measure of import and export level, exchange rate plays an essential role in any country's economy. The era of globalization has over the past several decades brought numerous opportunities to organizations to extend their operation business and trading activities beyond the domestic area. Any depreciation of home currency against other

---

currencies will considerably stimulate export value and decline import value. Many businesses, irrespective of being domestic or international, are influenced directly or indirectly by exchange rate movement. Besides the effect on trade balance in short and long run (see Fountas and Aristotelous, 1999; Sapir Sekkat, 1990), other potential importance of exchange rate is highlighted by many previous literatures. For example, Belke (2005) suggests that exchange rate variability exerts statistically significant and adverse influence on the unemployment rate in a number of Central and Eastern European Countries. In the later work, focusing on the case of Germany, Hacker and Hatemi-J (2004) points out that a real devaluation is likely to dampen output within few months and subsequently drives up longer term output.

It came as no surprise that any undesirable fluctuation of oil prices or exchange rates takes a drastic toll on nations' wealth. However, both of the variables display dynamic behaviours which are difficult to be captured. Hence, there is no doubt that the linkage between crude oil prices and exchange rates is not only an interesting subject for studies but also practically important to a number of individuals and organizations. Firstly, since it deeply involves multilateral economic interaction, the findings definitely catch interest of policy makers. More noticeably, if such a dependent relationship is demonstrated to be reliable and stable, the role of crude oil prices in analysing the impact of exchange rate on major exporter or importers' economy is undeniably crucial. In addition, the result draws rational implications with respect to the most suitable monetary and exchange rate arrangements determination since the policy varies widely, ranging from exchange rate anchor, monetary aggregate target, inflation targeting framework or the join in currency union and so on. For example Dotsey and Reid (1992) re-examine Romer and Romer (1989)'s view and presents that the US's contractionary monetary policy is enacted in coincidence with massive oil prices shocks and the inclusion of the latter washes away the explanatory power of the former over percentage changes in GNP. In the similar line of reasoning, Bernanke, Gertler and Watson (1997) argue that oil prices shock is not the crucial culprit for the recession but the fact that aiming to place inflation under control, Federal Reserve oughts to raise up interest rates in response to a drastically increasing trend displayed by oil prices. Frankel (2006) claims that the US's monetary policy exert a pronounced influence on some agricultural and mineral commodity prices. In particular, the lower interest rates stimulate real commodity prices. Besides, it is worth mentioning that relevant policy to develop nation's petroleum industry can be implemented or improved. Secondly, empirical evidence in support of such

connection brings benefit to corporations which currently engage in overseas transactions or oil-to-related activities, are capable of conducting some effective hedging technique or putting down some strategies to mitigate the potential risks inherent in their revenues. Thirdly, retail traders, investors, hedge fund or corporate hedgers can obtain useful guidance to design their optimal portfolios or make speculation for profit maximization. To elaborate on it, market participants are likely to keep a close track on the movement of predictor for the purpose of initiating prompt and effective adjustment in the response variable's market. Last but not least, the finding is relatively useful to multiple researchers in examining the predictive power of commodity prices on exchange rates or other macroeconomic variables and vice versa.

Our research is undeniably novel in several perspectives. The first and foremost point involves our analytical examine on the role of exchange rates of major oil exporting countries in accounting for the fluctuation of crude oil prices. This idea appears at the first glance to be theoretically counter-intuitive; however it turns out not to be true in practice and the empirical approach generates many appealing results, brings interesting discussions and offers economic importance. Unfortunately, a little attention has been paid to gain deeper insight into this direction. We are definitely not the pioneers but we are highly intrigued by this puzzle and determine to be dedicated to addressing this challenge theoretically and empirically. Secondly, another striking feature of our study relates to a thorough comparison about differences in each variable's predictive ability across countries and at diverse frequencies. The intuition behind our choice lies in highly active markets of both crude oil and exchange rates so their dynamic behaviours or short term effect are likely to vary with frequency and locations. Although weekly data is undeniably the heart of our research, daily and monthly observations are also taken into consideration. More noticeably, our focus on weekly observations is opposed to low frequency preference, for instance: monthly or quarterly data, in majority of previous works. Thirdly, from our knowledge, none of earlier related work has been carried out on Mexico. Likewise, a very little care has been taken to the linkage between Norwegian exchange rate and oil prices after 2000's, nonetheless this period is of paramount importance and should be placed emphasis due to the long period following the nation's official abandonment of pegged currency regime in 1992 and the occurrence of global financial crisis in 2008. Fourthly, in other prior related studies on Norway, authors use different base currency, for example : Akram (2002) chooses European currency unit (ECU) , Bernhardsen and Røisland (2000) use German mark and Norway's

major trading partners ,commonly referred to as trade-weighted exchange rate index whereas we show high favour toward United State Dollar. More noticeably, majority of papers on Canada use the common US Dollar denomination however mistakenly ignore “Dollar effect”, which is likely to distort the empirical implication. We recognize its crucial role in our experiments and take it into consideration by switching base currency to Euro in a later part. Last but not least, we decide to go the extra mile by placing relationship under scrutiny in the presence of structural break at unknown date. As such, our empirical analysis has a number of novel features and differs substantially in some crucial aspects from the existing literature.

## 1.2 Objectives

This research attempts to empirically examine the possible short and long run relationship between crude oil prices and exchange rates of the world’s large oil exporter. Three countries taken into account are Canada, Mexico, Norway; their currencies are Canadian Dollar (CAD), Mexican Peso (MXN), and Norwegian Krone (NOK) respectively. United States Dollar (USD) is treated as the base currency since it predominantly serves as the invoicing and settlement currency for all oil trading in centralized international exchange market. Another reason argues for the preference of USD will be discussed later.<sup>1</sup>

The rationales behind the choice of above mentioned countries are briefly presented as follows:

- According to International Energy Statistics of EIA they are ranked among top ten of the world’s leading oil exporting countries basing on the number of barrels of crude oil exported per days.
- The crude oil consistently accounts for a high proportion of nation’s total export earnings during the period of study.
- These countries have their own currency and maintain a long history of operating market-determined floating exchange rate regimes.
- All of them actively participate into international trade.

---

<sup>1</sup> See section 3.1

- Their small open economies combined with massive commodity export volume plausibly characterize themselves as price takers.

**Table 1. General information about Canada, Norway and Mexico <sup>2</sup>**

Country	No. barrels per day(thousands)*	FER Starts **	Oil export over total export ***	GDP per capita(USD)	Population (millions)
Canada	2733	1970		50271.1	35.54
Mexico	1220	Dec 1994		10230.0	125.4
Norway	1218	Dec,1992	45%	97363.1	5.136

*Note: \* indicates number of barrels ( thousands) exported per day in 2013 ; \*\* presents when floating exchange rate regime is adopted( year), \*\*\* indicates the percentage of oil export over country's total export*

### 1.3 Research questions

The research is aimed at addressing the following questions:

1. Is there any long run relationship between oil prices and currency exchange rates of the world's major oil exporting countries?
2. Can crude oil prices impact on exchange rates of these given countries in a long and short run?
3. Can the movement of chosen exchange rates contribute to explaining the fluctuation of crude oil prices?
4. Compare the predictive power of chosen model with random walk model in out of sample dynamic forecast.

<sup>2</sup> The information from table mostly is aggregated from

<http://www.eia.gov/beta/international/analysis.cfm?iso=NOR>

<http://www.eia.gov/beta/international/analysis.cfm?iso=CAN>

<http://www.eia.gov/beta/international/analysis.cfm?iso=MEX>

<http://www.eia.gov/beta/international/rankings/#?product=57-4&cy=2013>

5. Are the results sensitive to the choice of frequency?
6. Does “dollar effect” play any role in the relationship?

## 1.4 Structure of paper

The remainder of this research is organized as follows. The next section introduces the theoretical framework which primarily places an emphasis on the reasons why oil prices and exchange rates of large oil exporting countries are possibly connected and responsive to each other. Section 3 defines the data and characterizes descriptive statistics. Section 4 presents methodology of the research. Section 5 performs empirical analysis. Section 6 summarizes the main findings and discussions. Section 7 points out some shortcomings inherent in the research, draws conclusion and then puts down some further suggestions

## 2. THEORETICAL FRAMEWORK

This section is primarily designed to providing comprehensive explanations to the main intriguing inquiries about the possible linkage between oil prices and exchange rates of oil exporting countries and about how they are responsive to each other

### 2.1 The effect of crude oil prices on US Dollar

Golub(1983) states that the growth in oil prices implies the wealth reallocation from savings of oil-importers to the revenue of oil producers through a well-presented channel defined as current accounts of balance of payments ;and then a strength of effect on exchange rate adjustment is attributed to the differential portfolio preferences. On the one hand, the current account surplus might induce these oil exporting countries' incentives to buy additional products or goods denominated in US dollar, this tendency is likely to strengthen US dollar (Grise, 2010).On the other hand, the extra income can be encouraged to make aggregate consumptions or investment in other foreign currencies rather than USA dollar. Consequently if such an unexpected excess supply of USD dollar far exceeds its excess demand in the foreign exchange market, the depreciation of USD dollar is unavoidable. In the similar line of reasoning, Krugman(1980) adds that in the short run, OPEC countries typically show a high favour toward US dollar measured goods, however, the long run effect relies heavily on their import's geographic distribution instead of their portfolio preference. Simply put, when it comes to long-term, OPEC tends to cease USD-based asset investments and transfer extra capital to their importers' locations. It can be used for inference that in response to oil price hike, appreciation trend is predicted to be observable in US dollar, nonetheless the pattern is then assumed to shift back to dollar depreciation,

### 2.2 The effect of crude oil prices on currency values of oil exporting countries

There are two possible transmission channels that could account for a positive influence of crude oil prices on currency values of oil exporting countries.



---

### 2.2.1 Dutch disease

The first plausible explanation is based on Dutch disease developed by Corden and Neary in 1982 as the main framework. Dutch disease refers to an adverse impact on nation's economy as a result of a sudden and steep surge in foreign currency inflows. In response to it, country's real exchange rates will experience an appreciation and thereafter costs of other industries' products are inevitably on upward trend, making them less price competitive in the international export market. This phenomenon typically takes place following the discovery or excessive exploitation and export of natural resource. In the wake of higher oil, oil exporting country's economy is assumed to consist of 3 sectors, namely Oil Sector (or Booming sector), the Lagging Sector and the Non-Tradable Sector. The first two can produce tradable goods. To facilitate clarification, the impact of resource boom on economy can be split into two components: spending effect and resource-based effect.

#### *Spending effect*

Sudden surplus wealth prompts aggregate consumption and stimulates the demand for both trade and non-traded goods in exporting countries. By assumption, the excess demand for the latter can be served locally whereas that for the former is expected to be met internationally by increased import. (See Corden, 1984). To address with such effect, additional demand in non-tradable sector can be satisfied partly by extra production and the remainder will be wiped out by increasing the relative price of non-traded goods (Akram, 2000) in the light of demand-supply equilibrium in domestic market. Meanwhile, the output price of the tradable sector remains unchanged in global market. The compound effect is that real exchange rate suffer from appreciation pressure (Bruno & Sachs, 1982; Treviño, 2012)

#### *Resource based effect*

When oil prices soar, petroleum companies in exporting countries will take advantage of this temporary trend and accelerate their production for the sake of profit, triggering the climb in labour recruitment. This induces labour resource transfer from lagging and non-tradable sectors into petroleum one. Combined with the excess labour demand driven from spending effect, it can be inferred that the higher wage in oil sector is followed by the higher wages in other sectors. (Corden 1984) Thereafter, resource boom exerts an inflationary pressure on real wage. As a result of labour mobility, overall wages in home country will undergo upward movement and hence the same trend can be observed in the prices of domestic good

and services. This tendency provides insight into a strengthening of value of home currency afterward. (Bruno & Sachs, 1982; Treviño 2012).

In short, as reflected from the net effect of two channels, the oil windfall translates into an appreciation of currency value of oil exporting countries. The resource based effect is estimated to be less powerful compared to spending effect because given a modern technology of drilling and production activities, additional petroleum demand does not require to recruit a large number of new employees.

### **2.2.2 Trade theory**

The second rationale is laid down on the foundation of macroeconomic perspective and trade theory. (Chen 2004; Chen, Rogoff & Rossi 2008). From the theoretical standpoint of a well-developed small open economy, in which oil constitutes for a large proportion of its export and domestic economic development and activities rely heavily on petroleum sector, a climb in oil prices is accompanied by the appreciation of home currency (Akram, 2000). The intuitive reasoning should be traced to the terms of trade and portfolio balance of payments. Backus and Crucini (2000) state that the volatility in price of oil tends to capture some exogenous shocks to the terms of trade. Simply put, the fluctuation in former primarily accounts for much of the variation the latter, (see Yousefi & Wirjanto, 2002 ). Furthermore, as previously discussed, the rise in petroleum wealth is deemed to translate into trade balance surplus and extra foreign holdings of its domestic currency (Zhang, Dufour & Gabraith 2013). Apparently, in response to the combined effects of terms of trade and balance of payments, the relative demand of its domestic currency from foreign trading partners and domestic export sector should be on an upward trend. Typically, the extent of appreciation is determined by degree of reliance of the local economy on oil earnings (Kilian & Park, 2009 ; Bodenstein, 2011).

## **2.3 The ability of currency value of major oil exporting countries to explain the movement of crude oil prices**

Although the effect of oil prices on currency value is clear-cut, the idea of examining the ability of exchange rates of major oil exporting countries to explain the fluctuation of crude oil prices appears to be novel and not very well-established. Merely, few recent innovative

researches attempt to address the challenge have proposed new approaches both theoretically and empirically.

In earlier work, by applying a conventional class of present value models on quarterly observations from January 1974 to March, 2001, Engel and West (2005) reach the affirmative conclusion that under some circumstances, exchange rates have a remarkable predictive ability over future macroeconomics fundamentals , notably money supplies, inflation, and interest rate and so on, while displaying approximate random walk behaviour. A plausible explanation is that exchange rates should be treated as durable asset prices which are critically determined by market's rational expectations about present and future economic conditions. The intuition of their pioneering empirical research is strongly supported by findings of the prior related work, conducted by Andersen, Bollerslev, Diebold & Vega (2003). These authors provide the convincing empirical evidences that the high frequency exchange rates tend to respond to fundamentals-to-related news quickly and effectively in asymmetric fashion: generally, bad news causes more profound impact, compared to good news.

The forecasting power of exchange rate is again confirmed in the very recent innovative paper. Chen, Rogoff, & Rossi ( 2008) empirically demonstrate that country-specific commodity currency ,namely Canadian dollar ,Australian dollar, New Zealand dollar, South African rand and the Chilean peso with USA dollar as a base currency, have a strong prediction toward the fluctuation of its corresponding commodity export price in both in-sample and out-of-sample . They build on Engle and West's analysis to carry out their investigation that commodity prices can be classified as unique exchange rate fundamentals for these corresponding countries, the primary interpretation involves the clear causality which is affirmatively proved in their earlier work by employing the present-value theoretical approach (2003). Another striking implication in the research is that there is less powerful evidence in support of the reverse direction. They conduct Granger causality and out of sample forecast methodology at quarterly frequency to explore dynamic behaviours of the two, with the assistance of Rossi (2005b)'s approach, which allows for parameter instability. A rational reasoning behind their findings is that exchange rates are strongly forward- looking whereas commodity market are less developed and placed under regulation and more noticeably their prices result from the balance between supply and demand. Furthermore, currency market is viewed to be more well-functioning and price efficient than

commodity market. Hence, exchange rates are prone to incorporate valuable information of market about future development of commodity prices.

Groen and Pesenti (2009) are strong proponent of Chen, Rogoff & Rossi's view, they carry out extensive investigation on whether commodity currencies are useful in predicting their corresponding commodity prices and fortunately many promising outcomes emerge ,especially in the shortest horizon of less than one-quarter. For the sake of comparability, they devote more effort to aggregating information about supply and demand conditions from various countries, and taking into consideration a large number of alternative indices and sub-indices of spot prices. Exchange rate based model is shown to beat naïve statistical benchmark models. Nonetheless, when it comes to across a wide range of commodity price indices and across forecasting horizons, random walk or autoregressive specifications provides the most superior outperformance.

In light of the above discussed considerations, it is reasonable to infer on the possible predictive power of exchange rates for crude oil prices, well-known as a king of commodity. The rational fundamental explanation still lies in superior forward looking feature of exchange rate market compared to oil market. It is relatively obvious that each major exporting country alone is completely insufficient to alter international oil prices by monitoring its output supply. Meanwhile, oil prices in international market are primarily contingent on demand and supply condition. According to Hamilton (2008), short run demand and supply of oil is found to be completely price-inelastic. In this spirit, Askari and Krichene(2010) find that extremely low short-run price elasticity of oil demand and supply sheds a light on significant susceptibility of oil prices to prevailing shocks, perhaps global terms of trade shocks or future macroeconomic shocks. Market expectations about the prospect of fluctuation of oil prices or anticipations about the development in the real economy which impact on demand and supply of oil prices are likely to be embedded in its currency market via a forward looking channel. As a result, it is rational to keep a close track on movements of a small group of exchange rates of major crude oil exporters, which might process and reflect effectively a rich source of useful information about potential behaviour of oil market.

Furthermore, the findings from other related works described below contribute to reinforcing our assumptions and motivating our studies.

---

Trehan ( 1986 ) highlights the essential role of exchange rate in any investigation on the effect of oil prices shocks on USA economy. The omission of exchange rate variable distorts the empirical results and induces a significantly biased estimates ; the undesirable findings is ascribed to substantial impact of value of dollar on oil prices .After adding exchange rate to VAR model, the influence of dollar oil prices on real gross national product is not robust anymore.

Breitenfellner and Cuaresma(2008) point out that the inclusion of relevant information about USD/Euro and its determinants remarkably enhances the exchange rate's explanation over crude oil prices' movement during the period from 1983 to 2006 with the availability of monthly data. Their primary techniques are VAR and VEC against the benchmark namely simply autoregressive (AR). The former is well-suited to short horizons and the latter offers the best forecasting performance in long horizon

## 2.4 The effect of US dollar on crude oil prices

Since oil trading invoices in international market are predominately expressed in USD dollar, its demand and supply are obviously affected by the fluctuation of US dollar value and consequently crude oil prices are prone to be vulnerable to its movement. (Coudert, Mignon& Penot, 2005; Trehan , 1986).To facilitate more intuitive explanation, the compound effect should be broken down into two parts: demand and supply .

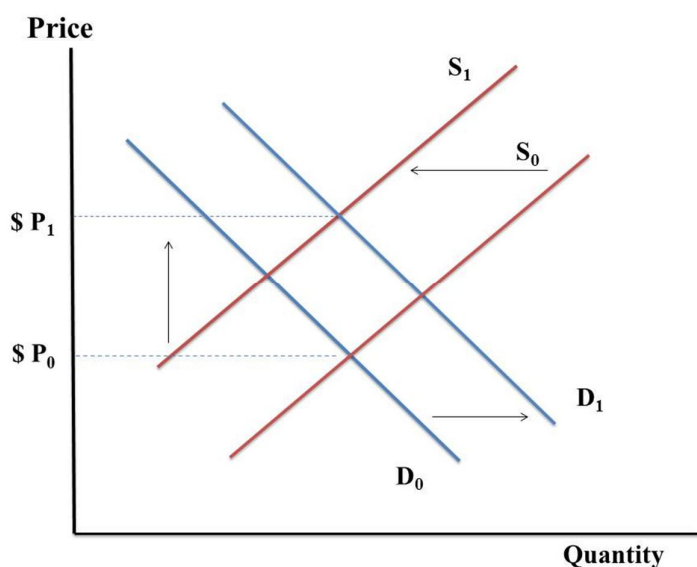
### 2.4.1 Demand side:

Ceteris paribus, a weakening of US dollar is more inclined to driving up demand of consumers .The intuition behind this trend is fairly straightforward. Oil price is perceived to be less expensive in domestic currency by consumers in oil importing countries which are under floating exchange rate system. Aggregately, this tendency possibly entails the growth in global oil demand and contributes to generating current account surplus in consuming countries. (Brown and Philips (1984) ; Huntington (1986); Coudert, Mignon& Penot,( 2005) ; ).In the very recent work, Schryder and Peersman ( 2014) reveal that the under the control of global crude oil price and country-specific real GDP ,the value of US dollar is a major driver of oil demand in the 65 oil-importing countries where the majority of their local transactions are not denominated in US dollar. Another prominent finding is that such a

statistically significant and pronounced influence is much more robust than the effect of a change in the global crude oil prices quoted in US dollar.

As illustrated from figure 1, the demand curve will move to the right. To restore to equilibrium level, oil prices must climb up again. It is appropriate to draw an inference that oil prices is negatively linked to US dollar. (Trehan, 1986; Akram, 2008) .

**Figure 1. The effect of USD dollar value on crude oil prices in international market**



### 2.4.2 Supply side:

There is no doubt that the income earned from oil trade occupies the large portion of oil exporting countries' revenue; meanwhile, their domestic companies have to use local currency to cover all expenditures and taxes. Consequently, *ceteris paribus*, the exporters whose currency rates are not pegged to US dollar will suffer from a massive loss in the face of US dollar devaluation (Coudert, Mignon & Penot, 2005). Even though they might engage in other importing activities with USA, it is extremely difficult for them to exploit monetary transmission or hedging technique to cover up a significant imbalance as a large fraction of their imports are likely to be quoted in non-USA dollar currencies and oil accounts for a vast majority of nations' total export. (Grisse, 2010) In other words, they might have strong motivation to restrict the quantity of oil supply at the decreased USD price. In the figure 1, the supply curve is expected to be shifted toward left. In order to bring system back to the

---

equilibrium, the price of oil in the world market is supposed to soar from  $P_0$  to  $P_1$ , which enables oil producers to offset enormous loss and regain purchasing power. (Trehan, 1986; Akram, 2008) This scenario provides insight into the adoption of US dollar-to-pegged exchange rate system in some oil producing countries, notably OPEC.

In a nutshell, the effect of USD dollar fluctuation perceived by producers appears to be more robust than the one perceived by consumers. Due to its extremely low short run price elasticity, the shifts in demand and supply inevitably trigger profound pressure on its price.

## 2.5 Literature review

There are several studies to examine the ability of crude oil prices in explaining exchange rate fluctuation and vice versa. This intriguing challenge has been addressed from different perspectives, ranging widely from a large set of data generating processes, samples, restrictions, assumptions and so on. Overall, positive evidence emerge from most of studies, in favour of connection and causality.

Amano and Norden( 1995) present that in the small open economy, the exogenous shock in the terms of trade has a remarkable influence on exchange rate in the long run. However, such a shock can be captured adequately by real oil prices. With the application of two-step single equation procedure developed by Engle and Granger on monthly observations from January,1973 to June,1993, they deliver some empirical documents to support a robust linkage between the real domestic price of oil and real effective exchange rates in the United States, Germany and Japan. Three years later, in the same line of reasoning, they proceed further studies and suggest that oil prices and US real effective exchange rates form a stable equilibrium relationship. The former has strong predictive ability over the latter, nonetheless there still lacks of appealing evidence to support the converse. Error correction model (ECM) is proved to beat the random walk significantly in terms of out of sample forecasting performance regardless of larger horizon. Another interesting finding is that oil price is subject to continuously vigorous shocks over the post-Bretton Woods period.

Having performed single equation error correction model, combined with general to specific model on quarterly observation over the period from 1971 to 1997, Akram (2002) claims that oil prices expressed in US dollar has significant non-linear influence on Norwegian nominal exchange rate. The striking point lies in the strength of effect on krone/ECU

exchange rate which becomes more robust in response to the substantial downward trend of crude oil prices below 14 USD. Six years later, with the similar interest, the author exploits structural VAR model on quarterly data of an indicator of global activity level, the real trade-weighted US Dollar exchange rate, real interest rate and a group of four commodity prices : oil, food, metals and industrial raw material. His insight is that the depreciation in US dollar value can translate into the rise in commodity prices. He also underscores a remarkable explanatory power of real interest rate and real exchange rate over the fluctuations in commodity prices at multiple horizons. More importantly, there is a little evidence for the opposite direction. Of particular notice in his later research is the overshooting behaviour of real oil prices and metal prices in the wake of interest rate shock.

Coudert, Mignon and Penot(2005 ) employ Vector Error Correction Model(VECM)<sup>3</sup> on a sample of monthly observations between 1974 and 2004 and uncover empirical evidence that the real effective exchange rates of dollar suffer from depreciation pressure in the wake of increased oil prices ,not the other way round. The primary mechanism through which this stable tie is transmitted is found to be USA net foreign investment asset rather than the terms of trade with intuitive rationale that the authors solely detect cointegration between the former and exchange rates of dollar and oil prices.

Lafrance and Chow(2008) perform relatively innovative and complicated methods namely multiple expanding and rolling window regressions over different sample period and claim that commodity price future and interest rate expectation can offer additional forecasting ability over the value of Canadian dollar .However the equations do not make a considerable improvement over random walk model notwithstanding their passing the simple Meese-Rogoff out-of-sample predictability test. The parameter instability and insignificance in some certain periods might be responsible for their parsimonious specification. Besides, the authors strive to make a clean comparison among various frequencies and confirm about the slow adjustment process associated with lower frequency, which perhaps originates from time aggregation bias.

---

<sup>3</sup> VECM is originally derived from VAR model and well-known as a restricted form of VAR. However different VAR, VECM necessitates the variables are stationary in their first differences and cointegrated .As reflected from its name, VECM includes error correction feature into its equation.



Later work on examining similar connection, such as that of Grisse (2010), finds that the rise of oil prices entails the depreciation of the trade-weighted US Dollar exchange rate in both short and long run, nonetheless the reversal of relationship solely holds within the same week. It is noteworthy that in employing structural VAR model, the paper takes into account the surprise component of announcement of development and economics news in financial market for a purpose of controlling US and world economic evolution. Another key underlying issue in the research is that in the long-run, the volatility of real US short-term interest rates can shed light on the variation in both variables.

Chan, Tse, and Williams (2011) estimate the decoupling behaviours on daily basis in terms of restriction-based causality tests and a rolling out-of sample forecasting method. The currency futures returns and commodity returns in four commodity exporting countries namely Australia, Canada, New Zealand, and South Africa merely share contemporaneous correlation in futures market. However, there is no evidence of causality in either direction. They blame undesirable findings on the informational efficiency in future markets.

In the most recent modern work, Rogoff, Rossi and Ferraro (2012) strongly agree on the short run connection and reveals that oil prices can be treated as the efficient predictor of Canadian US dollar nominal exchange rates at daily frequency. More appealing implication from their experiment is that such forecasting ability vanishes for monthly and quarterly data. This can be ascribed to high sensitivity of data generating processes toward frequency, in particular when it comes to investigating high frequency data, the short-lived effect is likely to be dispersed over time

A recent comprehensive study by Beckmann and Czudaj(2012) utilizes Vector Error Correction method on monthly data for major net oil-exporting countries (Russia, Mexico, Canada, Norway, and Brazil ) and net oil-importing countries (Eurozone, Japan, South Africa, Sweden and the United Kingdom) to examine the relationship between oil prices and exchange rates with U.S. dollar as a base currency. A pattern of positive association can virtually be seen across oil exporters whereas negative co-movement is displayed for importing countries. An increase in oil prices translates into appreciation of exchange rates of oil exporters but it leads to depreciation for importers through nominal rate and price differential. The connection for exporters is more robust compared to the one for importers. The reversal of relationship merely holds up in some cases .

### 3. DATA DESCRIPTION AND GRAPHS

#### 3.1 Data description

The currency rate data is bilateral exchange rates, which collected from the USA Federal Reserve Bank.<sup>4</sup> The real crude oil prices are defined as the spot price per barrel denominated in US dollar.<sup>5</sup>

Since according to EIA's report, in 2014 approximately 98% of Norway's crude oil export is directed to European countries, we choose to use Brent crude oil also known as North Sea Brent (Brent) as a benchmark for real crude oil prices in the case of Norway. However, for other countries, we find West Texas Intermediate price (WTI) an ideal proxy because the United States received roughly 97% of Canada's oil export, 68% of Mexico's in 2014. All data for crude oil prices is compiled from U.S Energy Information Administration (EIA).

In light of literature framework presented previously, it could be inferred that US dollar value forms a negative connection with crude oil prices, whereas currency value of major oil exporting country is expected to positively related to oil prices. It implies that the effect of crude oil prices on CAN/USD; NOK/USD; MXN /USD is assumed to be more obvious compared to other ratios. As such, US dollar should be treated as the base currency. Of a particular note is the significant dominance of US economy in Canada and Mexico's international trade, notably oil sector, which seem to foreshadow the close connection.

To explore the decoupling behaviours properly, we solely keep the observations of the date when all variables are recorded. We decide to place our main focus on weekly data because it allows for the timing of announcement, flow and process of information, effect of news releases, its capability to reduce time aggregation bias and capture both short and long run behaviours. Nonetheless, we also make an effort to assess whether the timing drives the results of our experiments or not by virtually carrying out the identical analysis over a common sample period at daily and monthly intervals. It is worthwhile to recall that in earlier related works, different authors hold different perspective in terms of frequency

---

<sup>4</sup> Source : <http://www.federalreserve.gov/releases/h10/hist/>

<sup>5</sup> Source : [https://www.eia.gov/dnav/pet/pet\\_pri\\_spt\\_s1\\_d.htm](https://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.htm)

---

choice. For example: Chan, Tse, and Williams (2011) or Rogoff, Rossi and Ferraro (2012) show high preference toward daily observations; more prominently, Zhang, Dufour and Galbraith (2013) are inclined to daily and 5 minutes data. The rationale lies in the objective of their research being geared toward embodying extremely fast dynamic or contemporaneous movements between oil prices and exchange rates. Thus, their findings can reflect truly how quickly new information or speculative activities is transmitted across markets and thus are definitely catches much attention from financial market participants who are strongly interested in short decision intervals. In contrast to above mentioned authors, Chen, Rogoff and Rossi (2008) switch their focus to relatively low frequency, quarterly data since their insight is to embed business transaction and capital mobility at the expense of time aggregation bias.

We construct weekly data or monthly data by simply taking the average value of all observations in each week or each month. In general, daily, weekly and monthly data sets contain roughly 3917, 820, and 189 observations respectively. Although we acknowledge the availability of the data for all variables back to 1986, our entire sample merely covers the period from 4 of January 2000 to 14 of September 2015 for a number of reasons. Firstly, amongst our five countries, Mexico and Norway started abandoning their pegging exchange rate regime and introduced their own currencies relatively late, just around December 1994 and December 1992 respectively. Since then, Norwegian currency had undergone some period of managed float in which monetary policy targets at achieving a stable Krone against European Currency Unit (after 1999 known as Euro) by controlling price inflation. (See Gjedrem, 1999 and Norges Bank, 1999). Secondly, the very long span of data are more prone to be vulnerable to multiple structural breaks which are believed to play a major role in empirical failures. This issue might originate from the number of steady shifts in industrialized world, production disrupted by political turmoil, globalization trend, exogenous shocks and so on. Hence, in order to reduce structural breaks, we take a heed to recent years and short horizon rather than the relatively longer horizon. Nonetheless, our sample which spans a comparatively short time period of 15 years still includes a dramatic collapse during global financial crisis and its subsequent recovery of world economy. Therefore, the findings are extremely up-to-date and relatively informative, especially convey intuitive implications about their recent relationship and have a potential importance for future forecasting.

All variables during empirical analysis are expressed into logarithmic form. To be more precise, all original values are converted into logarithmic terms by using this formula:

$$LX = \ln X$$

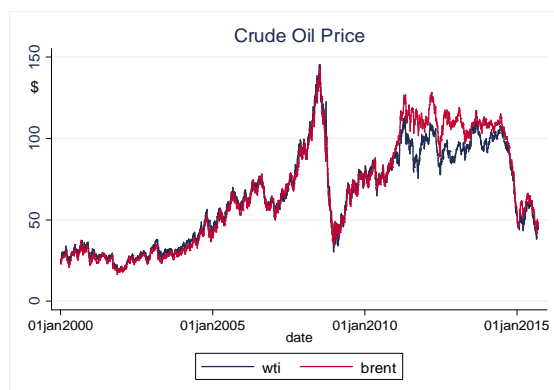
It is a wise option to apply logarithmic transformations to our data for many reasons. Firstly, the exponential patterns with consistent upward fluctuation are easily visible in the whole raw data; such exponential feature is likely to blur crucial connection between variables and hence, should be diminished effectively by treating them in logarithm form. Secondly, the visual representation of log transformed data is better compared to original one's. Thirdly, converting data into logarithms is useful in turning substantially skewed data to be fairly symmetrical or normal, and therefore contributes considerably to eliminating heteroscedasticity.

## 3.2 Graphs

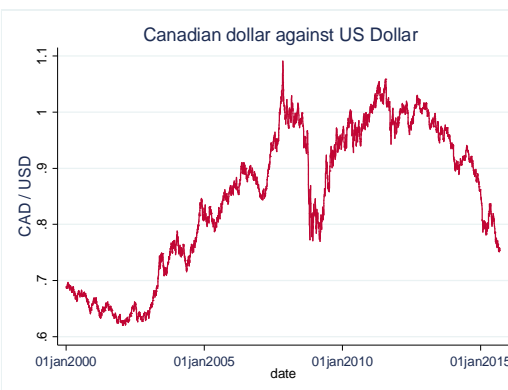
The useful starting point in any empirical analysis virtually involves a visual inspection of data. Time plots of three concerned currency exchange rates (CAN/USD; NOK/USD; MXN /USD) and crude oil prices (both Brent and WTI) from January 2000 onward are drawn in Figure 2.1, 2.2 and 2.3.

**Figure 2. The development of Crude oil prices(Brent and WTI) and exchange rates (CAN/USD; NOK/USD; MXN /USD)**

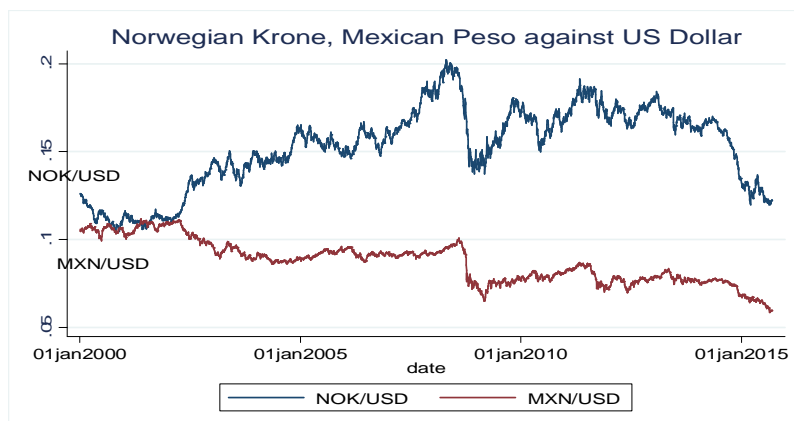
**Figure 2.1. Crude oil prices(WTI, Brent)**



**Figure 2.2. Canadian dollar against US dollar**



**Figure 2.3. Norwegian Krone and Mexico Peso against US dollar**



Our first impression is that both crude oil series appear to consistently move together and even overlap at some points, however, after the late 2010, Brent prices tend to display greater volatility and clearly outperform WTI, the price discrepancy becomes wider from early 2011 till the middle of 2012. We notice that the period from 2007 to 2009 is virtually characterized by bust and boom; such significant upheavals can be attributed primarily to a massive advance of global economy and then world's financial crisis. In contrast, a steady upward trend seems to dominate the pre-2007 period in all series, except for Mexico, more specifically; MXN/USD underwent a gradual decline from 2002 to 2004. More interestingly, the unprecedented surge of oil prices in July, 2008 coincides with the remarkable peak of the given exchange rates. Similarly, the collapse of former at the end of 2008 is in parallel with a large devaluation of the latter. We easily recognize rebounds in all these sequences by the mid-2009s as all currency rates strive to climb back to its pre-appreciation level and more importantly, their sharp swings again are consistent with the spike in oil prices. It is noteworthy that from 2004 to 2008, oil prices exhibit a steep growth with some slight fluctuations; this tendency is again in parallel with the drastic increase in the exchange rates. Likewise, the extraordinarily large ascent in the middle of 2011 and then followed by a big plateau, can be apparently observable in all sequences. The subsequent period from August 2014 till April, 2015 painfully witnesses a drastic collapse without any break of Norwegian and Canada value, this overshooting behaviour is again deemed to be in concurrence with a dramatic plummet of crude oil prices, and then followed by a slight recovery in May, 2015.

In short, all sequences, apart from Mexico, virtually share the similar movement pattern during the sample period and, this visual evidence appears, at the first glance, to support the proposition of decoupling between exchange rates of Norway and Canada and oil prices. Nonetheless, figure inspection must be undertaken to verify about the suspicion

### 3.3 Contemporaneous Correlation

Prior to exploring long and short run relationship, it is a good idea to look at weekly return fluctuation of the two oil prices indices and three exchange rates from 2000 onward, illustrated in following table. The weekly return is calculated as follows:

$$R_t = \ln\left(\frac{S_t}{S_{t-1}}\right)$$

**Table 2. Contemporaneous correlation matrices between the weekly returns of exchange rates and crude oil prices**

	<b>RBRENT</b>	<b>RWTI</b>	<b>RCAN</b>	<b>RNOR</b>	<b>RMEX</b>
<b>RBRENT</b>	1.0000				
<b>RWTI</b>	0.5168	1.0000			
<b>RCAN</b>	0.2374	0.3720	1.0000		
<b>RNOR</b>	0.3643	0.1760	0.3921	1.0000	
<b>RMEX</b>	0.1811	0.2021	0.4429	0.2330	1.0000

The common feature we notice is that all variables form positive correlation to each other .In other words, there is evidence of co-movement between the oil prices and the currencies, although this relationship is less obvious in the case of Mexico and WTI price. In line with our proxy choice discussed in preceding section, returns of Norwegian exchange rates exhibit far greater correlation with the return of Brent prices rather than with those of WTI . The same rule is applied to Canada and Mexico. Their returns are more likely to be correlated to WTI's than Brent's. Two pairs ,Canada and WTI, Norway and Brent seem to move most closely together as their correlation magnitudes reach up to more than 0.36 ,this effect can be captured from the graph though their roughly identical patterns. These figures signal promising results in later part of our data analysis. Of a particular note is the fact that overall the currency variables display pretty high positive correlation with each other, especially in the case of Canada and Mexico.

In a nutshell, we find that the chosen major oil exporters' currency returns are contemporaneously correlated to its corresponding oil prices index return, although the relationship becomes less obvious in the case of Mexico.

## 4. METHODOLOGY

We now turn to discussion of the empirical strategy to uncover the short and long run relationship between crude oil prices and exchange rates of oil exporters. We decide to employ two complementary approaches. The first one is to estimate the error correction model. The second one is to apply Vector Autoregression Model combined Granger Causality test. Both of them are probably the most relevant to our study's objective and also the most frequently used techniques in the previous related researches.

### 4.1 Error Correction Model

The purpose of Error correction model is to explore both short and long run behaviors between two variables. However, prior to implementation, we ought to conduct some prerequisite tests to meet its requirements. At the first stage, the property of each sequence must be determined. The most important and reliable application to identify the order of integration is Augmented Dickey Fuller (ADF) test. Nonetheless, another technique namely Phillips-Perron (PP) is encouraged for checking purpose. Hypothesis testing for ADF and PP test are below

- Null hypothesis: the series contains unit root or it is non-stationary
- Alternative hypothesis : the series doesn't contain unit root or it is stationary

Since then, we move into the next stage to carry out Engle Granger residual based test to examine the existence of cointegration between variables. Engle Granger points out that if two non-stationary series display the same order of integration and their linear combination results in stationary sequence, and then there should be co-integration between them.

Having detected pairwise cointegrating relationship, we embark upon developing Error correction model. The conventional ECM is derived from Autoregressive Distributed Lag (ADL) and well known as the restricted version of ADL specification. To be precise, it can be expressed as follows:

$$Y_t = \varphi_0 + \gamma_0 X_t + \gamma_1 X_t + \varphi_1 Y_{t-1} + \varepsilon_t$$

$$\Leftrightarrow Y_t - Y_{t-1} = \varphi_0 + \gamma_0 X_t - \gamma_0 X_{t-1} + \gamma_1 X_{t-1} + \gamma_1 X_{t-1} + (\varphi_1 - 1) Y_{t-1} + \varepsilon_t$$



After some arrangements and transformations, the basic structure of the ECM can be formulated:  $\Delta Y_t = \alpha + \beta_0 \Delta X_t - \beta_1(Y_{t-1} - \beta_2 X_{t-1}) + \varepsilon_t$

- $Y_{t-1} - \beta_2 X_{t-1}$  describes error correction mechanism thus equals to zero in the equilibrium.
- $\beta_0$  represents the short term or immediate impact of any change of X on Y in the current period or  $\beta_0$  can be seen as short-run elasticity.
- $\beta_1$  indicates the speed of adjustment used to bring the system back toward its long-run equilibrium after deviation,  $\beta_1$  is widely called as an error correction term.
- $\beta_2$  implies the long term influence of an increase of X on Y. Such effect can be diffused over period of time, relying on the error correction term  $-\beta_1$ .  $\beta_2$  can be called as long run multiplier.
- Since the residuals from cointegration regression reflect deviation from equilibrium state between Y and X, the lagged residuals can be included as an indicator of error correction. It can be defined as  $ECT_{t-1} = Y_{t-1} - \beta_2 X_{t-1}$  and then the equation should be modified as follows

$$\Delta Y_t = \alpha + \beta_0 \Delta X_t + \beta_1 ECT_{t-1} + \varepsilon_t$$

- The first differenced variables are preferable over those in level since the former are stationary and therefore spurious results can be eliminated in the regression.
- $ECT_{t-1}$  stands for one-period lagged value of residuals from the cointegration regression model. The essential condition to judge the suitability of ECM representation is that estimated coefficient of the lagged level of residual series must have negative sign and statistically significant at conventional level. This necessity translates into the convergence of two variables in a long-run.

## 4.2 Vector autoregressions model (VAR) and Granger causality test

It is admitted that error correction model can do a good job of pinpointing a short and long run effect, however it is usually not stable and thus not very useful in prediction. VAR

model is typically evaluated to be more well-specific econometric model and therefore offers more predictive content, relative to ECM. In addition, there are some shortcomings inherent in Engle Granger test, which possibly entail the failure to detect some long run relationship. One of the strongest criticisms for Engle Granger lies in its two stage procedure. The first step involves residual series generation and the second one is to estimate regression for such sequence and examine its stationarity property. Consequently, any error incurred in the first one is supposed to be transferred to the subsequence stage (see Asterious & Hall,2007).To avoid such an undesirable situation, we ought to employ another alternative but more advanced method, namely Johansen and Juselius Test which is proved to overcome such drawbacks and therefore can be utilized to verify the performance of Engle Granger.

In our second experiment, the first necessary step is to carry out Johansen method which is built on the combination of likelihood-based trace and maximum eigenvalue, given that all series are of the same order of integration.

Once the number of cointegrating vectors is identified, we proceed to construct VAR model. To simply put, for two endogenous variables and lag-length of  $p$ , the VAR( $p$ ) is made up of two variables can be expressed as

$$\begin{pmatrix} Y_{1,t} \\ Y_{2,t} \end{pmatrix} = \begin{pmatrix} c_1 \\ c_2 \end{pmatrix} + \begin{pmatrix} a_{1,1}^1 & a_{1,2}^1 \\ a_{2,1}^1 & a_{2,2}^1 \end{pmatrix} \begin{pmatrix} Y_{1,t-1} \\ Y_{2,t-1} \end{pmatrix} + \dots + \begin{pmatrix} a_{1,1}^p & a_{1,2}^p \\ a_{2,1}^p & a_{2,2}^p \end{pmatrix} \begin{pmatrix} Y_{1,t-p} \\ Y_{2,t-p} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix}$$

The matrix notation should be re-writteen as following equations:

$$Y_{1,t} = c_1 + a_{1,1}^1 Y_{1,t-1} + a_{1,2}^1 Y_{2,t-1} + \dots + a_{1,1}^p Y_{1,t-p} + a_{1,2}^p Y_{2,t-p} + \varepsilon_{1,t} \quad (4.5 a)$$

$$Y_{2,t} = c_2 + a_{2,1}^1 Y_{1,t-1} + a_{2,2}^1 Y_{2,t-1} + \dots + a_{2,1}^p Y_{1,t-p} + a_{2,2}^p Y_{2,t-p} + \varepsilon_{2,t} \quad (4.5b)$$

Later on, we employ Granger causality tests to determine a direction of causality.

For example in the equation (4.5a)

- The null hypothesis is that none of  $Y_{2,t}$  can offer predictive content for above and beyond lagged values of  $Y_{1,t}$ . In other words,  $\{ Y_{2,t} \}$  does not granger cause  $\{ Y_{1,t} \}$ .
- The alternative hypothesis is that  $\{ Y_{2,t} \}$  does Granger cause  $\{ Y_{1,t} \}$ .

## 5. EMPIRICAL ANALYSIS

### 5.1 Unit root test ( 4 of Jan 2000- 14 of September 2015)

We start out our empirical analysis by examining the property of individual sequence at weekly frequency. The results of the ADF, PP tests with a 5 per cent level of significance are reported in the following table. The graphs of LCAN, LNOR, LMEX, LWTI, LBRENT are suggestive of the presence of trend and their fluctuation around non-zero sample mean, pointing to the inclusion of intercept and trend in unit root test. Whereas graphs of their first differenced data indicate their movement around sample mean of approximately zero, as a consequence, no constant is selected for stationarity test.

**Table 3. Stationarity Test for all series (weekly data, 4 of Jan 2000 -14 of Sept 2015)**

Variables	Augmented Dickey Fuller		Phillips-Perron		Decision I(d)
	At Level Intercept & Trend	First Difference None	At Level Intercept & Trend	First Difference None	
LWTI	-1.63 (0.78)	-5.99	-1.65 (0.77)	-24.88	I (1)
LBRENT	-1.35 (0.87)	-5.96	-1.37 (0.87)	-22.29	I (1)
LCAN	-0.74 (0.97)	-5.08	-0.27 (0.99)	-23.88	I (1)
LNOR	-1.1 (0.93)	-6.00	-0.79 (0.97)	-23.4	I (1)
LMEX	-3.1 (0.11)	-5.94	-2.88 (0.17)	-24.31	I (1)

*Note : the figures in parentheses indicates p-value, the figures without parenthesis presents t-statistic*

Generally, ADF and PP tests yield comparable results in all series. The table reveals the existence of unit root for the level data since we fail to reject the null hypothesis.<sup>6</sup> In contrast, the stationarity feature is proved at their first differences. In short, the logarithm terms of all variables are found to be I(1).

<sup>6</sup> See section 4.1 for the null hypothesis.

## 5.2 Engle Granger residual-based approach for cointegration

Having identified the stationarity of all variables, we turn to investigate the pairwise relation between crude oil prices and exchange rates. Since the graphical illustration of individual sequence is indicative of trend, we construct long-run equilibrium relationship equations in this basic form  $Y_t = \alpha + \beta * X_t + \gamma \text{ trend} + \varepsilon_t$ , where  $\varepsilon_t$  is the residual.

And then residual sequences derived from Ordinary Least Square (OLS) regressions are subject to the same unit root checking procedure in previous section. If the  $\{\varepsilon_t\}$  series is proved to be stationary, we can conclude that two series  $Y_t$  and  $X_t$  are cointegrated of order (1,1). It is a wise option to use oil prices as dependent variable and exchange rates as explanatory variable. More noticeably, the test statistics here should be compared with critical values reported by Engle and Granger (1987) instead of those used in ADF test. We assume the maximum relevant lag to be 52 weeks (one year). So far, four fundamental approaches namely Final prediction error (FPE), Akaike's AIC information criterion (AIC), the Hannan and Quinn information criterion (HQIC) and Schwarz's criterion (SBIC) have gained acceptance for identifying the optimal lag structure. From our trial and error process, we decide to include 4 lags in LCAN and LWTI equation as suggested by HQIC; 4 lags in LBRENT and LNOR equation as proposed by FPE and AIC, 12 lags in LMEX and LWTI equation as suggested by FPE and AIC.<sup>7</sup>

---

<sup>7</sup> For LNOR and LBRENT pair, HQIC and SBIC indicates that the test with 2 lags is optimal, while FPE and AIC suggests 4 lags. Our intuition is to cover as many lags as possible.

For LCAN and LWTI pair, FPE and AIC suggests 12 lags, HQIC presents 4 lags, meanwhile SBIC indicates only 2 lags. Since the exercise with 12 lags does not release a very appealing result, we decide to take 4 lags

For LMEX and LWTI pair, HQIC and SBIC introduce only 2 lags, meanwhile FPE and AIC suggests 12 lags. Of course, 12 lags is preferable.

**Table 4. Engle Granger residual –based test for cointegration(weekly data)**

Pairs	Residuals At Level			Cointegrated
	ADF test statistics	Critical Value	No. lags	
LWTI - LCAN	-4.574*	-3.792	4	Yes
LWTI - LMEX	-1.689	-3.792	12	No
LBRENT - LNOR	-3.392	-3.792	4	No

Note: \*indicates the stationarity of residual series at 5% level.

The findings from table 4 reveal that residual series are stationary in the first two equations, whereas the remainders have random walk at their levels. In other words, it sheds a light on the presence of pairwise cointegrating relationship between crude oil prices and exchange rate of Canada from January 2000 onward. Unfortunately the same does not hold in either LMEX and LWTI or LNOR and LBRENT. The implication underlying the result is that merely Canadian US dollar exchange rates and WTI prices are expected to move together in the long run and share the common stochastic trend.

### 5.3 Error correction model

Once standard residual based test detects pairwise cointegration on LCAN-LWTI, we proceed to develop error correction model merely on this pair. And of course trend should be included. The results from estimated OLS regressions and corresponding Error Correction Model are expressed in the following forms:

$$LCAN_t = 0.2909026 * LWTI_t + 4.03e-06 * trend + -1.423252 + \varepsilon_t, \quad (1a)$$

$$\Delta LCAN_t = 0.093666 * \Delta LWTI_t - 0.0125187 * ECT_{t-1} + 0.0000464 + \varepsilon_t \quad (1b)$$

$$(0.0080771) \quad (0.0072798) \quad (0.0003439)$$

$$LWTI_t = 3.017278 * LCAN_t + 0.0000438 * trend + 4.576174 + \varepsilon_t, \quad (2a)$$

$$\Delta LWTI_t = 1.50219 * \Delta LCAN_t - 0.0432131 * ECT_{t-1} + 0.0005247 + \varepsilon_t \quad (2b)$$

$$(0.1301208) \quad (0.0091334) \quad (0.0013795)$$

Note: Standard error is in parenthesis below estimates

Fortunately, desirable values of error correction term show up in both equations. A negative sign of adjustment term combined with its statistical significance is in compliance with necessary conditions for ECM model as previously stated.<sup>8</sup>

For the first equation, significant negative value of adjustment term at 10% level implies that WTI prices and Canadian-US dollar exchange rates tend to converge in the long run and the former can exert effect on the latter. The estimated figure suggests that a 1 % rise in the former will cause deviation from the long-run equilibrium relationship during the current week and then Canadian exchange rate against USD dollar will respond to it by increasing a total of 0.2909026 % and distribute over future time period at a rate of 0.0125187 % in the subsequent week. The adjustment process is expected to be completed within one week.

In line with theoretical framework and graphical inspection, the upward movement in L<sub>CAN</sub> is associated with the increase in L<sub>WTI</sub>. This tendency is grasped precisely from the positive value of coefficient of L<sub>WTI</sub> in the regression equation (1a) and of  $\Delta L_{WTI}t$  in equation (1b). The short-run impact of crude oil prices is positive and significant at the 1 % level. It reveals that a ceteris paribus 1% increase in crude oil prices during the current week would trigger Canadian Dollar to appreciate 0.093666 % against US Dollar within the prevailing week.

Similarly, for the second equation, the coefficients of error correction term and  $\Delta L_{CAN}t$  are negative and significantly at 1 % level, indicating that the Canada exchange rate has robust predictive power over WTI oil prices. The interpretation behind the estimated equation is that a ceteris paribus 1% growth or drop in the former is expected to be immediately followed by 1.50219 % increase or decline of the latter within the same week. An appreciation in the former also disrupts the long term relationship and causing latter to be too low. In response to it, the crude oil will then rise up by a total of 3.017278 % to bring back the system to equilibrium with 0.0432% of the deviation corrected in each subsequent week. The speed to adjust to disequilibrium in this ECM model (2) is apparently higher than the previous one (1).

The short-run effect of Canadian USD dollar exchange rate on WTI price is positive and significant at the 1 % level. It is indicative that a ceteris paribus 1% appreciation of Canadian

---

<sup>8</sup> See section 4.1

---

dollar against US Dollar during the current week would lead to the 1.50219 % surge in WTI price within the same week.

The adjusted R-squared is not relatively high in both models, merely 14.15 % and 15.93 % , yet the p-value for the F-stat is statistically significant suggests that the ECM as a whole does not fit the data very well. The Durbin Watson statistics is not close to 2, revealing that the model might be subject to first-order autocorrelation.

It is a common practice to perform robustness check on the ECM models to evaluate its stability. We conduct Breusch-Godfrey Serial Correlation Test and ARCH test in the residuals up to 4 lags conducted .Hypothesis of these test are presented as below:

#### *Breusch-Godfrey Serial Correlation Test*

- The null hypothesis: the sequence is serially independent
- The alternative hypothesis: the sequence is serially dependent.

#### *ARCH test*

- The null hypothesis: autoregressive conditional heteroskedasticity (ARCH) is not present.
- The alternative hypothesis : ARCH is present

The results (both p-value equal to 0.0000) from both tests reject strongly the null hypothesis , with implication that the existence of serial correlation and heteroskedasticity in both ECM models are clear-cut.

## 5.4 Johansen and Juselius cointegration test

The next stage is to carry out our second approach. As mentioned earlier, taken together with the findings from ADF and PP tests that all variables are integrated at the same order, adopting Johansen test on corresponding pairs is warranted with an aim to verify Engle Granger's suggestion and with a hope to detect more cointegration relationship.

Hypothesis testing :

*For trace test :*

- $H_0 : R = r$  . The null hypothesis : The number of cointegrating vectors is less than or equal to  $r$
- $H_1 : R > r$  . The alternative hypothesis : the number of cointegrating vectors is more than  $r$ .

*For the Maximal Eigenvalue test*

- $H_0 : R = r$  .The null hypothesis : There exists  $r$  cointegrating relations in the given variables.
- $H_1 : R = r + 1$  . The alternative hypothesis: there are exactly  $r + 1$  cointegrating relations.

**Table 5. Johansen Cointegration test for each pair (weekly data)**

Variables	R	Trace Test		Max-Eigenvalue Test			Cointegrated
		Trace Statistic	Critical Value	Max Statistic	Critical Value	No.lags	
LCAN- LWTI	0	27.04	15.41	25.28	14.07	4	YES
	1	1.76	3.76	1.759	3.76		
LMEX-LWTI	0	11.18	15.41	10.57	14.07	12	NO
	1	0.61	3.76	0.61	3.76		
LNOR- LBRENT	0	18.30	15.41	15.79	14.07	2	YES
	1	2.52	3.76	2.52	3.76		

As expected, the outcome from Johansen test is more appealing. Table 5 reports that for the pairs: LCAN and LWTI, LNOR and LBRENT, the rejection of null hypothesis as  $r=0$  and the acceptance of null hypothesis as  $r=1$  implies that both Trace test and Maximal eigenvalue test agree on the presence of unique cointegrating vector at 5 % level. In contrast, for LMEX and LWTI, the table confirms the acceptance of null hypothesis as  $r=0$ . It translates into the absence of evidence of cointegration for the pairs: LMEX and LWTI. In short, the direct implication of the findings is that the equilibrium relationship or long term causality seem to be observable in the two pairs LCAN and LWTI, LNOR and LBRENT from 2000 onwards. There is no doubt that Johansen Test generally yields conflicting outcome with Engle Granger test in the case of Norway. It suggests that crude oil prices and exchange rates of



Norwegian Krone against US dollar share stable and long term linkage and further investigation should be carried out on this pair. It is worth noting that this promising result can be interpreted as evidence in favour of VAR model in subsequent section for forecasting.

## 5.5 Vector Autoregression Model (VAR) and Granger Causality Test

Having demonstrated the existence of cointegrating vector, we proceed with constructing VAR model in log levels on the foundation of Sims, Stock and Watson's demonstration in 1990. They deliver theoretical and empirical evidence that VAR model is applicable to a set of nonstationary variables as long as they are cointegrated since OLS still yields consistent parameter estimates. A number of later fruitful practical applications by Clarida(1997), Fanchon & Wendel (1992) Coudert, Mignon & Penot(2005) ,Ravnik & Zilic(2010), Perotti, 2002; de Castro & de Cos, (2006); Heppke-Falk, Tenhofen & Wolf (2006) strongly agree on this central point. According to Johansen test, L<sub>CAN</sub> and L<sub>WTI</sub>; L<sub>NOR</sub> and L<sub>BRENT</sub> display cointegrating relationship, hence estimating the VAR with raw data in levels can be justified. Thereafter we adopt Granger Causality test on each VAR model to identify the direction of causality between variables.

For example : Hypothesis testing for equation L<sub>CAN</sub>

- $H_0$ : WTI price does not Granger Cause Canadian US dollar exchange rate
- $H_1$ : Canadian US dollar exchange Granger causes WTI price

The same rule is applied to other equations

**Table 6. Granger Causality Test of LCNAN and LWTI equation (weekly data)**

Equation	Excluded	VAR(2) (Prob>Chi2)	VAR(4) (Prob>Chi2)	VAR(12) (Prob>Chi2)
LWTI	LCAN	0.000*	0.000*	0.000*
LCAN	LWTI	0.086***	0.058***	0.042**

*Note: Reported numbers are p-values*

\*, \*\*, \*\*\* indicate rejection of the null hypothesis at the 1%, 5 % and 10% significance level respectively

**Table 7. Granger Causality Test of LNOR and LBRENT equation (weekly data)**

Equation	Excluded	VAR(2)	VAR(4)
LBRENT	LNOR	0.002*	0.008*
LNOR	LBRENT	0.628	0.312

*Note: Reported numbers are p-values*

\*, \*\*, \*\*\* indicate rejection of the null hypothesis at the 1%, 5 % and 10% significance level respectively

Table 6 clearly shows for the case of Canadian exchange rates and WTI oil prices, there is strong evidence in support of bidirectional causality. The causality even can be observed at 1% level. However, according to table 7, only Norwegian exchange rate does Granger causes Brent oil prices, the reverse direction does not hold.

To verify about model's full adequacy, a common exercise is to perform a variety of check for robustness and stability.

**The stationarity test** in our VAR (LCAN-LWTI) and VAR (LNOR-LBRENT), all roots of the characteristic polynomial lie inside the unit circle, meaning that the defined VAR models

---

satisfy stability condition. Of particular notice is the fact that one pair is close to the limit, implying that some shocks may not die out quickly.<sup>9</sup>

**Lagrange-multiplier test** is designed to examine the serial correlation. For the VAR model of LCAN and LWTI, Lagrange-multiplier test yields the evidence of second order residual autocorrelation at 5% level but not at 1%. In contrast, there is no sign of residual autocorrelation up to 5 lag order, at 5% level.<sup>10</sup>

**Normality test** is used to check the normal distribution of the residuals in our VAR model. The null hypothesis of normal disturbances is apparently rejected by the Jarque Bera test in all equations, implying that the VAR model's disturbances are not normally distributed regardless of conventional level.<sup>11</sup>

**Lag exclusion test** is employed for ruling out unnecessary lags in our VAR model. The null hypothesis is strongly rejected up to four lags in all concerned equations. Taken together with the optimal lag selection criteria as discussed earlier, it suggests that up to four lags of each variable can sufficiently characterize the VAR models.<sup>12</sup>

**Impulse response function (IRF)** IRF is designed to track the responsiveness of endogenous variables in the VAR system after a single shock from one or more disturbance terms is applied to each variable. The IRF illustrated in following figure map out an effect of shock in individual variable .For the sake of brevity, only the first 10 weeks are paid attention.<sup>13</sup>

---

<sup>9</sup> See the graph of roots of companion matrix in figure A.2 in the appendix section

<sup>10</sup> Check Table A.5 in Appendix section for the results and hypothesis for Lagrange-multiplier test

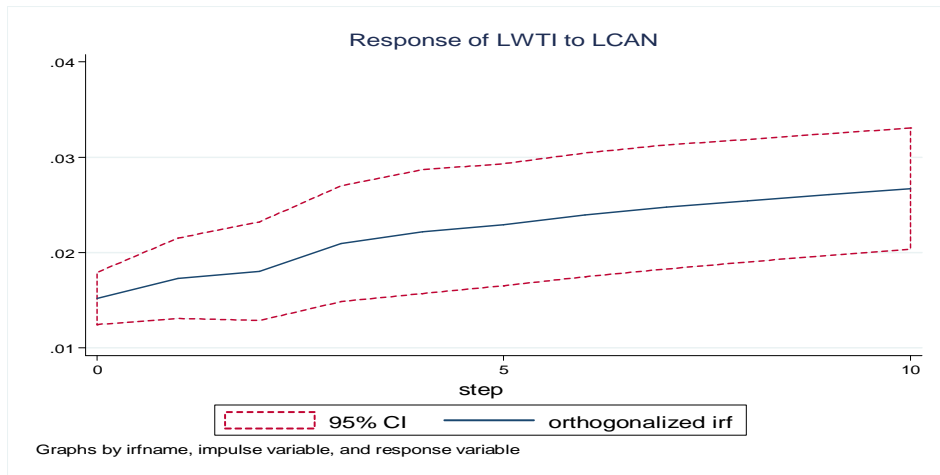
<sup>11</sup> See Table A.6 in Appendix section for the results and hypothesis for Normality test

<sup>12</sup> See Table A.6 in Appendix section for the results and hypothesis for Lag exclusion test:

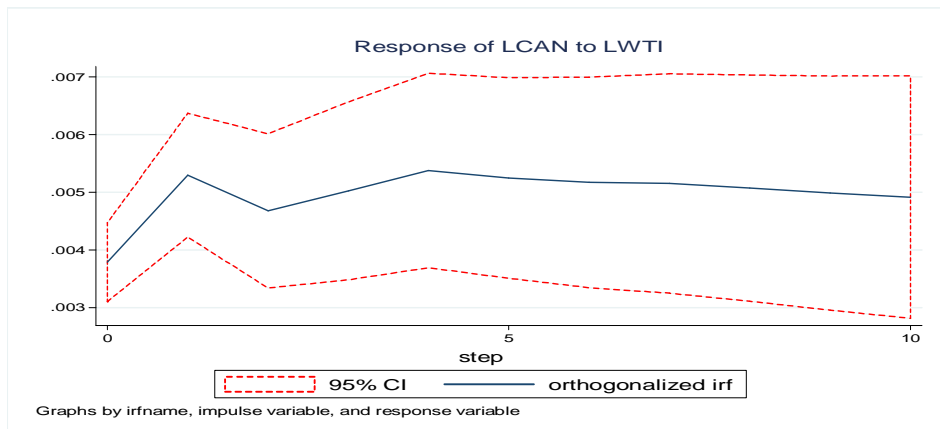
<sup>13</sup> The calculated impulse response functions are found in Table A.7, Appendix section.

The remainders of Impulse response functions are graphed in Figure A.3 , Appendix section.

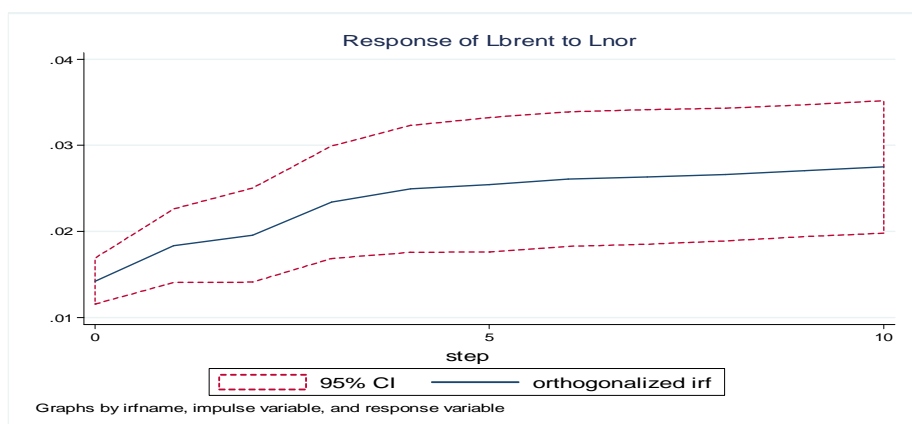
**Figure 3. Impulse response function of VAR model .Impulse:LCAN, Response: LWTI (weekly data)**



**Figure 4. Impulse response function of VAR model .Impulse:LWTI, Response: LCAN (weekly data)**



**Figure 5. Impulse response function of VAR model ,Impulse:LBRENT, Response: LNOR (weekly data)**



A one standard deviation positive shock in exchange rate of Canadian against US dollar increase steadily WTI crude oil prices .The effect is statistically significant even 10 weeks after the shock. The similar pattern can be observed in the response of Brent crude oil prices to a shock in exchange rate of Norwegian against US dollar. Interestingly, with one standard deviation positive shock in WTI crude oil prices CAD/USD rate is immediately on a steep rise for the first week, undergo a slight decline in the second week and then show steadily upward trend and finally followed by a gradual fall in the subsequent weeks. The graphical illustration of tabulated impulse response functions is generally consistent with theoretical framework in support of the proposition of the positive linkage between exchange rate and crude oil prices.

## 5.6 Gregory and Hansen Cointegration Test with Structural Break

Time plots of exchange rates and crude oil prices suggest some structural break patterns. It is possible to observe visually the sequence together with its significant tendency change however it imposes difficulty in spotting structural breaks together with its corresponding break points accurately with naked eyes. Perron (1989) claims that standard unit root tests, notably ADF, are biased towards the null given the presence of trend break .Following up on this intuition , Gregory and Hansen (1996) developed residual-based tests for cointegration which basically extends Engle Granger test and take into consideration

structural break at unknown time. They hold strong argument that the existence of structural break is likely to reduce power of Engle Granger test of the null hypothesis of no cointegration . Under necessary condition that all variables are I(1), we now run four following models with unknown break point .

- Model 1: Cointegration with a level shift (C)

$$Y_t = \alpha + \beta * X_t + \gamma * dum_t + \varepsilon_t$$

- Model 2: Cointegration with a level shift and trend (C/T)

$$Y_t = \alpha + \beta * X_t + \gamma * dum_t + \mu * t + \varepsilon_t$$

- Model 3: Cointegration with a regime shift (C/S)

$$Y_t = \alpha + \beta * X_t + \gamma * dum_t + \mu * t + \delta * X_t * dum_t + \varepsilon_t$$

- Model 4: Cointegration with a regime shift and trend

$$Y_t = \alpha + \beta_1 * X_t + \gamma * dum_t + \mu * t + \varphi * dum_t * t + \delta * X_t * dum_t + \varepsilon_t$$

Where  $dum_t$  represents dummy variable which equals to 1 if  $t > T_b$ , and zero otherwise, where  $T_b$  indicates the break point. Table 1 ADF\* values of cointegrating residuals with structural breaks.

**Table 8. Gregory and Hasen test for cointegration with structural break (weekly data)**

Variables	Model	ADF* test statistic	Breakpoint	Critical value			Cointegrated
				1%	5%	10%	
LCAN-LWTI	1	-5.14*	31mar2013	-5.13	-4.61	-4.34	YES
	2	-5.61*	31mar2013	-5.45	-4.99	-4.72	YES
	3	-5.37**	14apr2013	-5.47	-4.95	-4.68	YES
	4	-5.53**	24mar2013	-6.02	-5.50	-5.24	YES
LNOR-LBRENT	1	-4.00	04Jul2010	-5.13	-4.61	-4.34	NO
	2	-5.97*	09jun2002	-5.45	-4.99	-4.72	YES
	3	-4.23	12Sep2010	-5.47	-4.95	-4.68	NO
	4	-6.16*	05May2002	-6.02	-5.50	-5.24	YES
LMEX-LWTI	1	-2.96	12apr2009	-5.13	-4.61	-4.34	NO
	2	-4.45	31aug2003	-5.45	-4.99	-4.72	NO
	3	-4.59	03may2009	-5.47	-4.95	-4.68	NO
	4	-5.33	07sep2003	-6.02	-5.50	-5.24	NO

---

*Note: \*,\*\* indicates the rejection of null hypothesis of no cointegration at 1% and 5% level respectively*

Testing hypothesis:

- Null hypothesis : No evidence of cointegration
- Alternative hypothesis : cointegration presents

Table 8 summarizes the ADF\* values of cointegrating residuals in above mentioned four models. The critical values are reported by Gregory and Hansen in their papers, 1996. We find that WTI oil price and Canadian-US dollar exchange rate form a relatively long and stable relationship irrespective of level, trend or regime. The result is significant at 1 % level and the breakpoint is estimated to hover around from the end of March of 2013 to middle of April, 2013. However in the case of Norway, the indication in favour of equilibrium relationship merely emerges after allowing for trend. To elaborate on it, model 2 (trend) and model 4 (regime and trend) reveals a strong evidence of cointegration at even 1% level; and the breakpoint seems to be mid-2002. In parallel with results from Engle Granger and Johansen-Juselius tests , Mexican Peso-US dollar exchange rate and WTI price is the exceptional pair in which cointegration does not hold at any conventional level, regardless of inclusion of structure break, trend or regime .

## 6. DISCUSSIONS

### 6.1 Is there any long run relationship between oil prices and currency exchange rates of the world's major oil exporting countries?

We indeed discover a linear relationship between Canadian –US dollar exchange rates, Norwegian Krone-US dollar exchange rates and its corresponding oil price indices that is well-accepted in the light of academic literature. More interestingly, Engle Granger residual-based method detects a robust cointegration merely between WTI and CAD/USD whereas Johansen and Juselius method suggests that not only WIT and CAD/USD but also Brent and NOK/USD form unique cointegrating vector at 5 % significant level. It is apparent that a contradicting result between two approaches emerges in the case of Norway. Since Johansen's approach is widely evaluated to be more powerful and to overcome Engle Granger's drawbacks, we determine to trust its suggestion. As expected, further findings from VAR and Granger causality test provide a strong support in favour of the proposition of the more advanced approach. Our situation is previously faced by Coudert, Mignon and Penot(2005 ). Likewise, in employing Engle Granger procedure, these authors fail to reject unit root in the residuals from the regression, consequently they seek for assistance from Johansen test to check validity of results and afterward the fruitful outcome does highly meet their satisfaction .In other words, an indication that oil prices and real effective exchange rates of the dollar exhibit equilibrium relationship, becomes obvious in their Johansen technique.

Besides, we observe the clear presence of structural break in the graphical illustration of each individual series, and thus, we decide to go the extra mile to conduct Gregory and Hansen method with an aim to re-examine two pairs L<sub>CAN</sub> & L<sub>WTI</sub> , L<sub>BRENT</sub> & L<sub>NOR</sub> and with hopes of detecting cointegrated relationship between L<sub>MEX</sub> & L<sub>WTI</sub>. Indeed our findings prove the prevalence of structural breaks and its adverse influence on the power of standard residual based test, Engle Grange method. The findings are consistent with Johansen test for the first two pairs; unfortunately the absence of pairwise cointegrating relation still persists in the remaining pair L<sub>MEX</sub> and L<sub>WTI</sub>, irrespective of inclusion of structural shift, trend and regime. It is noteworthy that the efficiency of Gregory and Hansen approach is strongly recognized as an effective tool and its role contributes considerably to



---

the success of some earlier related work. For example, Zhang (2013) is interested in exploring whether the price of oil is linked to the real effective exchange rate of US dollar, and the evidence in favour of strong connection only emerges after two structural shifts are allowed. Similarly, in investigating a long run equilibrium relationship between real exchange rates and corresponding commodity prices in 58 commodity exporting countries, Cashin, Cespedes, and Sahay (2003) acknowledge that among of these, ten countries display a shift in their long run equilibrium relationship and as a consequence, the remarkable conflicting results between the conventional cointegration test and the Gregory–Hansen test are relatively obvious. Following these authors, Issa, Lafrance and Murray (2008) are a strong proponent of Gregory Hasen importance as the approach is proved to be essential to identify accurately the unknown break date at which the negative linkage between energy prices and the Canadian dollar switches its sign to be positive in the early 1990s. The timing of break is admitted to conform with major changes in legislations, trade and investments regarding to the nation’s energy sector. It is a common sense that one typically takes a heed to structural shift to address the challenge after his expected result fails to present at the first stage. As such, we believe that negligence on structural break or inaccurate identification on breakpoint would distort the findings in time series analysis. For instance, Chan, Tse and Williams (2011) find none of Granger causality between commodity price and currency in either direction, notwithstanding their great effort on dividing the main sample into sub-periods combined with undertaking an innovative method. We are suspicious that they might select wrong breakpoint as they simply assume the starting period of financial crisis, notably June 2007, as a breakpoint without conducting any technique. We realize a couple of researchers hold such a similar belief which has no firm ground and might undermine their experiments. Our break dates from Georgy Hansen test point to the strong evidence against other authors’ assumptions relating to worldwide recession. There is no specific event which can be considered as the primary driver of structural shift in our analysis, however the occurrence of major developments such as change in country’s legislation, global demand or oil sector are followed by the break period, which accumulatively might be responsible for the shift. To gain more clarification on this perspective, it is a good idea to get back to Zhang’s paper (2013). The author found the first break date in November 1986 and another one in February 2005 which totally shows no connection with and even takes place long time prior to the latest global economic downturn.

It cannot be denied that majority of prior studies which we have gone through have successfully linked the fluctuation in crude oil prices to movement in exchange rates and our results in this part can be treated as offering confirmation and elaboration. Prime examples of this genre are articles by Coudert, Mignon and Penot(2005) ,Grisse (2010), Breitenfellner and Cuaresma1 (2008), Cayen ,Coletti, Lalonde and Maier (2010).

It is worthwhile to note that in a broader context, our study can be seen to be related to earlier comprehensive and innovative studies by Andersen, Bollerslev, Diebold and Vega ( 2003) ,Chen(2004) , Engel and West (2005) ; all of which attack a new line on the long-standing puzzle about a strong tie between real exchange rate and economic fundamentals. In addition, other papers also bring up interesting discussions and deliver convincing empirical evidences in favor of connection between more general or other commodity prices and exchange rates such as Chen and Rogoff(2002,2008),Lafrance and Chow (2008),Akram(2008), Groen and Paolo (2009), Cashin, Céspedes, and Sahay (2003)

## 6.2 Can crude oil prices impact on exchange rates of these given countries in a long and short run?

Basing on Error correction model and Granger Causality 's findings, we can reach a conclusion that crude oil prices exerts statistically significant and pronounced influence on Canadian-US dollar exchange rates, whereas it does not cause any impact on Norwegian Krone or Mexican Peso against US dollar at weekly frequency.

Concretely, ECM shows that for long-term effect, a ceteris paribus 1 % increase in WTI crude oil prices will cause deviation from the long-run equilibrium relationship during the current week and then Canadian exchange rate against USD dollar will correct it by raising up a total of 0.2909026 % and dissimilate over future time period at a rate of 0.0125187 % in the following week. With regards to short run effect, a ceteris paribus 1% increase in crude oil prices during the current week would trigger Canadian Dollar to appreciate 0.093666 % against US Dollar within the prevailing week.

Meanwhile, IRF of VAR model aimed at examining dynamic interactions implies that a ceteris paribus, one standard error shock to WTI price entails immediately 0.0037 point

---

increase in CAD/USD rate <sup>14</sup> in the current week and then the exchange rate begins to undergo a slight decline in the second week, afterward shows a steady upward trend and finally followed by a gradual fall in the subsequent weeks. The graph also reveals that the impact is primarily concentrated in the first five weeks following the oil prices shock. We will delve deeper into this interpretation later. Apparently, our findings in favour of positive response of CAD/USD on WTI price fluctuation conform with theoretical framework<sup>15</sup> and has been well-established in other earlier related work, (see Dufour and Galbraith ,2013; Rogoff ,Rossi and Ferraro,2012 ) Despite of different time horizon and sampling frequency, these authors also describe similar behaviour of exchange rate in the wake of positive oil prices shock : immediate appreciation and subsequent slight depreciation. Intuitively, this outcome definitely is crucial to monetary authority as it sheds a light on what possibly drives exchange rate of Canadian dollar against US dollar and how the evolution of effect expectedly looks like in the short and long run. Moreover, it is certainly beneficial to market participants for engaging in speculation activities or Forex trades and to some corporations operating businesses across their domestic area.

The case of Canada stimulates another interesting discussion. In 1993, Amano and van Norden investigate the country over the period from 1973 to 1992 and reach a surprising and contentious conclusion that the higher energy price leads to depreciation of Canadian dollar. Since their finding appears to be counter-intuitive and of course opposed to economic theory about the positive relationship between energy price and currency value of its energy exporting country, it is called into question by some researchers. In the same spirit, Issa, Lafrance, and Murray (2008) are dedicated to resolving the puzzle raised from Amano and van Norden's paper .They determine not only to re-examine their work by using Bank 's exchange rate equation developed by Amano and van Norden, but also to extend the sample period to 2005 .Later on, they confirm about accuracy of these previous authors 's initial findings , and discover that the transition which took place in the early 1990s , changes the sign of relationship from negative to positive . The break date spotted in their exercise corresponds to a period in which Canada embarked upon switching its status to major net energy exporter. They draw inference that the trace of earlier negative linkage involves Canadian domestic energy legislations which were in effect from 1970 to 1980, and the

---

<sup>14</sup> Check table A.7 in Appendix Table section

<sup>15</sup> See section 2.2

massive cost incurred in other industries in the context of surging energy price. Another appealing implication is that abandonment of National Energy Policy in 1985, the removing of restriction on foreign ownership in the oil and gas industry on 25 March 1992, implementation of new initiatives to boost the development of Alberta's oil sands and heavy oil resources, adopting The Canada-US Free Trade Agreement in 1989 contribute substantially to positioning Canada as the key and secure exporting player in the international energy market. This can be reflected clearly from the positive connection between the Canadian dollar and energy price from 1993 onward

It is important to note that the lack of previous research availability on Mexico makes it currently impossible to make comparison with our findings. With regards to Norway, the results seem to contradict prior studies. Bernhardsen and Røisland (2000) carry out analysis over a period from 1990 to 2000, document that the rise in oil prices can provide explanatory implication for remarkable strengthening of either krone measured against German mark or against trade weighted average index. Similarly, later work on this relationship, such as that of Akram(2002), explores the period from 1986 to 1998 and shows the non-linear effect of crude oil on NOK/ECU exchange rate. More prominently, one common feature of these studies is to include interest rate differential as an endogenous variable, implying the absence of direct causal link between estimated exchange rate and the interest rate. In short, the distinction between their findings and ours might be ascribed primarily to some different perspectives ranging from time horizon, benchmark currency, non-linear model and more notably the consideration of interest rate into estimation equation.

Besides, we decide to delve deeply into each country's current economic and monetary policies and conditions in order to search for thorough explanations underlying the results of Norway and Mexico.

In the case of Norway, we discover that the absence of effect of crude oil prices might be attributed largely to the existence of Government Pension Fund and official intervention of Norges Bank in bringing price inflation down. Contrary to our assumptions described in theoretical part about spending effect of Dutch disease<sup>16</sup>, the surplus wealth generated from the petroleum sector is placed under strict regulation and phased into the Norwegian

---

<sup>16</sup> See section 2.2.1

---

economy through the depositing mechanism namely Government Pension Fund (GPF) , instead of extra consumption on goods and service . Ministry of Finance is predominantly accountable for monitoring the Fund and determining its investment strategy with the consulting and operating assistance of Norges Bank Investment. The GPF's primary objective is to support government savings to subsidize public pension expenditure, given an increasing aging population in Norway, and to promote long-term management in the spending of government petroleum income. The latter action ensures an equal allocation of revenue from petroleum activities among both current and future generations, and thus it plays a crucial role in improving intergenerational flow of equity .Besides, the fund serves to address financial challenge in the face of oil prices decline , non-petroleum budget deficit or mainland economy downturn. Another striking feature lies in virtually worldwide capital investment with an aim to diversify risk, maximize financial returns and protect Norwegian economy from overheating and the adverse impact of oil prices volatility .As a result, it contributes partly to alleviating the effect of Dutch disease; the surge in oil prices is less likely to translate into an inflationary pressure on exchange rate. (See Velculescu ,2008 )The exemplary practice, combined with the massive asset value exceeding \$717 billion ,uniquely positions itself as the largest public pension Fund(PPF) in the world and the model to other sovereign wealth fund. In addition to GPF, in 2001 Norges Bank was given an authority to have official intervention in the foreign currency exchange market to control inflation rate ,aimed at achieving Krone stability against Euro currency for a couple of years.( Bjørnland,2009)

Despite of being designated as the world's major crude oil exporter, Mexico is considered as the largest net importer of refined petroleum products from the United States. More specifically, in 2014, approximately 44% of US exports of motor gasoline are directed to Mexico. In addition, the United States acts as Mexico's second largest supplier of goods imports, especially natural gas. Its natural gas demand is expected to be on high upward trend due to the expansion of power generation capacity. Meanwhile, United States is the destination of nearly 68 % Mexico's oil export. As a consequence, the effect of Dutch disease and trade theory is insignificant or unpronounced on the exchange rate of Mexico. It is worth mentioning that the crude-oil swap license for 75000 barrels a day between the United States and Mexico is officially approved last October,2015. This announcement means Mexico's state-owned oil company can export its heavy oil in exchange for USA's lighter grades in roughly equivalent amount, aimed at facilitating nations' refineries .In other

words, the swap transaction apparently plays a role in alleviating substantially, or to some extent removing completely, any impact of crude oil prices on exchange rate of Mexico in the near future.

### 6.3 Can the movement of chosen exchange rates contribute to explaining the fluctuation of crude oil prices?

While the impact of crude oil prices on exchange rate is not clear cut from our theoretical framework, empirical support for it shows up to be relatively impressive .

Surprisingly, the findings from error correction model and VAR uncover strong and robust evidence that CAD/USD and NOK/USD can have a predictive ability over the movement of WTI and Brent respectively. For instance, we can interpret the results of the former that a ceteris paribus 1% growth in the CAD/USD is expected to be immediately followed by 1.50219 % increase of the WTI price in the current week. The crude oil is expected to soar by a total of 3.017278 % to bring back the system to equilibrium with 0.0432% of the deviation corrected in each subsequent week. Meanwhile implication from VAR model is that WTI price is forecast to climb up by 0.015<sup>17</sup> within the same week and then exhibits a steady growth in response to a one standard error shock in CAD/USD rate, the outcome is undeniably comparable to suggestion from ECM.

The similar movement trend can be observed in the pair NOK/USD and Brent. A prominent feature from tabulated impulse response function of VAR models is a little difference in the response of WTI to CAD/USD and that of Brent to NOK/USD. Most noticeable is that in both countries, the rapid speed of growth or the positive effect appears to be more robust in merely the first five weeks after the currency shock. We will delve deeply into this part in later section.

In other words, the findings seem to confirm superior forward looking feature of exchange rate. As discussed earlier, exchange rate is in financial market which is prone to react to new information more quickly relative to commodity market. It appears to be useful in

---

<sup>17</sup> Check table A.7 in Appendix Table section

incorporating information and reflecting expectations from market participants efficiently. It is obviously of potential importance to policy makers in oil industry as well as companies whose activities are heavily dependent on oil.

Generally, our findings seem to contradict with some of earlier work but support some of others. For example, Chan, Tse, and Williams (2011) document that currency returns of the major commodity exporting countries (Australian dollar, Canadian dollar, New Zealand dollar, and South African rand) do not account for the fluctuation in the country-specific commodity return indices in terms of Granger causality and out of sample forecasting even at daily data. In contrast, using a very low frequency data, quarterly data, Chen, Rogoff and Rossi (2008) deliver an empirical indication in favor of such a direction and confirm the superior in sample and out of sample forecast performance of exchange rate based model compared with a random walk and an autoregressive benchmark. The remarkable distinguishing feature among the two studies involves the method. The latter's positive identification is achieved by exploiting more advanced technique which controls for time varying parameters..

#### 6.4 Compare the predictive power of VAR model with random walk model in out of sample dynamic forecast

It is natural to assess the extent to which our estimated model can account for the behaviour of oil prices and exchange rates, we conduct dynamic simulations of the model. To be precise, we implement out of sample dynamic forecast, and the most widely used method. VAR model is favourable to us over ECM model because of its superior stability combined with more desirable result in Johansen test. Our basic idea in this section is to compare the root mean squared error for forecast (RMSFE) generated by two approaches namely VAR model and random walk with drift model. The latter is a special case of an autoregressive integrated moving average model, more specifically ARIMA(0,1,0) with constant, the simplest and yet most important model. Its square root time pattern positions random walk as a good and common benchmark against which to assess the performance of other models. The equation for this model can be written as:  $\hat{Y}_t = \mu + Y_{t-1}$

Where  $\mu$  represents constant term, the average period-to-period change

Meanwhile, RMSFE is seen as a measure of the spread of the forecast error distribution and

$$\text{is defined as } \text{RMSFE} = \sqrt{E[(Y_t - \hat{Y}_{t|t-1})^2]}$$

The rationale behind our choice of dynamic and out of sample forecast is ascribed primarily to its robustness and efficiency but they are not the central heart of this research, so we do not need to hold deeper discussion here.

**Table 9. RMSFE statistics for 2 models in weekly out of sample dynamic forecasts**

Variables	Period 1			Period 2		
	VAR (RMSFE)	RW (RMSFE)	Better	VAR (RMSFE)	RW (RMSFE)	Better
LCAN	0.0068	0.0212	VAR	0.0302	0.0251	RW
LWTI	0.1228	0.1298	VAR	0.3018	0.1202	RW
LBRENT	0.0635	0.2756	VAR	0.0904	0.073	RW

Once weekly out-of-sample forecasts are generated for two periods, results are presented in Table 9.<sup>18</sup> Forecasting horizon ranges from 2 months ahead to 13 months ahead. Forecast quality is evaluated by comparing RMSFE for each model; the smaller the better. We recognize that the result is relatively inconclusive in this exercise and inevitably raises our suspicion about a high sensitivity of predicting performance to the choice of out of sample periods. Particularly, during the first period, all VAR models offer a superior explanatory power over a random walk model. However, for the second period the former never beats the latter. In other words, it poses difficulties in making an accurate judgement if exchange rate or crude oil prices can contribute to improving the forecasting power over random walk benchmark. Since both exchange rate and crude oil prices are highly exposed to various sources of risks and unanticipated volatility, each alone cannot be adequate to capture all short and long-run behaviours in the other. One of biggest criticism in our VAR model' predictive content involves its lack of adequacy with reference to an absence of normal

<sup>18</sup> See Figure A.1 in Appendix section for the graphs of out of sample forecasts of VAR model.



distribution and the suffering from higher order serial correlation. More importantly, our trial and error process shows that neither any of these models can be considered for long horizon predictability.

What we discover in this section is generally in parallel with Lafrance , Chow's claims in 2008. Notwithstanding a relatively innovative technique expectation, their equation cannot make considerable predictive ability improvement over random walk model. Even an integration of interest rate merely exerts a mild effect. The authors blame their parsimonious specification on the parameter instability and insignificance. Of particular notice is their acknowledgement about fragility of results to time horizon.

Nonetheless, the main conclusion which we draw from this experiment is quite distinct from some earlier work. A couple of previous authors have successfully addressed the measurement of explanatory ability of crude oil prices over exchange rate movement by means of in-sample and out of sample fit of several models.

For example, Amano and Norden (1998) document that a stable dynamic model using lagged oil prices uncover superior explanatory power over US real effective exchange rate in out-of-sample relative to a random-walk model. The omission of interest rate differentials in their experiment can be justified clearly with reference to the failure to find cointegration between it and real exchange rates.

In the same spirit, Akram (2002) points out that non liner oil prices effect model forecast better and generates more stable parameter estimates relative to linear model, particularly in the context of sharply falling krone value. The former undeniably beats random walk model in terms of forecasting power. We believe that consideration of non-linear effect and interest rate plays a crucial role in his appealing results.

In the more recent innovative work, Ferraro, Rogoff and Rossi (2012) undertake Diebold and Mariano (1995) test statistic for daily data and claim that the oil prices based model is more useful in predicting Canadian-US dollar at daily data, relative to random walk benchmark. They also highlight two key elements for fruitful outcomes. Real time data is essential to capture contemporaneous short run behaviours; and much care should be taken to time variation in models' relative forecasting performance. Both of these requirements point to strong evidence in favor of the ephemeral feature of predictive content. More interestingly, in contrast to Akram, they reveal that non-linearity does not forecast better than simple linear

model. Another striking finding in their experiment is that using lagged interest rate does not provide additional important implication for future behaviours  $t$  in exchange rate.

It is obvious that the distinct between our results and that of above mentioned authors can be traced to different methods, base currency, time horizon and frequency. More importantly, our findings from this exercise can serve as an illustration in which parameter instability might cause some drawbacks to time series modelling. This concern is already raised by Stock and Watson(1996) who document that the failure of exchange rate based model to outperform a random walk in predicting experiment is likely to originate from parameter instability. We also notice that integrating market information on interest rate differential does not always add some forecasting value over exchange rates' fluctuation. It could be argued that the issue of endogeneity should be subject to investigation prior to experiment otherwise under some circumstances, it might be detrimental to the whole analysis, nonetheless most of authors take it for granted without any preliminary examine.

## 6.5 Are the results sensitive to the choice of frequency?

All the analyses in previous sections are based on weekly observations. Now we would like to judge whether our results are merely confined to weekly data or not. In other words, we should re-examine the relationship at diverse sampling frequency to evaluate importance of timing. We perform the same cointegration test, ECM, VAR model and Granger causality test on monthly and daily data. A somewhat different picture emerges.<sup>19</sup> Here is the quick look at the results of Error correction model and Granger Test at monthly and daily intervals.

### *Monthly data*

$$LCAN_t = -1.400733 + 0.3027178 * LWTI_t + \varepsilon_t, \quad (3a)$$

$$\Delta LCAN_t = 0.1116711 * \Delta LWTI_t - 0.028492 * ECT_{t-1} + 0.0001815 + \varepsilon_t \quad (3b)$$

(0.0147737)                      (0.0280921)                      (0.0012439)

$$LWTI_t = 4.577529 + 3.021888 * LCAN_t + \varepsilon_t, \quad (4a)$$

---

<sup>19</sup> Tables A.1, A.2 & A.3 in Appendix section summarize our Engle Granger and Johansen tests' findings

$$\Delta LWTI_t = 2.074369 * \Delta LCAN_t - 0.1597427 * ECT_{t-1} + 0.0016513 + \varepsilon_t \quad (4b)$$

(0.2795302)                      (0.0370548)                      (0.0053942)

*Daily data*

$$LCAN_t = -1.39478 + 0.3012696 * LWTI_t + \varepsilon_t, \quad (5a)$$

$$\Delta LCAN_t = 0.0703923 * \Delta LWTI_t - 0.0054186 * ECT_{t-1} + 0.0000133 + \varepsilon_t \quad (5b)$$

(0.0036204)                      (0.0018581)                      (0.0000893)

$$LWTI_t = 4.576115 + 3.014277 * LCAN_t + \varepsilon_t, \quad (6a)$$

$$\Delta LWTI_t = 1.25022 * \Delta LCAN_t - 0.0133701 * ECT_{t-1} + 0.0001101 + \varepsilon_t \quad (6b)$$

(0.0643536)                      (0.0024703)                      (0.0003765)

*Note: Standard error is in parenthesis below estimates*

At the first stage, all the series, regardless of any frequency, achieves stationarity after first differencing. Concerning about Engle Granger test, none of cointegration exists in the exception of CAD/USD and WTI case. However, the results from Johansen-Juseleius are more intriguing and should be placed concentration (see table A.2 for more detail). For monthly data, merely CAD/USD and WTI share long run equilibrium relationship, whereas similar to weekly data, in daily data, cointegrated relation holds up for two pairs: NOK/USD and Brent; CAD/USD and WTI.

With regards to Error correction model, the striking feature is that the lagged error correction term in the equation (3b) is not statistically significant in the monthly data at any statistical conventional level, but turns out to be significant at 1 % level in daily data (5b). Meanwhile, as previously discussed it is significant at 10% level in our weekly data. We can observe a similar rule in Granger Causality test as the findings tend to lose significance at lower frequency. In other words, the positive response of Canadian value against USD to oil prices increase is of higher magnitude and more obvious in daily data compared to weekly data and such a positive long run impact becomes unpronounced when it comes to monthly data. The intuition behind Error correction model's findings and Granger causality test of VAR model lies in short-lived effect of crude oil prices on exchange rate of Canada which is supposed to spread over time and, as consequence, diminish at lower frequency. The graph of impulse function at weekly data can be served as a plausible explanation for the disappearance of short-lived effect at monthly intervals. Specifically, when there is oil prices shock, the exchange rate reacts very instantly; although the effect does not die out very quickly, a steep speed of growth or considerable change is virtually concentrated within the first few weeks.

Identical reasoning can be applied to explain Johansen- Juselius test's findings: equilibrium relationship between crude oil prices and NOK/USD tends to wash away at monthly data. This surprising outcome undeniably sheds a light on the preference of a very high frequency data from some authors in their previous related papers, for example Andersen, Bollerslev, Diebold and Vega (2003) use 5 minute returns.

These statistical results in this experiment echo the conclusion reached by Rogoff, Rossi and Ferraro (2012). In their recent innovative and comprehensive work, there is a robust indication suggesting a profound response of exchange rate of Canada to fluctuation of crude oil prices in daily observations however, the evidence fails to be visible at the monthly and quarterly frequency. More remarkably, they extend the analysis and reveal that the explanatory power is still extremely robust at daily interval even if they switch the base currency to British Pound.

Later work on similar relationship, Zhang, Dufour and Galbraith (2013) underscore that the robust causality running from dominant exporting commodity prices (Crude oil, gold and copper) to exchange rates of the three commodity economies (Canada, Australia and Chile) is susceptible to time units and data frequency. Their use of daily and five minute data is relatively novel and primarily aims to eliminate considerably time aggregation effect and catch very fast dynamic behaviours, definitely attract much attention from market participants who is inclined to short decision intervals.

Lafrance and Chow (2008) tell a comparable story over the sensitivity of commodity-currency relationship toward sampling frequency. Although the differences are found not to be statistically meaningful as our findings, they confirm that lower frequency data entails slower estimated speed of adjustment to equilibrium in error correction model, which is mainly attributed to the time aggregation bias.

The affirmative conclusion which we and other above-mentioned researchers draw about the existence of short-lived effect, appear to overturn existing literature. It is well-established from theoretical perspective that Dutch disease and trade theory effect should translate into business transactions, wealth reallocation and capital mobility, all of which are apparently time-consuming processes. As such, the exchange rates are theoretically supposed to require some time to respond to the fluctuation of oil prices. However, the empirical results from monthly and quarterly data provide a very little justification. In contrast, a very quick and

---

short-horizon reaction of exchange rate has never been convincingly proved in academic literature, even to some extent ignite debate among policymakers, economists and market investors, more particularly over a remarkably high statistical significance level that are found in our and others' experiments. The most possible explanation behind such surprising results is that exchange rate's movement contains valuable information about expectation from financial market participants and the majority of them typically attempt to evaluate economic news, trades constantly and even conduct speculative activities at a rapid pace.

In a nutshell, if instead we only pay attention to monthly or quarterly data, we would end up refusing relationship between NOK and Brent or impact of LWTI on LCAN. Our inference drawn from this experiment reasonably accounts for earlier related studies 's empirical failure in finding relationship between the two in the case of Canada.(see Cashin, Cespedes, and Sahay (2003)) .Nonetheless, it is worthwhile to highlight that although real time or extremely high frequency data ,notably daily frequency, is proved to be relatively efficient in capturing contemporaneous and very fast dynamic behaviours in a sense of establishing very strong and stable linkage between exchange rates and crude oil prices, it appears to be less convincing for forecasting in practice. The rationale lies in a very little chance in which financial market participants can gain access to the realized value of oil prices in order to make prediction about future movement in exchange rates.

## 6.6 Does dollar effect play any role in the relationship?

The implications from preceding sections that the causality is more likely to run from the fluctuation of exchange rates to movement of oil prices rather than the reverse direction ignite some suspicion<sup>20</sup>. More specifically, our findings unveil the remarkable explanatory power of Norwegian Krone US dollar exchange rates over Brent prices' movement, not the other way around. In addition, according to ECM, the response of WTI price to CAD/USD is robust irrespective of frequency, whereas the reverse effect changes and loses significance at lower frequency. One could argue that Norway's oil export volume is not sufficient enough to exert any influence on the global oil price .In addition, Norwegian krone does not fall into a group of the most tradable currency in international financial market , hence its ability to

---

<sup>20</sup> See section 6.2 and 6.3

grasp constantly and reflect efficiently the expectation of market participants about future movement of Brent prices as assumed <sup>21</sup>is called into question .In other words ,one might be reasonably concerned that “Dollar effect” possibly plays a role in our findings as a result of a common USD denomination in the exchange rates. From our theoretical perspective, since all oil contracts in international market are invoiced and settled in US dollar, US dollar might drive oil price and vice versa .Hence, it is crucial to examine whether the equilibrium relationship between exchange rates of oil exporting countries and oil price still holds up in the absence of US dollar in the denominators. It is worthwhile to highlight that in the majority of previous related studies about Canada, chosen exchange rate involves US dollar, and nonetheless most of the authors neglect the dollar effect.

We decide to choose Euro, ranked as the second most tradable currency in the world<sup>22</sup>, as a base currency instead. This means the similar investigation is carried out on two pairs: NOK/EUR and Brent, CAD/EUR and WTI at weekly frequency. We have an initial intention to check MXN /EUR and WTI as well; unfortunately we failed to find public availability of relevant data. We collected data on Norwegian krone-European exchange rates from Norges bank, and Canadian dollar-Euro exchange rates from bank of Canada <sup>23</sup>. All variables are also transformed into logarithm terms. Surprisingly, although we employ all necessary techniques ranging from Engle Granger, Johansen and Juselius to Georgy Hansen , two pairs do not exhibit any cointegrated relationship.(see following table for reference)

---

<sup>21</sup> See section 2.3

<sup>22</sup> Source:[http://www.investopedia.com/articles/forex/08/top-8-currencies-to-know.asp?header\\_alt=b](http://www.investopedia.com/articles/forex/08/top-8-currencies-to-know.asp?header_alt=b)  
<http://www.moneyshow.com/articles.asp?aid=currency-40506>

<sup>23</sup> Sources : [http://www.norges-bank.no/en/Statistics/exchange\\_rates/currency/EUR/](http://www.norges-bank.no/en/Statistics/exchange_rates/currency/EUR/)  
<http://www.bankofcanada.ca/rates/exchange/10-year-converter/>

**Table 10. Johansen and Juselius test for cointegration as Euro is used in the common denomination (weekly data)**

Variables	R	Trace Test		Max-Eigenvalue Test			Cointegrated
		Trace Statistic	Critical Value	Max Statistic	Critical Value	No.lags	
LNOK/EUR-LBRENT	0	10.077	15.42	6.7542	14.07	2	NO
LUSD/EUR-LBRENT	0	14.2829	15.41	12.051	14.07	2	NO
LCAD/EUR-LWTI	0	8.3716	15.41	6.4029	14.07	4	NO
LUSD/EUR-LWTI	0	16.4441	15.41	14.1711	14.07	2	YES
	1	2.2730		2.2730			

It is apparent that our finding in this exercise is not in parallel with Akram 's discovery in 2002 as the author indeed detects a strong tie of Norwegian Krone-Euro exchange rate to oil price. However, more remarkably, different from ours, his sample period spans from 1986 to 1998 .Of course, the oil-currency relationship is likely to change over time due to many factors such as the trend of industry development, monetary policy, the management of Norwegian government pension fund and so on.

To obtain a stronger verification about the “Dollar effect”, we place USD/EUR and two oil price indices under scrutiny .More precisely, we examine if there exists a linkage between USD/EUR and WTI; USD/EUR and Brent. For better understanding, we construct the following simple equation.

$$\ln \left( \frac{\text{NOK}}{\text{USD}} \right) = \ln \left( \frac{\frac{\text{NOK}}{\text{EUR}}}{\frac{\text{USD}}{\text{EUR}}} \right) = \ln \left( \frac{\text{NOK}}{\text{EUR}} \right) - \ln \left( \frac{\text{USD}}{\text{EUR}} \right)$$

$$\ln \left( \frac{\text{CAD}}{\text{USD}} \right) = \ln \left( \frac{\frac{\text{CAD}}{\text{EUR}}}{\frac{\text{USD}}{\text{EUR}}} \right) = \ln \left( \frac{\text{CAD}}{\text{EUR}} \right) - \ln \left( \frac{\text{USD}}{\text{EUR}} \right)$$

We first take Norway for clarification. According to earlier empirical findings, the equilibrium relationship between NOK/ USD and Brent price is detected and more importantly, the strengthening of Norwegian Krone US dollar exchange rates stimulates the

surge in Brent price. Hence, we doubt that USD might be responsible partly for such impact since US dollar value is expected to be negatively linked to oil price. At the first stage, we decided to remove dollar effect by examining if NOK/EUR and Brent price are responsive to each other. Surprising results emerges and there is no connection between the two at all. Following such undesirable outcome, we move to next stage to examine if USD/EUR can provide any implication for movement in Brent price and vice versa. The same reasoning is also applied to the case of Canada. This means USD/EUR and WTI should be placed under scrutiny.

The results from Johansen and Juselius are summarized in table 10.<sup>24</sup> An appealing feature shows up. On the basis of Johansen test and Gregory Hansen test we merely find a strong indication in favor of connection between USD/EUR and WTI but no sign of linkage between USD/EUR and Brent, despite of relatively identical graphical pattern of the two oil indices.

Following up on the cointegration test, we construct VAR model merely between EUR/USD and WTI and thereafter implement Granger causality test on the pair. Table below indicates clearly that USD/EUR Granger causes price of WTI but the reverse does not hold.

**Table 11. Granger Causality Test of LUSD/EUR and LWTI (weekly data)**

Equation	Excluded	VAR(2)	VAR(4)
LUSD/EUR	LWTI	0.950	0.227
LWTI	LUSD/EUR	0.009*	0.017*

*Note: Reported numbers are p-values*

*\*, \*\*, \*\*\* indicate rejection of the null hypothesis at the 1%, 5 % and 10% significance level respectively*

Hypothesis testing for equation LWTI is as follows. Similar rule is applied to equation LUSD/EUR

---

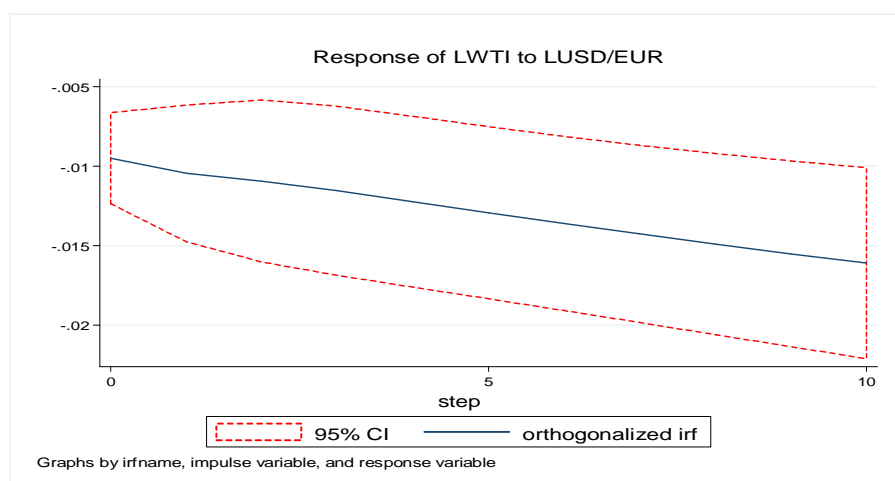
<sup>24</sup> The results from Engle Granger and George Hansen tests is reported in table A.10 & A.11 in Appendix section.



- $H_0$ : Dollar-Euro exchange rate does not Granger cause WTI price
- $H_1$ : WTI price Granger causes W Dollar-Euro exchange rate

The negative connection between the two and steady downward pattern of WTI price in response to appreciation of US dollar against Euro can be visible in a graph of IRF function below. There is no doubt that it is in line with our academic theory and our expectation.

**Figure 6. The impulse response function ,impulse :LUSD/EUR, response : LWTI (weekly data)**



As reflected directly from its names, North Brent crude oil is extracted from North Sea in Northern Europe, and virtually traded in Europe; meanwhile, West Texas Intermediate crude oil are mostly traded in America and the majority of its sale is directed to USA with a massive amount each year from its large trading partners: Canada and Mexico. More remarkably, according to EIA, US is widely designated as the world's largest net oil importing country<sup>25</sup>. Similar to the reasoning made on the connection between oil prices and exchange rates of major oil exporting countries, it could be inferred that currency value of oil importing countries is negatively linked to oil prices. In other word, the combined negative effect of US Dollar value on West Texas Intermediate crude oil stems not only from its

<sup>25</sup> Source : <https://www.eia.gov/tools/faqs/faq.cfm?id=709&t=6>  
<http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=5&pid=57&aid=3&cid=regions&syid=2009&eyid=2013&unit=TBPD>

predominant position as the invoice and settlement currency in international market, but also from its tremendous amount of oil import during the last couple of decades. Thus, this can be served as an intuitive explanation for our empirical findings that the linkage between value of US dollar and WTI becomes visible and much more robust than the linkage between US dollar and Brent.

Our result in this section obviously reinforces the revelation from some of earlier related work. For example, Trehan (1986) points out the substantial influence of US dollar on oil price. Later work on the same perspective, Breitenfellner and Cuaresma (2008) agree on the central point about the negative correlation between USD/EUR and oil price from 1950 to 2007, and underscore the strong explanatory power of the former over the latter, yet the reversal causality is not present.

However, we ought to admit that absence of evidence about the predictive ability of oil price over the movement in value of USD dollar is somehow inconsistent with some previous studies. For instance, Coudert, Mignon and Penot (2008) highlights the role of oil price in accounting for the fluctuation in US dollar and finds that the transmission mechanism should be US net foreign asset. Later and more comprehensive research by Grisse (2000) confirms the negative response of US dollar value in the wake of soaring oil price merely within the prevailing week.

We would like to put down a possible rationale behind our contentious outcome that NOK/USD is positively linked to Brent prices yet there is no sign of connection between Brent price with NOK/EUR or USD/EUR. As a matter of fact that USA does not import Brent oil from Europe due to geographical inconvenience, it could be inferred that some economic factors might influence both Norwegian Krone -US dollar exchange rates and Brent prices simultaneously, and NOK/USD tends to react to the change driven from such determinants more instantly than Brent does. This finding seems to cancel our conclusion in earlier section, implying that NOK/USD can neither be treated as the reliable predictor nor driver for fluctuation in Brent price.

With regards to Canada, since approximately 97% of the country's oil export is destined for USA, interaction between two economies inevitably is connected to WTI prices. Despite the fact that the surge in WTI prices is proven to entail appreciation of CAD/USD, yet CAD/EUR and WTI are not related, we still believe that to some extent, WTI does exert an

influence on Canadian dollar value however owing to the long-term efficient hedging strategies of nation, the effect becomes minor and appears not to be visible without the help of US dollar effect. More noticeably, Ferraro, Rogo and Rossi (2012) 's claim that the predictive ability of oil price over CAD/GBP over WTI holds up strongly seems to support our assumption and reasoning. Another concern in this exercise is that the Euro is the official currency shared by 19 member states of European Union, some of which engage excessively into oil exporting activities whereas others' economies heavily rely on oil import. In other words, it is possible that Euro might be somehow affected by oil price. If Euro value and Brent prices exhibit even just a slight positive co-movement, the relationship between CAD/EUR and Brent might turn out to be unpronounced. Concerning about the earlier empirical finding that CAD/USD is a remarkable indicator for the fluctuation in WTI, our experiment about USD/EUR and WTI provides a strong evidence that this direction of causality is attributed to US dollar effect.

In short, we indeed recognize the sensitivity of our findings to the base currency.

## **7. LIMITATION , CONCLUSION AND SUGGESTION**

### **7.1 Limitation**

There is no doubt that our empirical analysis is flawed in several respects which might distort the findings. The most likely source of bias is attributed to the omission of potentially relevant explanatory variables which serve as determinants of exchange rate or crude oil fluctuation, for example interest rate differential (see Akram 2002, 2008 ; Grisse(2010), Bernhardsen and Røisland (2000) ). Another limit to inference involves the exclusion of shock in individual countries' terms of trade or global economy or exogenous, international market which may influence both currency and oil prices simultaneously (See Coudert, Mignon and Penot,2005). We already face with this issue in our experiments. The absence of measurement of how the two react to the announcement of economics and global news may play a role in empirical failure (see Grisse(2010) for example). The focus of our study is just linear relationship and therefore another shortcoming may arise from the neglect of nonlinear effects, notably in the case of Norway. In addition, the choice of base currency and the sample period do matter a lot , for example : Akram used Krone/ European currency from 1986 to 1998 and found the robust relationship. Last but not least, one of strong criticism for this study is that crude oil prices rely primarily on global shock, whereas exchange rate is contingent on country-specific shock .One could argue that a weighted-average of currency of country's large trading partners might help remove considerably the country specific shocks and offers a better prediction for future global crude oil prices,

### **7.2 Conclusion**

The goal of this research is to deepen our understanding of the link between crude oil prices and exchange rate. We can summarize the empirical findings into some main points:

Over a span of 15 recent years, there indeed exists the long and short run relationship between oil prices and exchange rate of selected oil exporting countries with the notable exception of Mexico. The positive connection is consistent with economic intuition described previously in theoretical frameworks. Regardless of level of frequency, bidirectional causality is found in the case of Canada, meanwhile only unidirectional effect for Norway. In other word, Norwegian appreciation against US dollar can translate into rise

---

in Brent price, not the other way around. The possible reasoning can be traced to the presence and exemplary practice of Government Pension Fund (GPF) in Norway.

The surprising findings point to a strong empirical evidence of timing importance in the crude oil prices and exchange rate relationship. To be precise, the two are more closely connected and more responsive to one another at the low frequency than the high frequency. In other words, the positive response of Canadian value against USD on WTI oil prices is of higher magnitude and more obvious in daily data compared to weekly data and such a pronounced and sustained influence washes away when it comes to monthly data. The plausible explanation involves in the short-lived effect, which is prone to spread over time and, as a consequence, vanishes at lower frequency. Similarly, we find no evidence in favour of cointegrated relationship between NOK/USD and Brent crude oil at monthly data yet it becomes robust at weekly and daily data according to Johansen test. We strongly agree on the central point that exchange rates respond very quickly and can reflect efficiently traders' expectations, however, we decide to take the view that these expectations tend to last for fairly short horizon because market participants are likely to assess constantly all publicly available information and trades.

By extending the standard cointegration method allowing a single structure break, absence of evidence about cointegrated relation between MEX/USD and WTI price still persists regardless of the choice of trend, regime or level. This is primarily ascribed to the massive import of refinery petroleum products and other goods from United States. In contrast, when structure break and trend are taken into account, we see a strong indication in favour of equilibrium relationship between Brent crude oil prices and NOK/USD by residual-based approach. The result now turns out to be in parallel with Johansen test's suggestion.

Less positive are the inconclusive forecast results for 3-12 month horizon that in the first period, the VAR model generates the lower mean square errors (MSE) relative to random walk whereas the latter provides a superior performance over former in the second period. In other words, empirical finding still provides no consensus on which model outperforms in the forecasting competition, yet holds a caution that the sample period drives the forecast results due to the ephemeral feature of predictive content. For the longer horizon, a trial and error process suggests that for both models, the predictability at longer horizons is not robust at all in either direction..

To assess the extent to which the “US dollar” plays any role in our empirical findings, we decided to explore another avenue of our analysis by using other cross exchange rates which does not involve US dollar. We uncover surprising results that neither Canadian dollar - Euro exchange rates nor Norwegian Krone-Euro exchange rates form any linkage its corresponding oil price. More remarkably, WTI price is negatively responsive to the appreciation of USD/EUR meanwhile the latter is not connected to Brent price .The implication underlying our findings is that some other economic elements might exert an influence on both Norwegian Krone -US dollar exchange rates and Brent prices simultaneously.And hence, NOK/USD can neither be served as the reliable predictor nor be the determinant of fluctuation in Brent price.Meanwhile, in the case of Canada, Dollar effect indeed presents and contributes considerably to the cointegrated relationship ,especially the direction of causality running from CAD/USD to WTI prices.We believe that the impact of WTI on the value of Canadian dollar value still exists but it might be not significant .We also have to acknowledge that the evidence of relationship between the two is likely to be susceptible to the base currency.

### 7.3 Further research

Non-linear effect and a number of possible channels through which the relationship between oil prices and exchange rate is transmitted, for example: net foreign assets or the terms of trade, are beyond the scope of our study, but they could be potential avenues for future research. It would be of interest to identify the aggregate demand and supply shocks in oil prices market and then incorporate these measures into system (see Kilian (2009) for theoretical explanation). Frankel (2006 ) delivers empirical evidence that the shift in monetary policy is responsible partly for crude oil prices fluctuation so it is also recommended to include interest rate differential in the further studies.(see Akram 2008 or Grisse,2010 for recent empirical application).Moreover, our study is confined to the case of crude oil prices and exchange rate of its major exporters. One might potentially extend the approach to look at relationship between currencies and other commodities rather than oil, such as copper, gold , coal and so on in the spirit of Chen, Rogoff & Rossi(2008) and Lafrance & Chow (2008).We leave these issues for future research.

---

## References

- Akram, Q. F., (2000), When Does the Oil prices Affect the Norwegian Exchange Rate?, *Norges Bank's Working papers*, Research Department.
- Akram, Q. F., (2002), Oil prices and exchange rates: Norwegian evidence, *Norges Bank's Working papers*, Research Department.
- Akram, Q. F., (2008), Commodity prices, interest rates and the dollar , *Norges Bank's Working papers*, Research Department.
- Alquist, R., L. Kilian and R.J. Vigfusson (2011), Forecasting the Price of Oil, in: G. Elliott and A. Timmermann, *Handbook of Economic Forecasting Vol. 2*, Elsevier.
- Amano, R., and Norden, S.V. (1993) 'A forecasting equation for the Canada-U.S. Dollar exchange rate,' in *The Exchange Rate and the Economy* (Ottawa: Bank of Canada)
- Amano, R.A. and Norden, S.V. (1998a). Oil prices and the rise and fall of the US real exchange rate, *Journal of International Money and Finance*, V.17 (2): pp. 299–316.
- Amano, R.A. and Norden, S.V. (1998b). Exchange Rates and Oil prices, *Review of International Economics*, V. 6(4): pp. 683–694.
- Andersen, T. G., Bollerslev, T., Diebold, F.X. and Vega, C. (2003), Micro Effects of Macro Announcements: Real-Time Price Discovery in Foreign Exchange, *The American Economic Review*, Vol. 93, No. 1 (Mar., 2003), pp. 38-62.
- Askari, H. and N. Krichene (2010) An oil demand and supply model incorporating monetary policy, *Energy*, vol 35(5), 2013-2021.
- Asteriou, D., And Hall, G., S., (2007) *Applied Econometrics* (Revised edition) , Published by Palgrave Macmillan
- Backus, D.K. and M.J. Crucini (2000), Oil prices and the Terms of Trade, *Journal of International Economics*, 50, 185-213.
- Beckett, S., (2013) , Introduction to time series using Stata (1st), *A Stata Press Publication*, Stata Corp LP, College Station, Texas .
- Beckmann, J. , Czudaj, R. , (2012), Oil prices and U.S. dollar exchange rates dynamics, *University of Duisburg-Essen*.
- Belke, A., (2005), Exchange Rate Movements and Unemployment in the EU Accession Countries—A Panel Analysis , *Review of Development Economics*, 9(2), 249–263.
- Bénassy-Quéré, A., Mignon, V., Penot, A. (2005), China and the Relationship between the Oil prices and the Dollar, *CEPII Working Paper* , No. 2005-16.

- 
- Bernanke, B., S., Gertler, M. and Watson, M. (1997). Systematic monetary policy and the effects of oil prices shocks, *Brookings Papers on Economic Activity*, 1, pp. 91–124.
- Bernhardson, T., Røisland, Ø., Factors that influence the krone exchange rate, 2000, *Norges Bank, Economic Bulletin*.
- Best, R. (2008), An Introduction to Error Correction Models, *Oxford Spring School for Quantitative Methods in Social Research*.
- Bjørnland, H.C. (2009), Oil prices Shocks and Stock Market Booms in an Oil Exporting Country, *Scottish Journal of Political Economy*, Volume 56, Issue 2, 232-254.
- Board of Governors of the Federal Reserve System (2015), Bilateral exchange rate data, URL: <http://www.federalreserve.gov/releases/h10/hist/>, (retrieved 20th September 2015).
- Bodenstein, M., Erceg, C.J. and L. Guerrieri (2011), Oil Shocks and External Adjustment, *Journal of International Economics*, 83, 168-184.
- Breitenfellner, A., Cuaresma, J. C. (2008), Crude Oil prices and the USD/EUR Exchange Rate, *Monetary Policy & The Economy*.
- Brown, S.P.A., Phillips, K.R. (1984), The Effects of Oil prices and Exchange Rates on World Oil Consumption, *Economic Review*, Federal Reserve Bank of Dallas.
- Bruno, M., Sachs, J. (1982), Energy and Resource Allocation: A Dynamic Model of the "Dutch Disease", *National Bureau of Economic Research*, XLIX, 845-859.
- Cayen, J.P., D. Coletti, R. Lalonde and P. Maier (2010), What Drives Exchange Rates? New Evidence from a Panel of U.S. Dollar Exchange Rates, *Bank of Canada W.P.* 2010-5.
- Chan, K., Tse, Y., Williams, M. (2011), The Relationship between Commodity Prices and Currency Exchange Rates Evidence from the Futures Markets, *National Bureau of Economic Research*. Working Paper, 11859
- Chen, Y.C. (2002), Exchange Rates and Fundamentals: Evidence from Commodity Economies, *University of Washington*.
- Chen, Y. C. (2005), Exchange Rates and Fundamentals: Evidence from Commodity Currencies, *University of Washington*. Working Paper.
- Chen, Y.C., Rogoff, K. (2002) Commodity Currencies and Empirical Exchange Rate Puzzles, *International Monetary Fund (IMF)*. DNB staff report. Working Paper 02/27.
- Chen, Y.C., Rogoff, K. (2003), Commodity currencies, *Journal of International Economics*, 60:133–60.
- Chen, Y.C., Rogoff, K. S. (2006), Are the Commodity Currencies an Exception to the Rule?,



---

*University of Washington* , Working Paper.

- Chen, Y.C., Rogoff, K.S, Rossi, B .( 2008). Can exchange rates forecast commodity prices? *National Bureau of Economic Research*, Working Paper, 13901.
- Clarida,R. , H. (1997), The Real Exchange Rate and US Manufacturing Profits: A Theoretical Framework with some Empirical Support , *The National Bureau of Economic Research*, The Federal Reserve Bank of New York, U.S.A.,*Int. J. Fin. Econ.* 2, 177-187.
- Corden, W.M. (1984). Booming sector and Dutch Disease economics: Survey and consolidation, *Oxford Economic Papers*, 36(3): 359-380
- Corden, W. M.,Neary, J. P. (1982), Booming Sector and De-industrialization in a Small Open Economy , *Economic Journal* , 92,825–848.
- Coudert,V., Mignon , V. , Penot , A. , (2008) , Oil prices and the Dollar. *Energy Studies Review*, 15.
- de Castro, F. and de Cos, P. H.,( 2006), The economic effects of exogenous fiscal Shocks in Spain: A SVAR Approach, Banco de Espana, *Documentos de Trabajo*, No 06104/2006.
- Dotsey, M., Reid, M., 1992. Oil shocks, monetary policy and economic activity. *Economic Review*, Bank Richmond Econ. Rev. 78, 14-27.
- Eikaa,T. U. , Magnussen , K. A. , (2000), Did Norway gain from the 1979-1985 oil prices shock, *Economic Modelling*. 107 -137.
- Endres, W. , (2009), Applied econometric time series, Second Edition , *Iowa State University* , John Wiley & Sons, Inc.
- Engle, R.F., Granger, C.W.J. (1987), Co-integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*, 55, 251-276.
- Engel, C. , West , K. D. , (2005) Exchange Rates and Fundamentals, *Journal of Political Economy*, vol. 113, no. 3.
- Fanchon,P., Wendel, J. (1992) ,Estimating VAR models under non-stationarity and cointegration: alternative approaches for forecasting cattle prices , *Applied Economics* ,24(2):207-17.
- Ferraro, D, Rogoff, K., Rossi, B. (2011), Can Oil prices Forecast Exchange Rates? *National Bureau of Economic Research*, Working Paper, 17998.
- Robert Lafrance,R. ,Chow,L., (2008), Futures beacon: Can commodity futures and interest rate expectations help predict the value of the Canadian dollar?, *International Department Bank of Canada*,Presented at the 2008 CEA Meetings, University of British Columbia, Vancouver, June 7.

- Kilian, L. and R. Vigfusson (2011), Nonlinearities in the Oil Price-Output Relationship, *Macroeconomic Dynamics*, forthcoming.
- Fountas, Stilianos and Kyriacos Aristotelous (1999) , Has the European Monetary System Led to More Exports? Evidence from Four European Union Countries, *Economics Letters* ,62:357–363.
- Frankel, J. (2006) ,The effect of monetary policy on real commodity prices, In Asset prices and monetary policy, ed. John Campbell, 291–334. Chicago: *University of Chicago Press*.
- Fratzscher, M., Schneider, D., Robays, I. V. , (2014) , Oil prices, Exchange Rates and Asset Prices, *European Central Bank*, Working Paper Series, No 1689.
- Gjedrem, S. (1999), “Challenges to economic policy”, *address at the Annual Foreign Exchange Seminar, arranged by the Association of Norwegian Economists in Gausdal*, Norway, 28 January 1999.
- Golub, S.S. (1983), Oil prices and Exchange Rates. *The Economic Journal* ,93, 576–593.
- Government administration Services in Norway , (2015), The Government Pension Fund , URL : <https://www.regjeringen.no/en/topics/the-economy/the-government-pension-fund/id1441/> , (retrieved 20th October, 2015 ).
- Gregory, A.W., Hansen, B.E. (1996), Residual-based Tests for Cointegration in Models with Regime Shifts, *Journal of Econometrics*, 70, 99-126
- Gregory, A.W., Nason, J. M. & Watt, D. G. ,(1996), Testing for structural breaks in cointegrated relationships, *Journal of Econometrics* ,71 (1996) 321-341.
- Grise, C. (2010), What Drives the Oil-Dollar Correlation? *Federal Reserve Bank of New York*.
- Groen, Jan J.J. and Paolo A. Pesenti (2009), .Commodity prices, commodity currencies, and global economic developments, *National Bureau of Economic Research*, Working Paper No. 15743.
- Guo, H. , and Kliesen, K. L. , (2005) , Oil prices Volatility and U.S. Macroeconomic Activity, *Federal Reserve Bank of St. Louis Review*, 669–683.
- Hacker, R. S. and Hatemi-J, A. (2004). The effect of exchange rate changes on trade balances in the short and long run Evidence from German trade with transitional Central European economies, *Economics of Transition*, Volume 12 (4), 777–799.
- Hamilton, J.D., 1983. Oil and the macroeconomy since World War II, *Journal of Political Economy*, *The University of Chicago Press* ,Vol. 91, No. 2 , pp. 228-248
- Hamilton, J. D. (2008). Understanding crude oil prices. *National Bureau of Economic Research*. Working Paper 14492.

- 
- Heppke-Falk, K. H., Tenhofen, J. and Wolf, G. B., (2006 ),The Macroeconomic Effects of Exogenous Fiscal Policy Shocks in Germany: a Disaggregated SVAR Analysis”,*Deutsche Bundesbank Discussion Paper Series 1:Economic Studies*, No 41/2006
- Huntington, H.G. (1986) ,The U.S. Dollar and the World Oil Market, *Energy Policy*, Vol 14(4), 299-306.
- Issa, R., R. Lafrance and J. Murray (2008), .The Turning Black Tide: Energy Prices and the Canadian Dollar,*Canadian Journal of Economics* ,41(3), 737-759.
- Johansen, S. (1988), Statistical Analysis of Cointegration Vectors, *Journal of Economic Dynamics and Control* ,12, 231–254.
- Johansen, S. & Juselius, K. (1990), Maximum Likelihood Estimation and Inference on Cointegration with Application to the Demand for Money, *Oxford Bulletin of Economics and Statistics* , 52, 169–210.
- Kilian, L. and C. Park (2009): The Impact of Oil prices Shocks on the U.S. Stock Market. *International Economic Review*, 50 (4), 1267-1287.
- Komuves, Z., Ramirez, D. , M.(2013) Economic Infrastructure, Private Capital Formation, and FDI inflows to Hungary: A Unit Root and Cointegration Analysis with Structural Breaks , *Department of economics yale university*, Economics Department ,Working Paper No. 123
- Krugman, P.R. (1980), Oil and the Dollar. *National Bureau Of Economic Research. Working Paper* ,No. 554
- Krugman, P. (1983a), Oil and the dollar, in Bhandari, J. and Putnam, B.(eds), *Economic Interdependence and Flexible Exchange Rates*, MIT Press: Cambridge, MA.
- Lafrance , R. , Chow,L. ,(2008),Can commodity futures and interest rate expectations help predict the value of the Canadian dollar? , *International Department* , *Bank of Canada*.
- Loungani, P., 1986. Oil prices shocks and the dispersion hypothesis, *The Review of Economics and Statistics* , 68, 536-539.
- Norges Bank Investment Management, (2015), Government Pension Fund Act , URL : <http://www.nbim.no/en/the-fund/governance-model/government-pension-fund-act/> , (retrieved 20th October,2015).
- Norges Bank. (1999), ‘Norges Bank’s submission on economic policy for 2000’’, *Document submitted to the Ministry of Finance* on 21 October 1999.
- Ravnik,R., Zilic, I., (2011)The use of Svar analysis in determining the effects of fiscal shocks in Croatia ,*Financial theory and practice*, 35(1)25-58(2011)

- Sapir, Andre´ and Khalid Sekkat (1990) , Exchange Rate Volatility and International Trade. In Paul de Grauwe and Lucas Papademos (eds.), *The European Monetary System in the 1990s*. New York: Longman, pp. 182–198.
- Schryder, S. D. , Peersman , G. , (2014), The U.S. Dollar Exchange Rate and the Demand for Oil , Norges Bank/ECB workshop on "Monetary Policy and Commodity Prices"
- Sims, C., Stock, J. and Watson, M. (1990) , Inference in linear time series models with some unit roots, *Econometrica*, 58, 113-144.
- Stock, J., and M. Watson (1996) ‘Evidence on structural instability in macroeconomic time series relations,’ *Journal of Business and Economic Statistics* 14, 11–30
- Perron, P., (1989), The great crash, the oil prices shock and the unit root hypothesis, *Econometrica* , 57, 1361-1401.
- Perron, P., (1990a) , Testing for a unit root in a time series with a changing mean, *Journal of Business and Economic Statistics*, 8, 153-162.
- Perotti, R., (2002) “Estimating the Effects of Fiscal Policy in OECD Countries”, *European Central Bank Working Paper*, No. 168
- Trehan, B.(1986) Oil prices, Exchange Rates and the U.S. Economy: An Empirical Investigation. Federal Reserve Bank of San Francisco, *Economic Review* , no. 4 (Fall), pp. 25–43.
- Zhang, Y. (2013), The Links between the Price of Oil and the Value of US Dollar, *International Journal of Energy Economics and Policy* , Vol. 3, No. 4, 2013, pp.341-351.
- Zhang, H. , J. Dufour, J., M. , Galbraith, J. , W. ,(2013), Exchange rates and commodity prices: measuring causality at multiple horizons, *Scientific Series*, Quebec, ISSN 2292-0838.
- Velculescu ,D., (2008), Norway's Oil Fund Shows the Way for Wealth Funds ,*International Monetary Fund European Department*.
- Yousefi, A., Wirjanto, T.S.,(2003), Exchange rate of the US dollar and the J curve: the case of oil exporting countries, *Energy Economics* , 25, 741–765.
- Wooldridge, J. M. (2009). *Introductory Econometrics: A Modern Approach* (4 ed.). SouthWestern, a part of Cengage Learning.
- U.S. Energy Information Administration , (2015) West Texas Intermediate crude oil prices and Brent oil prices data. URL : [http://www.eia.gov/dnav/pet/pet\\_pri\\_spt\\_s1\\_d.htm](http://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.htm) (retrieved 20 September, 2015).

## APPENDIX TABLES

Table A. 1. Engle Granger test on monthly and daily data

Pairs	Monthly data			Daily data		
	ADF test statistics	Critical Value	Coint	ADF test statistics	Critical Value	Coint
LCAN->LWTI	-3.768	-3.831	YES	-4.196	-3.338	YES
LWTI->LCAN	-4.568	-3.831	YES	-4.315	-3.338	YES
LNOR->LBRENT	-2.626	-3.831	NO	-2.652	-3.338	NO
LBRENT>LNOR	-3.037	-3.831	NO	-2.810	-3.338	NO
LMEX->LWTI	-2.873	-3.831	NO	-0.584	-3.338	NO
LWTI->LMEX	-1.76	-3.831	NO	-1.534	-3.338	NO

Table A. 2. Johansen test on monthly and daily data

Variables	R	Monthly Data			Daily Data		
		Trace Test	Max Test	No.lags	Trace Statistic	Max Statistic	No.lags
LCAN- LWTI	0	25.64	23.48	2	32.34	30.46	1
	1	2.16*	2.16*		1.88*	1.88*	
LMEX-LWTI	0	8.44	7.70	2	4.54	4.07	1
	1	0.74	0.74		0.46	0.46	
LNOR- LBRENT	0	12.59	8.92	2	20.32	17.94	1
	1	3.67	3.67		2.38*	2.38*	

Note: \*indicates the cointegration at 5% level.

Table A. 3. VAR model and Granger causality test on monthly and daily data

Table A.3.1 Granger causality test of LCAN and LWTI equation on monthly and daily data

Equation	Excluded	Monthly		Daily	
		VAR(2) Prob>Chi2	VAR(6)	VAR(2)	VAR(6)
LWTI	LCAN	0.000*	0.000*	0.000*	0.000*
LCAN	LWTI	0.268	0.043**	0.000*	0.000*

\*, \*\*, \*\*\* rejection of the null hypothesis at the 1%, 5 % and 10% significance level respectively

**Table A.3.b Granger causality test of LBRENT and LNOR equation on monthly and daily data**

Equation	Excluded	Daily	
		VAR(1)	VAR(3)
LBRENT	LNOR	0.000*	0.001**
LNOR	LBRENT	0.658	0.454

\*, \*\*, \*\*\* rejection of the null hypothesis at the 1%, 5 % and 10% significance level respectively

**Table A. 4. Lag exclusion test of VAR model (weekly data)**

Equation	Lag	Prob>chi2
LCAN	1	0.000
	2	0.000
	3	0.001
	4	0.063
LWTI	1	0.000
	2	0.000
	3	0.000
	4	0.000
LBRENT	1	0.000
	2	0.000
	3	0.055
	4	0.002
	5	0.010

Hypothesis testing for lag 1:

- $H_0$ : The first lag should not be included in the equation
- $H_1$ : The first lag should be included in the equation

The same hypothesis testing is applied to other lags

**Table A. 5. Lagrange-multiplier test for serial correlation in VAR model.**

VAR(LCAN-LWTI)			Var (LBRENT-LNOR)	
Lag	Chi2	Prob>Chi2	Chi2	Prob>Chi2
1	3.9106	0.41824	8.0991	0.08801

---

2	4.9061	0.29707	4.4593	0.34740
3	3.3694	0.49801	8.3399	0.07989
4	7.2712	0.12223	12.7500	0.01256

---

- $H_0$ : no autocorrelation at lag order
- $H_1$ : autocorrelation at lag order

**Table A. 6. Normality test of Var Model (LNOR-LBRENT)**

**Jarque-Bera test**

Equation	Chi2	df	Prob>chi2
LNOR	160.497	2	0.00000
LBRENT	149.998	2	0.00000
ALL	310.495	4	0.00000

Equation	Chi2	df	Prob>chi2
LCAN	572.315	2	0.00000
LWTI	565.928	2	0.00000
ALL	1138.243	4	0.00000

- $H_0$ : the sequence is normally distributed
- $H_1$ : the sequence is not normally distributed

Equation	Skewness	Chi2	df	Prob>chi2
LNOR	-0.22452	6.856	1	0.00000
LBRENT	-0.25915	9.133	1	0.00000
ALL		15.989	2	0.00000

Equation	Skewness	Chi2	df	Prob>chi2
LCAN	-0.218	6.448	1	0.00000
LWTI	-0.227	7.023	1	0.00000
ALL		13/471	2	0.00000

**Table A. 7. Tabulated Impulse response function of VAR model (weekly data)**

Step	Response of LWTI to LKAN			Response of LKAN to LWTI			Response of LBRENT to LNOR		
	oirf	lower	upper	oirf	lower	upper	oirf	lower	upper
0	.015	.012	.018	.0037	.0031	.00447	.0142	.0116	.016887
1	.017	.013	.022	.0053	.0042	.00637	.0183	.0141	.022622
2	.0180	.0129	.023	.0047	.00334	.006014	.0196	.0141	.025045
3	.0209	.0148	.027	.0050	.0035	.006567	.0233	.016861	.029928
4	.0221	.0157	.029	.0054	.00369	.007064	.025	.017578	.032309
5	.0229	.0165	.029	.0052	.0035	.006985	.0254	.017619	.033226
6	.02395	.0175	.030	.0052	.0033	.006997	.026	.018269	.033887
7	.0248	.0183	.031	.0052	.00325	.007055	.0263	.018521	.034148
8	.0254	.019	.032	.0050	.00311	.007033	.0266	.018902	.034316
9	.0261	.0197	.032	.005	.00296	.007016	.0270	.019404	.034709
10	.0267	.0203	.033	.0049	.00281	.007018	.0274	.019794	.035186

**Table A. 8. Breusch-Godfrey LM test for autocorrelation of VAR model (weekly data)**

Lag	ECM( LWTI->LKAN)		ECM( LKAN>LWTI)	
	Chi2	Prob>Chi2	Chi2	Prob>Chi2
1	50.991	0.0000	65.369	0.0000
2	126.02	0.0000	87.778	0.0000
3	126.12	0.0000	108.940	0.0000
4	153.76	0.0000	115.149	0.0000

- $H_0$ : the sequence is serially independent
- $H_1$ : the sequence is serially dependent.

**Table A. 9. LM test for autoregressive conditional heteroskedasticity (ARCH) of VAR model (weekly data)**

Lag	ECM( LWTI->LKAN)		ECM( LKAN>LWTI)	
	F	Prob>F	F	Prob>F
1	22.497	0.0000	18.746	0.0000
2	15.747	0.0000	10.345	0.0000
3	10.775	0.0000	10.991	0.0000
4	9.733	0.0000	8.331	0.0000

- $H_0$ : Autoregressive conditional heteroskedasticity (ARCH) is not present.
- $H_1$ : ARCH is present



**Table A. 10. Engle Granger test for cointegration as the base currency is switched to Euro ( weekly data)**

Pairs	Residuals At Level			Cointegrated
	ADF test statistics	Critical Value	No. lags	
LNOK/EUR - LBRENT	-2.753	-3.792	2	NO
LUSD/EUR - LBRENT	-2.945	-3.792	4	NO
LCAD/EUR -LWTI	-2.419	-3.792	4	NO
LUSD/EUR-LWTI	-2.964	-3.792	2	NO

**Table A. 11. Gregory and Hasen test for cointegration with structural break as the base currency is switched to Euro ( weekly data)**

Variables	Model	ADF* test statistic	Breakpoint	Critical value			Cointegrated
				1%	5%	10%	
LNOK/EUR-LBRENT	1	-4.13	17nov2002	-5.13	-4.61	-4.34	NO
	2	-4.92	17nov2002	-5.45	-4.99	-4.72	NO
	3	-4.13	14apr2013	-5.47	-4.95	-4.68	NO
	4	-5.04	24mar2013	-6.02	-5.50	-5.24	NO
LEUR/USD-LBRENT	1	-4.14	12sep2010	-5.13	-4.61	-4.34	NO
	2	-4.00	08sep2002	-5.45	-4.99	-4.72	NO
	3	-4.25	12Sep2010	-5.47	-4.95	-4.68	NO
	4	-4.21	05May2002	-6.02	-5.50	-5.24	NO
LCAD/EUR-LWTI	1	-3.34	10apr2010	-5.13	-4.61	-4.34	NO
	2	-4.36	21feb2010	-5.45	-4.99	-4.72	NO
	3	-3.38	10jan2010	-5.47	-4.95	-4.68	NO
	4	-4.56	10jan2010	-6.02	-5.50	-5.24	NO
LEUR/USD-LWTI	1	-4.36*	08sep2002	-5.13	-4.61	-4.34	YES
	2	-5.00**	17nov2002	-5.45	-4.99	-4.72	YES
	3	-4.28	08sep2002	-5.47	-4.95	-4.68	NO
	4	-5.22	09feb2003	-6.02	-5.50	-5.24	NO

*Note: \*,\*\* indicates the rejection of null hypothesis of no cointegration at 10% and 5% level respectively*

Testing hypothesis:

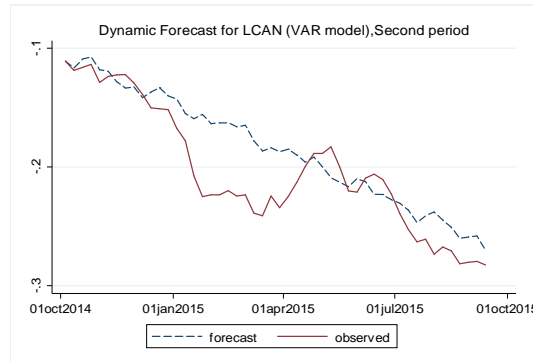
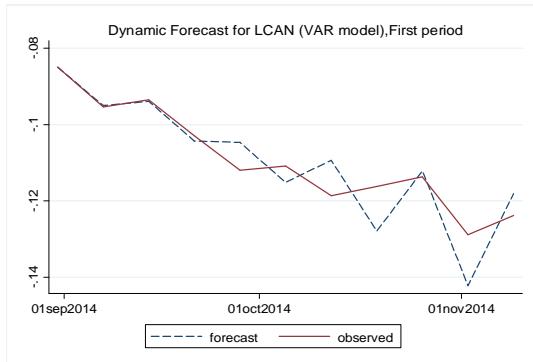
- Null hypothesis : No evidence of cointegration
- Alternative hypothesis : cointegration presents

**APPENDIX FIGURES**

**Figure A. 1 Out of sample dynamic forecast of VAR model (weekly data)**

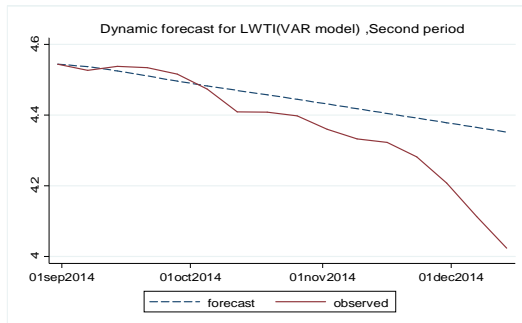
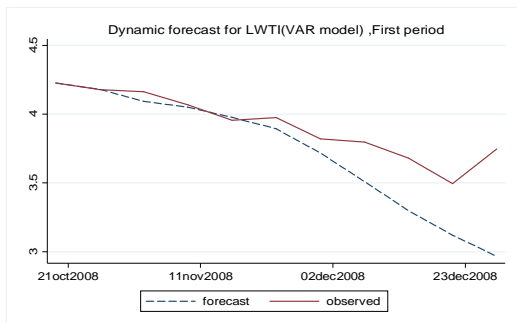
**Figure A.1.1 Dynamic forecasts for LKAN (VAR model), first period**

**Figure A.1.2 Dynamic forecasts for LKAN (VAR model), second period**

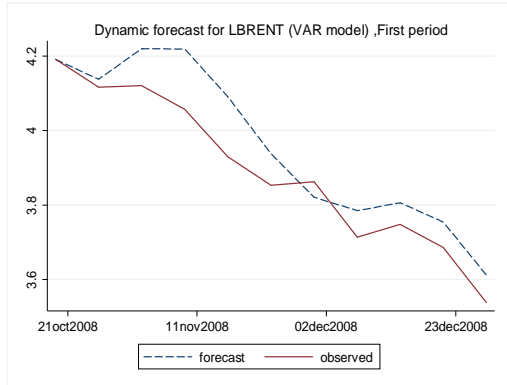


**Figure A.1.3 Dynamic forecasts for LWTI(VAR model), first period**

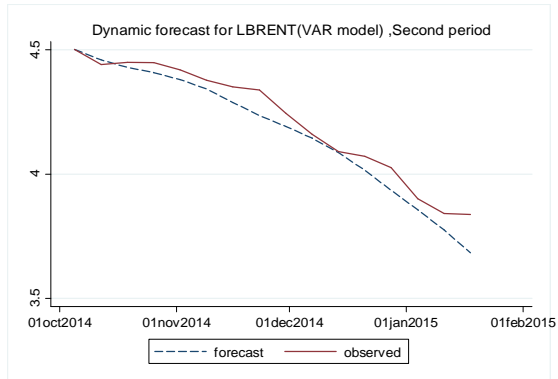
**Figure A.1.4 Dynamic forecasts for LWTI (VAR model), second period**



**Figure A.1.5 Dynamic forecasts for LBRENT(VAR model), first period**

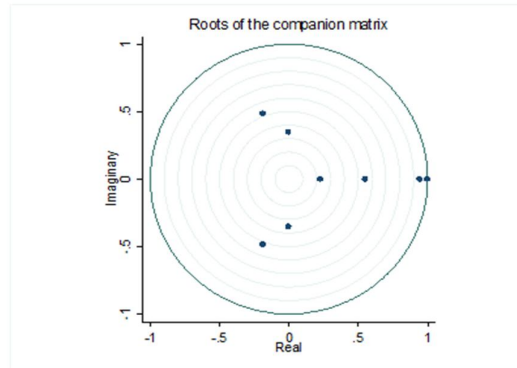
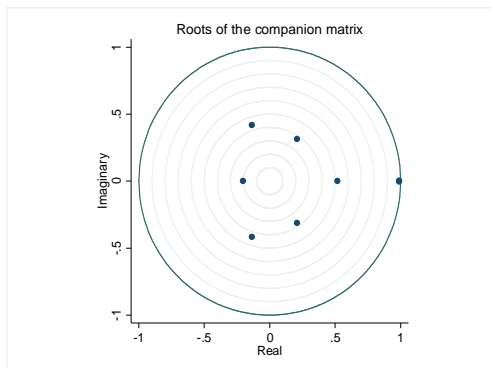


**Figure A.1.6 Dynamic forecasts for LBRENT ( VAR model) ,second period**



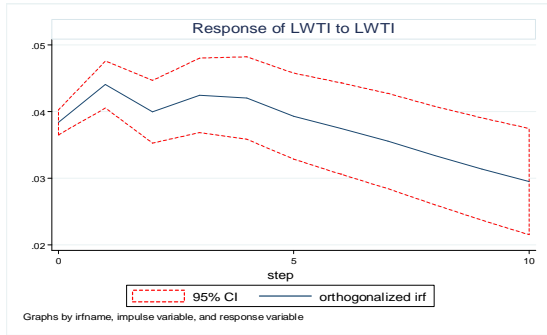
**Figure A. 2. Inverse roots of the characteristic polynomial in VAR model(weekly data)**

**Figure A.2.1 Roots of the companion matrix in VAR model of LNOR and LBRENT**      **Figure A.2.2 Roots of the companion matrix in VAR model of LKAN and LWTI**

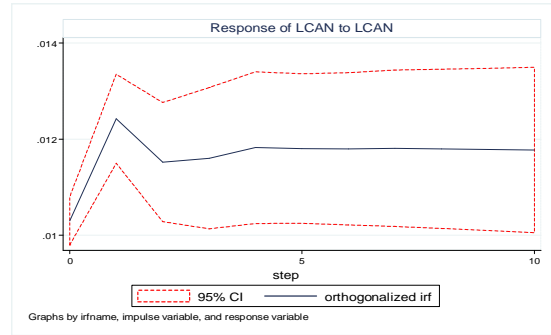


**Figure A. 3. Impulse response function of VAR model (weekly data)**

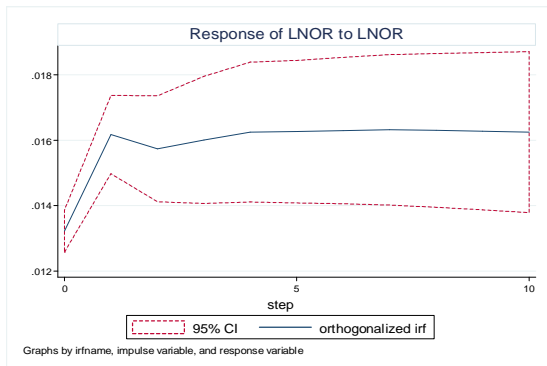
**Figure A.3.1 Impulse :LWTI, Response : LWTI in VAR model**



**Figure A.3.2 Impulse :LCAN, Response :LCAN in VAR model**



**Figure A.3.1 Impulse :LNOR, Response :LNOR in VAR model**



**Figure A.3.2 Impulse :LBRENT, Response :LBRENT in VAR model**

