Modelling the joint dynamics of Exchange rates, Interest rates and Oil prices using Vector Autoregression

Independent Study Thesis

Presented in Partial Fulfillment of the Requirements for the Degree Bachelor of Arts in the Department of Mathematics and Computer Science at The College of Wooster

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The College of Wooster
2022

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Abstract

The Farey Sequence of order n is the sequence made up of all non-negative irreducible proper fractions between 0 and 1, arranged in increasing order, with denominators not exceeding n. (Note that in this definition, order does not refer to the size of the sequence). The terms of the Farey Sequence have geometric applications that include the Farey Starburst and Ford Circles. In addition, the sequence can be found within a graphic representation of non-negative rational values called the Farey Tree, which is contained within the Stern-Brocot Tree.

Acknowledgements

I would like to take the opportunity to thank my advisor for her constant encouragement and flexibility in working around my student teaching experience. I also would like to thank the entire Mathematics and Computer Science department at the College of Wooster for creating an amazing major experience by maintaining patience and friendly faces throughout my hours of questioning.

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Chapter 1

Structural Vector Autoregression

This section introduces the concept of Structural Vector Auto-regression (SVAR). Though we mathematically showcase and define how the methodology works, it is essential for us to mention why we chose this approach. Variables we are analyzing; Oil prices per barrel, exchange rate, and interest rate showcase a dynamic and, on some occasions, a co-integrated relationship. They do not only rely exclusively on their past values but are also dependent on the past values of each other, as showcased by the work we mention and summarize in our literature review.

Due to this inter-dependent symbiotic relationship, we choose to implement the SVAR approach. The SVAR models combine theory, statistical causality, and correlation which helps us cater our analysis to specific avenues we hope to analyze. Due to the orthogonal structural component, we use an amalgamation of past work to create a model which will help us understand theoretically and statistically why oil-producing nations are so economically and financially diverse. As SVAR models also incorporate impulse functions, we can stimulate the effects of oil price, exchange rate, and interest rate shocks specific to each nation. This gives us a pathway to see how each shock affects different countries in a non-similar manner.

1.1 Introduction

The vector autoregressive methodology is widely used to model multivariate time series. VAR models consist of a system of equations. They are estimated by regressing each variable in their respective models. These regressions are done on the variable's lags and the lags of other model variables up to some pre-specified maximum lag order, p. The basic notion of the model is; that every variable in the model is dependent on its lags along with the lags of every other model variable, along with rendering certain exclusion restrictions on the interaction of lagged model variables[6, 7]. When analysts are dealing with economic variables of complex natures, they note that the aforementioned variables are dependent on their past values. Along with dependent on the past values of other variables. Mathematically, we can denote these variables as $y_{1t}, y_{2t}, \ldots, y_{kt}$. With this expansion the forecast of $y_{1,t+h}$ at the end of the period t becomes

$$\hat{y}_{1,t+h} = f_1(y_{1,t}, y_{2,t}, \ldots, y_{k,t}, y_{k,t-1}, y_{k,t-2}, \ldots)$$

We can then write the general forecast of the k^{th} variable as,

$$\hat{y}_{k,t+h} = f_k(y_{1,t}, y_{2,t}, \ldots, y_{k,t}, y_{k,t-1}, y_{k,t-2}, \ldots)$$

A set of time series y_{KT}, $k = 1, \dots, K$,$t = 1, \dots, T$ is called a multiple time series. As stated before, a major objective of the analysis is implementing suitable function $f_1, \dots, f_k$ that may be used to garner forecasts with good analysis predictability for the variables of the system. It is often important to understand the dynamic inter-relations between the variables in an analytical model to find such functions. Obtaining an understanding of the entropic and dynamic structure of the predictive system is an essential objective in a multiple time series analysis[6, 7].

1.1.1 Vector Auto-regressive Process

Considering a uni-variate time series y_t and a forecast $h = 1$ period into the future. We can write $f(\cdot)$ as a linear function[6, 7].

$$\hat{y}_{T+1} = v + \alpha_1 y_T + \alpha_2 y_{T-1} + \dots$$

Assuming that we use a finite number, p, of the past y values. The equation morphs to

$$\hat{y}_{T+1} = v + \alpha_1 y_T + \alpha_2 y_{T-1} + \dots + \alpha_P y_{T-p+1}$$

Acknowledging that the true y_{T+1} will not be exactly equal to the predicted $\hat{y}_{T+1}$. We describe the residual forecast error,

$$u_{T+1} = y_{T+1} - \hat{y}_{T+1}$$

$$y_{T+1} = \hat{y}_{T+1} + u_{T+1} = v + \alpha_1 y_T + \alpha_2 y_{T-1} + \dots + \alpha_P y_{T-p+1} + u_{T+1}$$

Rewriting the equation in auto-regressive form,

$$y_T = v + \alpha_1 y_{T-1} + \cdots + \alpha_P y_{T-P} + u_T$$

Where the quantitative variables $y_T, y_{T-1}, \ldots, y_{t-p}$ and u_t are now random variables By assuming that the forecast errors are uncorrelated, implying that u_t and u_s are uncorrelated when $s \neq q$. We define an auto-regressive process. Considering multiple time series, our equations become[6, 7],

$$\hat{y}_{T+1} = v + \alpha_{k_1,1} y_{1,T} + \alpha_{k_2,1} y_{2,T} + \cdots + \alpha_{k_k,1} y_{k,T} + \alpha_{k_1,P} y_{1,T-P+1}$$

Where $k = 1, \ldots, K$

We can simplify the notation by letting; $y_t = (y_{1t}, \ldots, y_{kt})'$, $\hat{y}_t = (\hat{y}_{1t}, \ldots, \hat{y}_{kt})'$ along with,

$$A_i = \begin{bmatrix} \alpha_{11,i} & \cdots & \alpha_{1k,i} \\ \vdots & \ddots & \vdots \\ \alpha_{K1,i} & \cdots & \alpha_{KK,i} \end{bmatrix}$$

The equation then can be compactly be written as,

$$\hat{y}_{T+1} = v + A_1 y_t + \cdots + A_P y_{T-P+1}$$

Assuming that the y_t's are random vectors, the predictor is the optimal forecast obtained from a vector auto-regressive model of the form[5, 7]

$$y_T = v + A_1 y_{t-1} + \cdots + A_P y_{t-P} + u_t$$

Where $u_t = (u_{1t}, \ldots, u_{kt})'$ is a sequence of independently distributed random k-vectors with zero mean error.

In terms of the assumptions of the VAR processes,

$$y_T = v + A_1 y_{t-1} + \cdots + A_P y_{t-P} + u_t$$

In the equation, $y_t = (y_{1t}, \ldots, y_{kT})'$ is a $(kx1)$ random vector, the A_i are fixed (kxk) coefficients matrices, $v = (v_1, \ldots, v_k)'$ is a fixed $(kx1)$ vector of intercept terms which permits the possibility of a non-zero mean $E(y_T)$[6]

$u_t = (u_{1t}, \ldots, u_{KT})'$ is a dimensional white noise or innovation process that has the properties $E(u_t) = 0$, $E(u_t u_s') = 0$ for $s \neq t$

We can define a VAR(1) for two variables in matrix form as,

$$\begin{bmatrix} y_{1,t} \\ y_{2,t} \end{bmatrix} = \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} + \begin{bmatrix} a_{1,1} & a_{1,2} \\ a_{2,1} & a_{2,2} \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-2} \end{bmatrix} + \begin{bmatrix} u_{1,t} \\ u_{2,t} \end{bmatrix}$$

in a linear equation form,

$$y_{1,t} = v_1 + a_{1,1} y_{1,t-1} + a_{1,2} y_{2,t-1} + u_{1,t}$$

$$y_{2,t} = v_2 + a_{2,1} y_{2,t-1} + a_{2,2} y_{2,t-1} + u_{2,t}$$

Defining a VAR(2) for two variables in matrix form,

$$\begin{bmatrix} y_{1,t} \\ y_{2,t} \end{bmatrix} = \begin{bmatrix} v_{01} \\ v_{02} \end{bmatrix} + \begin{bmatrix} a_{11,1} & a_{12,1} & a_{11,2} & a_{12,2} \\ a_{21,1} & a_{22,1} & a_{21,2} & a_{22,2} \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \\ y_{1,t-2} \\ y_{2,t-2} \end{bmatrix} + \begin{bmatrix} u_{1,t} \\ u_{2,t} \end{bmatrix}$$

in linear equation form,

$$y_{1,t} = v_{01} + \overbrace{a_{11,1}y_{1t-1} + a_{12,1}y_{2t-1}}^{lag\ (1)} + \overbrace{a_{11,2}y_{1t-2} + a_{12,2}y_{2t-2}}^{lag\ (2)} + u_{1,t}$$

$$y_{2,t} = v_{02} + \underbrace{a_{21,1}y_{1t-1} + a_{22,1}y_{2t-1}}_{lag\ (1)} + \underbrace{a_{21,2}y_{1t-2} + a_{22,2}y_{2t-2}}_{lag\ (2)} + u_{2,t}$$

In terms of writing the VAR(1) and VAR(2) models in condensed form.

$$y_t = v_t + Ay_{t-1} + u_t \longrightarrow lag(1)$$

$$y_t = v_t + A_1y_{t-1} + A_2y_{t-2} + u_t \longrightarrow lag(2)$$

VAR models are based on either monthly or quarterly data. Implying the use of an example borrowed from economist Lutz Killian's book, *Structural Vector Auto-regressive Analysis* [7],

y_t denotes a k-dimensional vector of time series data, which consists of U.S. real Gross National Product (GNP) growth (Δgnp_t), the domestic rate of inflation (π_t) and the domestic short-term nominal interest rate (i_t) for $t = 1, \ldots, T$.

A quarterly VAR(2), lag 2, model for the three model variables will be written as a system of three equations,

$$\Delta gnp_t = a_{11,1}gnp_{t-1} + a_{12,1}\pi_{t-1} + a_{13,1}i_{t-1} + a_{11,2}gnp_{t-2} + a_{12,2}\pi_{t-2} + a_{13,2}i_{t-2} + u_{1t}$$

$$\pi_t = a_{21,1}gnp_{t-1} + a_{22,1}\pi_{t-1} + a_{23,1}i_{t-1} + a_{21,2}gnp_{t-2} + a_{22,2}\pi_{t-2} + a_{23,2}i_{t-2} + u_{2t}$$

$$i_t = a_{31,1}gnp_{t-1} + a_{32,1}\pi_{t-1} + a_{33,1}i_{t-1} + a_{31,2}gnp_{t-2} + a_{32,2}\pi_{t-2} + a_{33,2}i_{t-2} + u_{3t}$$

Where the zero mean innovations $u_{it}, i = 1, 2, 3$ are serially uncorrelated if the lag order is chosen appropriately.

Compactly the model can be represented as,

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + u_t$$

Where,

$$y = \begin{bmatrix} \Delta gnp_t \\ \pi_t \\ i_t \end{bmatrix}, A_i = \begin{bmatrix} a_{11,i} & a_{12,i} & a_{13,i} \\ a_{21,i} & a_{22,i} & a_{23,i} \\ a_{31,i} & a_{32,i} & a_{33,i} \end{bmatrix}, u_t = \begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{bmatrix}$$

What Killian defines as the innovations vector u_t is a linearly unpredictable component of y_t. The example equation defined in dynamic simultaneous equation models is known as a reduced form, which is expressed as a model that showcases and analyzes the current value of the data as a linear function only of its lagged values and the lagged values of other model variables. Our analysis focuses on the use of VAR models for structural modeling.

1.1.2 Structural Vector Auto-regressive

A vector auto-regressive in its structural form is generalized as,

$$y_t' A_0 = \sum_{l=1}^{P} y_{t-l}' A_l + v + \Sigma_t' \quad for \;\; 1 \leq t \leq T$$

where p is the lag variable length, T is defined as the same size. y_t' is a $nx1$ vector of endogenous variables and ϵ_t is a $nx1$ vector of exogenous structural shocks, A_l an n x n matrix of parameters for $0 \leq l \leq p$, v is a $1xn$ vector of parameters

It is important to note that the distributions of ϵ_t which is conditional to past information is a Gaussian with mean zero and the identity matrix as the co-variance matrix, I_n(n x n). We can write the general equation in a more compact form.

$$y_t' A_0 = x_t' A_+ + \epsilon_t'$$

where, $A_+ = [A_1', \ldots, A_p']$, $x_t' = [y_{t-1}', \ldots, y_{t-p}']$, for$1 \leq t \leq T$.

From the equation, we note that the parameters of the structural model are (A_0, A_+) along with the assumption of A_0 being invertible. The reduced form of the matrix is written as,

$$y_t' = x_t' B_+ + u_t'$$

where $B = A_+ A_0^{-1}$, $u_t' = \epsilon_t' A_0^{-1}$.

For an example of an SVAR, we use a model analysis done by econometricians; Eric M. Leeper, Christopher A. Sims, Tao Zha, Robert E. Hall and Ben S. Bernake. On a paper titled, *What does monetary policy do?*The paper discusses the inter-relationships of the price index of commodities, industrial output and the influence of monetary policy[9]. The analytical model used by the author is mathematically written as,

$$a_{11}\Delta LogP_{c,t} + a_{31}R_t = c_1 + b_{11}\Delta LogP_{c,t-1} + b_{21}\Delta Logy_{t-1} + b_{31}R_{t-1} + \epsilon_{1,t}$$

$$a_{12}\Delta LogP_{c,t} + a_{22}LogY_t = c_2 + b_{12}\Delta LogP_{c,t-1} + b_{22}\Delta Logy_{t-1} + b_{32}R_{t-1} + \epsilon_{2,t}$$

$$a_{13}\Delta LogP_{c,t} + a_{23}LogY_t a_{33}R_t = c_3 + b_{13}\Delta LogP_{c,t-1} + b_{23}\Delta Logy_{t-1} + b_{33}R_{t-1} + \epsilon_{2,t}$$

The model is an SVAR(1), lag 1, model. $\epsilon_{i,j}$ are uncorrelated random shocks which are Gaussian with zero mean and the identity matrix as a covariance matrix. $P_{c,t}$ is the price index of commodities, y_t is the output and R_t is the nominal short term interest rate [9].

From the collective left hand sides of the equation we note the matrix A_0 of the equation can be written as,

$$\begin{bmatrix} a_{11} & 0 & a_{13} \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

The first equation,

$$a_{11}\Delta LogP_{c,t} + a_{31}R_t = c_1 + b_{11}\Delta LogP_{c,t-1} + b_{21}\Delta Logy_{t-1} + b_{31}R_{t-1} + \epsilon_{1,t}$$

Called the *monetary policy equation*, we note that the interest has a lagging response to the output [9]. Occurring due to the delay in the availability of data during contemporaneous periods. However, monetary policy contemporaneously responds to commodity prices due to the data on developments in commodity markets being available freely[9]. From inferring to the first row on matrix A_0 and the equation, there exists an identifying restriction. This restriction imposes that monetary policy has no long-run effects on output. Based on the economic theory of monetary policy having long-run neutrality.

The second equation,

$$a_{12}\Delta LogP_{c,t} + a_{22}LogY_t = c_2 + b_{12}\Delta LogP_{c,t-1} + b_{22}\Delta Logy_{t-1} + b_{32}R_{t-1} + \epsilon_{2,t}$$

The equation characterizes the behavior of finished good producers. From the equation and the corresponding matrix, we note that output responds to commodity prices contemporaneously, as commodities are used as inputs in output production. However, they react sluggishly to interest rates due to lags in the periods. This phenomenon was researched by C. Christiano, M. Eichenbaum, and C.Evans in their 2005 paper titled, *Nominal rigidities and the dynamic effects of a shock to monetary policy*[2, 9].

The third equation,

$$a_{13}\Delta LogP_{c,t} + a_{23}LogY_t a_{33}R_t = c_3 + b_{13}\Delta LogP_{c,t-1} + b_{23}\Delta Logy_{t-1} + b_{33}R_{t-1} + \epsilon_{2,t}$$

From inferring the matrix and the equation, we note no identifying restrictions on the third equation. Reflected by commodity prices being set in active competitive markets. Therefore, respond to disturbances in the economy.

1.1.3 Vector Error Correction Model

The $VAR(P)$ model is a general modeling framework that is often used to analyze the joint dynamics of inter-relationships between stationary variables. When we imply stationarity, we mean that the statistical properties of a time-series data set are time-invariant. Hence one of the initial steps in time series analysis is to test whether the data-set is stationary or not. Most economic time-series data sets are non-stationary, and any regression analysis involving non-stationary time-series may lead to spurious results. Therefore, a stationarity test is used. If the data is non-stationary, we use differentiation to make it stationary. However, this causes extreme data loss[7].

Most economic variables are non-stationary, implying they exhibit persistent upward or downward movement. These movements are driven by stochastic trends prevalent in the time series. If the same trend is present in a set of integrated variables driving their respective trends jointly, they are co-integrated. Certain linear combinations of integrated variables are found to be stationary. Therefore, there exists a need to carry out a co-integration test. The test aims to analyze whether the linear combination of non-stationary variables is stationary. For instance, if we have two stationary time-series variables y_1 and y_2 that only achieve stationarity if we differentiate them with an order of 1. Now, if their linear combination is stationary, it is implied that they are co-integrated[7]. These co-integrating relationships are imposed by re-parameterizing the VAR model into a Vector Error Correction Model (VECM)[7].

Co-Integration

In this portion, we first introduce the concept of the co-integration process using a graphical example from Killian (2017). The concept of the Co-integration process was introduced by C.W.J. Granger and Robert Engle in 1987[4, 3].

Suppose we have a single equation model of the form,

$$y_t = a + bx_t + cz_t + e_t$$

where y_t does not display seasonally repetitive trends, but the explanatory variables x_t and z_t are shown to display seasonal behaviors. Now if a case exists where the seasonal components (i.e. trends) of the two variables are identical[4, 3]. We simply create a variable that is a ratio of x_t and z_t which has a coefficient of f such that $f = c/b$. As the seasonal component in x_t will be exactly the reverse of the seasonal component in z_t, the model will be deemed stationary[4, 3].

Kilian uses the log of U.S. quarterly GDP and investment from 1947-1988 as two such variables. From the first graph we note that both time series

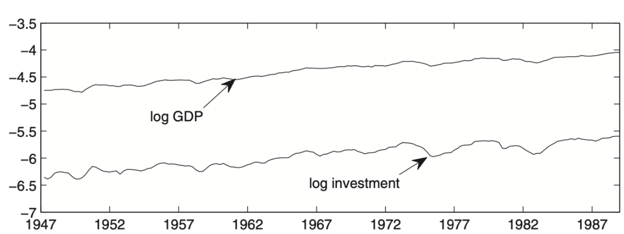


Figure 1.1: Logs of quarterly U.S. real GDP and real investment[6, 7]

variables are driven by the same trend. Due to this phenomenon the log of the

GDP-Investment ratio will be fluctuating about a constant mean. More

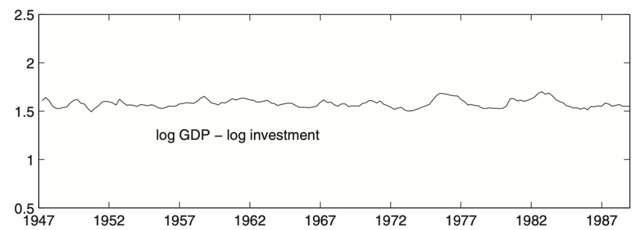


Figure 1.2: Logs of the ratio quarterly U.S. real GDP and real investment[6, 7]

formally we can define co-integration in a VAR(p) model as,

Definition 1.1 : The variables in a K-dimensional process y_t are classified to be co-integrated if the components together are uniformly integrated at the order d, I(d). Where there exists a linear combination $z_t = \beta' y_t$ where $\beta = (\beta_1, \ldots, \beta_K) \neq 0$ such that z_t is I(d^*) with $d < d_*$.

The VEC model

In a system of economic variables, there exist many linearly independent variables that are co-integrated. When we implement the concept of the co-integration in a VAR(p) model

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t$$

The individual variables in the model are assumed to be in form I(0) or I(1). I(0) implies that the series is without a trend and is found to be stationary while being integrated by order of zero. On the other hand, I(1) is a stationary series integrated by order of one.

When we subtract y_{t-1} on both sides of the equation and re-arrange the terms, we structure the vector error correction model to be,

$$\Delta y_t = \Pi y_{t-1} + \Gamma_1 \Delta y_{t-1} + \cdots + \Gamma_{p-1} \Delta y_{t-p+1} + u_t$$

Where,

$$\Pi = -(I_k - A_1 - \cdots - A_p)$$

and

$$\Gamma_i = -(A_{i+1} + \cdots + A_p) \quad i = 1, \ldots, p-1$$

In the matrix, Π, I_K is the identity matrix of K-dimensions and A_l, where $0 \leq l \leq p$ are K-dimensional matrices of the parameters. In the VEC equation, the only non-stationary variable is y_{t-1} and as Δy_t is $I(0)$. Hence, to achieve uniformity Πy_{t-1} is required to be integrated to the same order, $I(0)$. The matrix Π is the singular as the variables have individual unit roots, the characteristic polynomial,

$$det(I_K - A_1 - \cdots - A_p)$$

where z = 1. In the case the matrix has a rank of r, then it is implied that there are r linearly independent co-integrating relationships. We can decompose the Π matrix as $\alpha\beta'$ where β' is the co-integrating matrix and α is referred to as the loading matrix. Substituting $\Pi = \alpha\beta'$ in the VEC model, we formally define the VECM equation as it explicitly includes the Error Correction (EC) term $\alpha\beta' y_{t-1}$

$$\Delta y_t = \alpha\beta' y_{t-1} + \Gamma_1 \Delta y_{t-1} + \cdots + \Gamma_{p-1} \Delta y_{t-p+1} + u_t$$

It is important to note that the co-integration vector is not unique. If we multiply β' by a non-zero constant, it will lead us to an entirely new co-integrating vector. Many linearly independent co-integrating vectors may also exist.

Assuming that an equilibrium relationship between two variables is given by $y_{1t} = \beta_1 y_{2t}$ and Δy_{1t} is dependent on divergences from y_{1t} in the period $t-1$,

$$\Delta y_{1t} = \alpha_1(y_{1,t-1} - \beta_1 y_{2,t-1}) + \gamma_{11,1}\Delta y_{1,t-1} + \gamma_{12,1}\Delta y_{2,t-1} + u_{1t}$$

$$\Delta y_{1t} = \alpha_2(y_{1,t-1} - \beta_1 y_{2,t-1}) + \gamma_{21,1}\Delta y_{1,t-1} + \gamma_{22,1}\Delta y_{2,t-1} + u_{2t}$$

The model can be described as a VECM with a lag order of 1. Which we can rewrite as,

$$\Delta y_t = \alpha\beta' y_{t-1} + \Gamma_1 \Delta y_{t-1} + u_t$$

Chapter 2

Literature Review

2.1 Introduction

There seems to be an abundance of literature that focuses on the impact of oil prices on the dollar and exchange rates. Though the relationship between oil prices and interest rates seems to be a little theoretical and, to an extent, can be classified as vague.

The first paper titled *"Oil and the dollar"*, written by Paul Krugman in 1980. The first paper used the three-country model to showcase the effects of an oil price increase on the dollar in long and short runs. The reason behind the importance of Krugman's paper was that it specifically looked at the relationship as a problem of multilateral economic relations. He states that an increase in oil prices cannot be limited to modeling an increase in a nation's import bill. Even the most minimalist model would require at least three countries in the most realistic sense. Therefore, an increase in oil prices offers an exciting example of a possible conflict between an asset market and a goods market.

The second paper is written by Q. Farooq Akram, titled *"Commodity prices, interest rates, and the dollar"* gives us a detailed overview of how the shocks on commodity prices, interest rates, and the dollar affect each other. The analytical model used in the paper is a vector auto-regressive model with orthogonal impulse functions. The paper's subject and the analytical method used give us an exemplary process for our analysis. Akram also orders the orthogonal vector using the Cholesky decomposition vector. In an orthogonal impulse function, the order matters as it is the order that pertains to the global identification problem (i.e., uniqueness of a solution of a matrix). The order is based on the work done by past economists Martin Eichenbaum, Charles L. Evans in their paper titled *"Some empirical evidence on the effects of shocks to monetary policy"*.

Akram basing his analysis on Eichenbaum and Evans gave an excellent reason to go over their analysis ourselves. We will be using structural vector auto-regression models and orthogonal impulse functions, garnering the basis for theoretical inference. Therefore, from their study, we fully grasp how theory is applied to the order of orthogonal impulse functions.

The fourth paper is titled, *Oil shocks and Kuwait's Dinar exchange rate: The Dutch Disease Effect*. Written in 2010 by Usama Al-Mulali and Normer Chesab. Even though our analysis does not pertain to the effects of the Dutch Disease, this paper is essential as a past resource it delves into the asset of why Kuwait's policy of having a fixed exchange rate pegged to a basket of currencies voided the nation from having high inflation during slow economic periods. A prevalent situation in Saudi Arabia, Qatar, Iraq, and the UAE.

The fifth paper is titled, *Not all oil prices are alike: Disentangling demand and supply shocks in the crude oil market*. The paper written by Lutz Killian in 2009 states the methodology of modeling oil prices as exogenous variables is a flawed approach. In these analyses, ceteris paribus conditions are assumed, varying the oil price while holding everything else constant. The author mentions that this thought experiment is not well defined for two reasons. Firstly, the reverse causality from macroeconomic aggregates to oil prices implies that the cause-and-effect is no longer well defined in relating changes in real oil prices to macroeconomic variables. Secondly, like any other commodity, the oil price is driven by distinct supply and demand shocks. As the shocks are distant, stochastic, and individualistic, each has a different effect on the real price of oil, which causes other aggregate variables to change distinctly between various phenomena.

2.2 Oil and the Dollar

2.2.1 Introduction

The paper written in September of 1980 by Paul Krugman was published at an interesting point in the 20^{th} century. The first oil crisis has occurred almost nine years before, caused by the Arab Oil embargo in 1973 in retaliation for the United States' support for Israel in the Yom Kippur War. The embargo lasted a whole year where it was extended to all nations that had voiced their support for Israel. Again catalyzed by the Iranian Revolution in 1979, the second oil crisis had just about finished. Though the revolution only accounted for a four percent drop in oil production, oil prices doubled in response.

Hence, Krugman was in a unique position when he wrote his paper. Papers on the relationship had been written before, but they were far too simple. Dr.Krugman mentioned that the other analyses simply limit the model to an increase in a nation's import bill; this is not an accurate assessment. The dollar needs to be analyzed as a commodity, the frequency of the trades, and the lag variables between import and the export expenditure accounts required a more detailed dynamic model. In the paper, Krugman uses a dynamic partial equilibrium model that uses the assumptions of the Marshall-Lerner conditions. We describe these conditions in the sections ahead. He mentions an interesting point in terms of understanding the relationship subjective to time frames, *"In the short run before the OPEC spending has risen to absorb its higher income, the financial question is the right one. While in the long run, when it is time for OPEC to spend its income. the "real" question becomes appropriate.* When Krugman mentions the "real" questions, he means the ones which he asks at the beginning of the introduction. First, *How does US Oil import dependence compare with that of other Countries?* Second,*How much of its increased income will OPEC spend on US goods?* While the main "financial" question he asks is: *How will an OPEC nation invest their surplus?*

2.2.2 Assumptions, Model and Methodology

Assumptions of the Oil Market

The analysis assumes a model of three countries; America, Germany, and OPEC. America and Germany sell manufactured goods (Marks) to OPEC and each other. While the only export OPEC has to offer is oil, whose value is exogenously fixed in dollars.

Germany's trade balance with respect to the United States is defined to be;

$$T = T(V)$$

Where V is defined to be the mark price of the dollar.

Oil imports are assumed to be exogenously fixed in terms of volume.

$$O_A = \overline{O}_A$$

$$O_G = \overline{O}_G$$

OPEC spends γ share of it expenditure on German products and $(1 - \gamma)$ on American products. γ in general depends on the dollar mark exchange rate

$$X_A = [1 - \gamma(v)]X$$

$$X_G = \gamma(V)X$$

Where X_A is the OPEC expenditure for US goods and X_G is the expenditure for German goods. X is defined to be the total OPEC expenditure. On the question of what determines OPEC expenditure, Krugman states, "*The crucial aspect of actual OPEC spending behavior that we want to capture is the lag in the adjustment of OPEC imports to exports earning*." Therefore, he assumes that

OPEC dollar spending adjusts gradually to the level of dollar export earnings.

$$\dot{X} = \lambda(P_O\overline{O} - X)$$

Where $\overline{O} = \overline{O}_A + \overline{O}_B$ are the total oil exports and P_O is the price of Oil.

Assumptions of the Asset Market

In the model there are only two assumed assets; dollars and marks, each held by all three countries. America holds a fixed dollar value of marks in its portfolio, and Germany holds a fixed mark value of dollars in its portfolio.

$$\frac{M_A}{V} = H_A$$

$$\frac{D_G}{V} = H_G$$

Where M_A is the American holdings for marks, D_G is the German dollar holdings. While H_A and H_G are constant terms.

OPEC will be assumed to allocate its wealth between dollars and marks. Let w_O be the OPEC wealth measured in dollars.

$$W_O = D_O + \frac{M_O}{V}$$

Where D_O is the OPEC dollar holdings and $\frac{M_O}{V}$ the mark holdings. Krugman further assumes that a fraction, α, of this wealth is held in marks and $1 - \alpha$ in dollars.

$$\frac{M_O}{V} = \alpha W_O$$

$$D_O = (1 - \alpha)W_O$$

Describing the Dynamic Behavior

The German current account,

$$B_G = T(V) + \gamma(V)X - P_O\overline{O}_G$$

We can note from the equation above that the German account can be described as the net exports to America ($T(V)$) added to the net exports to OPEC ($\gamma(V)X$) subtracted by the oil imports from OPEC ($P_O\overline{O}_G$).

Similarly, we can write the current American account as,

$$B_A = -T(V) + [1 - \gamma(V)]X - P_O\overline{O}_A$$

In the paper it is important to note that the appropriate Marshall-Lerner conditions hold. Now if the condition is satisfied, then assuming that a nation that begins with a zero trade deficit is affected by currency depreciation. This will cause its balance of trade to improve (i.e. may lead to a trade surplus). As the conditions are satisfied,

$$\frac{\partial B_G}{\partial V} > O \quad \frac{\partial B_A}{\partial V} < O$$

We can simply write OPEC account as a difference between the exports ($P_O\overline{O}$) and imports (X).

$$B_O = P_O\overline{O} - X$$

Using the assumptions, we have written Krugman derives the equation for the change in exchange rate.

$$\frac{\dot{V}}{V} = \frac{-[B_G + \alpha B_O]}{\left[\frac{M_A}{V} + \alpha(1-\alpha)W_O + D_G\right]} \tag{2.1}$$

From the above equations we can note some special cases.

In the special case that OPEC holds no marks, i.e. $\alpha = 0$,

$$\frac{\dot{V}}{V} = \frac{-B_G}{\frac{M_A}{V} + D_G}$$

In this situation, we note that the rate of change depends heavily on the German Exchange account. Hence, if the exchange account were to fall (i.e., the price of oil goes up), then the rate of change of the exchange rate would increase. But, on the other hand, if the account were to increase, say in the long run, OPEC has a surplus of funds as the oil price increased, the rate of change would fall.

In the special case that OPEC holds no dollars, $\alpha = 1$,

$$\frac{\dot{V}}{V} = \frac{B_A}{\frac{M_A}{V} + D_G}$$

In this case, we note that the rate of change of the exchange rate depends on America's current account. Hence, America is free to manipulate its currency.

Except in the case of $\alpha = 0$ or 1, there is no one relationship between a country's current account and its exchange rate. Therefore to iterate his findings, he draws the figure Even though how Krugman finds the slopes of

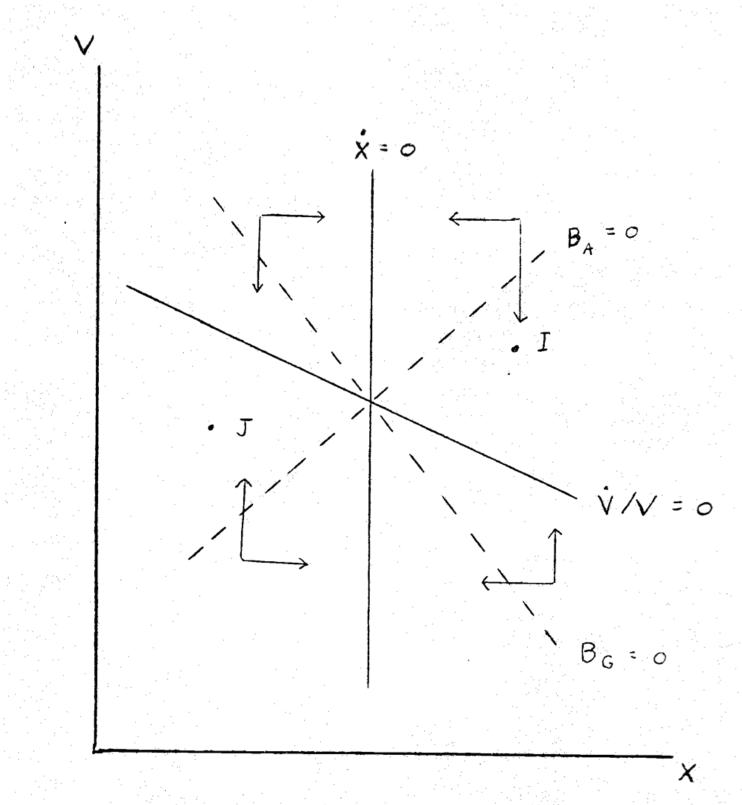


Figure 2.1: Relationship between Exchange Rates & Total OPEC expenditure[8]

the current account of America and Germany along with the slope for $\Delta(V)$ is a little pedantic the intuition behind the graph is quite simple.

If OPEC expenditure were to rise from its long-run level, it would directly affect Germany's balance of payments. First, it would improve the current account as part of the expenditure would fall for German goods. Second, it will worsen the German Capital account, as in the long run, OPEC would be running a current account deficit of which it would part-finance by the liquidation of its marks holdings. Therefore, this gives us inconclusive results. Hence, to ensure the model makes sense, Krugman stimulates an increase in the oil price.

Effects of an Oil Price Increase

The effects of an increase on the oil price primarily depend on three parameters, α: Share of Marks in OPEC's portfolio. γ: Share of goods in OPEC's imports.$\sigma = \frac{O_G}{\overline{O}}$: The German Share in the world oil imports

The impact in the short run depends on whether α is greater or less than σ.

While the long run is impacted by whether γ is greater or less than σ.

It is also important to remember that OPEC spending lags behind income. Now, if there is an increase in oil prices, it will first increase industrial country import bills without affecting the exports. The German and American accounts will worsen due to an oil price increase, as $(P_0\overline{O}_G)$ and $(P_0\overline{O}_A)$ in B_G and B_A will increase. There will be an improvement in their capital accounts as OPEC will invest their trade surplus in marks and dollars. If OPEC spends more on dollars than America's share of the industrial world's current deficit, then the effect is favorable on the dollar. If OPEC spends less on dollars than compared to America, then the effect on the dollar is unfavorable. Ultimately an increase in oil prices will lead first to a dollar appreciation and later conclude on an even greater dollar depreciation.

2.2.3 Conclusion

From the paper, we can conclude two crucial points. First, the effect on Oil price depends on whether the burden of a nation's higher imports is greater or less than the improvement caused by OPEC investments and imports. Second, in the long run, the importance of OPEC investment falls. The only variable that matters is OPEC's import preferences, as those transactions would offset an increase in oil prices for the nation OPEC is importing from.

2.3 Commodity prices, interest rates and the dollar

2.3.1 Introduction

Written by Q. Farooq Akram in 2009, the paper talks about fluctuations in commodity prices. It investigates whether a decline in real interest rates and the US dollar contributes to higher commodity prices. The paper analyzes the behavior of real prices of crude oil, foods, metals, and industrial raw materials. The analysis is based on structural vector Auto-regressive models estimated on quarterly data over the Q1 1990 quarter to Q4 2007.

In the paper, the author mentions that an increase in commodity prices has coincided with relatively low-interest rates in general, along with a decline in the US dollar value. Akram states the post-1990's surge, what he dubs the Greenspan era, is predominantly accounted for by the aforementioned factors that were further exacerbated by the spillover effects of the growing economy. The paper focuses on to what extent real interest rates and the declining dollar can account for high commodity prices. The question is whether these prices display overshooting behavior in response to these prices. Accordingly, the slowdown caused by the real estate crisis in 2007 after several years of high growth may explain the decline in both variables. Akram states that "A negative relationship between the value of the dollar and the dollar prices of commodities follows from the law of one price for trade-able goods." Therefore, a decline in the dollar's value must be outweighed by an increase in the dollar price of commodities and/or a fall in their current foreign prices to ensure the same price when measured in dollars.

The paper bases its analysis on a five-variable vector auto-regressive (VAR) model for four commodity prices; real oil prices valued in US dollars, aggregate price indices of food, aggregate price indices of metal, and aggregate price indices raw materials.

In each VAR model, the author includes a measure of global activity levels, real interest and exchange rates with respect to the US dollar, real oil prices (in USD), and the real price of other commodities. Furthermore, according to Akram, research suggests that higher real interest rates cause higher commodity prices while adverse shocks to economic activity lead to lower rates and prices.

2.3.2 Assumptions, Models and Methodology

The author assumes the condition that gains from a commodity holding, of storage cost, equals the nominal interest rate.

$$E_t pc_{t+1} - pc_t = i_t + s(i_t)$$

In the above equation, $E_t pc_{t+1} - pc_t$ is the expected revaluation of a commodity over a period, which is a measurable price increase from the period t to $t+1$, given that there is information available at time t. i_t is the nominal interest rate at t, and $s(i_t)$ is the storage cost.

The above condition is also known as Hotelling's law, a no-arbitrage condition in economics that states that it is rational for producers to manufacture their products in such a manner that they are similar as possible.

Due to this condition, there exists a negative relationship between commodity prices and interest rates. This implies that a decline in the nominal interest rate will coincide with an increase in commodity prices. A lower nominal interest rate would cause agents to invest less in bonds and more in the commodities market. This increase in demand for commodities would cause an upward rise in prices. In addition, lower interest rates would reduce the carrying cost, which would cause an inventory demand for commodities which would put upward pressure on the price. Along with their effects, we note that a lower interest rate would also increase economic activity and thereby increase the demand for commodities, translating to higher prices.

The variables used in this analysis are defined; PCO, the real price per barrel of crude oil, PCF, the real price of food, PCM, the real price of metals and PCI, the real price of industrial raw materials.

All the variables are measured in dollars. Therefore to note the relationship between the mentioned variables and real interest rates (*ri*) and real exchange rates (*rex*), the author draws the cross plots. From the cross plots, we note an inversely proportional relationship between the real oil price and real interest rates. While the corresponding cross plots for food industrial raw materials prices suggest a positive relationship between the other commodity prices and real interest rates.

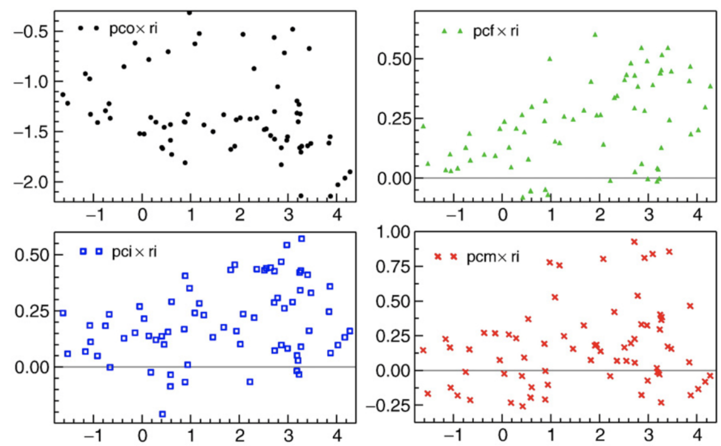


Figure 2.2: Real commodity prices (in logs) vs real interest rates[1].

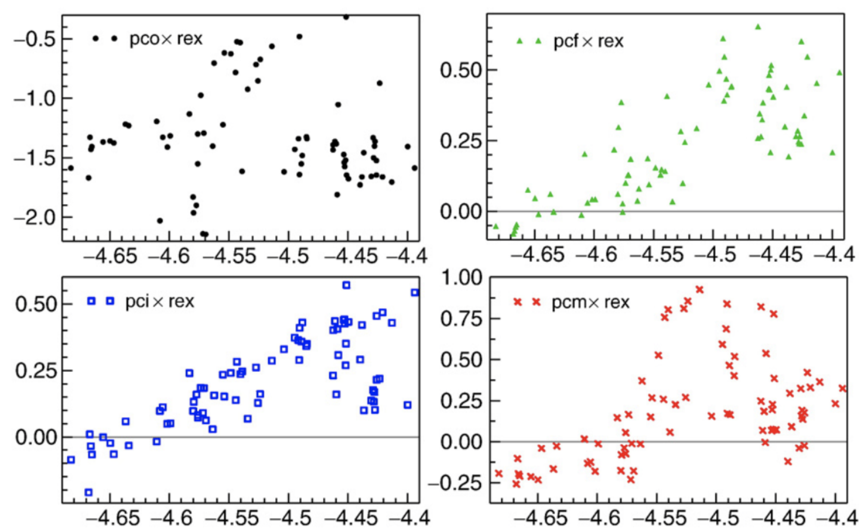


Figure 2.3: Real commodity prices vs the real exchange rate [1].

In the case of real exchange rates, there seems to be an absence of a linear relationship between real oil prices and the dollar's real value. Giving us an indication that a weak dollar may not constitute a systematically high oil price. While we note that this is not the case for a relationship between other commodities and the real exchange rate. Thereby suggesting that a weak dollar goes with high commodity prices.

Model Specification

As the analysis used by the author is based on VAR models. The structural form of the model used in the analysis is defined to be,

$$Az_t = A_1 z_{t-1} + A_2 z_{t-2} + \cdots + A_1 z_{t-1} + B_{\varepsilon_t}$$

ε_t $(0, \Sigma_\varepsilon)$. A is a k x k invertible matrix of structural coefficients, which is used to describe the contemporaneous relationship among the variables that are present in z. B is defined to also be a k x k of structural coefficients which represent the effects of k structural shocks.

To identify the shocks in the analysis, the author defines the matrix B_ε

$$B_\varepsilon = \begin{bmatrix} * & 0 & 0 & 0 & 0 \\ * & * & 0 & 0 & 0 \\ * & * & * & 0 & 0 \\ * & * & * & * & 0 \\ * & * & * & * & * \end{bmatrix} \begin{bmatrix} \varepsilon_{y0} \\ \varepsilon_{ri} \\ \varepsilon_{rex} \\ \varepsilon_{pco} \\ \varepsilon_{pcxo} \end{bmatrix}$$

The aggregate variables are in logs, where $pcxo = pci, pcm, pcf$, the commodity prices except oil. $y0$ is log of industrial production volume in Organisation for Economic Co-operation and Development (OECD) countries. This variable is added to the analysis to account for the interaction between the global economic activity level and, financial variables and commodity prices.

The author runs the following lag selection tests to find the best lag values for his analysis; Akaike information criterion, Final Prediction Error, Hannah-Quinn Criterion, and Schwarz criterion. We will be describing these tests in detail in our chapters ahead

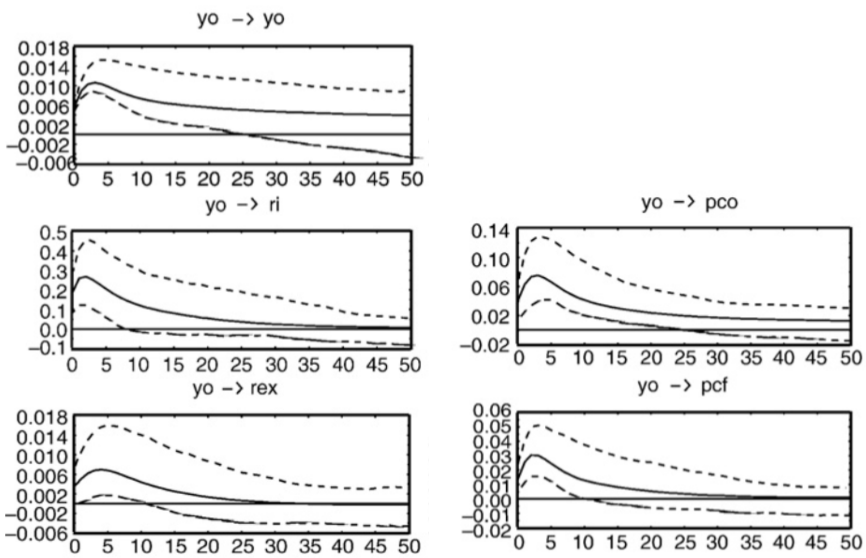
	VAR with *pcf*	VAR with *pcm*	VAR with *pci*
Akaike information criterion	2	2	2
Final prediction error	2	2	2
Hannah–Quinn criterion	1	1	1
Schwarz criterion	1	1	1

Figure 2.4: Lag Selection tests used [1]

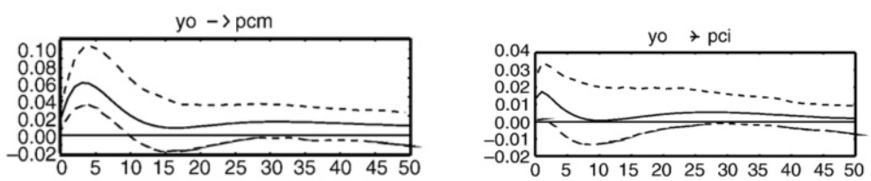
$$B_\varepsilon = \begin{bmatrix} * & 0 & 0 & 0 & 0 \\ * & * & 0 & 0 & 0 \\ * & * & * & 0 & 0 \\ * & * & * & * & 0 \\ * & * & * & * & * \end{bmatrix} \begin{bmatrix} \varepsilon_{y0} \\ \varepsilon_{ri} \\ \varepsilon_{rex} \\ \varepsilon_{pco} \\ \varepsilon_{pcxo} \end{bmatrix}$$

Noting the B_ε matrix, the "*" entries in the matrix are written to represent the unrestricted parameter value. At the same time, the zeros suggest the associated shocks in the respected variables do not contemporaneously affect the corresponding endogenous variables. The setup of the first row implies that the economic output ($y0$) may respond contemporaneously to ε_{y0}, while the others do not. The second row showcases that the real interest rate (ri) may respond contemporaneously to ε_{y0} and shocks directly to the real interest rate. In the third row, we note that the real exchange rate will respond contemporaneously to ε_{y0} and ε_{ri} along with shocks directly to the real exchange rate. From the fourth and fifth row, we conclude that the author assumes that shocks to commodity price exclusive of oil do not have contemporaneous effects on oil prices, while the opposite cannot be said.

Impulse Function analysis: Shocks on industrial economic activity



(a) Shocks: $yo \longrightarrow y0,\ ri\ ,\ rex$ (b) Shocks: $yo \longrightarrow pco,\ pcf,$

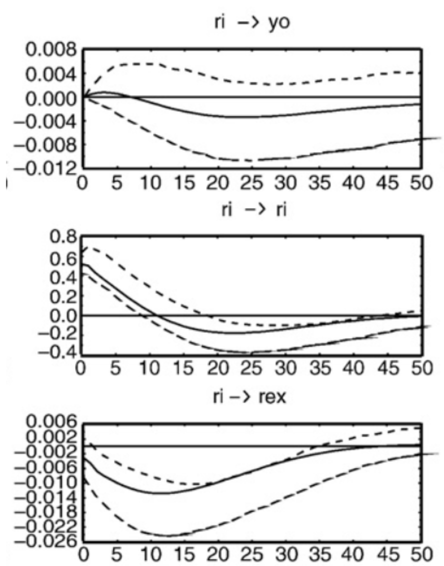


(c) Shocks: $yo \longrightarrow pcm$ (d) Shocks: $yo \longrightarrow pci$

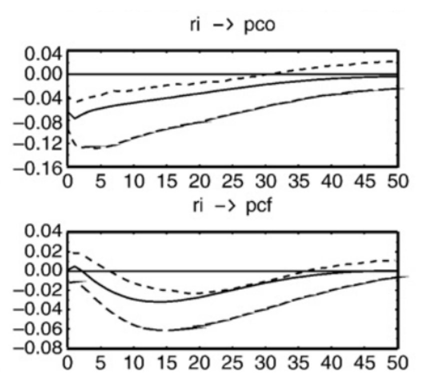
Figure 2.5: Effects of economic activity shock [1]

An exogenous increase in the world economic will lead to higher interest rates(ri) and commodity prices($pco,\ pcm,\ pcf,\ pci$). The effects of a shock on yo have a lasting positive effect on the oil price over 50 quarters. We note that the effect on real exchange rates is weak and is statistically insignificant. The impulse function responses between real interest rates and commodity prices in response to the shock in yo indicate that the relationship between real interest rates and commodity prices is shock-dependent. In the case of the commodity price of metals, a shock in *yo* will increase the prices, which later will stabilize after a little over 15 quarters. High economic activity will cause an increase in the commodity price of industrial raw materials though it will gradually decrease and stabilize.

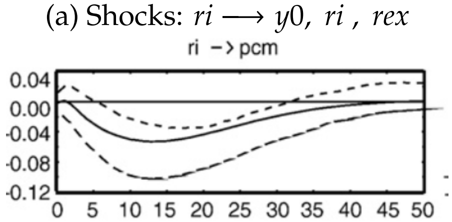
Impulse Function analysis: Shocks on real interest rate



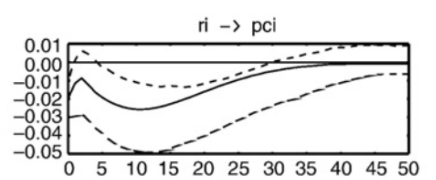
(a) Shocks: $ri \longrightarrow y0,\ ri\ ,\ rex$



(b) Shocks: $ri \longrightarrow pco,\ pcf,$



(c) Shocks: $ri \longrightarrow pcm$



(d) Shocks: $ri \longrightarrow pci$

Figure 2.6: Effects of real interest rate shock[1]

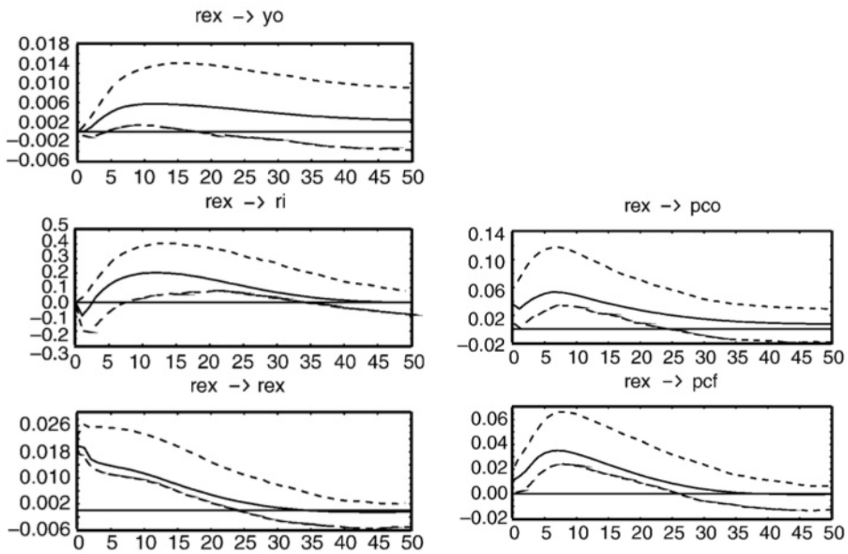
A shock in the real interest rates will cause economic activity to fall, the real exchange rate appreciates throughout the quarters of simulation. This behavior of the exchange rate is indicative of studies and analysis done which suggest that the gradual appreciation and thereafter depreciation of the variable. Oil price on the other hand fall immediately and increase thereafter in response to the shock. Commodity prices of food, do showcase a decline but rise gradually after a delay as the interest rate shock dissipates over time.

In the case of the commodity prices of metals, we note that there is a gradual appreciation of prices over time as individuals may look to invest/save in precious metals. In the case of the commodity prices for industrial raw materials, there seems to be an upward pressure on prices which seems significant as interest rate shocks made the economic activity fall.

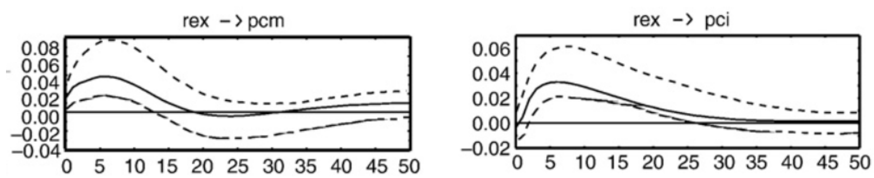
Impulse Function analysis: Shocks on real exchange rate

A shock in the real exchange rate leads to lower interest rates in the short run. Along with higher economic growth and higher commodity prices. Oil and food prices show a significant growth over a period of 24 quarters. A real exchange rate depreciation leads to higher real interest rates over time. The author states that this phenomenon could be a result of central banks' response of possible higher inflation brought about by exchange rate prices pass-through to consumer prices.

For commodity prices of metals and industrial raw materials, we note that they initially increase over the $0-20^{th}$ quarter, after which the effects of the exchange rate shock dissipate over time.



(a) Shocks: $rex \longrightarrow y0,\ ri\ ,\ rex$ (b) Shocks: $rex \longrightarrow pco,\ pcf,$



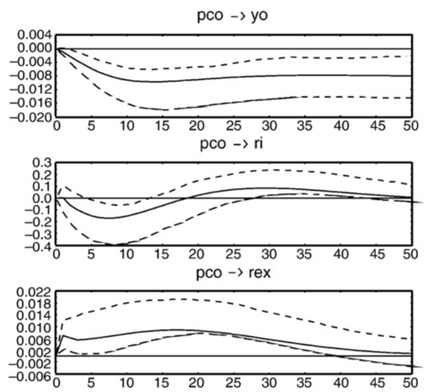
(c) Shocks: $rex \longrightarrow pcm$ (d) Shocks: $rex \longrightarrow pci$

Figure 2.7: Effects of real exchange rate shock[1]

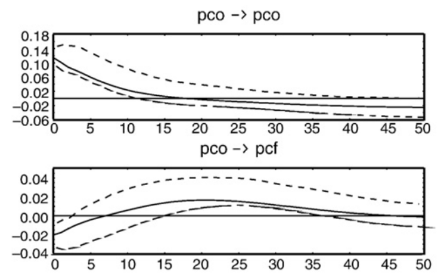
Impulse Function analysis: Shocks on real price per barrel of crude oil

A shock to the oil prices will the cause the economic activity to fall for a, statistically significant, long period of time. Real interest rates will fall in the short run along the real exchange rate, though the effect of the latter will last for a longer period of time. In the case for food prices, we note that the effect of an oil price shock will cause a fall in the food prices, which will gradually rise in lieu of initial higher transportation cost and later adjust.

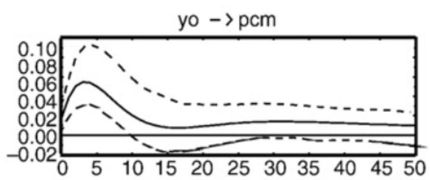
For the commodity prices of metals, a shock in *pco* will cause a sudden appreciation in prices, which will later adjust after a little over ten quarters.



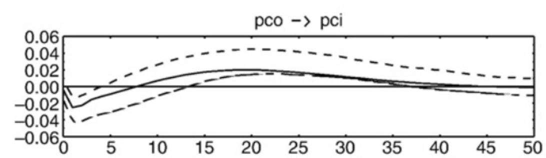
(a) Shocks: $pco \longrightarrow y0,\ ri\ ,\ rex$



(b) Shocks: $pco \longrightarrow pco,\ pcf,$



(c) Shocks: $pco \longrightarrow pcm$



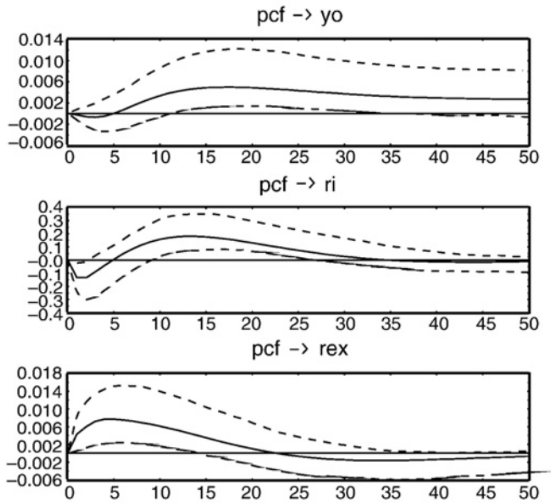
(d) Shocks: $pco \longrightarrow pci$

Figure 2.8: Effects of real price per barrel of crude oil shock[1]

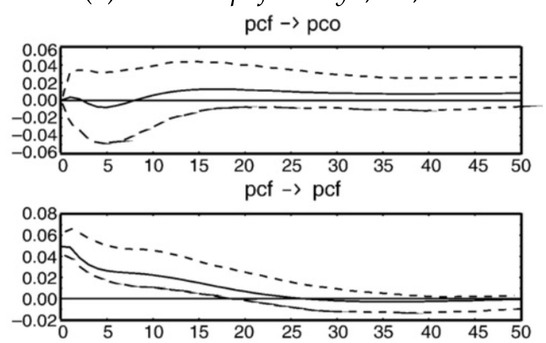
While in the case of commodity prices of industrial raw materials, we note that there will be an initial depreciation in prices due to the high transportation costs. However, the following adjustment will stabilize the prices.

Impulse Function analysis: Shocks on the real price of food

A shock on the food prices will depreciate the real exchange rate in the short run, due to the trade effects of higher food prices. An increase in the real interest rate will seen following the high activity due to depreciating exchange rates. The shock on pcf will not pco in any extreme manner. After a extremely insignificant price oscillation the pco will stabilize. The analysis did showcase what impulse shock on pcf will do to the commodity prices of metals and industrial raw materials.



(a) Shocks: $pcf \longrightarrow y0,\ ri\ ,\ rex$



(b) Shocks: $pcf \longrightarrow pco,\ pcf,$

Figure 2.9: Effects of real price of food shock[1]

2.3.3 Conclusion

The evidence in the paper suggests that interest rate and dollar exchange rate shocks contribute significantly to movements in commodity prices. The analysis found that commodity prices rise when the real interest rate falls and when the real price of the dollar depreciates. Commodity prices of food and metals display delayed responses to interest rate shocks.

The paper also found that shocks to the real interest and the real exchange rates account for fluctuations in commodity prices in all horizons. Another significant finding of the paper is that fluctuations attributable to oil price shocks in the analysis account for a large driving force for the world economy.

2.4 Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates

2.4.1 Introduction

The paper written in 1995 by Martin Eichenbaum and Charles L. Evans showcases the effects of shocks in contractionary monetary policy (i.e., any policy set by central banks that decrease the money supply in an economy). The analysis done by the author finds that, firstly, these shocks will lead to a ”sharp, persistent increase” in the US interest rate. This will cause the spread between the US and foreign interest rates to decrease. Secondly, contractionary monetary policy shock is associated with an increase in the real and nominal exchange rates. Finally, the author notes that the dollar continues to appreciate but is not contemporaneous to any specific time period.

The paper contradicts the hypothesis that an expected depreciation should offset larger interest rate differentials induced by a contractionary US monetary policy in the dollar. However, the authors’ empirical results indicate that the opposite is true; expected future appreciations in the dollar magnify larger returns.

Eichenbaum and Evans introduce the concept of a forward premium bias. A forward premium bias is a phenomenon in which the expected future price for a currency is greater than the current spot price. The authors find that future changes in the exchange rate tend to have a negative relationship with the forward premium. Therefore, we can state that future uncertainty can affect the expectation of a future premium.

In the paper, the authors found what they classify as a new *monetary-policy-induced* puzzle. A contractionary shock leads to a rise in the US interest rates relative to foreign interest rates. A rise that they found is associated with a persistent appreciation of the dollar. Consequently, they concluded that a high-interest rate would be associated with an appreciating currency, leading to a conditional negative forward premium bias. Which is a phenomenon that higher interest rates will appreciate the currency.

The authors test their hypotheses on four models. A benchmark model simulates monetary policy shocks; another model simulates orthogonalized shocks on the ratio of non-borrowed to total reserves; a model simulates orthogonalized shocks on the federal funds rate; a final model simulates shocks on the Romer and Romer index of monetary policy. For our analysis, the first three are pertinent; therefore, we chose to ignore the implications of the fourth model.

2.4.2 Assumptions, analysis and empirical results

The author define mathematically monetary policy shocks as,

$$V_t = \zeta(\Omega_t) + \epsilon_{V_t}$$

Where V_t is the time t setting of the monetary authority's policy instrument, ζ is the linear function, Ω_t is the information set available to the monetary authority when V_t is set. ϵ_{V_t} is a serially uncorrelated shock that is orthogonal to the elements of Ω_t. Along with the orthogonality conditions on ϵ_{V_t}, the variable corresponds to the assumption that shocks that occur on date t do not affect the elements of Ω_t.

ϵ_{V_t} can represent a kaleidoscope of factors that influence policy decisions. Including but not limited to; views of the members of the decision-making boards, political factors, and technical factors like measurement error prevalent in the data available to the decision-makers.

The analysis is conducted on Non-Borrowed Reserves instead of measures based on broader monthly aggregates. The motivation for doing so is based on "the idea that innovations to non-borrowed reserves primarily reflect exogenous shocks to monetary policy, while innovations to broader monetary aggregates primarily reflect shocks to money demand." The authors further postulate that a more accurate measure of exogenous shocks to the supply of money can be determined by implementing a ratio of Non-Borrowed Reserves to total reserves, which the authors denote as NBRX. Through this understanding, we can conclude that,

$$V_t = \frac{NBR_t}{(Total\ Reserves)_t}$$

All the results were generated using data from 1974 to 1990. All VARS estimated utilize six lags of all variables. The authors considered five nominal exchange rates,s_t^{For}, where

$For = Yen,\ Deutschmark,\ Lira,\ French\ Franc,\ UK\ Pound.$ s_t^{For} denotes the logarithm of the number of dollars needed to buy one unit of foreign currency. If the value of the dollar depreciates, there will be a rise in s_t^{For}.

s_{Rt}^{For}, logarithms of five real exchange rates. Such that,

$$s_{Rt}^{For} = s_t^{For} + P_t^{For} - P_t$$

Where P_t^{For} is the foreign price level as time t, and P_t is the US price level at time t.

Benchmark Model with five variables.

The benchmark model is a VAR model with five variables. US industrial production (Y), US consumer price level (P), ($NBRX$), spread of US and foreign exchange rates ($R^{For} - R^{US}$) and the real exchange rate (s_t^{For}).

All the variables are in logarithms except for R^{For} and R^{US}. As the impulse functions used in this analysis are orthogonal the order matters,

$$[Y,\ P,\ NBRX,\ R^{For} - R^{US},\ s_t^{For}]$$

We can rewrite the above order in matrix form,

$$B_{\varepsilon} = \begin{bmatrix} * & 0 & 0 & 0 & 0 \\ * & * & 0 & 0 & 0 \\ * & * & * & 0 & 0 \\ * & * & * & * & 0 \\ * & * & * & * & * \end{bmatrix} \begin{bmatrix} \varepsilon_Y \\ \varepsilon_P \\ \varepsilon_{NBRX} \\ \varepsilon_{R^{For}-R^{US}} \\ \varepsilon_{s_t^{For}} \end{bmatrix}$$

From the above matrix we note that contractionary money policy shocks is measured as a part of a negative occurrence on $NBRX$, which is orthogonal to Y_t and P_t. From the graph we can also ascertain that US monetary policy authorities only look at the domestic production at time t (Y_t) along with US consumer price at time t (P_t). $R^{For} - R^{US}$ and s_t^{For} have no effect on the $NBRX$.

From the results of the benchmark model, a contractionary shock to the US monetary policy will cause a persistent and statistically significant decrease in the spread of foreign and US nominal interest rates. The estimated orthogonal response functions of nominal and real interest rates are very similar.

A contractionary shock to US monetary policy ($NBRX$) will lead to a persistent appreciation in nominal and real exchange rates. The authors mention that the maximal effective impact of monetary shocks on s_{Rt}^{For} does not occur contemporaneously. The same is noted in s_t^{For}, in the results of the benchmark model, the maximal impacts on $[s_t^{Yen},\ s_t^{DM},\ s_t^{Lira},\ s_t^{FF},\ s_t^{PD}]$ with are equal to $[-1.91,\ -2.96,\ -3.00,\ -1.86]$ percent occur after $[24,\ 35,\ 38,\ 37,\ 39]$ months after the simulated shock. According to the authors, these results support a broader view that the overshooting in which exchange rates appreciate initially then depreciate after a period of time.

A phenomenon that the authors note is not prevalent in the models, or any of their further analyses is an assumption of interest rate parity. The concept of interest rate parity states that a fall in $R^{For} - R^{US}$ which is caused by an interest rate increase for the US due to contractionary monetary policy, is offset by a depreciation of the dollar between the time period of t to $t+1$. They define, Ψ_t^{For}, as the ex-post difference in return between investing in a dollar in a one-period foreign bond and investing the same amount in a one-period US treasury bond.

$$\Psi_t^{For} = R_t^{For} - R_t^{US} + (s_{t+1}^{For} - s_t^{For})$$

If the interest parity which is a not arbitrage condition holds then,

$$E_t \Psi_t^{For} = 0$$

Where E_t is the expected returns at time t

The results of the benchmark model find that the condition of expected returns equaling zero does not hold. When a contractionary shock causes a fall in $R^{For} - R^{US}$, the s_t^{For} declines due this occurs primarily for two reasons. First, $R^{For} - R^{US}$ falls as interest rates increase. Second, the dollar's value appreciates, thereby causing the parity to not hold. Excess returns fall for a significant time after contractionary monetary policy shock. After the shock, the authors conclude that the expected returns from investing in foreign short-term bonds fall with respect to the returns from investing in short-term US treasury bonds.

Orthogonalized Shocks to the ratio of the non-borrowed to total-reserves(*NBRX*)

The model is a VAR model with seven variables which have the corresponding order,

$$[Y,\ P,\ Y^{For},\ R^{For}\ NBRX,\ R^{US},\ s_t^{For}]$$

Where Y is the US industrial production, P is the US consumer price level, Y^{For} the foreign output, R^{For} the foreign interest rate, R^{US} the 3-month treasury yield and s_t^{For} the real exchange rate.

$$B_\varepsilon = \begin{bmatrix} * & 0 & 0 & 0 & 0 & 0 & 0 \\ * & * & 0 & 0 & 0 & 0 & 0 \\ * & * & * & 0 & 0 & 0 & 0 \\ * & * & * & * & 0 & 0 & 0 \\ * & * & * & * & * & 0 & 0 \\ * & * & * & * & * & * & 0 \\ * & * & * & * & * & * & * \end{bmatrix} \begin{bmatrix} \varepsilon_Y \\ \varepsilon_P \\ \varepsilon_{Y^{For}} \\ \varepsilon_{R^{For}} \\ \varepsilon_{NBRX} \\ \varepsilon_{R^{US}} \\ \varepsilon_{s_t^{For}} \end{bmatrix}$$

From the matrix we note that US monetary policy is affected by the domestic industrial production, the US consumer price level, the foreign output and the foreign interest rate. While the feedback from the 3-month US treasury bill rate is ignored along with the exchange rate.

In terms of the results, the key difference noted by the authors in comparison to the benchmark model is that a contractionary shock in monetary policy leads to an increase in the US interest rate, along with all other foreign interest rates, except the pound. Is consistent with the fall in $R_t^{For} - R_t^{US}$, the interest rate spread we note that in all cases the condition $R_t^{For} < R_t^{US}$ holds. The shock also leads to what the authors call a ”pronounced, persistent appreciation in real and nominal interest rates.” Similar to the benchmark model the $E_t\Psi_t^{For}$ falls for a substantial amount of time.

Orthogonalized Shocks to the Federal Funds Rate

The model is a VAR model with seven variables which have the corresponding order,

$$[Y,\ P,\ Y^{For},\ R^{For}\ FF,\ NBRX,\ s_t^{For}]$$

Where FF is the federal funds rate. The matrix form for impulse functions can be written as,

$$B_\varepsilon = \begin{bmatrix} * & 0 & 0 & 0 & 0 & 0 & 0 \\ * & * & 0 & 0 & 0 & 0 & 0 \\ * & * & * & 0 & 0 & 0 & 0 \\ * & * & * & * & 0 & 0 & 0 \\ * & * & * & * & * & 0 & 0 \\ * & * & * & * & * & * & 0 \\ * & * & * & * & * & * & * \end{bmatrix} \begin{bmatrix} \varepsilon_Y \\ \varepsilon_P \\ \varepsilon_{Y^{For}} \\ \varepsilon_{R^{For}} \\ \varepsilon_{FF} \\ \varepsilon_{NBRX} \\ \varepsilon_{s_t^{For}} \end{bmatrix}$$

Ascertaining from the matrix we the US Federal Funds rate (FF) take contemporaneous feedback from the domestic industrial product, domestic consumer price level. Foreign output and the foreign interest rate. While feedback from US monetary policy and the real exchange rate are ignored.

The model’s results are similar to the past two analyses. A positive shock to the federal funds rate garners a sharp decline in the *NBRX*. A shock to the FF, a contractionary monetary policy is associated with appreciations in the nominal and real exchange rates. The maximal impact of the monetary shocks on s_{Rt}^{For} and s_t^{For} do not occur contemporaneously. As impacts to the shocks on $[s_t^{Yen},\ s_t^{DM},\ s_t^{Lira},\ s_t^{FF},\ s_t^{PD}]$ occur at periods of $[22,\ 31,\ 33,\ 32,\ 30]$ months after the shock. A contractionary monetary policy shock is associated with an increase in returns to investing in short-term US bills when compared to foreign bills (i.e., $E_t\Psi_t^{For}$ falls)

2.4.3 Conclusion

The authors found that a contractionary monetary policy shock. First, it leads to a significant and persistent appreciation in the exchange rates, both nominal and real, which causes a breakdown of the assumptions of the interest rate parity. The second finding strengthens the belief that future changes in the exchange rate are negatively related to the forward premium.

2.5 Oil shocks and Kuwait's Dinar exchange rate: The Dutch Disease Effect

2.5.1 Introduction

In the study, the authors first describe the concept of a Dutch Disease model. They state that one of the best models that describe the phenomenon is the Core Model. The core model was developed in 1982 by M. Gorden and P.

Neary in their paper titled "*Booming sector and De-industrialization in a small open economy*." The model describes the existence of a non-tradable sector (i.e., the service/labor sector) and two tradable sectors; the booming sector(oil or natural gas) and the non-booming sector (manufacturing sector). During a natural resource boom, there will be an increase in the demand for labor in the booming sector. Thereby causing a movement of labor of the service sector to the booming sector from the non-booming sector. This increased demand for labor will cause an upward price on the price, and as the price of the commodity in the booming sector is set by the global market, it will be detrimental for the sector in the long run. This causes the probability of the service sector to increase, but it will eventually fall due to the resource movement effect. The resource movement effect is often called direct – de-industrialization. This effect will cause a fall as more resources will be allocated to the booming sector and not enough resources towards the other sectors. The authors mention that all past research on Dutch disease comes to the same conclusion. The disease persists by causing a real appreciation of the national currency and, therefore, reduces the manufacturing sector's share as the exports become more substitutable due to higher prices. They also mention studies that have found that nations that employ a fixed exchange rate regime cause the reduction of the dash disease to a fixed interest rate will cause high inflation compared to new nations that use floating exchange rates.

The idea of a crawling peg exchange rate is introduced. It is defined as a system of exchange rate adjustments for a fixed exchange rate currency that is allowed to fluctuate within a band of rates. It is done by a coordination buying or selling of currency adjusting the transaction frequency to keep the currency within range. H. Roemer in their 1994 paper titled *"Citizen Funds and Dutch Disease in developing countries,"* along with N. Usui in 1996 with the paper titled, *"Dutch Disease and policy adjustments to the oil boom: A comparative study of Indonesia and Mexico."* Talk about the prevalence of Dutch disease in Indonesia is very small due to a government instituted policy. Passed in 1987, the country moved to a crawling peg exchange rate. This helped it maintain a uniform real value of its local currency—the paper analyses whether the – Disease exists in Kuwait. Kuwait is chosen as it has used a fixed rate peg to a basket of currencies, including the dollar, for over three decades. It is important to note that oil contributes over 90 percent of Kuwait's total exports and 95 percent of its foreign earnings.

2.5.2 Assumptions, analysis, and methodology

The study aims to find whether the effects of a fixed interest rate (based on a basket of currencies) counteract the prevalence of the Dutch disease model in Kuwait. The model used in the analysis is defined as,

$$Log\ REXCH_t = \alpha + \beta_1 Log\ OP_t + \beta_2 Log\ GDP + \beta_3 Log\ TB_t + \beta_4 Log\ OEXPV_t + \epsilon_t$$

When $Log\ REXCH_t$ is the log of the Real Exchange rate (dinar per USD), $Log\ OP_t$ is the log of oil prices (USD per barrel), $Log\ GDP$ is the log of the GDP (millions in USD), $Log\ TB_t$ is the log of the trade balance (millions of USD) and $Log\ OEXPV_t$ is the log of the petroleum exports (millions of USD).

Tests run on the data

The authors chose to run the Augmented Dickey-Fuller test to test for stationarity. We will be talking about the ADF tests and the other tests run by the author in our chapters ahead. The ADF test helps determine whether the variables in the data set are stationary.

They further use the Johansen-Julius co-integration test. The test is used to determine whether there is a long-run relationship between the variables in the regression model. The JJ test is based on the Vector Autoregressive (VAR) model, where the Akaike Information Criteria determine the lag length.

The VAR model of lag p, in the study, is written in the form,

$$Y_t = \mu + \sum_{k=1}^{p} \Pi_k y_{t-k} + \epsilon_t$$

In the model, y_t is a given g-vector of order lag 1 variables, μ is the g-vector of constants and ϵ_t is a g-vector of white noise residuals at time t with zero mean and constant variance.

In the study, $g = 5$ with four independent variables and one dependent variable. The author chooses to only use the lag length as 2. The JJ methodology is based on two kinds of likelihood ratio tests. The trace and maximum eigenvalue test.

The trace test statistic is defined as,

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{g} ln(1 - \lambda_i)$$

Where λ_i is the eigenvalue of the Π matrix, r_i is the number of co-integration vectors, g is the number of variables, and T is the number of observations. The null hypothesis under the trace test implies that there are less than or equal to r co-integrating vectors, while the alternative hypothesis is the general one.

The maximum eigenvalue test is written as,

$$\lambda_{max}(r, r+1) = -T\ ln(1 - \lambda_{r+1})$$

The null hypothesis of the maximum eigenvalue test is that there are exactly r co-integrated vectors against the alternative hypothesis of (r + 1).

The author now tests for causality; they do so using the Granger causality test. The test addresses the degree of variable x causes variable y, thereby finding how much of the past values can be used to explain the current value of y. While also analyzing whether adding past values of x can improve the explanation of y. x will be defined as the Granger variable of y if the past values of x help predict the present values of y.

$$y_t = \sum_{i=1}^{K} \alpha_i y_{t-i} + \sum_{i=1}^{K} \beta_i x_{t-i} + \mu 1t$$

$$x_t = \sum_{i=1}^{K} \lambda_i x_{t-i} + \sum_{i=1}^{K} \lambda i y_{t-i} + \mu 1t$$

If there exists a causality, which is unidirectional from x to y if the estimated coefficients on the lagged values of x are found to be statistically significantly different from zero as a group in y_t and the set of estimated coefficients on lagged values of y in x_t are not statistically significantly different from zero.

If there exists a causality, which is unidirectional from y to x if the estimated coefficients on the lagged values of y are found to be statistically and significantly different from zero as a group in x_t and the set of estimated coefficients on lagged values of x in y_t are not statistically significantly different from zero.

Bilateral causality exists between both variables x and y when the set of lagged coefficients of x in y_t and y in x_t are both statistically significantly different from zero. If there is no statistical significance of the lag coefficients of x and y in y_t and x_t respectively, there will be no causality.

If there is no co-integration amongst the variables of the model, the authors propose using a Vector Error Correction Model (VECM). The VECM investigates the short-run temporal causality between the variables. VECM is a special form of the VAR model that is co-related. The VEC model in terms of the study would look like,

$$
\begin{aligned}
Log\ REXCH_t = \alpha_1 + \beta_1 ect_{t-1} + \sum_{i=1}^{l} \xi_i \Delta REXCH_{t-1} + \sum_{i=1}^{l} \varphi_i \Delta log(OP)_{t-1} \\
+ \sum_{i=1}^{l} \delta_i \Delta Log(OEXPV)_{t-1} + \sum_{i=1}^{l} \lambda_i \Delta log(GDP)_{t-1} + \mu
\end{aligned}
$$

Where Δ is the first difference operator, α_i, is the constant term, $\beta_1, \xi_i, \varphi_i, \delta_i, \lambda_i$ are the parameters. $\beta_1 ect_{t-1}$ is defined as the lagged error correction term obtained from the co-integrating equation and μ_i is the white noise error.

In the case there exists no co-integration, we revert to the VAR model, which makes the equation,

$$Log\ REXCH_t = \alpha_1 + \sum_{i=1}^{l} \xi_i \Delta REXCH_{t-1} + \sum_{i=1}^{l} \varphi_i \Delta log(OP)_{t-1} + \sum_{i=1}^{l} \delta_i \Delta Log(OEXPV)_{t-1} + \sum_{i=1}^{l} \lambda_i \Delta log(GDP)_{t-1} + \mu$$

In the study when the authors run the ADF test, it showcased that all the variables in the model are stationary. After which the JJ co-integration test was implemented to find indicators between the independent and dependent variables. The lag length used by the authors for the JJ test is four. The results of the test indicated that there exists a long run relationship between the exchange rate and the dependent variables oil prices, the value of oil exports, GDP and the trade balance.

After running the VEC model with respect to the log of the exchange rate,

$$Log\ EXCH = -\ 5.342513 - 0.059738\ Log\ OEXPV\ +\ 0.48595\ Log\ GDP - \ 1.82\ x\ 10^{-5} Log\ TB\ +\ 0.015831\ log\ OP$$

The above tells us that the oil price and GDP are positively related to the Kuwaiti Exchange rate. An increase of a percent in the value of petroleum exports will decrease the exchange rate(fewer dinars for dollars) by 0.059 percent. Petroleum exports increase the foreign capital inflows, which appreciates the Dinar. An increase of 1 percent in its GDP will increase the exchange rate (more dinars for dollars) by 0.45895 percent. The oil price is positively related to the exchange rate, increasing 1 percent, causing the exchange rate to increase (more dinars for dollars) by 0.015831 percent.

From the Granger causation tests results, the authors found that the oil price and petroleum export value cause Kuwait's exchange rate in the short run. While the t-test was significant for the lagged error correction model ($ect(-1)$), indicating that all the variables Granger cause the exchange rate in the long run. More importantly, the test indicated that oil prices cause the oil prices positively, indicating that increases in oil prices will cause the exchange rate to fall in the short run.

2.5.3 Conclusion

The authors conclude that there exists no prevalence of the Dutch disease model in Kuwait from the indications of the study. An increase in the oil prices caused the exchange rate to depreciate. So, too, the increase in the oil prices Granger positively caused Kuwait's exchange rate in the short run. The authors also stated that Kuwait's exchange rate is pegged to a basket of currencies; the pound, Euro, USD, and yen. In contrast, UAE, Iraq, Saudi Arabia, and Qatar are pegged primarily to the dollar. The authors believe this choice caused higher inflation in the latter states. So the authors concluded that it seems better for Kuwait to keep its exchange rate pegged on a basket of currencies or move towards a crawling peg exchange rate.

2.6 Not all oil prices are alike: Disentangling demand and supply shocks in the crude oil market

2.6.1 Introduction

Using a structural vector autoregressive model, the study addresses two issues. First, identify the underlying demand and supply shocks in the global oil markets. This identification is important in understanding the distinct oil fluctuations and US economic response to these distinct fluctuations, though this is a factor that does not pertain to our analysis. Second, implementing a measure of monthly global real economic activity is the structural decomposition of oil prices into three components: crude oil supply shocks, shocks to the global demand, and demand shocks specific to the global oil market. The last shock is implemented to capture shifts in the price of oil driven by suffusion uncertainty in the oil market. The paper's main aim is to showcase that oil price increases may have different effects on the real oil price, depending on the underlying cause of the price increase. For instance, in times of extreme uncertainty, the precautionary demand for oil causes an immediate, prolonged, and monument Teri risk in oil prices. The second oil crisis can be used as an example; it only affected about four percent of the supply, though oil prices doubled. Finally, in the case of a boom in economic activity, which causes upward pressure on all commodity prices, we note that the increase in the real price of oil is slow, delayed, and completely non-contemporaneous. However, the increase can be classified as substantial.

In light of the mentioned examples, we note that the oil price shocks historically are caused by a combination of global aggregate demand shocks and precautionary shocks due to uncertainty. The author states that the oil price change since 2003 has not been followed by a major US recession and is caused mainly by the rise in sustained strong demand for crude oil, exacerbated by the economic expansion during that period.

2.6.2 Assumptions, analytical models, and methodology

Like any other commodity, Oil prices have their price is determined by the market. Therefore, the author's usual approach is to classify critical determinants of oil prices. He then distinguishes between these essential three key demand and supply shocks. Shocks to the current physical availability of crude oil (oil supply shocks), shocks to the current demand for crude oil driven by fluctuations in the global business cycle (aggregate demand shocks), and shocks driven by shifts in the precautionary demand for oil (precautionary demand shocks).

The author describes precautionary demand shocks arising from a shift in conditional variance instead of the conditional mean of supply. In simple terms, it implies a disparity in how much availability there is going to be there in the future due to uncertainty. All of the works we have read through have come to the same conclusion as the author when we know that the oil supply shock is the most extensively studied of all oil shocks. This is due to the extensive amount of available data on global crude oil production. Though recent research, majorly by the author in 2008 for his paper *"A comparison of the effects of exogenous oil supply shocks on output and inflation in G7 countries"*, shows that oil supply shocks measures alone do not explain the bulk of oil price fluctuations.

However, informal evidence based on theories of elimination suggests that demand shocks also play an important role in the crude oil market. The problem with analyzing and quantifying these demand shocks is that there are no readily available indices that capture a shift in demand for industrial commodities driven by the global business cycle. The in-availability of a quantifiable index and the fact that precautionary demand shocks are in-observable make the analysis of these shocks highly elusive. If the phenomenon was observable in the case of precautionary demand shocks, the study would prove difficult as uncertainty coupled with human thought is a highly non-linear process, creating a further challenge.

Rather than modeling the expectations directly, the author uses an alternative approach in his study, devising an explicit measure of changes in the real global activity which affects the demand for all industrial commodities. After creating a control for oil and supply shocks to the business cycle-driven demand for all industrial commodities, he then makes a structural dynamic simultaneous equation model to pin down the demand specific to the oil market component.

The author constructs a monthly index of global real economic activity to account for a measure of the component of worldwide economic activity that drives the demand for industrial commodities in the global market. He develops the index based on dry cargo single voyage ocean freight rates, explicitly designed to capture shifts in demand for industrial commodities in the global business market. Research has indicated that world economic activity is the most important determinant of the demand for transport services. Martin Stopford wrote a book titled "*Maritime Economics*. " In the book, Stopford documented that at low levels of freight volumes, the supply curve of shipping is relatively flat in the short and intermediate run periods. As the demand for shipping services shifts due to increased economic activity, the supply curve slope has become steeper, and the freight rates increase. While at full capacity, the supply curve has become vertical, as all the available ships are operational and running at full capacity. With this line of reasoning, the author uses the variable as an indicator of stop strong cumulative global demand pressure.

The proposed index is measured on a monthly frequency with data availability permitting it to be constructed as far back as the January of 1968. Though it is not free of drawbacks, the presence of a shipbuilding and scrapping cycle may weaken the link between real economic activity and the freight rate index. In addition, the pro-cyclical behavior of the shipbuilding and scrapping process may cause a lag in the indicator's capabilities, thereby endangering the contemporaneous effects.

In terms of advantages, the index is engineered to directly measure global economic activity. It does not require any exchange rate weighting, which aggregates real economic activity in all nations due to already showcasing global demand. It incorporates shifting country weights, changes in real outputs with changes in the propensity to import industrial commodities for a given unit of real output.

The index of the global economic activity is based on representative single voyage rates of freighting costs available to the author via the monthly report on "*Shipping statistics and Economics*" published by the Drewry shipping consultants Limited. The rates are typically quoted in US dollars per metric ton. He constructs the index by first removing fixed effects caused by different routes, commodities, and ship sizes. He does this by first computing the period to period growth rates for each series, as far as the available data. The author later takes the equal-weighted average age of these growth rates, after which he cumulates the average growth rate. Next, he normalizes January 1968 to unity. He then deflates the series with the US consumer price index. After this, the real index must be devoid of trends. The cost of dry shipping cargo has fallen due to technological advancements in shipbuilding and freight cargo methodology. The author's interest in the study centers on cyclical variation in ocean freight weights Rather than long-term trends. Therefore, he linearly de-trends the real freight rate index. Though the evidence on how the global business cycle affects the oil price is sparse, the understanding that higher global activity can cause upward pressure on commodity prices can be seen with historical evidence. We note that big rises in global activity drove a global economic boom in commodity markets since the early 2000s. Similarly, the recession periods of the mid-1970s and early 1980s caused bearish commodity markets. However, we can refer to Akram's 2009 paper for more quantitative analysis.

Decomposing the real price of oil

In his aforementioned study, the author found that the treatment of oil prices being exaggerated variables is not an accurate assessment. He states that without knowing what drove up the oil price, it will be highly improbable to accurately analyze the impact on the economy. Therefore, the author uses a methodology when he decomposes unpredictable changes in the real price of oil into mutually orthogonal components with the structural economic interpretation.

The Vector Autoregressive model is based on monthly data for $z_t = (\Delta prod, rea_t, rpo_t)$ where $\Delta prod$ is the percent change in the global crude oil production, rea_t denotes the real index of economic activity constructed by the author, while rpo_t is the real price of oil. rea_t and rpo_t are expressed in logs.

$$A_0 z_t = \alpha + \sum_{i=1}^{24} A_i z_{t-i} + \epsilon_t$$

ϵ_t denotes the serially and mutually uncorrelated error term. As the author is using orthogonal impulse functions,

$$e_t = \begin{pmatrix} e_t^{\Delta prod} \\ e_t^{rea} \\ e_t^{rpo} \end{pmatrix} \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_t^{oil\ supply\ shock} \\ \varepsilon_t^{aggregate\ demand\ shock} \\ \varepsilon_t^{oil-specific\ demand\ shock} \end{bmatrix}$$

The author states *"oil supply shocks are defined as completely random and unpredictable innovations for global oil production.* From the model we note that crude oil supply is the assumed not to respond to innovations demand for oil contemporaneously. Which is a valid assumption, as oil producing nations take time to respond to innovations to the demand shocks.

Innovations to global real economic activity that are not explainable based on all supply shocks are called aggregate demand shocks. The model sets the directive that an increase in the real price of oil driven by oil market-specific shocks will not affect real economic activity contemporaneously. This assumption is consistent with a slowing down of behavior of global activity after the oil price increase after a period. In simplistic terms, $\varepsilon_t^{oil-specific\ demand\ shock}$ does not affect $\varepsilon_t^{aggregate\ demand\ shock}$. Oil price movements that the first two shocks cannot explain can be explained based on oil supply shocks specific to the commodity.

2.6.3 Conclusion

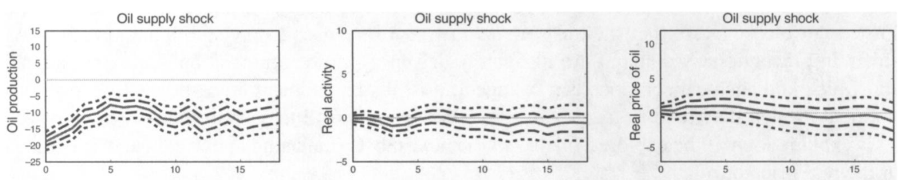


Figure 2.10: Effects of an oil supply shock[5]

The author states that an unexpected oil supply disruption will initially cause a sharp decline in global oil production. Which is followed by a partial reversal of the decline within the first year. This is a concurrent pattern shown when a decrease in oil supply in one region leads to an increase in the supply of another region. This shock also creates a small to a partially statistically significant increase in the real oil price for eight months. A shock on the

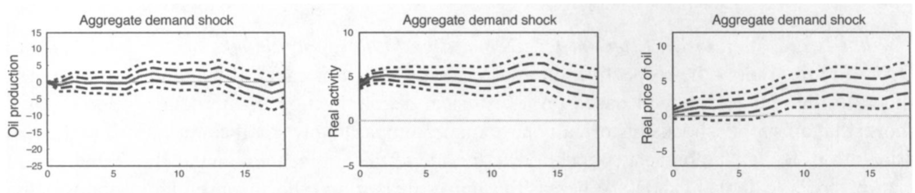


Figure 2.11: Effects of an aggregate demand shock[5]

aggregate demand on global economic real activity is highly significant and persistent. A decline is only seen after 14 months. This shock temporarily increases global oil production after a delay of half a year. This increase is offset by a production decrease eventually. Aggregate demand shock also causes a large persistent and statistically significant increase in oil price. Though the increase is delayed by a period of half a year.

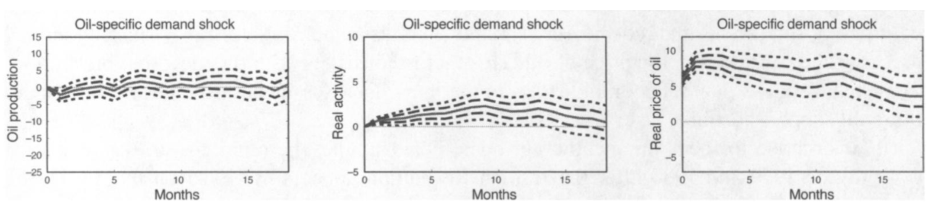


Figure 2.12: Effects of an oil market-specific demand shock[5]

An unanticipated oil market-specific demand shock has a large and persistent positive effect on the real price of oil. This effect is shown to be statistically significant. The shock also temporarily increases real economic activity and a very short decline in oil production.

The most interesting result of the analysis is that oil market-specific shocks only have a small positive effect on the real price of oil. The author states that this phenomenon is explained by the fact that supply disruptions in one region tend to trigger endogenous expansions of crude oil production in other regions that help offset the initial production shortfalls. Another interesting result is that oil supply shocks have a very small effect on the oil price. Aggregate demand shock plays a larger role in the oil price effect. This indicates that the increase is mainly due to a precautionary demand increase. Precautionary demand often increases due to uncertain supply future. In addition, concurrent major exogenous political events in the Middle East often cause oil price increases, the second oil crisis due to the Iranian revolution being an example.

In terms of the cumulative effect of oil demand and supply shocks on the real price of oil.

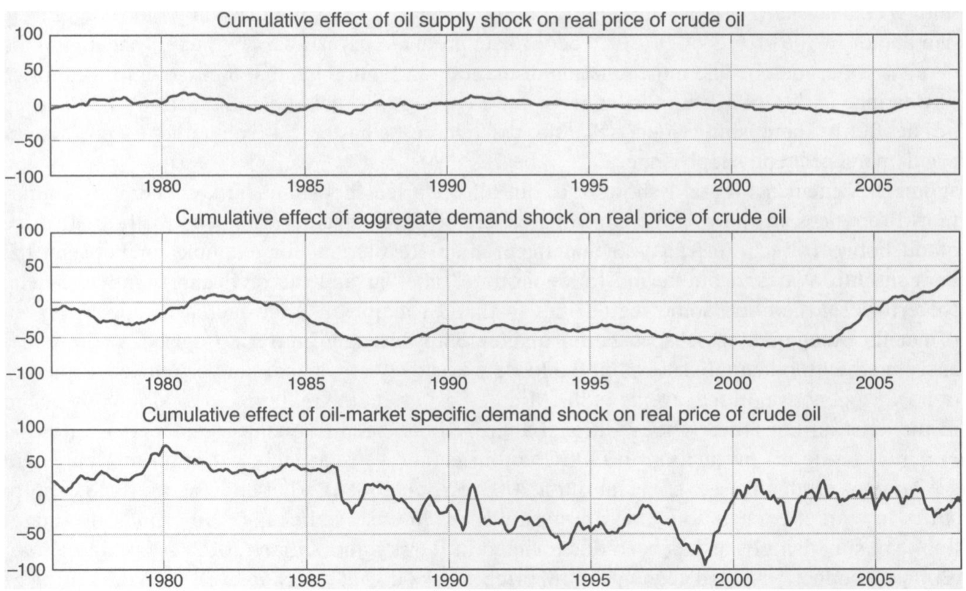


Figure 2.13: Effects of an oil market-specific demand shock[5]

From the data panel, we know that oil supply shocks have comparatively small contributions to the real price of oil. At the same time, aggregate demand shocks cause long swings in the real price. The oil market-specific demand shocks cause sharply defined oscillations in the price of the commodity. The author states that these results are concurrent with the view that precautionary demand shocks reflect rapid shifts in the market assessment of the uncertainty about the future oil supply shortfalls.

In conclusion, the author states that the study shows how different exaggerated variables affect oil prices, production, and economic activity differently—proving that analyzing oil price shocks as an exogenous process is an extremely flawed approach by primary for two reasons. Firstly, the existence of reverse causality from macroeconomic aggregates to oil prices. Secondly, oil prices are driven by a structural demand that directly affects nations on a global scale. For instance, a boom in the global business cycle will cause certain nations to grow, though it will drive up oil prices and other commodities detrimental to some nations.

2.7 Methodology - Future Steps for 452

Now that we have finished initial steps for 451, the future steps for our independent study include;

- Finding and cleaning the data-sets. We will looking for data in the databases of the St.Louis Fed, Kaggle and other various data-collections web-servers.

- We will be required to look for data in our respective three categories of analysis

  1. Exchange and interest rate data from a thriving oil producing nation.
  2. Exchange and interest rate data from a non-thriving oil producing nation.
  3. Exchange and interest rate data from a non-oil producing nation.

- After finding and inferring from the data-sets we will have to analyze whether we implement a VAR or a VECM model in light of whether there exists non-stationarity along co-integration in the respective sets

- If we were to implement a VECM model we would first like to find the form of the vector error correction model. The first process of this step would be to first find theoretical causal relationship between oil prices, exchange and interest rates.

- Considering that we are implementing auto-regressive models we would also have to run certain lag selection tests to decrease the residuals in our analysis. Therefore choosing the correct selection test is off the utmost importance.

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