The Effect of Oil Price Shocks on the Exchange Rate in Iran, Using the Markov-Switching Approach

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Abstract

This research analyzes how changes in oil supply, global demand, and oil prices have impacted Iran's real exchange rate in dollars. Monthly statistics were utilized from April 1990 to September 2015. Using a structural vector autoregression model, triple oil shocks were first derived. Then, the impact of shocks on the exchange rate was examined using a two-regime Markov-switching model within this period. The obtained results indicate that the real exchange rate in Iran frequently experiences low volatility (the second regime) and the exchange market was predominantly in a state of stagnation. Therefore, the effect of oil shocks in the second regime is highly significant. The real exchange rate is largely and negatively affected by oil price shocks and global demand shocks in this regime, i.e., the favorable global demand shock caused by the global economic expansion.

The increase in the price of oil causes a decline in the exchange rate and a rise in the value of Iran's national currency, resulting in the Dutch disease in the Iranian economy. According to the findings, the global oil supply shock has no significant impact on the exchange rate and, as a result, does not affect the Iranian exchange market significantly.

Keywords: oil supply, exchange rate, oil price shocks, Iranian economy, Dutch disease

JEL classification: F31, F41, Q43

1 Introduction

The instability and unpredictability of economic variables present challenges for both the process of making decisions and the provision of economic forecasts to companies and investors. Oil prices continue to rise despite shifts in the global energy system because they are used as a benchmark for the valuation of other fuels. Countries with a high reliance on oil imports have seen an increase in economic instability as a result of oil price fluctuations. An essential research topic in the investigation of energy economies is the correlation between the volatility of exchange rates and the volatility of oil prices (Farzanegan & Markwardt, 2009; Yildirim & Arifli, 2021). The real exchange rate reflects the country's economic position in the domestic and international economies and is regarded as an indicator of its economic competitiveness on the global stage. In most nations, exchange rate fluctuations are a result of non-monetary shocks. However, in oil-dependent nations, oil shocks are regarded as one of the most influential factors affecting exchange rate fluctuations (Wesseh & Lin, 2018; Yildirim & Arifli, 2021).

Iran, a member of OPEC, holds 10 percent of the world's oil reserves and relies heavily on revenue from the sale of crude oil to finance its economy (Dudlák, 2018). The petroleum sector is a major contributor to the national economy. Despite the country's strategic reliance on oil revenues, fluctuations in the global oil market and oil prices have the potential to disrupt Iran's economic structure and leave the country vulnerable. Considering that Iran's GDP is heavily dependent on oil revenues, fluctuations in oil prices can have a major effect on the country's economy (Farzanegan & Markwardt, 2009). Since 1986, real oil prices have tracked with Iran's GDP per capita. Moreover, since national income is directly proportional to oil prices, any change in oil prices will have an equivalent impact on consumption and aggregate demand. Consequently, changes in oil prices affect the Iranian economy mostly through any of these broad variables (Mukhtarov et al., 2021).

From a macroeconomic standpoint, changes in aggregate demand can affect economic performance and trends (Oskooe, 2012). Changes in oil prices can have varying impacts on the economies of countries that either import or export the commodity. These impacts can be theoretically analyzed from either the demand or supply side. The rising cost of oil has a domino effect on the economy because it drives up the price of transportation, which drives up the price of consumer goods, which drives down demand and eventually production. Manufacturers reduce output in response to rising oil prices, resulting in a drop in total output (Shahrestani & Rafei, 2020). As a result, industries dependent on oil may experience growth or contraction as a result of fluctuations in oil prices. Corden and Neary (1982) coined the term "Dutch disease" or "natural resources curse" to describe unintended consequences of oil revenue on supply and demand. The Dutch disease occurs when the government uses the increase in oil prices and foreign exchange revenues from abundant natural resources to inject money into the economy (Torvik, 2001). Higher oil prices lead to higher wages in oil-related industries, which in turn increases demand. When there is a shortage of supply relative to rising demand, prices in that country rise (Farzanegan & Markwardt, 2009).

Natural resource-rich countries import more consumer goods and rely less on their own production. That is why capital is moved from the tradeable (resources and manufacturing) to the non-tradeable (services) sectors in a Dutch disease scenario. Industrial sector competitiveness is reduced as a result of inflation spreading to other parts of the economy. Economic recession occurs when there is a decrease in both resources and incomes (Behzadan et al., 2017). Dutch disease is characterized by an increase in real effective exchange rates as a result of rising oil prices. As a result, domestic production becomes less competitive (Ito, 2017; Rahmati & Karimirad, 2017) as imports rise and exports fall as a result of lower costs. Since 1998, real effective exchange rates and oil prices have been moving in tandem. This phenomenon is known as the Dutch disease. The evidence presented thus far suggests that changes in the price of oil have a major effect on Iran's economy.

Many prominent linear econometric methods, including co-accumulation, Engel-Granger causality, and the vector autoregression (VAR) model, have been used to assess the empirical correlation between exchange rates and oil prices in numerous studies (Akram, 2004; Aloui et al., 2013; Golub, 1983; Turhan et al., 2014). Most of these studies have found either a long-term correlation or a causal link between the price of oil and the value of the currency exchange rate. Nonlinear methods have been used to investigate oil shocks' effects on currency rates in recent years. However, these techniques have been utilized infrequently in oil shock studies, indicating a research gap.

The Markov-switching model is used for this purpose. An introduction to Markov-switching models is provided by Hamilton (1989). The Markov approach allows for time-varying causality across regimes, which is not possible with linear models with fixed parameters and no structural (regime) changes. Unlike a linear model, which would need to be estimated independently for each regime, the Markov-switching model can make use of information about the varying probabilities of regime-switching to estimate the likelihood of being in a particular regime. When a sample has multiple breaks, it can be difficult to obtain reliable estimates using linear models due to the small size of the subsamples. As a result, more data are used in an estimation process in a Markov regime approach (Hamilton & Susmel, 1994). Parameter estimation in one regime can benefit from knowledge of the system's dynamics in another (Engel, 1994). In addition, we limit ourselves to a two-regime model to keep the Markov-switching model as straightforward as possible.

Moreover, in this study, Hamilton's MS-VAR model of Markov-switching vector autoregression is used (Hamilton, 1989, 2010). The primary goal of this study is to use the nonlinear Markov-switching method to analyze the impact of various oil shocks on the movement of Iran's real exchange rate from May 1990 to September 2015.

2 Transmission Mechanisms Between the Price of Oil and the Exchange Rate That Are Postulated in the Theory

There are three main channels through which the oil price affects the currency exchange rate, as documented in the academic literature. The oil demand and supply channel, the terms of trade channel, and the portfolio and wealth channel are some of the mechanisms that fall under this category (Buetzer et al., 2012).

2.1 Oil Supply and Demand Channel

According to research by Coudert and Couharde (2007), the supply and demand for oil are affected by changes in the value of the dollar because of the effect it has on oil prices paid and received by producers and consumers in countries other than the United States. Regarding the demand side of things, it is indeed crucial to remember that the price of a barrel of oil is quoted in US dollars and that all monetary transactions are conducted in US dollars (Behzadan et al., 2017; Coudert & Couharde, 2007). Therefore, the demand for oil in countries that are net importers is directly proportional to the price of a barrel, once that price has been converted into the local currency (Kilian, 2014). Because of shifts in the value of the currency exchange rate, this price is subject to frequent changes.

In regard to the distribution channel, Coudert and Couharde (2007) identify a number of different transmission mechanisms. To begin with, oil companies cover production costs (such as employee salaries, taxes, etc.) with the currencies of the countries in which they operate (the countries that produce the oil). On the other hand, the majority of these countries' currencies are tied to the value of the US dollar because the majority of oil-producing countries operate under a system that sets a fixed exchange rate. As a consequence, changes in the value of the dollar have an effect on the price that is paid to producers (Coudert & Couharde, 2007; Güntner & Linsbauer, 2018). Second, there is a correlation between the price of oil and drilling activity (Kilian, 2014). The truth is that if the price of oil were to rise, some places that are currently seen as difficult to exploit and unprofitable would become viable, leading to an increase in production capacity. A drop in the value of the dollar might affect the profits of oil-producing countries, and inflation can rise as a result. The dollar is tied to the currencies of these nations; thus, the value of each is worth less than the other. A fall in the value of one currency relative to another could result in a reduction in the quantity of oil available.

Short-term supply and demand, as reported by Coudert and Couharde (2007), are somewhat inelastic. When considering the immediate and distant consequences, this factor must be considered. As a result of these characteristics, price elasticity decreases (producers are not encouraged to cut back on output in the event of reduced prices) (Coudert & Couharde, 2007; Oskooe, 2012). The lack of cheap and readily available alternatives to oil may also be contributing to the inelastic nature of demand. Oil is expensive in part because there are few viable replacements. This means that the impacts on oil demand and supply will mostly be seen over the long term. In conclusion, a decline in the value of the dollar increases oil demand over the long term and decreases oil supply. The retail cost usually rises as a consequence (Güntner & Linsbauer, 2018; Kilian, 2014).

2.2 Trade Channel

Several studies have found that changes in oil prices can affect the value of the exchange rate in at least two ways (Basher et al., 2016; Bénassy-Quéré et al., 2007; Coudert & Couharde, 2007; Habib et al., 2016). These include both wealth effects and effects on trade terms. Both oil-producing countries and countries that are net consumers of oil are impacted by the terms of trade channel, albeit in different ways (Amano & Van Norden, 1995; Basher et al., 2016; Cashin et al., 2004). Increases in non-tradable prices and a real exchange rate appreciation are symptoms of the "Dutch disease," which can occur in oil-exporting countries in response to positive terms of trade shock. This mechanism is analogous to the Balassa-Samuelson effect (Mohammed Suliman & Abid, 2020), which is caused by the disparity in relative productivity between the tradable and non-tradable sectors. However, this model does not account for the role that income plays. According to Tokarick (2008), as long as the non-tradable good is treated as a normal good, this effect should contribute to a greater appreciation of the real exchange rate in the domestic country. In reality, increased profits and wages in the primary sector lead to greater demand for non-tradable goods, which drives up their prices. As a result of this rise, there is an increase in the value of the real exchange rate.

2.3 The Channel for Wealth and Portfolios

The models from Golub (1983) and Krugman (1980) consider the link between the price of oil and the exchange rate, and their respective effects on wealth, by analyzing investment decisions and current account deficits, respectively. They both date back to the early 1980s, when they were first introduced. These models presume a global division into OPEC, the United States, and the European Union (one exporting country and two importing countries, respectively). Whenever there is an increase in the price of oil, there is a corresponding redistribution of wealth from oil importers to exporters. In the oil industry, real wages go up when the price of oil goes up because more oil is produced. A rise in the relative cost of service goods has resulted from these factors. Since labor mobility has led to greater parity in real wages between sectors, and oil industry incomes have risen, we now have this situation (Mohammed Suliman & Abid, 2020). It has a negative effect on long-term economic growth, as the real exchange rate appreciates and the country's competitiveness falls. Golub (1983) claims that the effect on the exchange rate is determined by the portfolio preferences of both the oil-importing country and the oil-exporting country. Krugman (1980) assumes that OPEC countries are putting their wealth to use by gradually increasing their purchases of goods from industrialized countries. As a result, OPEC's portfolio choices will not have much of an effect on the real exchange rate in the long run, and instead, it will be determined by the geographic composition of imports from OPEC. In the short term, a positive oil shock causes the dollar to rise, but this effect quickly fades (Bénassy-Quéré et al., 2007; Coudert & Couharde, 2007; Golub, 1983; Krugman, 1980). This is predicated on the idea that oil-exporting countries have a marked preference for dollar-denominated assets over US-owned assets. In conclusion, two primary transmission mechanisms mediate the causal relationship between the price of oil and the exchange rate. First, when it comes to the demand and supply channels that establish the price of oil, the exchange rate is the primary factor. Second, the terms of trade and the wealth effects are impacted by the oil price, which in turn affects the value of the currency exchange rate (Mohammed Suliman & Abid, 2020).

3 Literature Review

Despite a large body of empirical literature on the topic, the direction of the causal relationship between oil prices and exchange rates remains unclear. Diverse studies on the effects of oil price shocks on exchange rates have reached conflicting conclusions about the nature of their relationship. The literature suggests a less direct correlation between oil prices and the prevailing exchange rate.

A nonlinear, bidirectional relationship exists between the real oil price and the actual Chinese and Indian effective exchange rates, as stated by Bal and Rath (2015). A rise in oil prices is associated with a temporary appreciation of the Canadian dollar, as reported by Basher et al. (2016) and Beckmann and Czudaj (2013). Nonetheless, studies by Chaudhuri and Daniel (1998) and Chen and Chen (2007) show that the real Canadian dollar exchange rate does not correlate with the real price of oil over the long term. Other factors, as demonstrated by Chaudhuri and Daniel (1998), account for the Canadian dollar's non-stationary behavior.

Habib and Kalamova (2007) compared the real exchange rates of the world's three largest oil exporters – Norway, Russia, and Saudi Arabia. Russia's real exchange rate was found to be positively correlated with the real price of oil over the long term. Despite this, they discovered no connection between the actual price of oil and the real exchange rates used by Norway and Saudi Arabia. According to research by Camarero and Tamarit (2002), the real exchange rate of the Spanish peseta is determined by real oil prices. However, using a structural VAR, Huang and Feng (2007) showed that unexpected increases in oil prices are associated with a rise in China's real exchange rate. Nonetheless, the results of the two studies demonstrate that there is no correlation between the real oil price and the real effective exchange rates of oil exporters and importers. Using a structural VAR, Buetzer et al. (2012) looked for different shocks to real oil prices and found no consistent evidence that oil exporters' exchange rates appreciate relative to oil importers' exchange rates for a sample of 43 countries. Countries with a large oil surplus may be more likely to intervene in the foreign exchange market to counteract the effects of appreciation pressures, which may explain the missing link (Habib et al., 2016). Therefore, it is essential to consider the nonlinearities approach when analyzing the long-term relationship between oil prices and exchange rates. Considering structural breaks, Zhang (2013) looked into whether the real price of oil correlated with the real effective exchange rate of the US dollar. He found that the oil price and the US dollar value do not significantly cointegrate except in the presence of structural breaks. According to research by

Beckmann and Czudaj (2013), who employed a Markov-switching vector error correction model (MS-VECM), the adjustment dynamics vary considerably across different regimes. Most countries' oil prices only respond to long-term deviations in one of the two regimes, and the speed of adjustment is often higher in one of the two regimes, making nonlinearities an important consideration when analyzing oil prices and exchange rates. To analyze the impact of oil shocks on real exchange rates for a cross-section of oil-exporting and oil-importing countries, Basher et al. (2016) employed a Markov-switching model. However, they found scant evidence that oil supply shocks affected exchange rates, even though their estimates showed substantial appreciation pressures following an increase in oil demand. Although oil-exporting and oil-importing countries feel the effects of global economic demand shocks, there is no discernible trend in the real exchange rate appreciating or depreciating in response. Table 1 shows a sample of related articles and the obtained results. The findings demonstrate that oil shocks' effects on real exchange rates are transitional.

Table 1: *A List of Related Articles, Research Variables, and Conclusions*

Authors	Investigated factors	Method used	Results
Nandi et al. (2024)	The effect of crude oil price on the nominal exchange rate in Bangladesh	Generalized autoregressive conditional heteroskedasticity (GARCH) and exponential GARCH models	• Oil price shocks have a long-term effect on exchange rate fluctuations. • Exchange rate shocks have an asymmetric effect, meaning that negative shocks cause higher exchange rate fluctuations than positive shocks.
Sokhanvar et al. (2023)	The effect of energy price shocks on commodity currencies during the war in Ukraine	Dynamic simulated autoregressive distributed lag (DS-ARDL) and cross-quantilogram (CQ) approaches	• A significant positive effect of the increase in energy prices on the value of the Australian dollar compared to the Japanese yen, the euro, and the British pound. • Comparing the effects of gas and oil price increases on the exchange rate shows that these exchange rate changes were mostly caused by gas price shocks.
Chatziantoniou et al. (2023)	The impact of oil price shocks on the exchange rate before and during the COVID-19 pandemic	Time-varying parameter vector autoregression (TVP-VAR)	• All oil exporters and importers without exception were net recipients of the shock. • The oil risk shock is transmitted to two other types of oil shocks in the period before and during COVID-19.
Urom et al. (2023)	Integration and transmission channels between interest rates and oil price shocks	TVP-VAR with stochastic volatility	• Higher integration occurs due to increased levels of external exposure through financial linkages, information asymmetry, and political stability. • The financial crisis reduces the level of integration.

Kocoglu et al. (2023)	The effect of oil price changes on the exchange rates in five Asian economies	Time-varying Granger causality model	• Heterogeneous effects of oil prices on exchange rates in different time horizons in terms of importance and magnitude. • Supporting the combined movement of oil prices and exchange rates against some important dates and events.
Zolfaghari & Sahabi (2017)	The exchange rate and economic sanctions against Iran	Markov-switching method	• Positive and low impact of sanctions on the exchange rate. • Positive effect of inflation on the exchange rate.
Riman et al. (2013)	The effect of oil price shocks on exchange rate volatility and domestic investment in Nigeria	Vector autoregression	• Confirming evidence of the "Dutch disease" in Nigeria. • Negative impact of crude oil price fluctuations on domestic investment in Nigeria. • Industrial production reacted negatively to the oil price shock.

Source: Author's classification.

Following the literature search, it becomes clear that studying the connection between Iran's currency and the ever-changing cost of crude oil is crucial. This study employs a Markov-switching nonlinear model to examine how three distinct oil price shocks affect corresponding changes in the real exchange rate. In particular, this research aims to address the following questions:

1. Do shocks in the price of oil affect the exchange rate in Iran? What are the effects of oil price shocks on the exchange rate in Iran in different regimes?
2. How significant is the impact of shocks in oil prices on the exchange rate in Iran?
3. What factors have the greatest impact on the exchange rate in Iran?
4. From a political perspective, which variables should be addressed?

4 Methodology

The primary objective of this study is to examine the effect of oil supply, global demand, and oil price shocks on the real exchange rate of the dollar in Iran. In this regard, monthly data for these variables were extracted for the period of 1990:04–2015:09. The triple oil shocks were first extracted using the structural vector autoregression (SVAR) model, and then their impact on the exchange rate was obtained using a two-regime Markov-switching model for the period between May 1992 and September 2015.

A two-step approach is used to identify the demand and supply shocks in the crude oil market. First, we construct these shocks employing the procedure developed by Kilian (2009). Second, using a Markov-switching framework, we empirically assess how Iran's exchange rates respond to changes in crude oil demand and supply. As such, oil shocks constructed in this manner are orthogonal variables in a regression setting.

As long as orthogonality holds, the regression coefficient estimates from a second-stage analysis are unbiased and independent of the other included and omitted regression variables. This is a special case of Markov-switching regressions, and the only effect of omitting variables is to increase residual variance in stage two (Boroumand et al., 2016). If the exchange rate does not respond linearly or symmetrically to oil price shocks, then perhaps the Markov-switching model can explain this. The Markov-switching framework has been effective when the adjustment appears to be driven primarily by exogenous events (Basher et al., 2016; Boroumand et al., 2016). Kilian's (2009) method is used to model the interplay between oil market and macroeconomic events; this method views external shocks as exogenous only insofar as they cause a change in the Markov process's regime but disregards their impact on underlying oil market and macroeconomic variables. However, the process that results in a Markov regime has no internal origin. Furthermore, oil prices and currency exchange rates have a history of fluctuating together. Oil prices and exchange rates have an asymmetrical or nonlinear relationship, which can be modelled using a two-regime Markov-switching model (Boroumand et al., 2016).

4.1 Data Extraction of Oil Price Shocks

A structural VAR (SVAR) model is employed as an initial point for the analysis. This model is defined as Equation 1.

$$A_0 y_t = A(L)y_{t-1} + \varepsilon_t \tag{1}$$

The real US dollar price of oil, global economic activity, and annual oil production worldwide are all included in y_t, which is described in detail in the Data section; ε_t represents the vector of structural innovations with an economic interpretation that are serially and mutually uncorrelated. Exclusion restrictions on A_0^{-1} in $e_t = A_0^{-1}\varepsilon_t$ are used to derive the structural innovations as Equation 2, where e_t denotes a VAR error vector (Kilian, 2009).

$$y_t = A_0^{-1}A(L)y_{t-1} + A_0^{-1}\varepsilon_t \tag{2}$$

In particular, the following are the three structural shocks that can be attributed: ε_{1t} stands for "shocks to the global supply of crude oil," which will henceforth be referred to as "oil supply shock." The symbol ε_{2t} (aggregate demand shock) represents a shock to the worldwide demand for all industrial commodities, which is driven by the worldwide real economic activity, and ε_{3t} represents a demand shock that is specific to the oil market (oil-specific demand shock).

A_0^{-1} is identified in Equation 2 by applying the following exclusion restrictions (Equation 3):

$$A = \begin{pmatrix} e_{1t}^{\Delta prod} \\ e_{2t}^{\Delta rea} \\ e_{3t}^{rpo} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{pmatrix} \varepsilon_{1t}^{oil\ supply\ shock} \\ \varepsilon_{2t}^{aggregate\ demand\ shock} \\ \varepsilon_{3t}^{oil-specific\ demand\ shock} \end{pmatrix} \tag{3}$$

The identifying restriction in this framework supposes that monthly fluctuations in crude oil demand are not met by corresponding fluctuations in production; in other words, the short-run supply curve of crude oil is assumed to be vertical. Real economic activity around the world is driven by oil market shocks, but these shocks do not even appear for at least a month. This restraint is in line with the gradual readjustment in real economic activity that has occurred worldwide as a direct result of changes in the price of oil. In conclusion, it is presumed that the real price of oil will respond within the same month to shifts in oil production and the level of real economic activity across the world. This constraint makes sense because oil prices react instantly to exogenous changes in the supply of crude oil or the real economy.

4.2 Markov-Switching Approach

In order to provide some initial results as a main basis, a linear regression model is generated using Equation 4 for each exchange rate. This helps provide some context for the analysis.

$$\Delta fx_t = \beta_0 + \beta_1 \varepsilon_t^s + \beta_2 \varepsilon_t^d + \beta_3 \varepsilon_t^p + \beta_4 \Delta fx_{t-1} + u_t \quad (4)$$

where Δfx_t represents the first difference in the log real exchange rate for Iran. The variables that make up the oil shock come from the SVAR model that was discussed in the previous section. These variables are oil supply shock (ε^s), global economic demand shock (ε^d), and oil demand shock (ε^p).

In order to estimate all of the model's parameters by using the MS-VAR model for K endogenous variables Y_t, the outline of this model is initially expressed in the m different regimes as follows.

In each regime, v_i represents the intercepts or means, B represents the coefficient of the lagged values of the variable for m regimes in Equation 5, P represents the number of interruptions (autoregressive terms of order), and $A_i u_t$ represents the residual (Ehrmann et al., 2003).

$$Y_t = \begin{cases} v_1 + B_{11}Y_{t-1} + \cdots + B_{P1}Y_{t-P} + A_1u_1 & if \quad s_t = 1 \\ v_m + B_{1m}Y_{t-1} + \cdots + B_{Pm}Y_{t-P} + A_m u_1 & if \quad s_t = m \end{cases} \tag{5}$$

where u_t is a k-dimensional vector of normally distributed, non-correlated basic error terms with normal distribution. The basic error term has a normal distribution with a mean of zero and variances of unity. If we assume A_t to be a regime-dependent matrix, then it is necessary to perform a premultiplication of the required basic error terms using A_t.

Using the Markov-switching model, it is assumed that the first order of the Markov chain generates the regime s_t and that the state in period $t + 1$ is only influenced by the state in the previous period (Nademi & Nademi, 2018). The transfer probability between regimes can be calculated using this assumption as Equation 6 (Ehrmann et al., 2003).

$$pr(s_{t+1} = j | s_t = i) = p_{ij} \qquad \sum_j^m p_{ij} = 1 \tag{6}$$

The transition probabilities matrix of P is obtained by placing these probabilities next to one another in a matrix $m \times m$ (Equation 7). Within this matrix, each element shows the probability of the occurrence of regime j following regime i.

It is important to note that the parameters of the conditional process are dependent on a regime that is presumed to be stochastic and cannot be observed. Therefore, the formulation of the process that generates the regime is necessary in order to provide a comprehensive description of the process that generates the data. The latter process is represented as an ergodic Markov chain in Markov-switching models. This chain has a finite number of states, and its state transition probabilities are defined by those probabilities.

$$P = \begin{bmatrix} p_{11} & \cdots & p_{1m} \\ \vdots & \ddots & \vdots \\ p_{m1} & \cdots & p_{mm} \end{bmatrix} \tag{7}$$

In Equation 7, we have $p_{i1} + p_{i2} + \ldots + p_{iM} = 1$ for $i = 1, \ldots, M$.

According to this specification, if the economy was expanding in the prior period, the likelihood of a regime flip is constant and unrelated to the longevity of the expansion in a two-regime situation (i.e., M = 2).

It is important to note that we are using the assumption that the oil shocks have already been predetermined at this point. This is in accordance with what Kilian (2009) has stated. It was decided to use a one-period lag of the dependent variable as an explanatory variable since this specification yielded superior results in terms of regression fit and residual diagnostics compared to a model that did not incorporate the lagged dependent variable.

4.3 Data

When comparing prices in the US and Iran, the real exchange rate is calculated as the product of the nominal exchange rate (black market) and the price ratio. In 2011, the Central Bank of Iran compiled a set of economic statistics, including the value of the rial and the Consumer Price Index (CPI) (Gharehgozli, 2017). The US CPI is also available from the Bureau of Labor Statistics (Blair, 2014; Horrigan et al., 2014). Similarly to how 2011 was chosen as the starting point for Iran's CPI, that same year will serve as the foundation for the US CPI.

The real exchange rate variable is defined as the product of the nominal exchange rate (informal market) and the price ratio between the United States and Iran. The values of the Iranian exchange rate and CPI were extracted from the Central Bank of Iran's 2011 collection of economic statistics. Additionally, the Bureau of Labor Statistics provides the US CPI. To be consistent with the base year of the CPI in Iran, the base year of the CPI in the United States has also been set to 2011.

In order to capture the oil supply shock, global oil production is estimated based on daily production in thousand barrels. The values of this variable are derived from the statistics of the US Energy Agency. Typically, indicators of the real activity of the global economy, such as world gross domestic product and world industrial production, are used to measure the demand shock of the global economy. Based on industrial product markets, Kilian (2009) calculated the Real Economic Activity Index (REA index), which is updated annually. This index has been used as an indicator of the global economy in recent years. This study used the monthly statistics of this index, which were obtained from Kilian's personal website. The average OPEC basket price is also used for the oil demand shock. This variable is measured in dollars per barrel using the US price index (Kilian, 2009; Nonejad, 2020). The oil price variable's values were extracted from the OPEC website (Saboori et al., 2016).

Throughout the years 1990 to 2015, monthly values of all variables were extracted and entered into the model. This time period was chosen because monthly data for Iran are available beginning in April 1990. Examining the integration of variables is necessary to prevent spurious regressions in economic modeling. We employ the augmented Dickey and Fuller (1979) unit root test for this purpose (Paparoditis & Politis, 2018).

To conduct our analysis, we relied on the likelihood ratio (LR) test developed by Ang and Bekaert (2002b), which has a distribution roughly of χ^2 (q), where q is the total number of undefined restrictions and nuisance parameters in the null hypothesis. The likelihood ratio test follows a chi-square distribution asymptotically between the n-1 and n regimes, as shown by Ang and Bekaert (2002b) and Bekaert and Ang (1998). Degrees of freedom are equal to the sum of the restrictions imposed by regime n on regime n-1 and the number of nuisance parameters in the n-regime model. The test statistics in likelihood ratio tests are calculated using Equation 8 (Ang & Bekaert, 2002a, 2002b; Bekaert & Ang, 1998).

$$LR = 2 \times [(\text{loglikelihood}(n) - \text{loglikelihood}(n-1)] \quad (8)$$

where n and n-1 refer to the models that have n and n-1 regimes, respectively.

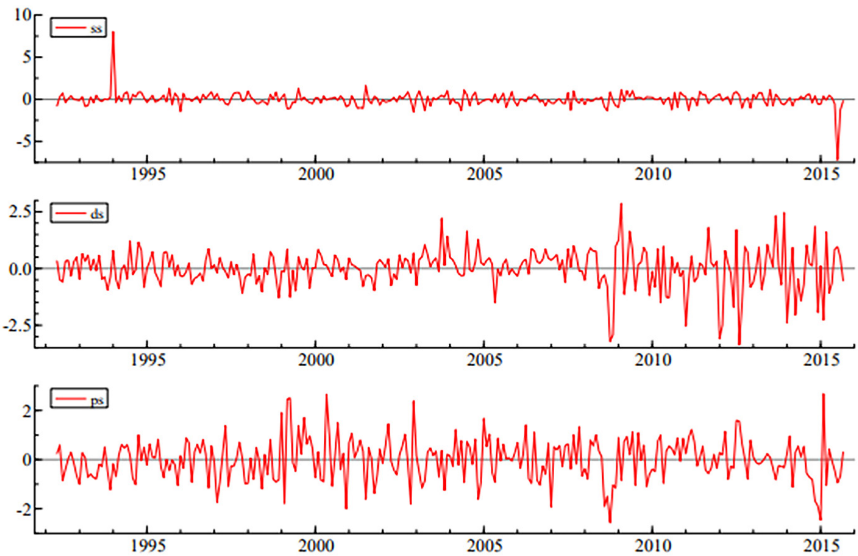
Using the fMarkovSwitching package in R, the Markov-switching models for exchange rates were estimated (Perlin, 2015). For each state, regression coefficients and error processes were estimated with state-dependent variances, resulting in two models with two sets of estimates. We allow volatility to vary across regimes because it is well known that exchange rates exhibit volatility clusters. The error term was assumed to be two different things for the purposes of estimating the models (normal, Student's t).

5 Findings and Discussion

Before estimating the research model, it is necessary to extract the triple oil shocks using the variables total oil production, actual economic activity, and oil price. There are several techniques, such as moving average, GARCH models, Hodrick-Prescott filter, etc., to extract shocks from economic variables (Fernández-Villaverde & Guerrón-Quintana, 2020; Khakimov et al., 2010; Roth, 2008). Following Kilian's (2009) study, triple oil shocks have been identified in this study and extracted using a structural vector autoregression model. Figure 1 displays the extracted shocks graph. It is important to note that the number of observations for the obtained shocks was reduced to 281 by adding the intervals of the vector autoregression model.

Figure 1 illustrates that oil supply shocks are much milder than aggregate demand and oil demand shocks. This means that changes in global economic activity and oil demand were more noticeable during the study period than changes in total crude oil production. A large and positive supply shock occurred in the early 1990s, and a large and negative supply shock occurred in the middle of 2015. Daily global oil production increased by more than 750,000 barrels in January 1994, compared to the previous month. The main cause of the higher growth in crude oil production and supply worldwide in 1990 was the rise in demand and consumption on a global scale. Obviously, oil prices fell in these years due to the increased growth of the global oil supply during the early 1990s. The graph indicates that the early 1990s saw more negative shocks to the oil price.

Figure 1: *Oil Supply Shock, Total Demand Shock, and Specific Oil Demand Shock Extracted From the Structural Autoregression Model*



Source: Author's calculations.

It should be noted that the war between Iraq and Kuwait at the start of the 1990s is regarded as one of the primary causes of variations in the supply of oil during these years. Therefore, changes in the price of oil were stabilized through the use of strategic reserves. After an adverse shock to total oil production in the middle of 2015, global oil production rose. The low price of oil was the main reason for this decline.

The total demand shocks graph also demonstrates that, up until 2008, real world economic activity had little fluctuation compared to the years that followed. This year, however, saw a significant negative shock, which is proof of a global economic downturn. To put it another way, the 2008 global financial crisis in America and Europe caused a sizable negative shock to the real activity of the global economy. The range of variable fluctuations in the actual global economic activity has grown over the ensuing years. In fact, there have been both positive and negative shocks to the world economy. The occurrence of these shocks amply demonstrates the recent instability of the world economy.

While the price of a barrel of oil was around 60 dollars at the start of 2007, it rose to over 96 dollars on the last day of the year. In 2008, the cost of oil products increased somewhat noticeably. Early in the summer of 2008, the price of oil rose to a record high of 148 dollars. However, as the global economic crisis of 2008 got worse, oil prices started to decline and eventually fell below 40 dollars per barrel at the height of the summer in 2008. This significant negative shock is clearly shown in Figure 1.

Therefore, the financial crisis of 2007–2008 initially caused an increase in the price of oil, but in the last months of 2008, it caused a negative shock in the price of oil. In 2011–2014, oil prices were often at higher levels and, as Figure 1 shows, often experienced positive shocks. In the last months of 2014, oil prices started a downward trend and experienced a significant negative shock. After a decline in oil prices until the beginning of 2015, oil prices again had a positive growth at the beginning of this year, which is seen as a positive shock.

In the following step, the effect of the three oil shocks on the real exchange rate of the dollar in Iran has been analyzed using the Markov-switching nonlinear model for the period from May 1992 to September 2015. The variables entered into the Markov-switching model must be stationary. Therefore, the augmented Dickey-Fuller (ADF) unit root test was performed for variables and the difference of non-stationary variables was used in the model. The statistical results of the ADF test are listed in Table 2.

Table 2: *The Results of the ADF Test*

Variables	Level		First difference	
	Intercept	Trend and intercept	Intercept	Trend and intercept
Δfx_t	-1.050	-2.049	-13.296***	-13.276***
ε_t^s	-16.580***	-16.852***	-	-
ε_t^d	-16.577***	-16.579***	-	-
ε_t^p	-16.539***	-16.510***	-	-

Note: *** denotes statistical significance at 1%.

Source: Author's calculations.

Based on the results of the unit root test, all variables related to the oil shock are stationary and do not require differentiation. However, the logarithm of the accumulated real exchange rate variable is of the first order and must be differentiated once. The first order difference of this variable is therefore used as the dependent variable in the main model. Notably, in the majority of comparable studies, such as Kilian (2009) and Basher et al. (2016), the exchange rate variable is non-stationary and its difference has been incorporated into the main model.

Prior to estimating the Markov-switching model, it is necessary to ensure that the nonlinear model is suitable for the investigated data. The LR test, which performs the linearity test based on the chi-square statistic, was used for this purpose. Using LR tests, a formal statistical procedure based on Bekaert and Ang (1998) and Ang and Bekaert (2002b), for determining the number of regimes is utilized to test the null hypothesis of a linear model against the alternative hypothesis of a Markov-switching model. Table 3 shows the result of the LR test.

Table 3: *The Results of the LR Test*

Statistical value	*p*-value
301.99	0.0000 ***

Note: *** denotes statistical significance at 1%.

Source: Author's calculations.

Before estimating the Markov-switching model, the number of model regimes must be determined. The regimes were determined by using the Akaike information criterion (AIC) value (Vrieze, 2012). Due to the fact that the value of this criterion was lower for the two-regime model than for other models, the Markov-switching intercept autoregressive heteroskedasticity (MSIAH) model with two regimes was chosen as the final model. An LR test with a significance level of 0 percent and statistical values less than 3854.873 reveals the necessity for a model with two regimes. We employed the MSIAH model presented by Guidolin (2011), which has a general form for a two-regime MS-VAR (m) process.

For estimating the variables, we consider two regimes and an MS-VAR model with intercept coefficients of the lagged values of the variables and regime-dependent variances (MSIAH). MSIAH (2)-VAR (1) is the scenario used in this study, with two regimes and one order for VAR. The estimation results of the final model are listed in Table 4.

Table 4: *Results Obtained From the MSIAH Model on the Effect of Oil Price Shocks on Real Exchange Rates*

Regime	Intercept	Supply	Demand	Oil	Δfx(–1)	Sigma
Regime 1	0.016	0.007	-0.006	0.001	0.259	0.076
	(0.216)	(0.348)	(0.517)	(0.046)	(0.010)	(0.000)
Regime 2	-0.007	-0.002	-0.003	-0.001	0.278	0.014
	(0.000)	(0.122)	(0.016)	(0.087)	(0.000)	(0.000)

Note: Student’s t-distribution for the errors.

Source: Author’s calculations.

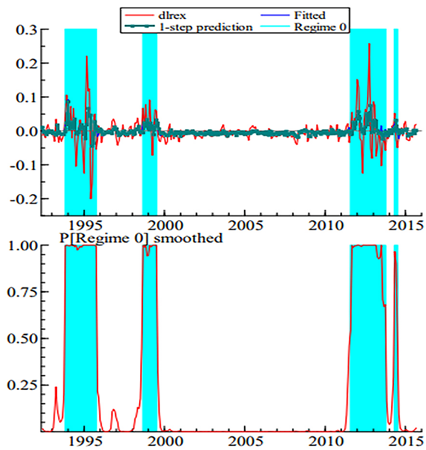
According to the findings, the first break of the dependent variable, namely the exchange rate, has a positive and statistically significant effect on the level of the variable in both regimes. This is significant because the first break of this variable revealed the dynamics of exchange rate changes and improved the model’s fit.

The intercept is positive in the first regime, while it is negative in the second. In contrast, the value of sigma in the first regime is significantly greater than in the second regime. Therefore, the first regime can be viewed as correlating with periods of prosperity and fluctuations in the exchange market, while the second regime can be viewed as correlating with periods of stagnation and low volatility in the exchange market. Based on the graphs and the classification of regimes, these outcomes are readily apparent. The results indicate that the global demand shock has a negative impact on the exchange rate under both conditions. In other words, the increase in the real activities of the global economy has increased the value of the national exchange rate under both prosperous and depressed exchange market conditions.

In the first regime, the obtained coefficient for total demand shock was not statistically significant, whereas in the second regime, it was significant at the 5 percent level. The obtained result can be analyzed such that the increase in the level of real economic activities in the world, from two areas, the increase in the price of oil and the increase in the export of oil-exporting nations, causes an increase in the value of the national exchange rate. In other words, these changes are a consequence of the Dutch disease in these nations.

In the first regime, the oil supply shock had a positive effect on the exchange rate, whereas in the second regime, it had a negative effect on the exchange rate. However, none of the regimes showed statistically significant effects from this shock. Therefore, fluctuations in global oil production play no significant role in the evolution of the Iranian exchange market. The oil price shock had a significant impact on both regimes' exchange rates. During a period of prosperity, the positive oil price shock caused the exchange rate to rise, whereas during a period of recession, it caused the exchange rate to fall. In other words, the increase in oil prices during the period of exchange market stagnation has left the Iranian economy vulnerable to the Dutch disease.

Figure 2: *Values of the Real Exchange Rate and Its Values Explained by the Nonlinear Model, Disturbance, and Separation of Regimes*



Source: Author's calculations.

Figure 2 depicts the graphs of the model's estimated values for the exchange rate and each regime. The first regime in Figure 2 is represented by the state zero, while the second regime is represented by the state one. As Figure 2 shows, the estimated model was able to have a good fit on the data. In addition, the periods included in each regime are specified, which is also listed in Table 5.

Table 5: *The Periods Included in the Regimes*

Regime	Period	Months
Regime 1	1995:10–1993:11	24
	1999:07–1998:09	11
	2013:10–2011:08	27
	2014:07–2014:05	3
Regime 2	1993:10–1992:06	17
	1998:08–1995:11	34
	2011:07–1999:08	144
	2014:04–2013:11	6
	2015:09–2014:08	14

Source: Author's calculations.

***Table 6:** Probability of Transition From One Regime to Another*

	Regime 1	Regime 2
Regime 1	0.928	0.023
Regime 2	0.072	0.977

Source: Author's calculations.

Table 5 shows that, based on the estimated nonlinear model, 65 months are included in the first regime and 215 months are included in the second regime. For more information, the probability of regime transitions is also shown. Table 6 shows the probabilities of transition from one regime to another. As can be seen, the probability of transition from Regime 2 to Regime 2 is equal to 0.977 and from Regime 1 to Regime 1 is equal to 0.928. Therefore, Regime 2 is more stable than Regime 1. As mentioned, Regime 2 refers to periods when the exchange market was in recession. Therefore, it can be concluded that the real exchange rate has been in a state of stagnation and low volatility for most of the time. In addition, the probability of transition from Regime 2 to Regime 1 is very low, about 0.02, while the probability of transition from Regime 1 to Regime 2 is about 0.07. This result is also expected because Regime 2 is more stable, and when the exchange rate is in this regime, it remains in this regime for a longer period of time.

6 Conclusion

In this study, the effect of various oil shocks on the dollar-rial exchange rate in Iran was investigated using a nonlinear model. In order to estimate the model, monthly statistics and data on the variables from 1990 to 2015 were utilized. First, the shock resulting from the global oil production variables was categorized as an oil supply shock. The variable shock of the world economy's real activity index was regarded as a global demand shock, and the average OPEC oil price shock was regarded as an oil demand shock (price shock). Using a SVAR model, oil shocks were extracted for the period from May 1992 to September 2015. Based on AIC, the Markov two-regime switching model, which considers the width from the origin, the model coefficients, and the regime-dependent variance, was selected as the final model to estimate the exchange rate model.

The Markov-switching model estimation revealed that the majority of the examined months fall within Regime 2, which is characterized by less volatile exchange rates and a stagnant exchange market. Additionally, the transition probability matrix indicates that this regime is more stable than Regime 1 (periods with high volatility). The results show that under Regime 2, both the overall demand shock and the specific oil demand shock have a negative and significant effect on the real exchange rate, leading to an appreciation of the national currency. As a result, only the price shock had a statistically significant and positive impact on the exchange rate in Regime 1, whereas the overall demand shock had no impact at all. The impact of overall oil supply disruptions was insignificant in both regimes.

Because the real exchange rate was frequently in Regime 2 during the review period, the results of this regime can be considered more significant than those of Regime 1. In other words, it can be argued that oil shocks have a significant impact on Iran's real exchange rate when the exchange market is in recession. According to the obtained coefficient, an increase in the real activity level of the global economy and the price of oil leads to a rise in the value of the national currency and the impact of the Dutch disease in Iran. This result is consistent with the subject's theoretical underpinnings and the findings of studies by Buetzer et al. (2012) and Basher et al. (2016).

Based on the obtained results, it can be suggested that, in the event of oil shocks and the presence of low volatility and stagnation in the exchange market, the cost of oil export revenues should be planned in a manner that does not weaken the tradable sectors. In this instance, part of the effects of the Dutch disease on the Iranian economy can be mitigated.

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