Analyzing the Impact of Oil Price Movements on the Economic Activity of Hungary

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ABSTRACT

This paper focuses on the investigation of both theoretical and empirical comprehension of the relationship between oil price movements and economic activity for a net crude oil importing country, Hungary, as a case study. Sample period for this research spans from 15th January 2000 to 15th February 2019. The sample period accounts for notable episodes in economic activity which may be linked with oil price falls or shocks (increases). To examine this relationship, we use monthly data on Brent oil price and Hungarian industrial production index to proxy its economic activity. So as to take into account the changes in the state of the economy we employ a regime switching approach, particularly the Markov switching model (MS) using two regimes, otherwise known as states.

After rigorous empirical analysis, using the Markov-switching model (MS), we found that a link exists between changes in oil-prices and economic activity. Although, the effect of an oil price shock does not immediately lead to changes in economic growth, it unfolds after the fourth quarter. This is logical because supply contracts could delay the effect of such oil shock from affecting economic growth.

Furthermore, we investigated if there is any asymmetric oil-price effect on the economic activity of Hungary. To analyze if such an effect exists, we employ Mork's positive and negative oil price specification and Hamilton's net oil price index (NOPI). The results from our investigation imply that positive and negative changes in the price of oil do not have same impact in Hungary's economic growth. Although Mork's specification implies that oil-price decline would propel growth in the economy of Hungary, this impact is lesser than the decrease associated when there is an oil price increase.

Keywords: economic growth, oil price shock, asymmetric effect, Markov-switching model.

ÖZ

Bu çalışma, net ham petrol ithal eden Macaristan'ın petrol fiyat hareketleri ile ekonomik faaliyeti arasındaki ilişkiyi hem teorik hem de ampirik olarak 15 Ocak 2000 ile 15 Şubat 2019 dönemleri için incelemektedir. Örneklem dönemi özellikle seçilmiştir, çünkü seçilen zaman dilimi önemli üretim hareketlerini içermekte ve bunun petrol fiyat hareketleri ile ilişkili olup olmadığının incelenmesine imkan sağlamaktadır. Bu ilişkiyi incelemek için, rejim anahtarlama yaklaşımı olan Markov anahtarlama regresyon modeli (MS) kullanılmıştır. Çalışmada, aylık verilerle Brent petrol fiyatı ile Macaristan'ın sanayi üretim endeksi kullanılmıştır.

Markov anahtarlama regresyon modelini (MS) kullanarak elde edilen ampirik sonuçlar, petrol fiyat getirisi ile ekonomik büyüme arasında ilişki olduğunu doğrulamaktadır. Bununla birlikte, bir petrol fiyatı şokunun etkisi ekonomik büyümeyi hemen etkilemese de 4. çeyrek sonrasında etkilediği bulunmuştur. Bu bulgu teorik olarak tutarlıdır, çünkü tedarik sözleşmeleri bu tür petrol şokunun etkisini ekonomik büyümeyi etkilemesini geciktirebilmektedir.

Ayrıca, Macaristan'ın ekonomik faaliyeti üzerinde herhangi bir asimetrik petrol fiyatı etkisi olup olmadığı da araştırılmıştır. Asimetrik etkinin olup olmadığını analiz etmek için Mork'un pozitif ve negatif petrol fiyatı belirleme metodu ile Hamilton'ın net petrol fiyatı artışları (NOPI) kullanılmıştır. Araştırmamızın sonucu, petrol fiyatlarının Macaristan'ın ekonomik büyümesi üzerinde asimetrik bir etkisi olduğunu göstermektedir. Mork'un metodu, petrol fiyat düşüşlerinin Macaristan'daki ekonomik büyümeyi artıracağını göstermesine rağmen, bu etkinin, bir petrol fiyatı artışı olduğunda ortaya çıkan üretimdeki yavaşlamadan daha az olduğunu göstermektedir.

Anahtar Kelimeler: ekonomik büyüme, petrol fiyatı şoku, asimetrik etki, Markov anahtarlama modeli.

DEDICATION

To my parents, Mr. and Mrs. Ezeh, I want to thank them for their words of encouragement. I appreciate them for constantly reminding me to always be purpose driven and goal oriented. Thank you for your divine tutelage and for instilling in me great values.

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To my family, thank you all for your unyielding support and for believing in me.

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LIST OF ABBREVIATIONS

ARCH	Autoregressive Conditional Heteroscedasticity
CIEC	Census and Economic Information Center
ECB	European Central bank
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
IEA	International Energy Agency
IMF	International Monetary fund
IPI	Industrial Production Index
LR	Log Likelihood
MS	Markov Switching
OECD	Organization for Economic Co-operation and development

Chapter 1

INTRODUCTION

No doubt there has been a great number of literature about the effects of oil-price movements to the economic growth since inception of the first crude oil crisis in October 1973 which started as due to oil ban proclaimed by the members of OPEC. Most empirical research was carried out after the groundbreaking empirical work of Hamilton (1983) who revealed that movements of oil prices as a one of the source of economic contraction in United States. Hamilton's (1983) pioneering study led most macroeconomists to engage on empirical research based on an assumed relationship between price of oil and growth in economy.

Such empirical evaluation has been done on the effects of oil price changes on economy growth for net oil exporting/importing nations. Empirical findings indicated that all countries, whether developed or developing countries, net oil exporting importing nations, are all affected by shocks in oil price, although the magnitude of these effects may differ between countries. The importance of the impact of oil price shock on the economy of non-oil exporting countries cannot be overemphasized. Crude oil is of great necessity in propelling global economic advancement among all countries.

Hungary is a small scale open economy that has encountered an economic growth in the previous decade and one of the most innovative and propelled economies among communist states. Although the country is energy-poor yet its economy is highly energy intensive, making it one of the highest energy intensive economy in the EU region; Thus, it relies heavily on imports to meet its energy demand. Hungary is a net oil importing country which consumes about 176,233 thousand barrel/day but produces only 17,020 thousand barrels/day as of January 2019 (Ceic, 2019), this means that Hungary's domestic production is less than 10% of the total amount of oil it demands/consumes daily. Hence, Hungary is heavily reliant on oil importation to meet its demand. Approximately two-thirds of Hungary's energy supply is sourced from fossil fuels (IEA 2017). 27% of its energy supply is oil, 31% is Natural gas, 8% renewables, 11% and 16% from nuclear and coal respectively. Hungary's residential sector is the largest oil consumer, with about 80% of the structures lacking economically proficient warming system. Also, the transportation sector is on the up-rise due to increase in private vehicle ownership and at such energy demand and consumption in the sector is rapidly increasing (OECD 2017).

Although Hungary's oil and gas reserves are limited, consumption of petroleum products is anticipated to rise significantly in coming years. A combination of growing demand and limited domestic reserves will mean that imports will increase since its domestic production is very low (OECD 2017).

1.1 Purpose of study

This research centers on analyzing effects of oil-price movements on Hungarian economic growth. Considering the fact that its domestic production of oil has reached its maximum and it's expected to decrease even further in future which makes Hungary a unique case, because it will become even more heavily dependent on energy imports in the future than at present. Therefore, it is paramount to analyze how vulnerable the economy of Hungary has been (or is) to movements in oil prices especially due to its high reliance in oil importation to meet its domestic demand.

For this purpose, the study uses monthly data on Brent oil price and industrial production index of Hungary to proxy its economic activity. The sample period covers January 2000 to February 2019 which includes both tranquil and recessionary periods such as the financial crisis of 2008 and European debt crisis. The analysis focuses mainly on how changes in oil price and oil price shocks affect the economy. Oil price increases is calculated with two approaches, positive oil-prices by Mork and net oil price index (NOPI) by Hamilton. Furthermore, due to the features of the sample period, two state Markov-switching model is employed.

1.2 Research question

The core question for this study is keen on investigating if any link exists between movements of oil price and economic activity of Hungary; If this relationship exists, then by what magnitude does movement in oil price affect the economic activity. Furthermore, we seek to examine the presence of asymmetry on how changes in oil prices influence the economy of Hungary; does an oil price decline result in an increase in economic growth?

Chapter 2

ECONOMIC OUTLOOK OF HUNGARY

Hungary's economy is a high income mixed economy and one of the most developed economies in the former Eastern Bloc. The liberalization of the economy was part of the transition process from a socialist economy to a free market economy. The country was viewed as one of the most prosperous emerging European nation after the fall of communism in 1989. According to the IMF report, Hungary's economy is among the 60 biggest economy with approximately $266 billion worth of output per annum (IMF report 2017). Also, based on per capita GDP the economy is situated at top 50 position on a global scale. Additionally, the economy is a very outward concentrated open economy and promotes international trade. In fact, it is positioned as the 35th largest export based economy globally. Hungarian economy is associated with about €71.6 billion in foreign direct investment (FDI), and this volume of FDI is the highest in the Central and Eastern European region (OECD 2018).

Due to slow rates of economic growth, the government implemented "New Economic Mechanism" in 1968, which led to creation of market style reforms to allow for the emergence of privately owned businesses. This policy is predominantly the reason why majority of the production capacity in the economy is privately owned. The productive capacity of the economy is majorly privately owned to the tune of more than 80%. Although Hungary has an export oriented economy that is endowed with many natural resources, however, fossil fuel resources are relatively small, hence the heavy reliance of imports to meet its local demand. It is paramount to note that over 83% of its oil consumption in the economy is met by imports (IEA 2017).

Oil production in Hungary is by a wide margin less than its consumption. Oil consumption in Hungary has increased significantly, whereas domestic oil production in Hungary is estimated to diminish to about 15,000 barrels per day (b/d). The annual domestic consumption of oil is expected to increase by about 3.8% and with decreasing domestic oil production, Hungary will become increasingly dependent on imports of oil to satisfy domestic consumption (OECD report 2018). In 1980s, coal satisfied more than half of the energy requirement in Hungary, but in 2019, it only accounts for less than one-fifth of the total energy production. Oil and natural gas were discovered in Hungary some decades after world war II. Between year 1970 & 2000, share of crude oil and natural gas in energy production increased significantly from about one-third to one-half; however, there was a noticeable fall in the proportion of their share generating energy to less than one-fifth in 2010. After the 1973 world economic crisis, the Hungarian economy was in downturn. The rapid increase in the oil price created an enormous amount of trade deficit as the earnings generated from exports could not balance for the increase in oil price, which in turn led to upsurge of foreign indebtedness; followed by slowed economic growth, high inflation, hence stagflation in the economy.

From 1990 to 1993 the economy of Hungary experienced a recession which caused its GDP decline significantly to about 18%. The GDP grew sluggishly in the following years at just about 1%-1.6% in 1996. Improvements in export performance played a huge role in further increasing the GDP to about 4.7% in 1997. Following the achievement of economic expansion, the government now focused on substantial structural reforms which led to the implementation of the national treasury, fully funded pension funds and many other notable reforms such as reform of higher education. After these rigorous reforms, the economy of Hungary has experienced some positive changes and the macroeconomic indicators have improved; inflation rate has declined from 14.2% to 3.61% in 2006 and unemployment rate reduced to about 6.5% (HCSO 2009).

Hungary was considered as one of the strongest economies in the former Eastern Bloc, largely because it attracted large influx of foreign direct investment and was able to maintain a stable sustained growth for some period (ECB report, 2004). Economy of Hungary was waxing so strong that it was barely affected by the Russian and the Asian crises in 1997. However, the 2009 global financial crisis had a huge adverse effect on the economy of Hungary relative to other other European countries (Business Blog, 2008). The country had to accept the program of the international monetary fund (IMF). The biggest question from this quick turnaround of event has been "what made Hungary which was perceived to be the most stable economy among the newcomers in EU to be the most vulnerable to the financial crisis? It was however suggested that the vulnerability of the economy was largely due to the large government debt that Hungary inherited during its transition from the communist to the market economy. Hungary, unlike other EU newcomers like Poland, did not receive any government debt forgiveness during their transition. Although large government debt is without doubt an issue for Hungary, the country is still faced with other shortcomings in the economy, especially in the public sector. The Hungary's government spending is estimated to be above 50% of GDP relative to other countries in Europe which had less than 35% government spending as a share of its GDP (OECD report, 2012). The high government spending in Hungary can only be possibly financed by generating revenue from high taxation and duties, hence, taxation and duties are very high in Hungary.

During the in 2008 and 2009 recession, a sharp decline in exports together with domestic consumption occurred. The fixed asset accumulation decreased significantly, causing the Hungarian economy to go into a recession with GDP growth of -6.6%, making this economic downturn one of the country's lowest record low in its history. The weak economic conditions led to uncertainty in the financial sector, banks granted a smaller amount loans which induced investment to fall significantly. The decrease in investment and fear of bankruptcy resulted to a fall in consumption and cutbacks in employment, which had a feedback to further decline in consumption following the severe recession. The Hungarian government got into a contract with the IMF for a bailout of US$25 billion with the objective of restoring the economic stability and business confidence. However, the economy showed indication of recovery in 2011 with a 1.7 percent growth in GDP. A graphical representation of the industrial production index clearly takes into account every period of economic downturn(boom) in Hungary, from the global crisis of 2008-2009, to the growth in GDP in 2011 after the crisis, the mild recession in Hungary in 2012, and the global oil crisis in 2014. These are notable events in the economy of Hungary and the Industrial production index clearly depicts every of these recession or growth in the economy, hence it can serve as a good proxy for the output of the economy of Hungary.

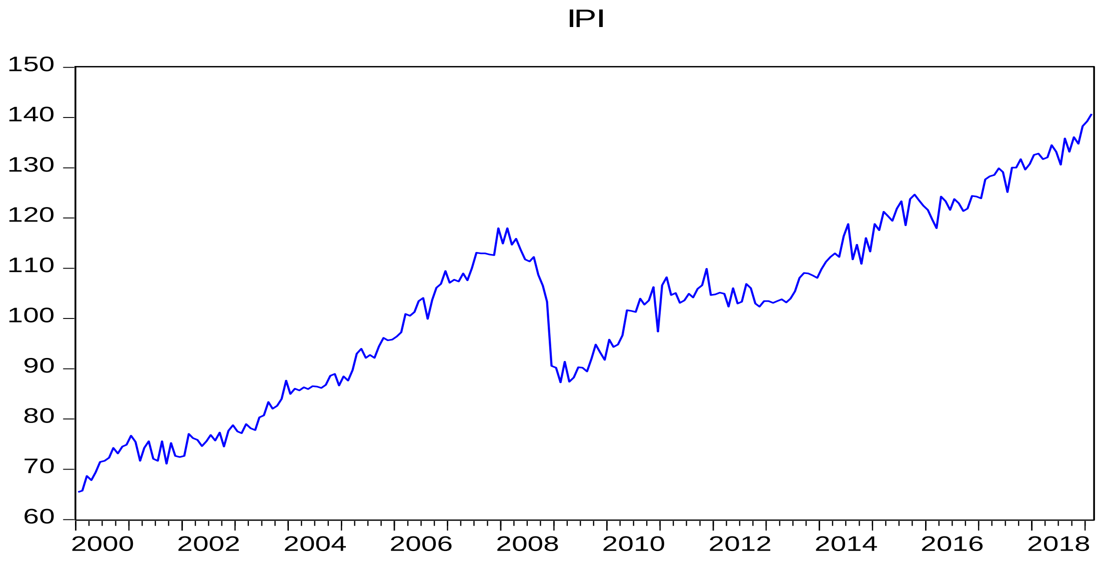

Figure 1: Industrial production index series

In terms of inflation rate, Hungary has been able to reduce its inflation significantly from 7.6% in 2007 to 2.9% in 2019 (ECB 2018). Hungary has preserved a fairly stable low rate of inflation over time, especially since the country target to adopt the euro as their official domestic currency. To be able to replace the forint (Hungary domestic currency) with the euro the country is expected to meet all conditions of the Maastricht treaty. These criteria could be followed from table 1 below.

Table 1: Convergence criteria

	Inflation rate	Government budget deficit –GDP	Government debt- GDP
Conditions	3%	3%	60%
Hungary (2019)	2.9%	2.2%	70.2%

Source: European central bank database

The data in the table clearly shows that Hungary has a high gross government debt to GDP. This substantial amount of debt to GDP has not only stopped Hungary from adopting the euro but it also affects their cost of borrowing and government bond yields.

2.1 The sectors

Hungary is a post industrial economy with a lot of active sectors. Among others, these sectors range from the industry sector, service sector and agricultural sector, which are they key sectors in the economy of Hungary.

2.1.1 The agricultural sector

Agricultural sector in Hungary is self-reliant and has been sustainable over the years. It accounts for about 4.8% of GDP. The country's agricultural products account for about 28%-30% of the total export, and its agricultural imports of just 8% (HCSO 2019). This makes the country one of the leading agricultural export based nation in Europe. Hungarian agriculture is said to be one of the quickest growing agrarian sector in Europe and has grown by almost 60% in the last decade (Zsoka Kovac, 2018). The agricultural sector of Hungary has about 218,000 employees and 28,000 operational enterprises.

2.1.2 The industry sector

The dominant sectors in the industry of Hungary are the heavy industry. The heavy industry includes the mining industry, automobile industry, metallurgy industry, electronic, steel and machinery industry, energy and chemical production, etc. The industry sector accounts for about 39% of GDP. The industry sector has about 1.3million employees and 126 thousand operational enterprises. The automotive industry in itself accounts for about 23% of Hungary's total exports; this is basically because original equipment manufacturers (OEMs) such as Audi, Suzuki, Opel, Daimler Benz own a production facility in the country. Due to the perceived huge investment by the automotive companies, a large number of equipment manufacturers and suppliers were attracted to Hungary, hence, boosting the industrial sector even more.

Furthermore, the electronic industry of Hungary accounts for about 24% of the manufacturing production. Hungary is the leading electronic producer in the whole of Central Europe. Hungary is also responsible for about 27% of all electronics manufactured within the European region. The industrial sector of Hungary has undoubtedly been the major source of its export oriented economy and has played a significant role in keeping its exports on a surplus.

2.1.3 The services sector

The service sector accounts for about 56.2% of GDP (world bank 2016). The role of the service sector has grown over time especially as a result of persistent large scale investments to the transportation sector and other service sector in the past two decades. The country's geographical location in central Europe contributed immensely in boosting the service sector; primarily due to its unique geographical position which makes it more beneficial and attractive for more investments. This sectors accounts for about 63.4% of the total employment in the country.

Table 2: Statistics of economic sectors in Hungary

	Industry sector	Agriculture sector	Service sector
Contribution to gross value added	39%	4.8%	56.2%
Operational enterprises	126 thousand	28 thousand	-
Employees	1.3 million	218 thousand	3.4 million

Source: world bank database

Chapter 3

LITERATURE REVIEW

The literature on oil price movements has been divided into two mainstreams. On one hand, the literature focused on origins of oil-price movements. They seek to identify and analyze reasons for the frequent fluctuations in oil prices, whether due to supply (repressions) or precautionary demand. Another strand of literature studies how fluctuations in oil prices impacts the economy and attempt to develop a suitable policy to accommodate these effects. Hamilton (1983), the most popular economist who contributed to this reports found in his empirical research that most decline in business activity in USA occurred just after a surge in oil-price. Thus, accordingly, rapid increase in price of oil could have a huge consequence on the stability of an economy.

3.1 Sources of oil price fluctuations

Sources of oil price movements and shocks are studied by Kilian (2009). The author argued that the effect of the shock could vary according to the source of shock; whether the shock is demand or supply related. The supply side effect is transmitted through a cost channel. Since oil is used for production, any rise in its price will cause an increased cost; hence, level of production drops. Contrary, demand side is transmitted through consumption and investment spending channel. However, few economists assert that the consequent of oil price shock is the same irrespective of its fundamental cause. According to Lutz Kilian (2006), the identification of these shocks is necessary not only because it is needed to analyze oil price swings, but more importantly, to redesign the macroeconomic policies in a manner that would be more suitable to manage these price shocks.

To understand more about these effects, it is necessary to understand the possible sources/cause of these fluctuations in oil price. The empirical studies by Kilian (2009) and Davig (2015) found that oil price shock could be caused by a number of reasons; oil price shock caused by exogenous disruption in production and shock triggered by business fluctuations. According to Kilian (2009), disintegration the changes in real oil prices indicates that oil price shocks in the past was propelled for the most part by a composition of both precautionary and aggregate demand shock. He further postulated that these effects are largely dependent on the underlying cause of that change, implying that how the economy respond is determined by the factor that caused the change in price. The author emphasized that, “no one cause of price shock has the same effect with another cause of price shock” Kilian (2009). For instance, expansion in demand for will prompt instant and significant surge in the crude oil price. Conversely, the consequent of a rise in aggregate demand will be a deferred increment in the real oil price, whereas disruptions in production (supply) will only lead to a negligible and brief increase in oil price.

3.2 Effects of oil price shock

There is another strand of literature which support that not only oil price increases influence economic condition, but also oil-price fluctuations also play an essential role on economic activity. Empirical literature revealed that oil price volatility hinders economic advancement. Volatility creates uncertainty which affects business confidence; see Ferderer (1996). Furthermore, the literature also suggests that movements of oil price could have asymmetrical impact on the economic expansion. According to Hamilton (1983), the author deduced that net increases in oil price has an obstructive consequence on economic activities, but he did not consider decreases in oil prices because its impact was inconsequential. A more recent research by Charfeddine et al (2018) found that price shocks slows down GDP growth in the USA. In addition, Mork (1989), in his empirical research revealed that oil price increases is unfavorable to the economy of United States, whereas oil price falls failed to improve output production. Although, Hamilton (1988) and Mork (1988) used different oil price specification in their empirical research, yet both research indicates that lower and higher oil prices affect output in different proportion.

Additionally, Ahmed (2016) claimed that a sudden decrease in price of oil will have crucial repercussions for importing nation. The countries importing oil will profit from decline in price as they will have access to lower import and subsidy fuel bills. However, they are likely to experience a reduction in foreign aids and foreign capital inflow from oil net exporting countries. These reductions in foreign aids, foreign investments and tourism revenues would lead to contraction in the economy of the net oil importing country. At such, there will be no growth in economic activity associated with oil price decreases. Similarly, Sardosky (1999) pointed out that this asymmetry could be as a result of sectorial shocks. Therefore, the extent of relative variation in prices has a major role to play, or as result of irreversible investment under uncertainty, focusing on the point that there is a loss in value with postponing investments. Also, hikes in oil cost could negatively influence previously investment decisions made by firms (Baumeister & Kilian 2016).

There have also been a lot of other theoretical perspectives on this topic. Some macroeconomists are inclined to the idea of a non-linear relationship. For instance, according to Cunado & Perez (2004), higher oil price leads to decline in aggregate demand. Thus, oil price rise will transfer income from oil importing and exporting nations. Ferderer (1996) reported that the reduction in income would force consumers to cut down level of consumption, leading to fall in total output of the importing country, ceteris paribus. Also, the oil price increases would result in a reduction of aggregate supply because higher oil price would induce industries to buy fewer energy. Hence, the efficiency of any specified amount of capital-labor will fall, thus reducing potential output. In this respect, a decrease in the factor productivity would prompt a reduction in real wage rate. Consequently, there would be a decrease in labor supply as a result of lower wages. It is important to note that this decline in labor supply is associated with voluntarily withdrawal from labor market as a result of the lower real wage, therefore potential output will be lesser than anticipated.

Furthermore, evidence of an empirical research for some countries in Asia signify that oil-price movements have a considerable effect not just on economic growth but also on price indexes. However, this impact is compelled just in the short-run; it has more significant when price is stated in domestic currency (Cunado & Perez de Gracia, 2005). Additionally, according to Katsuya (2017), in her empirical research on the economy of Russia, her findings suggest that persistent oil price hikes would cause higher rate of inflation.

A more recent study has also analyzed the non-linear form of oil price and economic outcome (see Zhang, 2008 and Jimmy 2012). According to Elder (2010), oil price shocks in general will discourage ongoing investments because volatility negatively affects various yardsticks for investment.

Many economists took a queue from Mork (1989) and Hamilton (1983) after their remarkable research. According to Davies, (1987), his analysis suggests the absence of a symmetrically feedback. The principal reason for the asymmetric response is largely due to the utilization of newly developed advanced technologies that are more energy efficient and cost effective. According to Joher 2011, when oil price falls, companies do not totally stop using new technologies immediately so as to reduce sunk cost to minimum. Hence, the fall in oil price have a minimal fallout on the economy compared to an increase in price.

Furthermore, Lee & Ni (2002) reported that industries with larger percentage of cost in oil, an oil price shock would only result in a decrease in supply, whereas, for others with lesser portion, an oil price shock for such industry would mainly reduce demand. However, according to Park (2009), the transmission of oil shock is not driven by domestic costs or productivity shocks. Rather it is primarily driven by the shifts in the final demand for both goods and and services. This implies that share of energy in total cost is not necessarily an essential element in describing distinctions on how real stock returns reacts among industries.

Moreover, according to Lilien (1982) who formed a dispersion hypothesis, which depends on the contention that variability in oil price will change balanced distribution among different sectors. Moreso, he argued that the increase or decrease in price would either expands or contracts the sectors that utilize oil in their production processes. To further explain, the theory simply suggests that a rise or fall in oil price will trigger growth or recession in an energy efficient sector relative to an energy intensive sector. Additionally, according to a research by the International Monetary Fund (IMF), a price fall will prompt higher economic output and lower the cost of imports associated with oil and energy. Hence, a negative oil price movement is likely to boost industrial production (Noura, 2017).

Chapter 4

DATA AND METHODOLOGY

4.1 Data

This research adopts monthly data. The sample estimation time starts from 15th January 2000 to 15th February 2019. The data set is comprised of Brent crude oil price and the industrial production index, both variables are denominated in US dollars so that exchange rate effect is also captured. The base year for both variables are 2010 and variables are seasonally adjusted. The industrial production index and Brent oil price indices are retrieved from Thomson Reuters data stream.

The Brent price is used as a proxy for crude oil price in this research because it totally accounts for over 65% of global oil production and transactions (Eurostat 2018). Also, it is predominantly the primary gauge for oil price in Europe; hence, it is very suitable for the purpose of this research. On the other hand, production index measures the real output produced in the economy. It also serves as an estimate for amount of output that is sustainable overtime. Industrial production is used to determine output because it represents the levels of production attained on a monthly basis, unlike GDP that is reported quarterly. Using industrial production index would help ascertain if movements in oil price cause any shift in production levels.

4.2 Methodology

The recent literature reviewed in this research have reached a consensus of a nonlinear relationship among the variables (Hamilton, 2009, Rodriguez, 2009, Jbir & Ghorbel,2 Bal & Rath, 2015). This implies that the relationship between the variables are not the same at all periods but may differ with structural breaks. Additionally, it is paramount to adopt the right model for this analysis. Thus, Markov switching model will be an ideal choice. This is primarily because the model allows for a different relationship at different state of the economy. For instance, the mean value of an estimated regression model could be different in expansionary and recessionary periods. However, specification of the model in each regime is linear. The model is flexible such that all parameters of the model or part of the model may be regime dependent.

The core unique feature of Markov regime switching model is that it accounts for different behavior in different states (otherwise known as regimes) of the economy, while at the same time estimates the probability of transition from one regime to another. Thus, this model allows for a classification of the state of the economy into different regimes. For the sake of this research, a two regime Markov Switching Model (MS) is utilized to see how variations in cost of oil affect the economy in recessionary periods and expansionary periods.

4.2.1 Markov switching regression model (MS)

A simple Markov-switching model with coefficients depending on an unobserved state variable, S_t can be written as follows;

$$y_t = \alpha_{St} + \beta_{St} x_t + \varepsilon_{St} \quad (1)$$

where $\varepsilon_{St} \sim \mathcal{N}(0, \sigma_{st}^2)$, S_t is the unobserved state variable which follows a first order Markov chain. y_t is the production index of Hungary and x_t indicates the oil price changes and volatility. Coefficients α, β, σ^2 of the model are to be estimated which are state dependent. We assume two states or regimes with transition probabilities defined as

$$P_{i|j} = P(S_t = i | S_{t-1} = j)$$

where i, $j = 0$ or 1. For instance, $P_{0|0}$ indicated the possibility to stay in regime 0 while $P_{1|1}$ indicates the probability to stay in regime 1, while $P_{0|1}$ would show the probability to move from regime '1' to regime '0'. Given this definition which states $P_{0|0}$ + (1- $P_{0|0}$) = 1 and (1-$P_{1|1}$) + $P_{1|1}$= 1 since 0 ≤ $P_{0|0}$, $P_{1|1}$ ≤1. It should also be noted that Hamilton (1989) assumed that the transition probabilities are constant and follows first-order Markov process.

4.2.2 Estimating oil price volatility

Empirical assessment supports argument of volatility as an exogenous shock to the economy that significantly affects aggregate output. (Hamilton, 1983, 2003, Kilian 2008, Mork, 1994). To generate the volatility in oil price we use of Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model of Bollerslev (1986). GARCH is specifically designed to model the conditional variance or volatility of a variable that changes overtime. In other words, the variance of the series changes overtime conditional on its past values hold fixed. GARCH family of models are widely adopted in many economic and financial research with high frequency data, at daily, weekly or monthly frequencies which depicts features of volatility clustering (Brooks, 2003). The GARCH model comprises of the conditional mean and conditional variance equations. For instance, the GARCH (1,1) model can be written as:

$$y_t = \mu + \phi y_{t-1} + u_t, \quad u_t|\mathrm{I}_{t-1} \sim \mathcal{N}(0, \sigma_{st}^2) \tag{2}$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \tag{3}$$

where equation (2) is the conditional mean equation and is specified as AR(1) model. Equation (3) is the conditional variance equation with σ_t^2 being the conditional variance of $u_{t,}$and I_{t-1} shows the information set at time t -1. Stationarity condition for the variance is that $\alpha_1 + \beta_1 < 1$.

4.2.3 Asymmetric effects of oil price

The different effects of oil price increases and decreases in the literature which was first introduced by Mork (1988). The author reported a significant relationship between real oil price increases and GNP which became insignificant when oil price fell for the US. Hamilton (1988) and Davis (1987) contended that oil price shock would discourage output growth more strongly than oil price falls. In this research, we would analyze the presence of asymmetric effect using two different approaches, namely of Mork (1989) and Hamilton (1983) respectively.

4.2.3.1 Mork (1989) specification

Mork (1989) calculated oil price for his model as a percentage change in the nominal price; such that price is equal to the difference between price at t and price at $t-1$. Furthermore, he distinguished between the negative and positive values of the percentage changes in oil prices into two separate variables as follows:

POP= (0 if oil price is ≤ 0, value of oil price if oil price is > 0)

NOP= (0 if oil price is > 0, value of oil price if oil price is ≤ 0).

For the sake of clarification, POP represents positive oil price, and NOP represents the negative oil price.

4.2.3.2 Hamilton (1996) specification

This model is based on net price increases. He proposed that the price in every month should be compared with the highest oil price within the year. If the value obtained from the difference in percentage change is positive, then that value is considered, but if it is negative then it is set to zero. The hallmark of this model is that it captures only the net increases in oil prices and ignores the price decreases (Rodriguez and Sanchez (2004)). The NOPI model can be represented as follows:

NOPI= [0; OilP – Max$\left(o_{t-1}, o_{t-2} \ldots o_{t-12}\right)$

Chapter 5

EMPIRICAL RESULTS AND ANALYSIS

The objective is to investigate the relationship between economic activity and oil price movements. Economic activity in this case is represented as the growth in industrial production index (IPI) and oil price shock is estimated as change(returns) in oil price. See Figure 2 for graphical representation of the variables.

5.1 Unit root test

First and foremost, a unit root test is carried out ascertain the stationarity of the series. This test is primarily performed to ensure that variables are stationary such that the mean, variance and the covariance of the series will not change with time (Enders, 1995). We used the ADF and KPSS test. Intercept is included in these specifications and the lag length is selected automatically.

Table 3: Unit root test

Variables	ADF test p-values at levels	ADF test p-values at first difference	KPSS test p-values at levels	KPSS test p-values at first difference
Oil price (O)	0.2005	0.0000***	0.8317	0.0901*
Industrial production index (IPI)	0.8658	0.0000***	1.7224	0.0775*

***,**,* indicates where p-values at 1%,5% and 10% are significant respectively

The null hypothesis for ADF test states that series has a unit root (not stationary). Conversely, the null hypothesis for KPSS test states that series is stationary. From the table above the tests carried out show that both oil price and the production index are stationary at their first differences. The p-values of the ADF and the KPSS tests at first difference for both variables indicate that the coefficients are significant.

Table 4: Normality test for oil price return

Skewness	-0.89145
Kurtosis	4.12983
Jarque-Bera	42.5109
Jarque-Bera p-value	0.0000**

***;**;* indicates significant at 1%, 5% or 10%. The null hypothesis for normality test is that series are normally distributed.

Normality test for oil price return evidences that the residuals of the series does not follow a conditional normal distribution. Furthermore, the skewness and kurtosis of oil return series reveals that it has a fat left tail (leptokurtic). For further clarification, we plotted the quantile-quantile graph shown in figure 2.

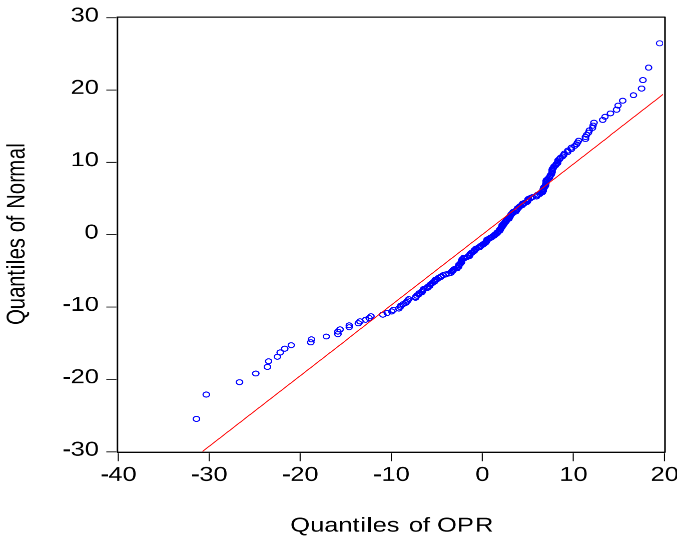

Figure 2: Quantile-quantile graph of oil price return series

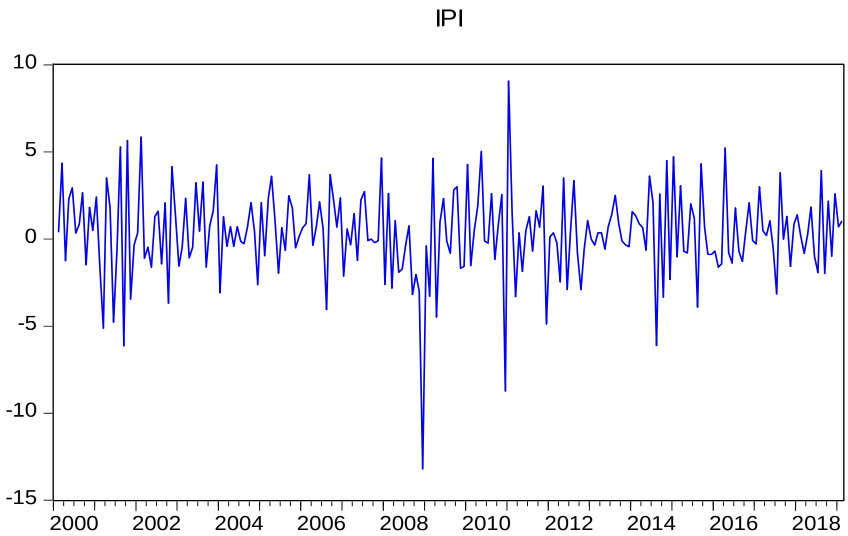

Figure 3: Industrial Production Index in first differences

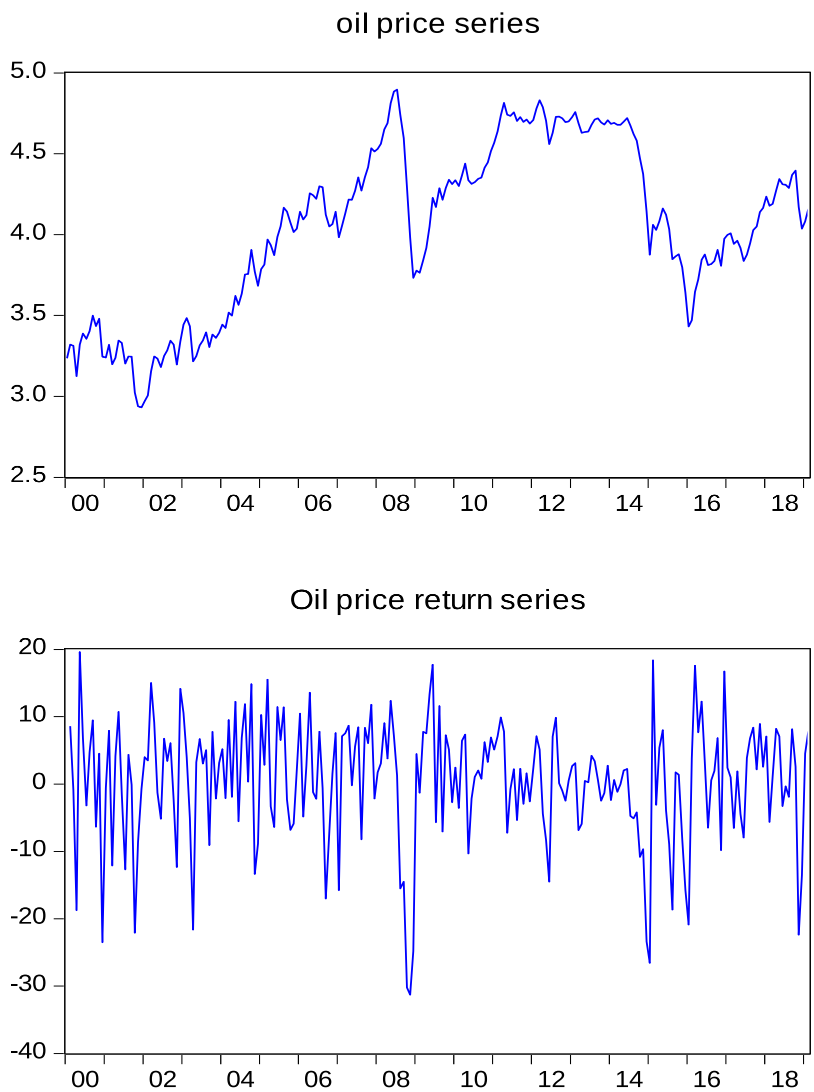

Figure 4: Oil price and oil price return series

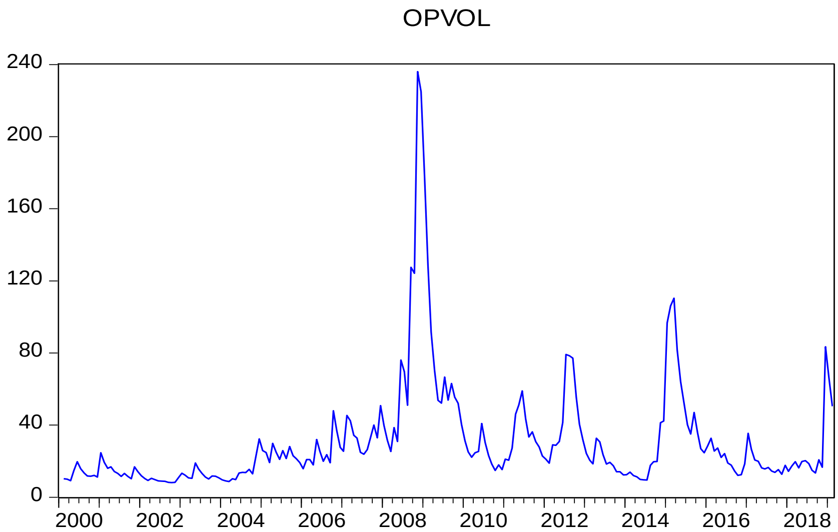

Figure 5: Oil price volatility series

The distinction between oil price and returns on oil price is that the former shows movements of prices within a given period and the later shows the periods where volatilities are present. Since it is computed as a change in logarithm of oil price, it shows periods where the values of oil price change rapidly from time to time, especially during the beginning of the sample till 2009. Additionally, the return on oil price reveals evidence of volatility clustering; periods where enormous changes in oil price are trailed by larger shifts, whereas slight changes are accompanied by slight changes.

5.2 MS estimates for oil price return and volatility

In this section we estimate the oil price returns and volatility on output of Hungary using the Markov switching model. The regime with high regime volatility coefficient is the expansionary regime and the regime with low volatility coefficient is the recessionary regime.

Table 5: MS estimates for returns and volatility

Regime 0			
Variable	Coefficients	z-statistics	p-values
C	-0.0111	-0.0323	0.9742
Opr	0.0105	0.5322	0.5945
Ov	0.006	1.5744	0.1154
Regime volatility	0.6511	9.8105	0.0000***
Regime 1			
C	1.5077	1.1858	0.2354
Opr	0.0748	1.1307	0.2581
Ov	-0.0171	-1.6733	0.0943*
Regime volatility	1.4018	9.2585	0.0000***
$P_{0\|0}$	0.966		
$P_{1\|1}$	0.827		
$Q^2(-6)$	3.1591		0.789
Estimates with lags			
Regime 0			
C	0.9549	2.8768	0.0040***
Opr(-12)	-0.0373	0.01716	0.0294**
Ov(-12)	-0.0065	0.7295	0.4557
Regime volatility	0.1839	0.9311	0.3518
Regime 1			
C	-0.1621	-0.2278	0.8197
Opr(-12)	-0.0031	-0.0795	0.9366
Ov(-12)	0.0003	0.5425	0.5874
Regime volatility	1.2083	11.7523	0.0000***
$P_{0\|0}$	0.778		
$P_{1\|1}$	0.788		
$Q^2(-6)$	2.471		0.872

***;**;* indicates significance levels at 1%, 5% and 10% respectively. Opr represents oil price returns, Ov represents Oil price volatilities obtained from GARCH estimates, regime transition probabilities are $P_{0|0}$ & $P_{1|1}$, Q^2 is the statistics for serial correlation of the standardized squared residual at lag 6.

First of all, the estimates confirm nonlinear relationship between oil price, its volatility and output growth. The likelihood-ratio test (LR) of linearity strongly rejects the linear model based on Davies (1987) upper bound p-values in all the models, not reported to save space. The regime volatility estimates are more than double in regime 1 than in regime 0. Thus, regime 0 is accepted as the recessionary regime and regime 1 being the expansionary phase of production. Our empirical studies also suggest that the oil price return at 5% level of significance causes a reduction in output in the fourth quarter of the recessionary regime. It is logical for the effect not to occur immediately because of a number of reasons. Firstly, most industries who are energy intensive usually have a long term (minimum of one year) supply contract with the supplier of their input (oil in this case). These supply contracts usually involve supplying a fixed quantity of the input at an agreed time and a fixed price. One of the major benefits of such contract is that it shields the buyer from any sudden increase in price of the input. The diagnostic tests, the Q^2 statistics show no correlations confirming the adequacy of the estimated models.

Lee (1995) proposes that oil price changes by themselves do not fully explain oil-output growth relationship, but rather, need to consider the volatilities associated with fluctuations in its price. Our empirical studies suggest that oil price volatility at 10% level of significance will scale down production in Hungary during expansionary period. Contrary to the consequence of oil price changes, the effect of volatility occurs immediately unlike the oil price returns effect that sets-in in the 4th quarter. Our empirical findings support other prominent empirical research; Federer (1996) found that returns and volatility has an adverse and significant effect on economic growth. He buttressed that even though they have similar effect, their time of impact differs; oil price volatility repercussion is instant, but the return has a postponed negative effect that only sets in after the fourth quarter. The smoothed transition regime probability graphs of the models indicate that the regime changes are well captured by the estimated models.

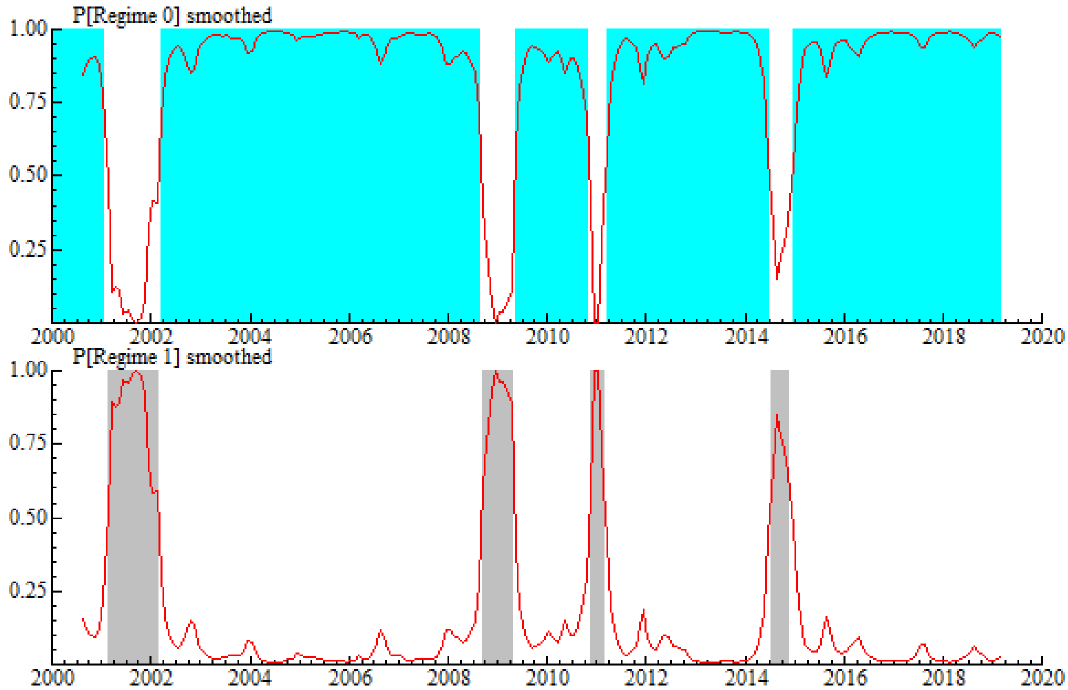

Figure 6: Smoothed regime probabilities of MS(2) model with oil price return and volatility without lags.

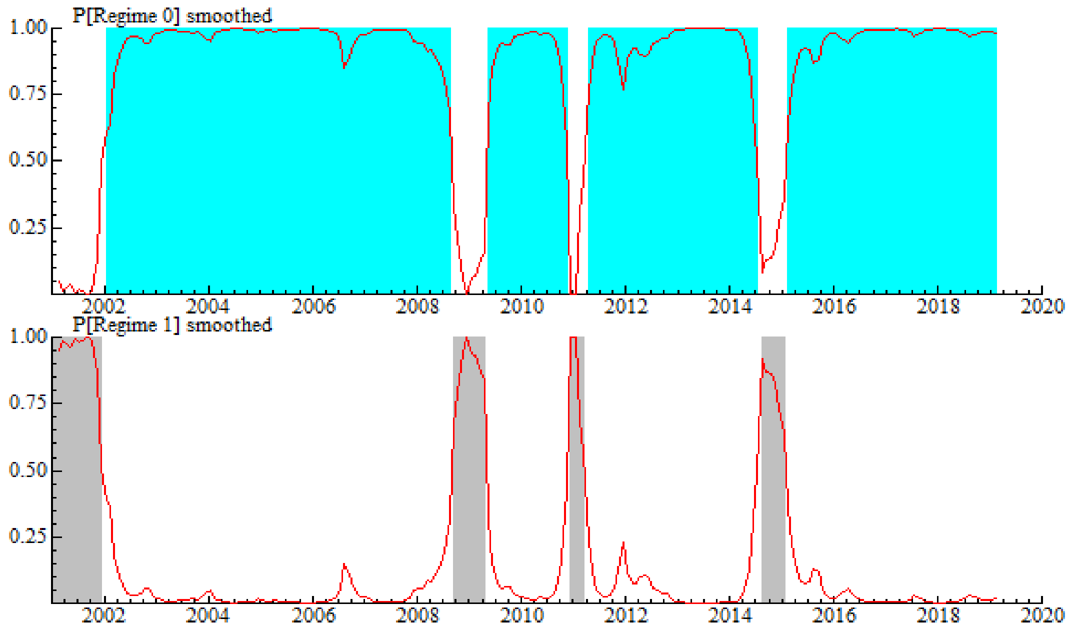

Figure 7: Smoothed regime probabilities of MS(2) model with oil price return and volatility with lags 12.

5.3 Asymmetric effects

We estimate the effect of oil price on economic activity by modelling oil price differently based on different specifications in order to investigate if the theory asymmetry holds in Hungary. Literature infers an asymmetric effect is evident when rising oil price leads to reduction in economic activity but a decrease in price of the same magnitude does not propel output to increase (Mork 1986, Hamilton 1996). We employed Mork's model of disintegrating oil price into positive and negative prices. Also we used Hamilton's technique of net increases in price.

Table 6: MS estimates for Mork's and Hamilton's asymmetric effect of oil price

Mork's Specification	Regime 1		
Variables	Coefficients	z-statistics	p-value
C	1.3021	2.0047	0.0450**
POP(-6)	-0.1459	-1.4824	0.1382
NOP(-6)	0.1605	2.1079	0.0350**
Regime volatility	1.2376	14.3837	0.0000***
	Regime 0		
C	0.0787	0.2842	0.7762
POP(-6)	0.0320	0.7920	0.4283
NOP(-6)	-0.0353	-1.2607	0.2074
Regime volatility	0.4157	0.0824	0.0000***
$P_{0\|0}$	0.815		
$P_{1\|1}$	0.9661		
$Q^2(-6)$	1.7692		0.937
Hamilton's NOPI	Regime 0		
Variable	Coefficients	z-statistics	P-value
C	0.6714	1.6567	0.0976*
NOPI(-6)	-11.6985	-2.4782	0.0132**
Regime volatility	0.1686	9.7740	0.0000***

	Regime 1		
C	0.3098	1.5659	0.1174
NOPI(-6)	3.7057	1.5455	0.1222
Regime volatility	1.37388	8.8080	0.0000
$P_{0\|0}$	0.8428		
$P_{1\|1}$	0.8051		
$Q^2(-6)$	3.9511		0.683

Note: POP represents positive price; NOP is for negative price; NOPI is for net oil price increases; p-values indicated as *** for 1%, ** for 5% and * at 10% level of significance respectively, regime transition probabilities are $P_{0|0}$ & $P_{1|1}$, Q^2 is the statistics for serial correlation of the standardized squared residuals at lag 6.

The empirical results for the asymmetric effect estimates suggest that positive oil price shock does not significantly affect economic growth in both recessionary and expansionary periods. The negative prices stimulate economic growth and this impact is highly statistically significant at 5% level. Our empirical results suggest that decreases in oil price will prompt output to increase by 0.16%. Furthermore, the NOPI is in line with prior expectation. Thus, net increases in oil price have a substantial obstructive consequence on economic activity in periods of recession. Increases in oil price would reduce output substantially by about 11.7% at lag 6 at the 5% level of significance. The magnitude of the effect associated with NOPI specification is larger than the positive price specification of Mork; primarily because NOPI is modelled in a way that it considers an oil price shock only when price at that time surpasses the maximum price in the previous year (see Figure 3 for graphical illustrations). Mork's specification of positive price changes provides a weak relationship between oil price and output. In essence, this empirical result suggests that increases and decreases in oil price impacts output of Hungary in different way. Our results are in line with several studies (see Haltiwanger and Davis 2001, Lee et al, 1995). The smoothed regime switching probability graphs are in figure 9. These graphs basically account for the switching regime reactions in the model.

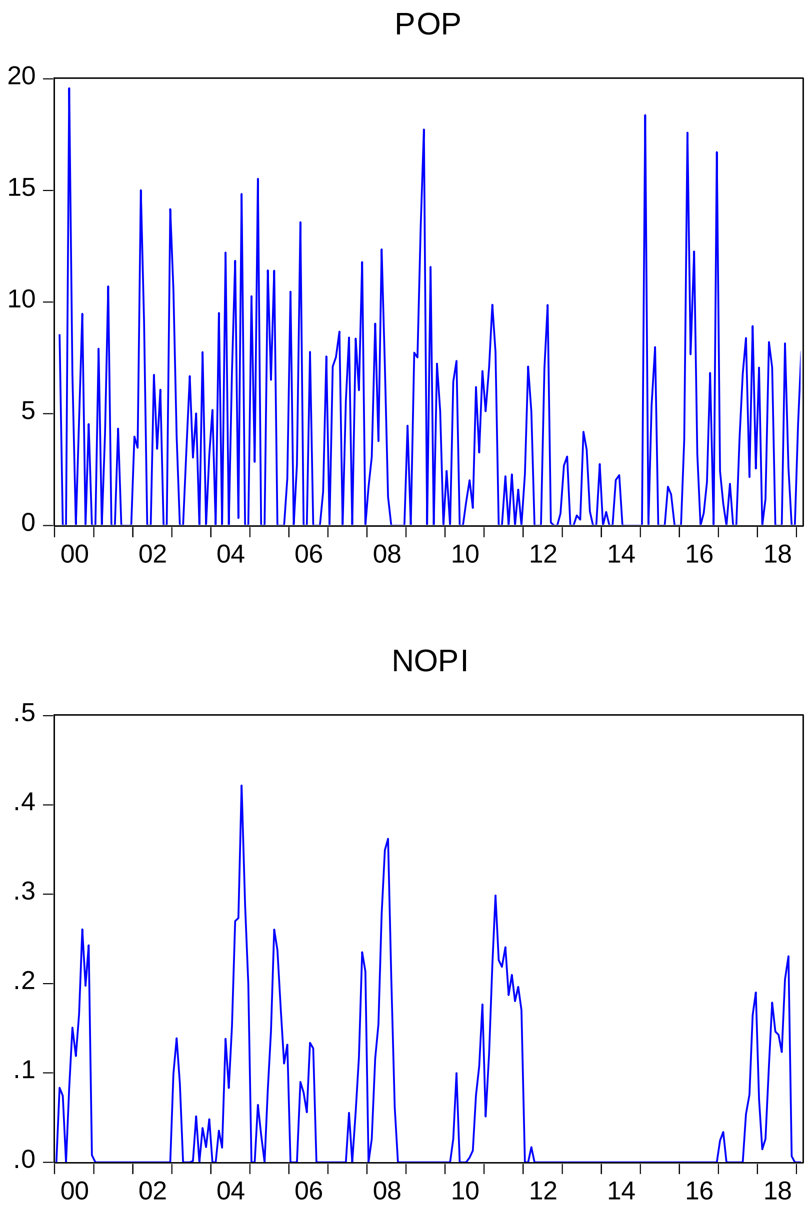

Figure 8: Positive oil price (POP) and Net oil price increases

Mork’s price is in the upper panel and the NOPI is shown below. These graphs look different based on how the variables were modeled. Hamilton argued that since positive price changes focus on every increase in price; it will overstate the degree of oil price movements (Jennie et al, 1997).

There are major distinctions between both graphs. The periods where the NOPI differs from the POP are associated with the energy crisis in 2001, the great recession of 2008-2009, 2012 recession in the Europe, the oil price steep drop in 2014 to 2016. According to NOPI specification by Hamilton, oil price only started increasing significantly again after 2016. Mork's approach considers every positive change in oil price even when these prices are subsequent to substantial decrease in oil price.

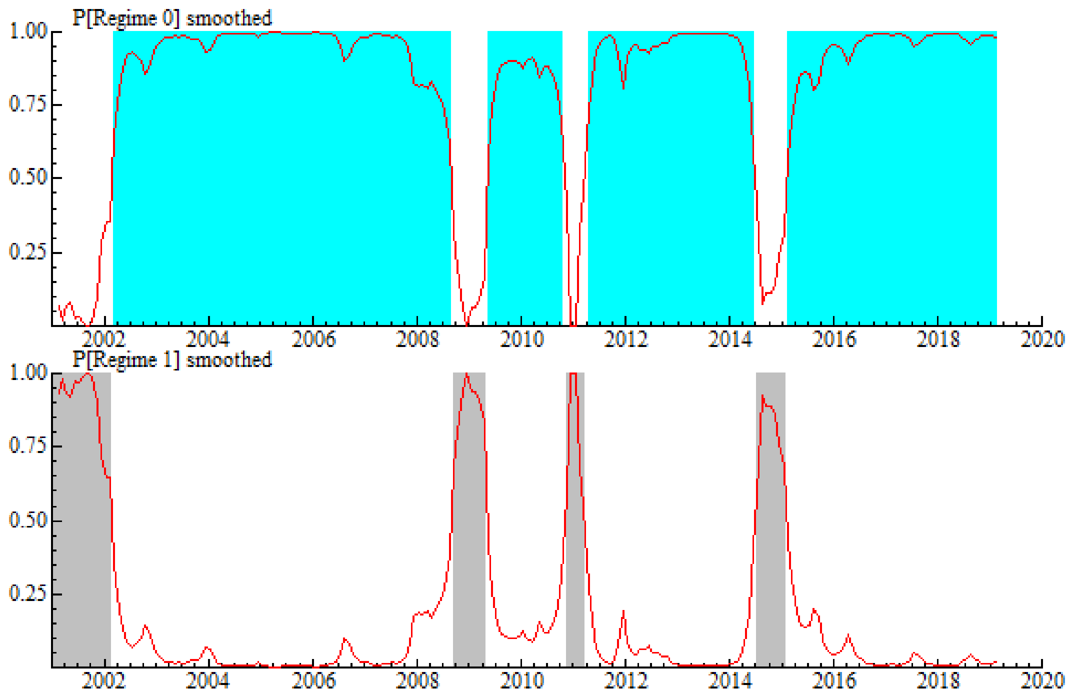

Figure 9: Smoothed regime probabilities of MS(2) model for NOPI at lag 6

Chapter 6

CONCLUSION AND FINDINGS

6.1 Conclusion

The objective of this paper is to investigate how oil price movements affect Hungary's economic activity over the monthly span of 2000:01 to 2019:02. Oil is an important commodity in commodities market and it also has the highest trade volume globally, hence oil is a very essential commodity in the world. Oil price has also been a source of economic fluctuations due to its unpredictable behavior (Kim 1992). The Brent crude oil price accounts for movements in oil prices and industrial production index represents economic activity. To this end, we employed a Markov switching model (MS).

Through empirical findings, we established that changes in economy of Hungary is linked with fluctuations in oil price. Empirical findings prove that oil price changes and the growth in economy of Hungary are negatively related in the recessionary regime. From an empirical standpoint, a good number of economic research also discovered that hikes in price of oil dampens output (see Huntington 1998, Hampton 1990, Hooker 1996, Mork 1989). Furthermore, although oil-price movements and economic activities are inversely related, however, empirical results confirm that this effect does not immediately slow down economic growth until the fourth quarter. The delayed outcome is mainly because of the crude oil reserve of Hungary and supply contracts. These supply contracts typically protect them from any immediate effect associated with unforeseen oil price increases until the expiration of such contract, typically one year or more.

Furthermore, due to substantial oil price changes over the years which has resulted in significant rise in volatility associated with price of oil, made volatility an important variable to be considered in this investigation. Empirical findings suggest that oil-price volatility contracts economic activity in the expansionary phase. Unlike oil price changes that has a lagged reaction, volatility affects output immediately. Oil price volatility over the last two decades have gained more grounds and its effects has become even more vital in the economic activity than oil price level. An environment with high volatility is likely to minimize the effect of oil price returns since it lessens the shock. According to Raphael and Shimon (2003), rising volatilities create market uncertainties that will prompt investors and businesses to postpone their investments (decline in business confidence).

Accordingly, we investigate asymmetric effect of oil price by employing the two specifications. Based on our empirical result, we found that for Mork's asymmetric specification, positive oil price does not have a significant effect on output. However, negative oil price leads to economic expansion and it's statistically different from zero with a coefficient of 0.16 at lag 6. However, net oil price increases based on Hamilton's specification induce an economic downturn substantially by 11.7% semi-annually. By and large, our results imply that declines and increases in oil prices impact economic activity of Hungary differently and these findings are supportive of other empirical results in the literature.

REFERENCES

Ahmed, S. M. (2016). The impact of oil prices on the economic growth and development in the MENA countries. *Middle East Economic Association. Paper*, (89073).

Asab, N. A. (2017). Asymmetric Oil Price Shocks and Economic Activity in Developing Oil-importing Economies: The Case of Jordan. *International Journal of Economics and Financial Issues*, *7*(2), 118-124.

Bal, D. P., & Rath, B. N. (2015). Nonlinear causality between crude oil price and exchange rate: A comparative study of China and India. *Energy Economics*, *51*, 149-156.

Baumeister, C., & Kilian, L. (2016). Forty years of oil price fluctuations: Why the price of oil may still surprise us. *Journal of Economic Perspectives*, *30*(1), 139-60.

Ceic (2019, July). Data report on four main macroeconomic sectors. Retrieved from https://info.ceicdata.com/our-insights-reports-economic-snapshot-q2-reports

Charfeddine, L., Klein, T., & Walther, T. (2018). Oil price changes and US Real GDP growth: Is this time different?. *University of St. Gallen*, *School of Finance Research Paper*, (2018/18).

Cunado, J., & De Gracia, F. P. (2005). Oil prices, economic activity and inflation: evidence for some Asian countries. *The Quarterly Review of Economics and Finance*, *45*(1), 65-83.

Davies, R. B. (1987). Hypothesis testing when a nuisance parameter is present only under the alternative. *Biometrika*, *74*(1), 33-43.

Davig, T., Melek, N. Ç., Nie, J., Smith, A. L., & Tüzemen, D. (2015). Evaluating a year of oil price volatility. *Federal Reserve Bank of Kansas City, Economic Review*, *100*(3), 5-30.

Davis, S. J., & Haltiwanger, J. (2001). Sectoral job creation and destruction responses to oil price changes. *Journal of monetary economics*, *48*(3), 465-512.

Elder, J., & Serletis, A. (2010). Oil price uncertainty. *Journal of Money, Credit and Banking*, *42*(6), 1137-1159.

Enders, W. (2008). *Applied econometric time series*. John Wiley & Sons.

Engle, R. F., & Bollerslev, T. (1986). Modelling the persistence of conditional variances. *Econometric reviews*, *5*(1), 1-50.

European central bank report (2010). Maastrict Treaty conditions. Retrieved from https://sdw.ecb.europa.eu

Ferderer, J. P. (1996). Oil price volatility and the macroeconomy. *Journal of macroeconomics*, *18*(1), 1-26.

Hamilton, J. D. (1983). Oil and the macroeconomy since World War II. *Journal of political economy*, *91*(2), 228-248.

Hooker, M. A. (1996). What happened to the oil price-macroeconomy relationship?. *Journal of monetary Economics*, *38*(2), 195-213

Huntington, H. G. (2005). The economic consequences of higher crude oil prices. *Energy modeling special report*, *9*.

Huson Joher, A. A., & Mokhtarul, W. (2011, January). The role of oil price shock on macroeconomic activities: an SVAR approach to Malaysian economy and monetary responses. In *ICAE 2011: Proceedings of International Conference on Applied Energy* (pp. 605-618). [ACAE].

International energy agency report (2017, April) Energy consumption. Retrieved from https://www.iea.org

Ito, K. (2017). CO2 emissions, renewable and non-renewable energy consumption, and economic growth: Evidence from panel data for developing countries. *International Economics*, *151*, 1-6.

Jbir, R., & Zouari-Ghorbel, S. (2009). Recent oil price shock and Tunisian economy. *Energy Policy*, *37*(3), 1041-1051.

Jiménez-Rodríguez*, R., & Sánchez, M. (2005). Oil price shocks and real GDP growth: empirical evidence for some OECD countries. *Applied economics*, *37*(2), 201-228.

Kilian, L., & Sims, E. R. (2006). The effects of real gasoline prices on automobile demand: a structural analysis using micro data. *NBER Working Paper Series*.

Kilian, L. (2009). Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market. *American Economic Review*, *99*(3), 1053-69.

Kim, I. M., & Loungani, P. (1992). The role of energy in real business cycle models. *Journal of Monetary Economics*, *29*(2), 173-189.

Lee, K., Ni, S., & Ratti, R. A. (1995). Oil shocks and the macroeconomy: the role of price variability. *The Energy Journal*, 39-56.

Lee, K., & Ni, S. (2002). On the dynamic effects of oil price shocks: a study using industry level data. *Journal of Monetary economics*, *49*(4), 823-852.

Lilien, S., & Pastena, V. (1982). Determinants of intramethod choice in the oil and gas industry. *Journal of Accounting and Economics*, *4*(3), 145-170

Mork, K. A. (1989). Oil and the macroeconomy when prices go up and down: an extension of Hamilton's results. *Journal of political Economy*, *97*(3), 740-744.

Mork, K. A., Mysen, H. T., & Olsen, Ø. (1990). Business Cycles and Oil Price fluctuations: Some evidence for six OECD countries. In *Recent Modelling Approaches in Applied Energy Economics* (pp. 239-260). Springer, Dordrecht.

Organization for economic co-operation and development (2017) report. Retrieved from http://www.oecd.org/economy/growth/going-for-growth-2017/

Organization for economic co-operation and development (2018) report. Retrieved from https://www.oecd.org/unitedstates/publicationsdocuments/reports/

Park, J., & Ratti, R. A. (2008). Oil price shocks and stock markets in the US and 13 European countries. *Energy economics*, *30*(5), 2587-2608.

Ran, J., & Voon, J. P. (2012). Does oil price shock affect small open economies? Evidence from Hong Kong, Singapore, South Korea and Taiwan. *Applied Economics Letters*, *19*(16), 1599-1602.

Raymond, J. E., & Rich, R. W. (1997). Oil and the macroeconomy: A Markov state-switching approach. *Journal of Money, Credit, and banking*, 193-213.

Sadorsky, P. (1999). Oil price shocks and stock market activity. *Energy economics*, *21*(5), 449-469.

Sánchez, G. (2015, October). Introduction to Markov-switching regression models using the mswitch command. StataCorp. Retrieved from https://www.stata. com/meeting/spain15/abstracts/materials/spain15_sanchez. pdf.

Sauter, R., & Awerbuch, S. (2003). Oil price volatility and economic activity: a survey and literature review. *IEA research paper*, *28*, 550-577.

Zhang, X., Lai, K. K., & Wang, S. Y. (2008). A new approach for crude oil price analysis based on empirical mode decomposition. *Energy economics*, *30*(3), 905-918.

World energy outlook report on Energy production (2017, January). Retrieved from https://www.iea.org/reports/world-energy-outlook-2017