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Monetary policy of oil-exporting countries with informality: a DSGE analysis of Iraq

Master's thesis

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Year of the defence: 2023

Declaration

1. I hereby declare that I have compiled this thesis using the listed literature and resources only.
2. I hereby declare that my thesis has not been used to gain any other academic title.
3. I fully agree to my work being used for study and scientific purposes.

In Prague on Nour Safar

1st of August 2023

References

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Abstract

The thesis investigates the efficiency of monetary policy using the New Keynesian Dynamic Stochastic General Equilibrium (NKDSGE) model in an economy reliant on oil exports and a large informal sector. The model is calibrated for the Iraq case to capture macroeconomic variables' responses to oil price shocks. The study aims to explore the impact of the shock on macroeconomic variables in the presence of the informal sector and how responses might change assuming a small informal sector. The model shows that the informal economy increases home prices and inflation, but the model does not reveal a Dutch disease. The study concludes that monetary policy, represented by the Taylor rule, is an inefficient tool for affecting macroeconomic variables.

Keywords

DSGE of Iraq, Monetary policy in Iraq, Informality in Iraq

Title

Monetary policy of oil-exporting countries with informality: a DSGE analysis of Iraq

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List of Abbreviations

GDP: Gross Domestic Production

(DSGE): Dynamic Stochastic General Equilibrium

(IRFs): Impulse responses functions

(FDI): foreign direct investment

(CPI): Consumer Price Index

(NKM): New Keynesian model

(CBI): Central Bank of Iraq

(UNESCO): United Nations Educational, Scientific and Cultural Organization:

(RBC): Real Business Cycle

(CMM): Classical Monetary Model

(SOE): small open economy

(UIP): Uncovered interest rate parity

(RER): Real Exchange rate

(NKPC): New Keynesian Phillips curve for Formal sector

(IMF): International Monetary Fund

(FRR): Financial Reserves revenues

(ROW): Rest of the World

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1 - Introduction:

Oil-exporting economies are often associated with terms like Dutch disease, resource curse, and mono-economy, but these economies differ due to economic effects and resource usage. Due to this, other factors play an important role in shaping macroeconomic variables.

While the blessing of natural resources principally should be the primary factor in improving the economy by increasing government spending and government revenues from resource exports, in some cases the opposite occurs, resulting in what is known as the Resource Curse Theory, in which resources "strengthen the role of noneconomic factors to justify low economic growth, try to provide reasons for lower economic growth, and hence the higher inflation rate in oil-rich countries in comparison with countries having no natural resources in the recent decades", (Abounoori et al., 2014, P 664). Of course, these effects differ between developed and developing countries; thus, the majority of economic indicators in oil-exporting emerging countries depend on oil, such as economic activity, fiscal revenue, revenues from oil exports, and the exchange rate. Consequentially, private sector competition is limited among these countries due to the limited size and role of the private sector and a decline in employment opportunities in non-oil sectors. Private sector growth is hampered by the government's and public sector's roles in terms of providing fundamental necessities and the ability to use oil revenues for government spending. (IMF report, 2016).

On the other hand, Dutch disease is a term that originated in the Netherlands when gas was discovered in the North Sea in the 1960s. Basically, it featured two points. First, the appreciation of domestic currency from gas exports made it difficult for the manufacturing sector to compete on international markets. The non-oil export sector declined due to effect of spending and movement of resources thus the production factors such as capital and labour shift from industry production to oil sector to non-oil sector are mobile, capital and labor will shift from the industrial and service sectors, this resulting in deindustrialization. (Benkhodja, 2014). A mono economy is when a single product is relied on for economic development.

Emerging economies are characterized by the existence of an informal sector as well. Many researchers define the informal economy as small producers and employees, including the self-employed and individuals who work from home. In addition, informal activities are not included in the economy's GDP. (Looney, 2005).

The economic models concerned with the oil export sector, along with the presence of the informal feature, make it different from the standard models in the literature. According to Ahmed and others, an emerging economy – such Iraq for example - is enjoying strength Informal sector compared to developed countries because emerging economies have a unique character.

This thesis examines the efficiency of monetary policy by using Dynamic Stochastic General Equilibrium (DSGE) model in an economy that is entirely dependent on oil exports and has a relatively large informal sector. The model is calibrated for Iraq to capture the responses of macroeconomic variables to the oil price shock and its effects on the entire economy. We want to explore the impact of the oil price shock on macroeconomic variables in the presence of the informal sector and how the responses might change assuming a small informal sector while keeping the rest of the variables the same. For this purpose, the model is linear around its steady state, and using Dynare software in the MATLAB environment, impulsive response functions (IRFs) give simulations to explain the results.

The informal sector exists in all sectors of the economy, beginning with informal consumer goods and informal production firms, whose inputs into production depend on labor alone, in addition to the informal wages and labor supply represented in the model. As far as we know, this thesis is the first attempt to find that simulated shocks to the economy have these two characteristics.

The thesis is organized as follows: the next chapter outlines a review of the literature, which focused on emerging oil-exporting economies in relation to oil price shocks and the role of monetary policy in these economies; Other papers have examined the impacts of existing of informality in emerging economies.

The third chapter provides some condensed information about the Iraqi economy after 2003, including information about the oil economy, the reality of Iraq's monetary policy as represented by the Central Bank of Iraq, and an overview of the informal economy, in addition to a definition of DSGE models and New Keynesian models. Chapter 4 deals with the theoretical model; it begins with the household sector by including the home and foreign goods that are consumed in the economy, then shows the Rest of the World (ROW) as representing the Real exchange rate and inflation. The model is closed by government authorities representing monetary and fiscal policies, and lastly, market clearing conditions are provided. Calibration, Simulation, and results appear in Chapter 5, with the conclusion.

2 - Literature review:

In the following we present the works that employed DSGE models to study oil exporting nations and others focused on the informal sector, especially in emerging economies, and their effects on macroeconomic variables and how monetary policy could react to different shocks.

Starting with the model by Medina and Soto (2005), they used the DSGE model to study monetary policy using the Taylor rule in the Chilean economy. They found that oil price shocks reduce output and increase inflation, with contractionary effects due to endogenous monetary tightening. They found that CPI and core inflation policies are similar, and if the central bank's inflation stabilizes, production will fall. An extension to this model, Tchoketch Kebir, H. (2022), investigates the macroeconomic effect of oil shock in the Algerian economy as oil dependence. It was found that changes in international oil prices make oil-dependent economies vulnerable, affecting GDP, inflation, and interest rates, and that export sector diversification is needed.

One of the most important academic papers for our study and holding many features for the oil emerging economy is the model built by Oladunni, S. (2020), which is the New Keynesian Small Open Economy. The DSGE model identifies structural conditions in net oil-exporting developing and emerging economies that make them more susceptible to adverse external events. Negative oil price shocks cause macroeconomic reactions, with oil output, income, government revenue, and consumption falling. Optimal monetary policy exercises result in the greatest welfare gain from stabilizing oil inflation. Addressing supply-side problems and structural deficiencies requires improving domestic productivity, establishing proper linkages, fiscal rules, strong monetary-fiscal policy coordination, and re-calibration to achieve diversification and self-sufficiency in critical sectors.

Regarding studying the optimal monetary policy of an oil-exporting economy Ferreros and Seneca (2018) used the New Keynesian Model (NKM). They found that a central bank may raise interest rates to stabilize inflation, but this may deepen the domestic recession further. The study highlights the importance of considering both factors when determining monetary policy in resource-rich economies.

Mukhamediyev (2014) analyzed oil price fluctuations affecting both oil-importing and oil-producing countries. Increasing oil prices boost many areas of Kazakhstan's economy, including production, trade, interest rates, inflation, consumption, and exchange rates. Conversely, opposite changes are observed for oil production, total employment, and real wages. The study highlights the impact of oil shocks on a small, open oil-exporting economy.

Regarding the Iraq case, which is the main goal of this thesis, there are two papers that study monetary policy efficiency using DSGE models: the first one is by Al-Shammari and Al-Salem (2022), The study examines Iraq’s monetary policies and oil

shocks using the DSGE model and reveals that Iraq's economy suffers from oil exports and rent, but monetary policy mitigates and benefits from these shocks. Negative monetary shocks and government spending affect GDP growth and investment. The impulse response graph shows that government expenditure is good, investment is poor, money supply is poor, and household consumption matches GP, indicating Iraq's dependency on the government and lack of a private sector.

The second paper, which is in Arabic, by Mohi S. R., Daghir M., and Salih L. (2022) This research examined Iraqi macroeconomics and monetary policy using Bayesian estimation of Iraqi data from a DSGE model by Smets, F., and Wouters, R. (2007). The study examines influence transmission and its effects via a number of monetary authority mechanisms and Iraqi monetary policy transmission to macroeconomic variables. The nominal fixed exchange rate through the foreign currency selling window illustrates inflation targeting. The Iraqi economy's financial shallowness, separation of monetary and real behavior, and lack of attention to potential production (natural unemployment rate) contributed to its fragility; hence, the exchange rate is employed as a nominal constant. The window of selling foreign money to regulate liquidity and sterilize Iraq's macroeconomic management partners' reckless economic actions.

While the papers before looked at oil shocks in the DSGE model, the papers in following look at the informal economy in developing countries and how it affects the macroeconomic variables. Begging with the closest model which studies oil price shock and informal sector by Haider et al. (2012), the paper presents a two-bloc open economy DSGE model that incorporates informal labor and production sectors, enhancing exposure to internal and external shocks in developing economies. Nine internal and seven external events are accounted for in the model. It evaluates the model's performance using conventional measures and calibrates it using data from the Pakistani economy as a benchmark. The learning and determinacy analysis suggests monetary authorities in developing economies should follow the Taylor principle and consider exchange rate fluctuations. The model can be extended to include banking and non-banking financial sectors to understand fiscal borrowing dynamics and their impact on monetary expansion and inflation. In addition, the study examines the dynamic effects of an international oil price shock on endogenous variables. The shock impacts on the marginal costs of formal and informal sector production, leading to inflation and a decrease in output and consumption. This leads to a decrease in domestic consumption, a decrease in demand for goods, and a substitution effect. The shock also increases the cost of firms producing these goods, leading to a depreciation in exchange rates and a tightening of policy interest rates. The study finds that both monetary policy specifications generate similar responses, with more adverse consequences observed in endogenous variables.

In closed economy model for Pakistan's informal sector, Ahmed et al. (2012) presents a general equilibrium in three shocks. The model performs well for private

investment but less for consumption. However, per capita consumption data and household surveys do not match, so empirical claims on consumption should be considered. The impulse responses to shocks are theoretically sound, with strong crowding-out effects on private investment and weak spillover effects on the informal economy. Two important extensions are sought: theoretical, involving micro-founding consumption and labor supply decisions, and empirical, developing quarterly time series of relevant macro variables for short-term policy analysis. One year later, they provided the estimation data by Bayesian approach of same model.

Lahcen's (2014) thesis looks at how macroeconomic features in developing economies with large informal sector, affect the response of the economy to shocks. By using Bayesian estimation for Moroccan data applied in the New Keynesian Small Open Economy (DSGE) model, which includes multiple sectors with monopolistic competition, nominal rigidity in prices, and a fixed exchange regime. The results show weaker price rigidities in the non-tradables sector and a more aggressive central bank reaction to inflationary pressures. The informal sector plays a shock-absorbing role for productivity shocks and pleads to exclude imported inflation from the inflation target.

By using Bayesian estimation data approach, Adu, O., Alege, P., and Olurinola, O. (2020) This study focuses on the informal economy's role in Nigeria's macroeconomic policy decisions and aggregates. It uses a NK-DSGE model to model the informal economy's behavior in the labor market and goods and services markets. The results show that macroeconomic policy is ineffective in an economy with a substantial informal economy. The study recommends implementing market-friendly policies to limit the informal economy's impact on the domestic economy. These policies encourage informal enterprises to register and pay taxes, ultimately boosting government revenues.

Lastly, Alberola and Urrutia (2020) found that informality is a crucial structural component in developing market economies, influencing labor market behavior, access to financial resources, and economic productivity. They built a closed economy model with nominal rigidities, labor and financial frictions, and endogenous informal workers. Informality mitigates demand and financial shocks but amplifies technological shocks. It also increases sacrifice in monetary policy activities. Understanding the model's outcomes requires adaptability, such as buffering salaries and credit cost pathways. Further reforms are needed to handle exchange rate fluctuations, external funding, and differential pay rigidities between official and informal sectors.

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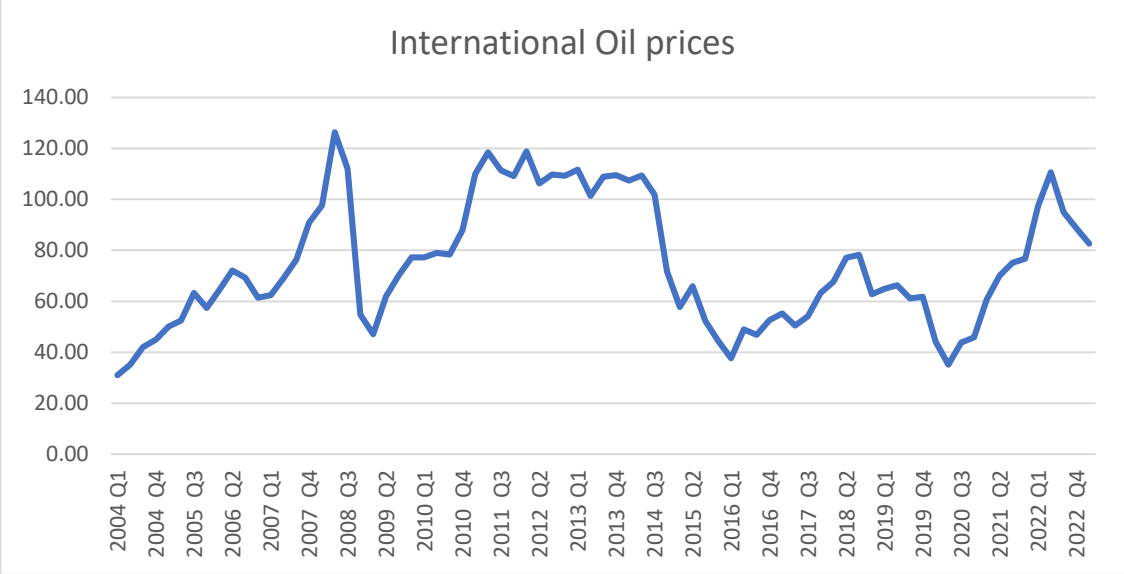
3 - An overview of the Iraqi economy after 2003, the Central Bank of Iraq, and the informal economy in Iraq

3.1 An overview of the Iraqi economy after 2003

After the collapse of the previous regime in March 2003, Iraq began a new era, which was accompanied by a new economic system and challenges related to the Central Bank of Iraq's tools under the mono-economy. As a result, international reserves play an important role in the macroeconomic stabilization of Iraq, which stabilizes the Dinar currency exchange rate and the inflation rate.

Iraq is considered an oil-exporting emerging mono-economy, according to "Iraq is one of the most oil-dependent countries in the world. Over the last decade, oil revenues have accounted for more than 99% of exports, 85% of the government's budget, and 42% of gross domestic product (GDP)" (The World Bank Website, 2022).

Figure 1: Quarterly data of International Brent crude oil prices since 2004[1]



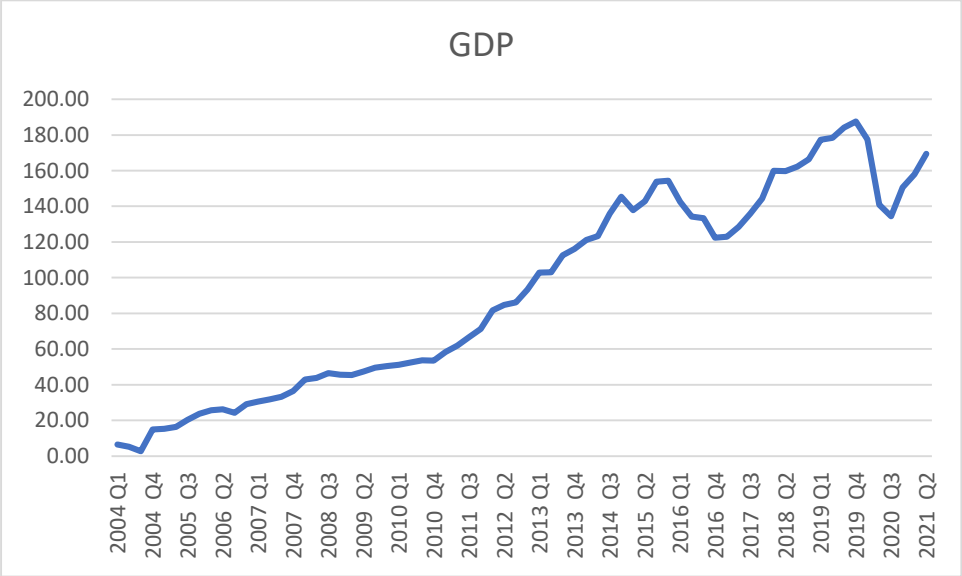
Resources in general in Iraq are not limited to oil, according to Iraq Economic Monitor report (2021), Iraq's resources include natural gas, as it has the thirteenth largest untapped natural gas reserves in the world due to its underdeveloped infrastructure and the fifth largest proven crude oil reserves in the world. These oil revenues, which represent foreign reserves, should be used to develop the non-oil sector of the economy, as they can be used to increase foreign investment, as there is a positive relationship between them (Bani Lam and Hammoud, 2021).

1 – The graph is generated from adjusted quarterly data of international Brent oil price monthly data, the data is provided in the Trading Economic website: https://tradingeconomics.com/commodity/brent-crude-oil

The negative effects resulting from Iraq's heavy dependence on oil exports have made the economy vulnerable to changing global oil prices, specifically the price of Brent crude - which is determined by non-national factors - to have the greatest impact on oil exports to all parts of the country. The country, and even the less affluent parts like the Kurdistan Regional Government, and the fact that the increase in Iraq's total GDP since 2003 has only stemmed from the oil sector. (Aidan, 2022).

Obviously from Figure 2 below, GDP since 2003 has increased, the most important two declines, the first one took place in between mid-2014 and early 2016, which decreased up to 70 percent (Stocker et al., 2018) , that negative oil price shock accompanied with increasing of government spending on military expenditures to fight the terrorism, and the second one in 2020 as a consequence of Covid-19 crisis, these two declines affected the Iraqi GDP negatively.

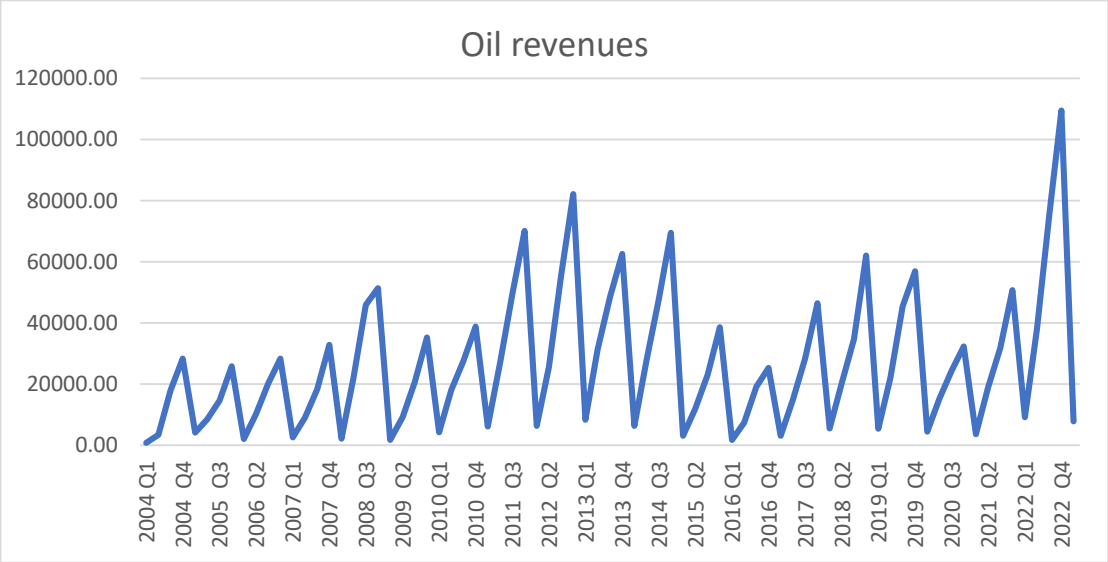
Figure 2: GDP of Iraq since 2004 depending on quarterly data[٢]



Intuitively, oil revenues are the most important economic factor in Iraq, which constitutes "about two-thirds of Iraq's GDP and for almost all export and fiscal revenues." (Nasr et al, 2012, p. 5), up to 95% of the financial revenues

2 - GDP of Iraq is shown by Dollar prices, the data are adjusted to be quarterly instead of monthly, the data are available on https://www.statista.com/statistics/326979/gross-domestic-product-gdp-in-./iraq

Figure 3: Oil revenues from exporting crude oil in Iraq depending on quarterly data[٣]



The macroeconomic effects of such an economy share features with oil-exporting emerging economies such as a small private sector and a weak employment sector; even with the high public employment rate, "the combined sectors of manufacturing and agriculture constitute less than 6 percent of GDP," (Iraq Economic Monitor, 2021, p. xi). The report of the Economic Monitor in Iraq states as well that "The contraction in non-oil sectors caused disruptions to employment, increased job losses" (Iraq Economic Monitor, 2021, p 2). While the investment is still at low levels of foreign direct investment (FDI), especially outside the energy sector, the hard environment in socio-political situations such as violent conflicts, poor business environments, and an underdeveloped financial sector

While many economists consider that Iraq suffers from Dutch disease, others go in the opposite direction which is "such analysis does not apply to Iraq, or indeed to the conflicts of any of the world's developing oil-exporting countries and leads to erroneous conclusions about the country's exchange rate." (Fattah, 2020)

3.2 Central Bank of Iraq (CBI)

Although CBI is a part of the executive authority in Iraq, but the Iraqi law gives it the decision independence. According to (Central Bank of Iraq: ANNEXA) Article (2) states mandate autonomous, accountable CBI, The Central Bank's independence ensures economic stability and potential intervention to meet financing needs, but

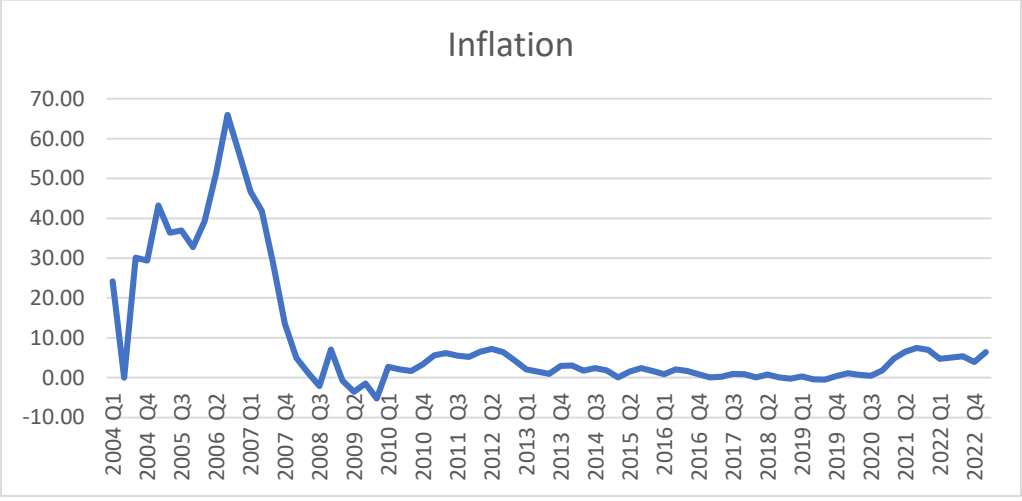
[٣] Oil revenues data are represented quarterly dollars after multiplied the oil revenues by Dinar in the exchange rate for each period, data of oil revenues in Iraqi Dinar is available on https://www.cbiraq.org/SeriesChart.aspx?TseriesID=422.

economically the increasing in independence of CBI "increased independence of the central bank does not necessarily lead to lower rates of inflation because monetary policies cannot guarantee the delivery of lower inflation on their own". (Ashoor et al., 2021, p. 14)

The main objectives of CBI as mentioned in Article 3 in CBI law is "achieve and maintain domestic price stability and to foster and maintain a stable and competitive market-based financial system. Subject to these objectives, the CBI shall also promote sustainable growth, employment, and prosperity in Iraq." (Central Bank of Iraq: ANNEXA, p.9). Implementing monetary policies related to exchange rates and holding official foreign reserves are functions mentioned in Article 4, in addition to other policies that help achieve the goals, such as legal reserves and Open market operations.

The main two tools that play an important role in shaping the policy are the foreign currency sale window and Treasury transfer auctions. While the latter is represented by the local debt by using bonds and is used by the Finance Ministry, the former is used by the Central Bank to control the money supply by selling and buying dollars. Through this tool, the CBI can achieve its aims, especially inflation targeting, in a direct way rather than through the transmission mechanism in normal standard monetary tools. This monetary policy system had a good and efficient role for the interest rate tool when it was raised to control inflation. This was the MP's success in the period after 2006, when inflation reached 53% and then fell to 2.8% in 2008. Even with this monetary policy regime, the Central Bank of Iraq has limited control over the price stability of the economy due to "real structural imbalances in the field of industry and investment and local markets, such as the labor market and the market for goods and services" (Khalaf et al., 2021, p.9).

Figure 4: CPI inflation of Iraq since 2004 depending on quarter data[4].



[4] Inflation data is available on the website of Central bank of Iraq on https://www.cbiraq.org/SeriesChart.aspx?TseriesID=422.

In 2022, consumer price inflation is still high due to increasing demand and foreign goods prices, and the economy still depends on cash-based transactions. "The currency in circulation remains the vast majority of broad money, the share of which has risen in contrast to the share of deposits". (Iraq Economic Monitor, 2022, p.10) This makes money supply an internal variable that interacts negatively with fiscal policy, which has a negative effect on the economy, (Nasr et al ,2012).

Other factors can affect economic growth outside of the Central Bank of Iraq; however, the political situation in Iraq plays a significant role in making economic reforms impossible. "The Iraq experience has repeatedly demonstrated that oil prices and reform drives are inversely related." This evidence in Iraqi appeared when "governments launched reforms under the pressure of low oil prices and the need for fiscal consolidation." (Iraq Economic Monitor,2021, p. xi), Iraq does not have sovereign wealth funds like other oil-exporting nations, which would help avoid the effects of oil price drops. "This has not only resulted in temporary budgetary issues for Iraq, but it has also allowed serious economic challenges to become ingrained in the country's political and social structures." (Baraka, 2020, p. 7) Although taxes have increased in recent years, their contribution to public revenues has been ineffective, a factor that contributes to the difficulty in collecting taxes due to a lack of security and an unstable political climate, Hassan, (Baraka, 2020).

3.3 Informal economy in Iraq:

Regarding Ahmed et al. (2012), some of the common features of emerging economies include existence of a large informal sector, small open economies vulnerable to external shocks, Weak Financial sector, and Weak economic and political institutions.

These characteristics are compatible with the financial sector of Iraq, which is characterized as underdeveloped, with the weak capital of operating companies in the Iraqi financial system limiting financial intermediation. The low levels of capital in market intermediaries limit the market's ability to meet the needs of investors seeking to purchase or sell securities. Weaknesses in company law, high levels of state ownership in banks and insurance companies, and poor interest rates and loan structures.

According to the UNESCO report in 2019, approximately two-thirds of all workers are employed in the informal sector, which accounts for approximately one-third of non-oil GDP and the majority of the private sector in Iraq. The majority of informal sector workers are young and less educated than those in the formal sector; therefore, the model assumes that the formal sector wage is higher than the informal sector wage, as in the Pakistan paper. The areas of informality in Iraq are in the food sector, clothing, street vendors, phone selling, and others. In addition, formal work includes informal workers, especially seasonal workers who get paid by cash in hand. "Technological factors Informal sector activities are generally low-technology activities." (UNESCO report,2019, p. 13).

Another manifestation of the informal sector is the desire to keep cash to hand for several reasons. On the one hand, "formal financial inclusion is low in Iraq as the population shows a strong preference for cash, partly due to a general distrust of the banking sector after decades of instability in the financial sector, when private deposits were lost and not reimbursed, and 'local traders' are also involved in informal financing. Shopkeepers and merchants who do not extend credit to customers receive lower daily habits than those who do." (International labour organization report, p.5) On the other hand, informal activities use cash in transactions. (Ahmed et al.,2012) report that these activities are represented in Iraq by individuals and families who need debt to meet all their needs, and this debt is done in most cases by informal borrowing (International labour organization report).

In addition, there is no tradeoff between informality and unemployment; it is just a matter of policy. The informal sector is identical to the formal sector in terms of the kind of product and the inefficiencies of the labor market, (Charlot et al., 2015).

3.4 An overview Dynamic Stochastic General Equilibrium models

This section presents an overview of DSGE models, drawing on the book by Gal, J. (2015), where dynamic stochastic general equilibrium (DSGE) models are used in the economic literature to study aggregated macroeconomic phenomena, most commonly the effects of monetary and fiscal policies on economic growth. These models are derived from microeconomic principles, which contrast with traditional macroeconomic models. As a consequence, the DSGE models are not subject to Luca's criticism in this particular case, as stated in his 1976 paper, as well as the work of Kydland and Prescott (1977), which was the starting point for the emergence of DSGE.

Research publication by Robert Emerson Lucas, Lucas, and RJ (1976) argued that it is not possible to predict the effects of economic policy based on historical data collected about economic change because the parameters of those models are not structural, and instead we must use deep parameters regarding preferences, technology, and individual behavior. To quote Lucas, "Given that the structure of an econometric model consists of optimal decision rules for economic agents and that optimal decision rules vary systematically with changes in the structure of series relevant to the decision maker, it follows that any change in policy will systematically alter the structure of econometric models" (Lucas J,1976).

Two schools of DSGE models emerged: the Real Business Cycle (RBC) and the New Keynesian Model (NKM), First, the real business cycle (RBC) theory beyond the papers of Kydland and Prescott (1982) and Prescott (1986) provided the basic framework for the macroeconomic study of changes in the economy. These derivatives lead to optimal solutions for economic variables such as consumption in the form of Euler's equation, labor supply, real money balance, and marginal cost,

among others. The behavioral equations in the RBC models are replaced by first-order terms for the time problems of consumers and firms. In addition, RBC focused on the quantitative components of the model evaluation process, such as calibration and simulation. This was done in order to obtain a more accurate assessment. In contrast to the traditional Keynesian theory of Keynes (1936), who believed that recessions could be resolved through economic policies aimed at increasing aggregate demand, the RBC states that cyclical fluctuations are not necessarily an indication of an inefficient allocation of resources.

which matches the results of the RBC model. However, as a result of RBC's inability to provide an explanation for changes in the economy that are not caused by monetary variables, RBC either plays no function at all for central banks or plays an unlimited role. This is one of the drawbacks of RBCs. As a result of this deficiency, attempts by Cooley and Hansen (1989) to integrate monetary aspects into RBC theory led to the creation of the Classical Monetary Model (CMM), which predicts the neutrality of monetary policy with respect to real variables. This model was developed as a result of their efforts.

On the other hand, according to (Walsh, 2010), neo-Keynesian models are used to capture the relationship between monetary policy, inflation, and the business cycle, and the name Keynesian came from the development of older versions of traditional Keynesian models in which aggregate demand plays a central role in determining output in the short run.
New Keynesian models share similarities with RBC models, including the hypothesis of benefit maximization of consumption and leisure for individuals and similar technology for firms affected by external stochastic shifts. and the balance of internal variables compatible with household, business, and market clearing decisions. The basic principles of the NKM, which emerged in the 1970s and 1980s, are as follows: first, monopolistic competition, which gives the power to set commodity prices and wages to the private sector and does not derive from Walrasian law; second, nominal inertia, which imposes constraints on firms and workers in terms of adjusting the prices; and third, the lack of neutrality of monetary policy in the short term, as changes in short-term nominal interest rates affect real interest rates, which in turn affect consumption, investment, and employment.
In macroeconomics, the use of MP is the most important factor. Changes in the interest rate can influence the financial assets, consumption, and investment decisions of both individuals and firms through the transfer mechanism. Therefore, it is necessary to focus on the interest rates of the most influential central banks around the world, where they do not change interest rates arbitrarily or capriciously.

4 The theoretical model

4.1 Model outline

The model is inspired by different works that focus on exporting oil and the informal sector in the economy. The academic papers studied the oil exporting economies such as Medina and Soto (2005), Oladunni (2020), and Omotosho (2019), and other works on informality with SOE (Lahcen, 2014), and closed economies such as Ahmed et al. (2012) and Adu et al. (2020). In addition to the main work that most DSGE model papers depend on, which is the work of Gali and Monacelli (2005), the model was adjusted to be in line with the case of the Iraq economy.

The model is built of two-sector for a small open economy (SOE) which depends on crude oil for export, the household sector consumes home goods CH which are non-tradable formal CF and informal goods CI, and consumes foreign imported goods Cf which are refined import oil CO and non-oil import goods CC, on the other hand, firms sector constitutes from oil firms which produce crude oil that is entirely destined for export and the oil prices are determined in the perfect competitiveness international markets, formal and informal non-tradable production firms producing goods that are consumed domestically, in addition to the governmental authority which is represented by the monetary authority and fiscal authority. The model interacts with the foreign economy by the exporting and importing sectors.

The non-tradable formal firms are featured in price stickiness following the Calvo, (1983), "The pricing system for the oil firm is such that it is a price taker in a dollar pricing world. Therefore, oil price is taken as given and typically, the firm makes zero profit." (Oladunni,2020, p .6), also the law of one price is considered for refined oil imported goods, in addition to a complete pass-through of the exchange rate.

Capital is not included in this model as in (Oladunni,2020) , following McCallum and Nelson (1999), who showed that, there is little relationship between the capital stock and output at business cycle frequencies Endogenous capital stock dynamics play a key role in equilibrium business cycle models in the real business cycle tradition, but as Cogley and Nason (1995) showed, the response of investment and the capital stock to productivity shocks actually contributes little to the dynamics implied by such models, (Walsh, 2010, P:330).

4.2 Households:

Households maximize the following inter-temporal function.

$$E_0 \sum_{t=0}^{\infty} \beta^t \, U(C_t, M_t, N_t)$$

Where:

$\beta^t \in [0,1]$: $inter - temporal\ factor\ realted\ to\ time\ preferences.$

E_0: $expectation\ opreator$

N_t: $Total\ hours\ number\ of\ working\ in\ economy.$

C_t: $Consumption.$

M_t: $money\ balance$

$$max_{C,N,M} = E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} + \frac{(m_t/P_t)^{1-v}}{1-v} - \frac{N_t^{1+\vartheta}}{1+\vartheta} \right]$$

Subject to the budget constraint

$$P_t C_t + (Q_t B_{t+1}) + m_{t+1} \leq E_{t+1} B_t + W_t N_t + E_{t+1} m_t + D_t + T_t$$

$\boldsymbol{\sigma} \geq \mathbf{0}$ degree of relative risk aversion, it lagrangian the curvature of the utility of consumption

$\vartheta \geq 0$ disutility of labor, inverse of the Frisch elasticity of labor supply

The Frisch elasticity of labor supply is the elasticity of hours worked to the wage rate; it captures the substitution effect in the wage rate on labor supply.

$\boldsymbol{v}$: $inverse\ elasticity\ of\ substitution\ between\ consumption\ and\ real\ balances$

Also, the higher the risk aversion leads to higher the role of money on output, in addition leading to stronger the smoothing of the interest rate, this reflects probably the central bank's objective not to agitate markets (Benchimol, 2018).

And transversality condition: which make household not bonds for infinity, so they cannot repay.

$$\lim_{T\to\infty}[m_{T+1} + B_{T+1}] = 0$$

$\boldsymbol{\beta^t} \in [0,1]: inter - temporal\ factor\ realted\ to\ time\ preferences.$

$\boldsymbol{E_0}: expe'tation\ opreator$

$\boldsymbol{N_t}: Total\ hour\ number\ of\ worked\ in\ economy.$

$C_t: Consumption.$

$M_t: money\ real\ balance$

$B_{t+1}: Quantity\ of\ one$
$- period\ nominally\ riskless\ discount\ bounds\ purchased\ in\ period\ t\ and\ maturing\ in\ period\ t$
$+ P_t: general\ price\ index\ of\ consumption\ goods$

$Q_t: price\ of\ Zero - copon\ bonds$

T_t: sum − lump taxes

Optimizing household utility is given by the lagrangian method.

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} + \frac{(m_{t+1}/P_t)^{1-v}}{1-v} - \frac{N_t^{1+\vartheta}}{1+\vartheta}\right] - \lambda(P_t C_t + Q_t B_{t+1} + m_{t+1} - E_{t+1}B_t - D_t - W_t N_t - E_{t+1}m_t$$

Where λ: is Lagrangian multiplier

By applying First-order conditions (Appendix), we get:

$$-\frac{U_{n,t}}{U_{c,t}} = \frac{W_t}{P_t}$$

$which\ is\ the\ marginal\ rate\ of\ substitution\ between\ consumption\ and\ labor\ is\ equal\ to\ real\ wage$

$$Q_t = \beta^t E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{1}{\pi_{t+1}}\right)\right]$$

$which\ is\ Euler\ equation$

The Euler equation states that households must be indifferent between consuming some more and saving some more at an optimum. Otherwise, households could increase utility by either consuming or saving some more (and therefore, they would not be in optimum).

The log-linearization of Euler equation:

$$\widehat{\boldsymbol{C}}_{\boldsymbol{t}} = \boldsymbol{\beta} \boldsymbol{E}_{\boldsymbol{t}}\left[\widehat{\boldsymbol{C}}_{\boldsymbol{t+1}}\right] + \frac{\mathbf{1}}{\boldsymbol{\sigma}}\left(-\widehat{\boldsymbol{R}}_{\boldsymbol{t}} + \boldsymbol{E}_{\boldsymbol{t}}[\widehat{\boldsymbol{\pi}_{\boldsymbol{t+1}}}]\right)$$

From the last two equations, one gets households intertemporal optimality conditions:

Which is labor supply:

$$\boldsymbol{N}^{\boldsymbol{\vartheta}} = \boldsymbol{C}_{\boldsymbol{t}}^{-\boldsymbol{\sigma}} \frac{\boldsymbol{W}_{\boldsymbol{t}}}{\boldsymbol{P}_{\boldsymbol{t}}}$$

While Bonds pay out 1 the period after the purchase at price Q_{t+1}Bonds yield is derived as (Appendix)*:*

$$Yeild\ of\ bond \cong \hat{R}_t$$

Which is nominal interest rate (Appendix)

where, the relation between price of bonds and nominal Interest rate is inverse*.*

$$Q_t = \frac{1}{R_t}$$

$\hat{R}_t$: $Interest\ rate$

$\boldsymbol{Q_t}$: $bond's\ price$

With increasing in Interest rate, this will increase the demand on bonds, which leads to decrease in the bond's price $\boldsymbol{Q_t}$

Real interest rate is given by Fisher Equation:

$$R_t = r_t E_t \pi_{t+1}$$

r_t: $real\ interest\ rate$

While the money demand is

$$\frac{m_{t+1}}{p_t} = C_t^{\frac{\sigma}{v}} (1 - Q_t)^{-\frac{1}{v}}$$

$\frac{m_{t+1}}{p_t}$: $Money\ demand$

Using the "money demand equation to determine the quantity of money that the central bank will need to supply in order to support, in equilibrium, the nominal interest rate implied by the policy rule" (Gali J, 2015, p. 34)*.*

4.3 The household aggregate basket

To make the model in line with the theory, we assume that the total consumption consists of Home non-tradable goods as Formal and informal sector, which both are consumed domestically, and Foreign imported goods which are imported refined oil and foreign non-oil imported goods, the oil price in the model consist of international prices which are the price that the oil sector sell its exports, and home oil sector which is used by domestic to purchase and consume imported oil, which the latter is subsidized by government.

The constant elasticity of substitution (CES) for total consumption is given by:

$$C_t = \left[(1-\upsilon)^{\frac{1}{\psi}} C_{H,t}^{\frac{\psi-1}{\psi}} + (\upsilon)^{\frac{1}{\psi}} C_{F,t}^{\frac{\psi-1}{\psi}}\right]^{\frac{\psi}{\psi-1}}$$

C_t: Total consumption

υ: Share of foregin imported goods in domestic economy, (degree of openess)

$\boldsymbol{\psi}$: intratemporal elasticity of subsitution between tradable and non $-$ tradable goods in the domestic economy.

The optimal allocation of any given expenditure between tradable and non-tradable goods yields to:

$$\boldsymbol{C_{H,t} = (1-\upsilon)\left(\frac{P_{H,t}}{P_t}\right)^{-\psi} C_t}$$

$$\boldsymbol{C_{F,t} = (\upsilon)\left(\frac{P_{F,t}}{P_t}\right)^{-\psi} C_t}$$

$$CPI = p_t = \left[(1-\upsilon)\left(P_{H,t}\right)^{1-\psi} + (\upsilon)\left(P_{F,t}\right)^{1-\psi}\right]^{\frac{1}{1-\psi}}$$

Foreign imported consumption is given by a composite consumption of oil refined and non-oil goods:

$$C_{f,t} = \left[(1-\alpha)^{\frac{1}{\varsigma}} C_{F,t}^{o\ \frac{\varsigma-1}{\varsigma}} + (\alpha)^{\frac{1}{\varsigma}} C_{F,t}^{f\ \frac{\varsigma-1}{\varsigma}}\right]^{\frac{\varsigma}{\varsigma-1}}$$

$C_{F,t}^{o}$: foreign refined Oil consumption .

$C^{f}_{F,t}$: Foregin non − oil goods imported from foreign economy.

$\varsigma > 0$ elasticity of subsitution between tradable home oil and imported goods in the domestic economy.

$\alpha \in [0,1]$: shre of non − oil foregin goods consumption.

The optimal allocation of expenditures between foreign oil and foreign non-oil goods implies:

$$C^{o}_{F,t} = (1-\alpha)\left(\frac{P^{o}_{F,t}}{P_{F,t}}\right)^{-\varsigma} C_{F,t}$$

$$C^{f}_{F,t} = (\alpha)\left(\frac{P^{f}_{F,t}}{P_{F,t}}\right)^{-\varsigma} C_{F,t}$$

$$P_{F,t} = \left[(1-\alpha)\left(P^{o}_{F,t}\right)^{1-\varsigma} + (\alpha)\left(P^{f}_{F,t}\right)^{1-\varsigma}\right]^{\frac{1}{1-\varsigma}}$$

$P_{F,t}$: total price of tradable consumption sector

$P^{o}_{F,t}$: Domestic oil price

$P^{f}_{F,t}$: Price of foreign goods in domestic currency

$$P_{H,t} = \left[(1-\omega)\left(P^{F}_{H,t}\right)^{1-\mu} + (\omega)\left(P^{I}_{H,t}\right)^{1-\mu}\right]^{\frac{1}{1-\mu}}$$

$P_{H,t}$: total price of home non − tradable goods

$P^{F}_{H,t}$: price of Formal non − tradable goods

$P^{I}_{H,t}$: price of informal non − tradable

$$C_{H,t} = \left[(1-\omega)^{\frac{1}{\mu}} C^{F}_{H,t}{}^{\frac{\mu-1}{\mu}} + (\omega)^{\frac{1}{\mu}} C^{I}_{H,t}{}^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}}$$

$C_{H,t}$: home non − tradable consumption

$C^{F}_{H,t}$: Consumption of home formal goods

$C^{I}_{H,t}$: Consumption of home informal goods

ω: Share of informal consumption in total nontradable consumption

μ: Elasticity of substitution between formal and informal nontradable consumption

Aggregate consumptions of formal and informal are given by:

$$\boldsymbol{C_{H,t}^{F} = (1-\omega)\left(\frac{P_{H,t}^{F}}{P_{H,t}}\right)^{-\mu} C_{H,t}}$$

$$\boldsymbol{C_{H,t}^{I} = \omega\left(\frac{P_{H,t}^{I}}{P_{H,t}}\right)^{-\mu} C_{H,t}}$$

Consumption expenditure by domestic household

$$P_t C_t = P_{F,t}^{o} C_{F,t}^{o} + P_{F,t}^{f} C_{F,t}^{f} + P_{H,t}^{F} C_{H,t}^{F} + P_{H,t}^{I} C_{H,t}^{I}$$

Labor supply and wages between formal and informal sectors:

4.4 Aggregate labor:

Labor supply and wages in the model are assumed to consist of Formal and informal labors, formal labor is used in Tradable oil production sector, and in the formal non-tradable sector, and the Informal labor supply is including in Informal non-tradable sector, same holds true for wages.

$$\boldsymbol{N_t = \left[\eta^{-\varphi}\left(N_{H,t}^{F}\right)^{1+\varphi} + (1-\eta)^{-\varphi}\left(N_{H,t}^{I}\right)^{1+\varphi}\right]^{\frac{1}{1+\varphi}}}$$

$\eta :\ fomal\ labor\ division\ of\ representative\ household$

$1-\eta : infomal\ labor\ division\ of\ representative\ household$

$\boldsymbol{\varphi}$: $inverse\ of\ elasticity\ of\ substitution\ between\ formal\ and\ informal\ labour$

Aggregate wage

$$\boldsymbol{W_t = \left[\eta\left(W_{H,t}^{F}\right)^{\frac{\varphi}{1+\varphi}} + (1-\eta)\left(W_{H,t}^{I}\right)^{\frac{\varphi}{1+\varphi}}\right]^{\frac{1+\varphi}{\varphi}}}$$

Household optimize wages earnings by choosing formal non-tradable and informal labor.

$$\boldsymbol{N_{H,t}^{FN} = \eta \left(\frac{W_{H,t}^{F}}{W_t} \right)^{\frac{1}{\varphi}} N_t}$$

$$\boldsymbol{N_{H,t}^{I} = (1 - \eta) \left(\frac{W_{H,t}^{I}}{W_t} \right)^{\frac{1}{\varphi}} N_t}$$

The formal labour supply $\boldsymbol{N_{H,t}^{F}}$ consists of oil sector labour $\boldsymbol{N_{H,t}^{FO}}$ and the formal non-oil labour supply $\boldsymbol{N_{H,t}^{FN}}$, while informal labour is given as $\boldsymbol{N_{H,t}^{I}}$.

Oil sector labour is considered as 1 percent of the formal non-oil labour supply $\boldsymbol{N_{H,t}^{FN}}$, which it is set as

$$\boldsymbol{N_{H,t}^{FO} = 0.01\ (N_{H,t}^{FN})}$$

Formal labor supply and its wage follows Ahmed et al., (2012)

$N_t^F depends\ on\ different\ levels\ of\ skills\ \ represented by (r)$

$$N_{H,t}^{F} = \left[\int_0^{\eta} \left(N_{H,t}^{F}(r) \right)^{\frac{p-1}{p}} dr \right]^{\frac{\rho}{\rho-1}}$$

p: $elasticity\ of\ substitution\ between\ labor\ types\ in\ formal\ sector$

$$W_{H,t}^{F} = \left[\int_0^{\eta} \left(W_{H,t}^{F}(r) \right)^{\rho-1} dr \right]^{\frac{1}{\rho-1}}$$

Aggregate wage in formal sector

Also, we assume that households have market power to set wages on its type of skill r, this leads to

$$\left(Max W_t^F(r) \right) W_{H,t}^{F}(r) N_{H,t}^{F}(r) - W_{H,t}^{F}$$

$We\ can\ get\ simplier\ form\ by$:

$$W_{H,t}^{F}(r) = \left(\frac{\gamma}{\gamma - 1} \right) W_{H,t}^{F}$$

$$W_{H,t}^{F}(r) = \kappa W_{H,t}^{F}$$

$\kappa = \left(\frac{\gamma}{\gamma - 1} \right)$: $Mark - up\ of\ type\ r\ wage\ on\ average\ wage\ in\ formal\ sector$

4.5 Rest of the world:

oil price, Real exchange rate, inflation, international risk sharing, and Uncovered interest rate parity (UIP):

Rest of the world is considered as closed economy in respect to the home economy, and terms of trade refers to the ratio between the exports of the economy to its imports, in this model, we assume that Iraq economy exports only crude oil, and imports foreign goods as refined oil and non-oil goods, where
P_t^{o*} $is\ international\ oil\ price$ which determined exogenously according to supply and demand of oil in international market, and
P_t^{f*}: $international\ foregin\ price$ of imported goods.

4.5.1 Real Exchange rate:

Real exchange rate is defined as the foreign price of domestic consumption basket e ($\boldsymbol{P_{T,t}^{f}}$) relative to foreign price in foreign consumption, by set this logic, and combined with (LOOP) one gets:

$$\boldsymbol{Q_t \equiv \frac{e\ P_t^{f*}}{P_t} = \frac{P_t^{f}}{P_t}}$$

$\boldsymbol{Q_t}$: Real Exchnage Rate

$\boldsymbol{e}$: $\boldsymbol{Nominal\ exchnage\ rate}$

$\boldsymbol{P_t^f}$: **foregin goods in home price**

$\boldsymbol{P_t^{f*}}$: **foregin goods in international price**

Where:

$$q_t = \int_0^1 \left(e_{i,t} + p_t^{*f} - p_t\right) di$$

$$\int_0^1 e_{i,t} di + \int_0^1 p_t^i di - p_t$$

RER in log-linearization form is:

$$\boldsymbol{q_t = p_t^f - p_t}$$

q_t: $log\ of\ RER$

In addition, the assumption of law of one price (LOOP) is applied to exports and non-oil imported goods, which implies a complete pass-through of the exchange rate.

$$P_{F,t}^{f} = e\left(P_{F,t}^{*f}\right)$$

$$p_{F,t}^{f} = \int_{0}^{1} \left(e_{i,t} + p_{i,t}^{i}\right) di$$

In loglinearisation form

$$\boldsymbol{p_{F,t}^{f} = e_t + p_t^*}$$

While the international non-oil goods price is

$$p_t^* = \rho_{p_t^*-1} p_{t-1}^* + \varepsilon_t^{p_t^*}$$

While the oil-imported refine by the government law of one price gap, which the oil domestic price is subsidized from government.

$$\boldsymbol{P_{F,t}^{o} = \frac{\mathcal{E}(P_{F,t}^{o*})}{\forall^{o}}}$$

Where $\forall^{o} = \frac{Q_t}{P_{F,t}^{o}}$ $\boldsymbol{follow\ AR(1)}$

The law of one price gap of oil is given by dividing RER on domestic price of oil imported. And by assuming that home manufactured goods in non-tradable sector are not exported, we can set that $P_t^{f*} = P_t^*$

4.5.2 - CPI, tradable oil goods, and non-tradable goods inflation:

Imported goods affect the domestic economy, where high dependent oil country economy depends on global oil prices, by change the oil revenues, which the latter affects the power purchase of imported goods, and lead to depreciation of currency as if there is a decrease in oil prices, as for small open economy, which does not have influence on international commodities prices, the increasing in prices put pressure on the CPI even if domestic inflation is low.

The inflation equation is given in literature by the relative total prices to the prices in previous time:

$$\pi_t \equiv \hat{p}_t - \hat{p}_{t-1}$$

The total inflation in the model is considered as the home inflation and foreign inflation and the total inflation CPI consists of foreign imported inflation.

$$\pi_{F,t} \equiv \hat{p}_{F,t} - \hat{p}_{F,t-1}$$

$\boldsymbol{\pi_{F,t}}$: Oil inflation consumption and imported goods inflation

And

$$\pi_{H,t} \equiv \hat{p}_{H,t} - \hat{p}_{H,t-1}$$

$\boldsymbol{\pi_{H,t}}$: home non − tradable sector inflation

Oil price inflation, follow AR (1)

$$\pi^o_{F,t} = \rho_{\pi^o}\pi^o_{F,t-1} + \varepsilon_t^{\pi^o}$$

and the inflation of foreign imported goods is

$$\pi^*_t = \rho_{\pi^*_t}\pi^*_{t-1} + \varepsilon_t^{\pi^*_t}$$

And the Informal inflation is related to the wages of informal production sector:

$$\widehat{\pi^{\mathrm{I}}_{\mathrm{t}}} = \widehat{\mathrm{W}^{\mathrm{I}}_{\mathrm{t}}} - \widehat{\mathrm{W}^{\mathrm{I}}_{\mathrm{t-1}}}$$

4.5.3 - International risk sharing

By assuming perfect international bond markets in all countries, where Euler equation is same in rest of the world, this yields to:

$$Q_t = \beta^t E_t\left[\left(\frac{C^{*f}_{t+1}}{C^{*f}_t}\right)^{-\sigma}\left(\frac{P^{*f}_t}{P^{*f}_{t+1}}\right)\left(\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}\right)\right]$$

$\boldsymbol{C^{*f}_t}$: consumption by foreign household.

$\boldsymbol{P^{*f}_t}$: foregin price in foreign economy.

This means that the return on risk-free b "Using the "money demand equation to determine the quantit

ond must be the same in domestic and foreign economy when expressed in same currency.

By dividing Euler equation by last foreign Euler equation, and using the definition of real RER and solve for C_t, (see Appendix for details)

$$C_t = \aleph C_t^{*f} (\mathcal{Q}_t)^{\frac{1}{\sigma}}$$

Where

$$\aleph = \boldsymbol{E_t}\left[\left(\frac{\boldsymbol{C_{t+1}}}{\boldsymbol{C^f_{t+1}}(\mathcal{Q}_{\boldsymbol{t+1}})^{\frac{1}{\sigma}}}\right)(\mathcal{Q}_{\boldsymbol{t+1}})^{\frac{1}{\sigma}}\right]$$

By assuming that small economy has infinitesimal size relative to rest of the world

$$C_t^{*f} = y_t^{f*}$$

Where $\boldsymbol{y_t^{f*}}$ is world output.

Imposing this condition on

$$C_t = \aleph y_t^{f*} (\mathcal{Q}_t)^{\frac{1}{\sigma}}$$

We can combine the last expression for one forward period, with Euler equation:

$$\hat{C}_t = E_t[\hat{C}_{t+1}] + \frac{1}{\sigma}(-\hat{R}_t + E_t[\widehat{\pi_{t+1}}])$$

We get:

$$\widehat{\boldsymbol{C_t}} = \boldsymbol{E_t}\widehat{\boldsymbol{y}}_{\boldsymbol{t}}^{\boldsymbol{f*}} + \frac{\boldsymbol{1}}{\boldsymbol{\sigma}}\boldsymbol{q_{t+1}} - \frac{\boldsymbol{1}}{\boldsymbol{\sigma}}(\widehat{\boldsymbol{R}}_{\boldsymbol{t}} + \boldsymbol{E_t}[\boldsymbol{\pi_{t+1}}])$$

4.5.4 - Uncovered Interest Parity (UIP)

Following (Gali J,2015), Assuming complete international financial markets, the price in terms of domestic currency of a risk-free bond denominated in foreign currency.

$$\frac{\varepsilon_t^i}{R_t^i} = E_t[Q_{t,t+1}\varepsilon_{t+1}^i]$$

$\varepsilon_{i,t}$: $bilateral\ exchange\ rate$

$$E_t[Q_{t,t+1}] = \frac{1}{R_t}$$

UIP expression is:

$$E_t\left[Q_{t,t+1}\left(R_t - R_t^i\left(\frac{\varepsilon_{t+1}^i}{\varepsilon_t^i}\right)\right)\right] = 0$$

Assuming that UIP holds means that investors are indifferent between investing in domestic or foreign assets.

4.6 – Firms:

This section illustrates the firms in the home economy, which consists of oil production for crude oil exports and formal and informal non-tradable goods.

4.6.1 - Oil producing firms:

This sector is a tradable sector in which the Crude oil output is totally exported to the rest of the world, and the prices of oil in international markets are set exogenously; therefore, the oil sector does not have the power to set prices in international markets.

The production function is given by*:*

By applying the logic in Gali and Monacelli (2005) in terms of production firms and the same in Oladunni (2020),

$$\boldsymbol{Y^{o}_{T,t} = A^{o}_{T,t} N^{FO}_{H,t}}$$

$\boldsymbol{Y^{o}_{T,t}}$: $Oil\ output\ production, for\ export$

$\boldsymbol{A^{O}_{T,t}}$: $\boldsymbol{Oil\ sector\ productivity\ variable\ of\ tradable\ sector}$.

$\boldsymbol{N^{FO}_{H,t}}$: $Labor\ employed\ in\ oil\ sector$

The minimization cost of the oil sector is given by the following:

$$\boldsymbol{min}\ \frac{W^{F}_{t} \boldsymbol{N^{F}_{H,t}}}{\boldsymbol{P^{O}_{T,t}}}$$

Subject to production function

$$\boldsymbol{Y^{o}_{H,t} = A^{o}_{H,t} N^{FO}_{H,t}}$$

And first order conditions yield to oil sector real marginal cost function as follows:

$$\boldsymbol{RMC^{O}_{t}} = \frac{W^{F}_{t}}{\boldsymbol{A^{o}_{H,t} P^{o}_{H,t}}}$$

The nominal marginal cost which represents the oil firm's price:

$$\boldsymbol{P^{o}_{H,t} = nominal\ MC^{O}_{t}} = \frac{W^{F}_{t}}{\boldsymbol{A^{o}_{H,t}}}$$

The revenues that government got from selling oil is given by $\boldsymbol{P^{*f}_{F,t}\ Y^{o}_{T,t}}$

Where international oil price and oil productivity follow AR (1)

$$P_{F,t}^{*O} = {}'\rho_{P_{F,t}^{*O}} P_{F,t-1}^{*O} + \varepsilon_t^{P_{F,t}^{*O}}$$

$$A_{T,t}^{o} = \rho_{A^o} A_{T,t-1}^{o} + \varepsilon_t^{A^o}$$

4.6.1 – Formal sector:

following Gail 2015, The production function is given by*:*

$$Y_{N,t}^{F}(j) = A_{N,t}^{F} N_{H,t}^{FN}(j)$$

$Y_{N,t}^{F}(j)$: $formal\ output\ production$

(j): $[0,1]$***Formal non − tradable sector firms***

$A_{N,t}^{F}$: ***Production factor which is the level of aggregate productivity***

$N_{H,t}^{FN}$: $Aggregate\ level\ of\ employment\ in\ formal\ sector.$

Dixit-Stiglitz (1977) Aggregation technology gives:

$$Y_{N,t}^{F}(j) \equiv \left[\int_0^1 Y_t^F(j)^{\frac{\varepsilon}{\varepsilon-1}}\right]$$

And aggregate level of employment in the tradable goods sector

$$N_{H,t}^{FN} \equiv \left(\int_0^1 N_{H,t}^{FN}(j)di\right)$$

$A_{H,t}^{F}$: $productivity\ follows\ AR(1)$

$$\widehat{A}_{H,t}^{F} = p_{A_{H,t}^{F}} \widehat{A}_{H,t-1}^{F} + \varepsilon_{F,t}^{a}$$

$$\varepsilon_{F,t}^{a} \sim iid(0, \sigma_a^2)$$

$p_{A_{H,t}^{F}}$:This is p between {0,1}, measures the correlation between the error term.

Companies solve their problems by 2 steps:

1 – minimize firms production costs:

By choosing the lowest possible level of labor

$$min \frac{W_t^F \boldsymbol{N_{H,t}^{FN}}}{\boldsymbol{P_{N,t}^F}}$$

s.t to production function

$$\boldsymbol{Y_{H,t}^F(j) = A_{N,t}^F N_{H,t}^{FN}(j)}$$

leads to marginal cost of production:

$$\boldsymbol{RMC_{H,t}^F} = \frac{W_t^F}{\boldsymbol{P_{H,t}^F\, A_{H,t}^F}}$$

$\boldsymbol{P_{H,t}^F}$: $Price\ of\ the\ formal\ goods$

$mc_{F,t}^{r}$: $Marginal\ cost\ of\ formal$ non
− tradable *which is calculated as total expenses required to manufacture one additional good*

Price setting:

As the formal non-tradable firms have the power to set prices, this leads to the New Keynesian Philips Curve.

Firms' max profits by minimize costs of goods, and set prices $\boldsymbol{P_t^F}$ subject to demand function for their goods given by

$$\boldsymbol{C_{H,t}^F} = (\boldsymbol{\omega}) \left(\frac{\boldsymbol{P_{H,t}^F}}{\boldsymbol{P_{H,t}}} \right)^{-\boldsymbol{\mu}} \boldsymbol{C_{H,t}}$$

And sticky price (Calvo,1983):

Calvo price of Formal production sector:

$$\mathcal{E}^F = (1-\theta)\frac{1}{(1-\theta)^2} = \frac{1}{(1-\theta)}$$

$\mathcal{E}^F$: $price\ change\ is\ sum\ of\ probabilities\ times\ duration$

$1-\theta$ $\ firms\ set\ optimally\ new\ prices$

θ: $firms\ do\ not\ change\ their\ prices, the\ higher\ \theta, less\ firms\ adjusted$

$\frac{1}{(1-\theta)}$: $Average\ duration\ of\ a\ price, no\ matter\ when\ was\ last\ time$).

$\boldsymbol{P_t^{*F}}$ $price\ adjusted, with\ probability\ \theta$

Aggregate price dynamic see (Appendix)

$$P_t = \left(\int_0^1 P_{t-1}(i)^{1-\mathcal{E}} di + \int_0^1 P_t^*(i)^{1-\mathcal{E}} di \right)^{\frac{1}{\mathcal{E}_p - 1}}$$

As all firms are identical, so they all set same price, then we can rewrite price index as

$$P_t = \left[\theta (P_{t-1})^{1-\mathcal{E}} + (1-\theta) P_t^{*1-\mathcal{E}} \right]^{\frac{1}{\mathcal{E}_p - 1}}$$

By dividing on P_{t-1} and take the log linearization gives:

$$\widehat{\pi_t} = (1-\theta)(\widehat{P_t^{set}} - \widehat{P_{t-1}})$$

$\pi_t^{1-\mathcal{E}}$: $is\ gross\ inflation, and\ P_t^{set}\ is\ price\ set\ by\ firms\ in\ period\ t.$

2- Maximize profits:

Regard Calvo 1983

$$\mathcal{P}_{T,t}^H(j): Price\ by\ a\ firm\ adusting\ its\ price\ in\ period\ t$$

$$max_{\boldsymbol{P_t^F}} E_t \sum_{k=0}^{\infty} \theta^k\, E_t[Q_{t,t+k} \left(\boldsymbol{Y_{t,t+1}^F} \left(\boldsymbol{P_t^{setF}} - mc_{F,t}^n \right) \right)]$$

θ^k: $a\ parameter\ that\ measures\ the\ degree\ of\ nominal\ rigidity, and\ the\ larger\ this\ parameter\ is\ the\ fewer\ firms\ adjust\ their\ prices$

$Q_{t,t+k}$: $stochastic\ discount\ factor\ of\ the\ domestic\ household\ for\ one\ period\ ahead\ nominal\ pay-offs$

$Y_{T,t+k}$: $production\ of\ tradable\ goods$

$\boldsymbol{P_t^F}$: $the\ adjusted\ prices\ of\ formal\ tradable\ goods$

subject to the assumption of Calvo pricing (1983), and the following demand function:

$$\boldsymbol{Y_{t,t+1}^F}(j) = \left(\frac{\boldsymbol{P_t^{setF}}(j)}{\boldsymbol{P_t^F}} \right)^{-\mathcal{E}} \left(C_{t+k}^F + \int_0^1 C_{t+k}^F\, di \right)$$

$\frac{W_t^F}{\boldsymbol{A_{F,t}}} = MC_{F,t}^n$

$MC_{T,t}^n$: $nominal\ marginal\ cost$

$\frac{W_t^F}{P_t^F A_{F,t}} = MC_{F,t}^r$

$MC_{T,t}^r$: $real\ marginal\ cost$

From above, we get New Keynesian Philips Curve (Appendix)

New Keynesian Phillips curve for Formal sector

$$\pi_t^F = \beta E_t[\pi_{t+1}^F] + \lambda_F(\widehat{mc}_{F,t})$$

$$\widehat{mc}_{F,t} - P_t^F = MC_{F,t}^r$$

π_t^F: $consumption\ inflation\ of\ formal\ non-tradable\ goods$

"The new Keynesian Phillips curve (NKPC) implies that real marginal cost is the correct driving variable for the inflation process. It also implies that the inflation process is forward-looking, with current inflation a function of expected future inflation. When a firm sets its price, it must be concerned with inflation in the future because it may be unable to adjust its price for several periods" (Walsh, 2010, p. 336).

4.6.3 – informal sector firms

By following Ahmed et al., (2012), that labour is the only input factor of this sector.

The production function of the informal sector is given by:

$$Y_{H,t}^I(j) = \varsigma N_{H,t}^I(j)$$

ς: $\boldsymbol{Provides\ information\ on\ the\ productivity\ of\ informal\ labour}$

Informal sector firms solve the following profit maximization problem by:

$$Max Y_{H,t}^I - \frac{W_t^I}{P_{H,t}^I} N_t^I$$

Subject to production function

$$Y_{H,t}^I(j) = \varsigma N_{H,t}^I(j)$$

Leads to

$$P_{H,t}^I = \frac{W_t^I}{\varsigma} = mc_{H,t}^I$$

The marginal cost is the change in the total cost that arises when the quantity produced is increased, the cost of producing an additional quantity.

P_t^I: $price\ of\ informal\ sector\ nontradable.$

4.7– Government

4.7.1: Monetary policy and the Exchange regime in Iraq:

According to the report (IMF 2021, pp. 1795), the monetary policy arises from the lack of mechanisms to ensure the exchange rate at the central bank of Iraq (CBI) foreign exchange window and the market rates, which are represented as the retail exchange rate of commercial banks and exchange bureaus for the sale of foreign currency from sources other than the CBI foreign exchange rate window, do not deviate from each other by more than 2%.

The ER arrangement is a conventional peg arrangement; the CBI laws give the Board of CBI the authority to formulate exchange rate policy; and it is an ER anchor vis-à-vis the US dollar. (Ashoor et al., 2021).

Basically, the Taylor rule (Taylor 1993a) is used to explain the policy behavior of central banks; it shows how the central bank should adjust its nominal interest rate in a systematic manner in response to deviations in inflation and changes in the real exchange rate. This helps maintain price stability and achieve maximum sustainable growth.

The Taylor rule is set to be in line with the case of Iraq:

$$\widehat{\boldsymbol{R}}_{\boldsymbol{t}} = \boldsymbol{\rho}\widehat{\boldsymbol{R}}_{\boldsymbol{t-1}} + (\mathbf{1}-\boldsymbol{\rho})(\boldsymbol{\phi}_{\boldsymbol{\pi}}\boldsymbol{\pi}_{\boldsymbol{t}} + \boldsymbol{\phi}_{\boldsymbol{e}}\boldsymbol{q}_{\boldsymbol{t}}) + \boldsymbol{\varepsilon}_{\boldsymbol{t}}^{\boldsymbol{R}}$$

denotes the log deviation of output from its steady state and where and $\phi_\pi, \phi_q > 0$ and is assumed to satisfy determinacy condition*:*

R_t: $nominal\ interest\ rate\ shifter$

π_t: $gross\ inflation\ rate$

$q_{t:real\ exchnage\ rate}$

ϕ_π: $sensitivity\ of\ central\ bank\ with\ respect\ to\ inflation$

ϕ_e: $sensitivity\ of\ central\ bank\ with\ respect\ to\ exchnage\ rate.$

ε_t^R: $exogenous\ stochastic\ shock\ with\ zero\ mean$,

Bullard and Mitra (2002) demonstrated that a unique stationary equilibrium exists so long as the inflation parameter in Taylor rule should be greater than zero. This is referred to as the Taylor principle, because John Taylor was the first to emphasize the significance of interest rate principles that required responding to changes in inflation by more than one-for-one. (Walsh, 2010).

Making the model be in line with Iraq, which its monetary policy is considered as fix exchange rate regime (IMF 2021, pp 1795), making changes in the nominal exchange rate equal to zero is demanded, where $\Delta e_t = 0$

In addition, by following (Lahcen,2014, p. 27), removing the Uncovered Interest parity (UIP) by replacing it with the equation auto-regressive process for the nominal exchange rate to prevent the international fluctuations in interest rate to affect the local economy this choice is by rejecting UIP condition at least in short term.

$$e_t = \rho_e \hat{e}_{t-1} + \varepsilon_{e,t}$$

This assumes that domestic interest rate is a function of the interest rate of the world economy:

$$R_t = R_t^*$$

This isolates the economy from the large extent domestic interest rate fluctuations in its foreign counterparts, in such case, CB enjoys some leverage over MP", same is applied to international risk sharing which is replaced by standard Euler equation.

4.7.2 - Fiscal policy:

As in other oil-exporting economies, Iraq's fiscal policy is insufficiently supported by taxes, which are "not a major "source of government revenue.". (Ghiaie et al., 2022)

practically, "The tax burden for the period 2010-2018 did not constitute a significant burden for the individual in Iraq", weak role of the tax system due to its inability to provide the budget with sufficient revenues" (Husain and Ayesh, 2020, P. 239), for this reason, tax is not included in the model.

1 - *Government spending:*

The general budget constraint of the government is given by:

$$\boldsymbol{T_t + FRR_{t-1} + B_t = FRR_t + R_{t-1}B_{t-1} + G_t}$$

$B_t = \log of \ \ Government\ bonds$

$R_{t-1}: Interest\ rate$

$G_t = Government\ spending$

$T_t = \text{lump} - \text{sum} \ \ taxes$

$FRR_t: Financial\ reserves\ revenues.$

Including FRR following (Al-Shammari and Al-Salem, 2022) and (Ghiaie et al., 2022) represents the financial reserve fund, the main aim of this reserves to provide a stable source of income for government, for instance when this was used during Coronavirus crisis when the international oil prices dropped suddenly.

FFR is given by the previous FRR in addition to the oil selling revenues in international markets of the current period:

$$FRR_t = FRR_{t-1} + P_t^{*o} C_t^{*o}$$

The government spending equation is assumed to be:

$$\hat{G}_t = \rho \hat{G}_{t-1} + (1-\rho)((B_t - R_{t-1}B_{t-1}) - FRR_t - \boldsymbol{FRR_{t-1}}) + \varepsilon_t^R$$

For bonds, following Shatmanov, I. (2016)

$$\hat{B}_t = R_{ss}\hat{B}_{t-1} + R_{ss}\frac{B_{ss}}{Y_{ss}}\hat{R}_{t-1} + R_{ss}\frac{B_{ss}}{Y_{ss}}\pi_t$$

The oil price subsidy represents the government expenditure to provide subsidized oil in domestic markets, following (Benkhodja, 2014)
The equation be as:

$$P_{F,t}^{o} = (1-x)P_{F,t-1}^{o} + xP_{F,t}^{OS_t}$$

Where:

$P_{F,t}^{OS_t}$: $\boldsymbol{is\ price\ subsidized\ by\ government} = \frac{\mathfrak{E}(\boldsymbol{P_{F,t}^{o*}})}{\forall^{\boldsymbol{o}}}$

$0 < x < 1$: $fuel\ pricing\ parameter, measures\ pass - through\ effect\ of\ oil\ prices.$

$\forall^{o}$: $law\ of\ one\ price\ gap\ associated\ wuth\ import\ price\ of\ oil.$

$when\ x = 1\ there\ is\ full\ pass - through, and\ when\ x = 0\ it\ is\ full\ subsizdied.$

The oil subsidy is given by the difference between total cost of imported fuel $O_t P_{F,t}^{OS_t}$
In domestic price, and the amount form oil sales in domestic economy $O_t P_{F,t}^{o}$

$$OS_t = e(P_{F,t}^{OS_t}) - P_{F,t}^{o}$$

4.8 - General Equilibrium:

Aggregate Demand:

The market clearing condition refers to the fact that the overall economy output $\boldsymbol{Y_{GDP}}$ defined as Oil exported output, and domestic non-tradable output.

Therefore,

$$\boldsymbol{Y_{GDP} = C + G + X - M}$$

In loglinearise terms

And the formal and informal goods in domestic markets equal to the domestic output and government spending. The aggregate resource in the formal sector is given as:

$$\boldsymbol{Y^F_{N,t} = C^F_{N,t} + G_t}$$

And same to informal sector:

$$\boldsymbol{Y^I_{N,t} = C^I_{N,t}}$$

Thus, the total non-tradable market clearing is:

$$\boldsymbol{Y_N} = Y_t^F + Y_t^I = \boldsymbol{C^F_N + C^I_N + G_t}$$

Labour supply market is given as the total labor supply is the aggregate of Formal labour supply and informal labour supply.

$$N_t = \boldsymbol{N^F_{H,t} + N^I_{H,t}}$$

Regarding export and import sectors:

Export sector is given as:

$$\boldsymbol{X = P^{o*}_{F,t}\, Y^o_H}$$

While the import sector is given as:

$$\boldsymbol{M = P^{f*}_{F,t}(CC) + P^{o*}_{F,t}(CO)}$$

Where oil exported sector equal to foreign demand for domestic oil production:

$$\boldsymbol{Y^o_H = C^{o*}_{F,t}}$$

Where C_t^{o*} is considered as export, as it is demanded from foreign economy, and the foreign household act as same as the domestic household.

$$C_{F,t}^{o*} = (1 - a^*)\left(\frac{P_{F,t}^{o*}}{P_{F,t}^*}\right)^{-\varsigma^*} C_{F,t}^*$$

5 - Calibration, simulation, and results:

Calibration of the DSGE models means "assigning values to the parameters, in some form. No one form is more correct than the other, but it is always necessary to proceed with caution and common sense" (Costa Junior, 2016, P. 260). Thus, the model parameters are calibrated to be in line with the Iraqi economy; for this aim, we used papers that have economic similarities with Iraq as an oil economy that includes a large informal sector. For this reason, the related papers that are used in the calibration process are mentioned in the following table with parameter values:

The parameter that represents foreign imported goods in the domestic economy (Openness degree) is set at 0.62; it was taken from the global economy website that provides information for Iraq, and the parameter that indicates the share of non-oil foreign goods was taken from the trading economic website; the links are provided in Table 1 as well.

Omega, which is informal consumption in non-tradable consumption, is 0.55 in Ahmed (2012); I put it at 0.45, equal to the informality economy size of Iraq, which is between 40 and 50 percent.

The ratio of government spending to total GDP is set at 0.35; it is taken from the Statista website, and the ratio of total exports to total GDP is 0.42; it is taken from the World Bank website. Import ratios are taken from the trading economic website by counting them from the detailed descriptions of many imports.

Parameters	Description	Value	Study
σ	Degree of relative risk aversion	7.25	Mohi S R, Daghir M, Salih L Y (2022)
v	inverse elasticity of substitution between consumption and real balances	0.30	(Shatmanov, 2016)
υ	Share of foreign imported goods in domestic economy degree openness (Iraq Trade openness	0.62	https://www.theglobaleconomy.com/Iraq/trade_openness/
ψ	elasticity of substitution between domestic and foreign goods	0.61	Medina and Soto, (2005)
β	inter-temporal factor related to time preferences.	0.96	(Oladunni, 2020)
α	share of non-oil foreign goods consumption	0.82	https://tradingeconomics.com/iraq/imports
ς	elasticity of substitution between imported refined oil and imported non-oil goods in the domestic economy.	0.18	Omotosho, B. (2019)
μ	Elasticity of substitution between formal and informal non-tradable consumption	0.7	Ahmed et al., (2012)
ω	Share of informal consumption in total non-tradable consumption	0.45	Assumed
φ	inverse of elasticity of substitution between formal and informal labour	3	Lahcen, M. A. (2014)
κ	Mark-up of type r wage on average wage in formal sector	1.25	Ahmed et al., (2012)
ϕ_π	sensitivity of central bank with respect to inflation	1.5	Oladunni, S. (2020)
ϕ_q	sensitivity of central bank with respect to exchange rate	0.109	Omotosho, B. (2019)
x	oil rule	0.3	Benkhodja (2014
θ	Calvo price	0.26	Lahcen, M. A. (2014)
ρ_{AF}	Productivity persistence for domestic non-tradable firms	0.74	Oladunni, S. (2020)
ρ_G	government spending persistence	0.72	Omotosho, B. (2019)

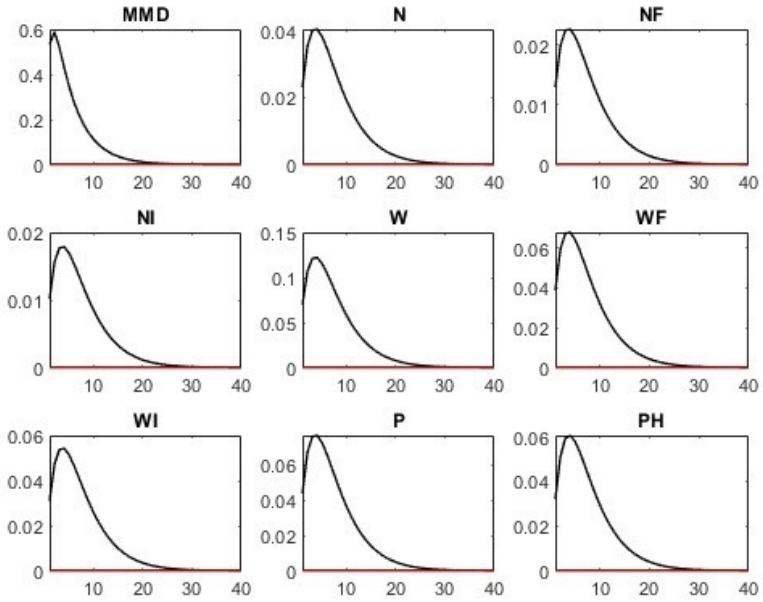
ρ_R	interest rate persistence	0.28	Mohi S R, Daghir M, Salih L Y (2022)
ρ_e	nominal exchange rate persistence	0.80	Lahcen, M. A. (2014)
ρ_{A^o}	Productivity persistence for oil production firms	0.85	Oladunni, S. (2020)
ρ_{pc_w}	international import goods price persistence	0.90	Oladunni, S. (2020)
ρ_{pic_w}	international non-oil inflation persistence	0.8	Oladunni, S. (2020)
ρ_{pio_w}	international oil inflation persistence	0.8	Oladunni, S. (2020)
ρ_{po_w}	international oil price persistence	0.8	Omotosho, B. (2019)
ε_{AF}	Productivity shock for domestic non-tradable firms	0.70	Mohi S R, Daghir M, Salih L Y (2022)
ε_G	Government spending shock	0.098	Omotosho, B. (2019)
ε_R	Monetary policy shock	0.01	Costa J (2016)
ε_e	Exchange rate shock	0.194	Mohi S R, Daghir M, Salih L Y (2022)
ε_{po_w}	International oil price shock	0.90	Mohi S R, Daghir M, Salih L Y (2022)
ε_{pio_w}	International oil inflation price shock	0.01	Assumed

ε_{A^o}	Oil productivity shock	0.01	Assumed
ε_{pc_w}	International non-oil price shock	0.01	Assumed
ε_{pic_w}	International non-oil price shock	0.01	Assumed
$\frac{g_{ss}}{y_{ss}}$	ratio of government spending to total GDP	0.35	https://www.statista.com/statistics/372118/ratio-of-government-expenditure-to-gross-domestic-product-gdp-/in-iraq
$\frac{x_{ss}}{y_{ss}}$	ratio of total exports to total GDP	0.42	https://www.worldbank.org/en/country/iraq/overview
$\frac{m_{ss}}{y_{ss}}$	ratio of total imports to total GDP	0.15	https://tradingeconomics.com/iraq/imports
$\frac{cf_{ss}}{m_{ss}}$	ratio of foreign non-oil goods imports to total imports	0.82	https://tradingeconomics.com/iraq/imports
$\frac{co_{ss}}{m_{ss}}$	ratio of foreign oil goods imports to total imports	0.18	https://tradingeconomics.com/iraq/imports

Simulation and results

The model is simulated by using the software Dynare 5.4 in the toolbox on MATLAB after putting the model in its log-linearized form around the steady state for each variable, and in a practical sense, The condition for unique equilibrium and stability in the model depends on the law of Blanchard and Kahn (Blanchard and Kahn, 1980), which refers to the fact that the model is stable and has a unique equilibrium when the magnitude of the eigenvalues of the matrix , "the number of eigenvalues with an absolute value greater than 1 (unstable root) is equal to the number of forward-looking variables, the system has a unique solution, and it is also stable on a saddle path" (Costa J,2016, 261). The model simulation has IRFs for the oil price shock, to study the impacts of this shock on the macroeconomic variables of the economy.

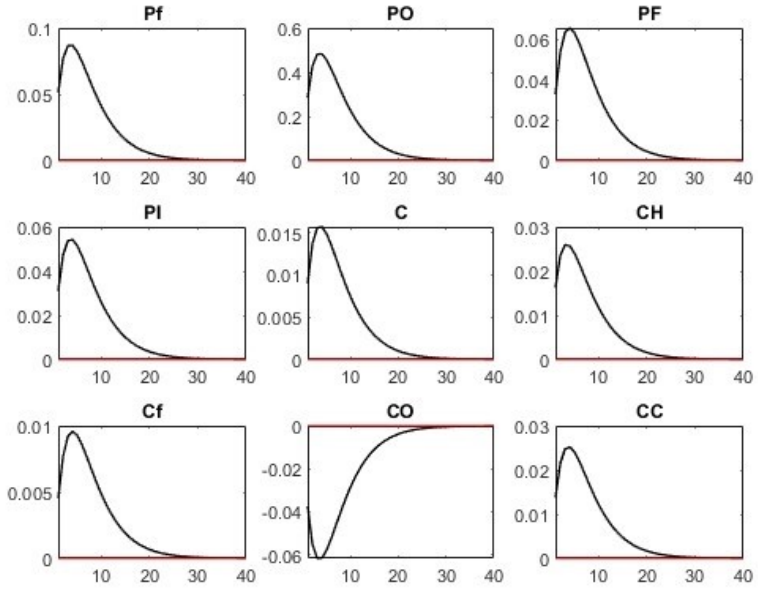
Figure 5: IRFs of the positive oil price shock (1)



Oil positive prices shock stimulate the economy, as it obviously seen in the Figure 5, Money demand MMD increased, as mentioned earlier according to (Benchimol, 2018), high value of risk aversion related to output, also as a response to the labour supply and wages increasing in the formal WF, NF and informal WI, NI sectors.

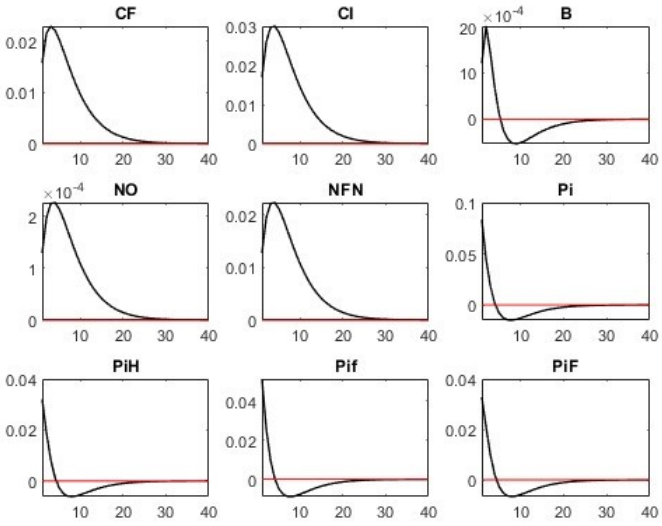
Prices of goods have increased in all sectors, home price PH and foreign price as well Pf.

Figure 6: IRFs of the positive oil price shock (2)



Consumption of goods increased in the home and foreign markets, except of the oil consumption as its international price part increased, this leads to decreasing up to 6 percent of its consumption. in addition, the informal consumption goods also increase as household enjoying more welfare.

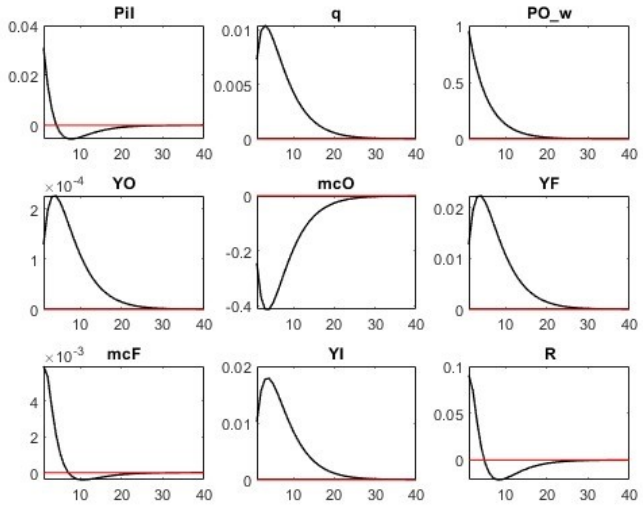
Figure 7: IRFs of the positive oil price shock (3)



Similar to other labors supply, increasing oil prices motivate the oil sector and leads to an increase in the oil labour supply.

as a consequence of prices increasing, the inflations increase as well, also the real exchange rate increase as 1 percent, RER increased as the international prices increasing lead to depreciation of the international currencies with of domestic currency.

Figure 8: IRFs of the positive oil price shock (4)



Intuitively, as oil depends on the economy, increasing oil prices increase oil productivity, and at the same time increases the non-oil production sector of both formal and informal sectors, as the formal one increases more than the informal sector, this result gives an important result regarding to analyzing Dutch disease effects.

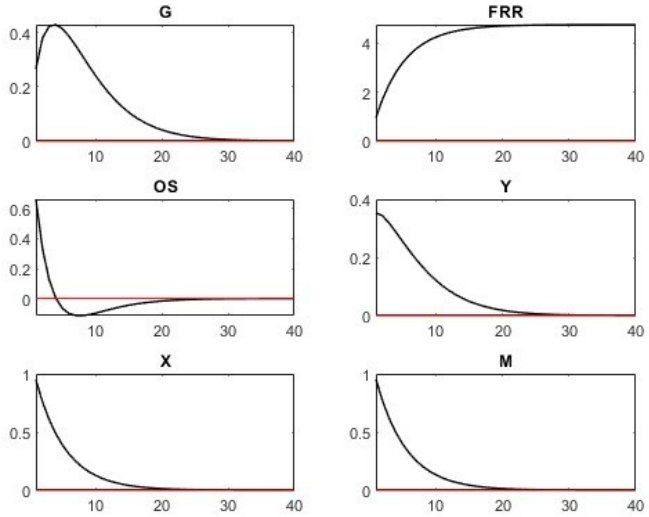
Government authority is represented by the Monetary policy which is Taylor rule R, and fiscal policy as government spending G, both increase in response to oil shock.

Nominal Interest rate R increases to mitigate the inflation effects.

Government spending G increase as it is related to the financial reserves revenues FRR, which the latter increased due to oil shock, also the government increased as increasing in Oil subsidy OS to provide the oil in domestic markets with lower prices.

And by the increasing of government spending, public debt (Bonds) increased as well.

Figure 9: IRFs of the positive oil price shock (5)



GDP, which is represented in this model as Y increased as well, which it includes exports and imports, these both sectors represent the foreign sectors have increased as well.

Simulation the model for a small size of informality:

In this second simulation, we try to find the response of the same economy if the informal sector is small. To see how the economy responds to the oil price shock, I change the parameters of the informal sector to reduce its effect and keep the same values for other variables. Thus, the assumption of a small informal economy comes just from the parameters changing and not from giving space to other sectors parameters.

The informal sector parameters are set for small informal sizes:

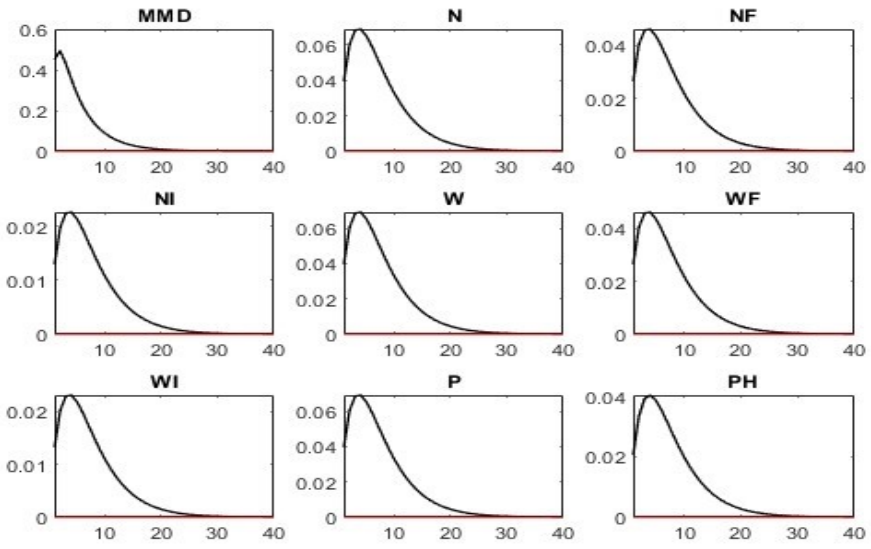
kappa= 2 instead of 1.25, this means that the formal labour wages have significantly higher wages than in informal sector.
mu = 0.3 instead of 0.7, this parameter represents the elasticity of substitution between formal and informal non-tradable consumption, and by decreasing the parameter, make it difficult for household to change between the two types of goods.

omega = 0.2 instead of 0.45 means that there is less sharing of informal consumption to the total consumption

phi = is set as 1 instead of 3, which makes it difficult for employees to change between formal and informal labour.

we can see the impacts of these changes as

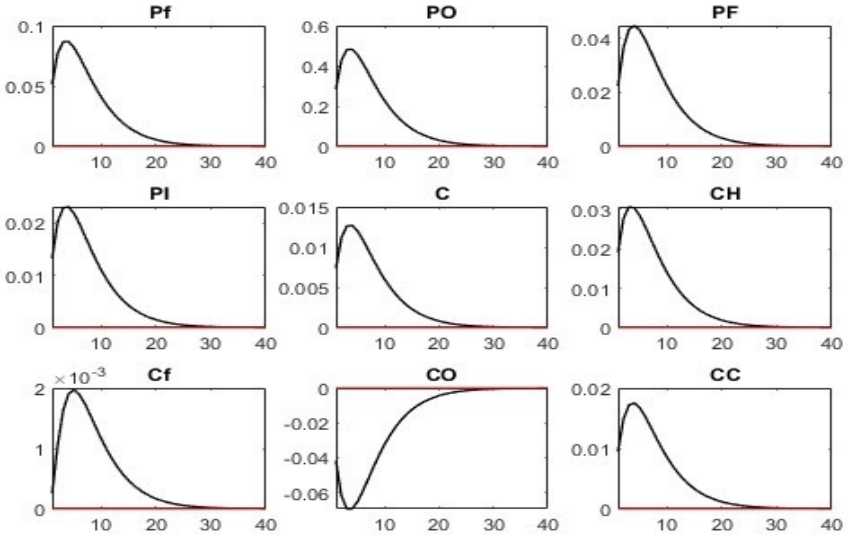
Figure 10: IRFs of the positive oil price shock (6)



Real money balance MMD decreased by 10% compared to MMD in Figure 5. This decrease could be explained by the decrease in purchase power, which is represented by the increase in foreign imported goods Cf, where Cf is the largest part of the total consumption C, in addition to the decrease in wages as well.

In both domestic sectors, especially in the formal one, NF increased from 1.5 percent to 2.5 percent, and in the informal one, NI increased from 1 percent to 1.5 percent. As a consequence of the supply and demand law, wages decreased as well; the formal wages declined from 4 percent to 2.5 percent, and the informal market wages declined 2.5 percent.

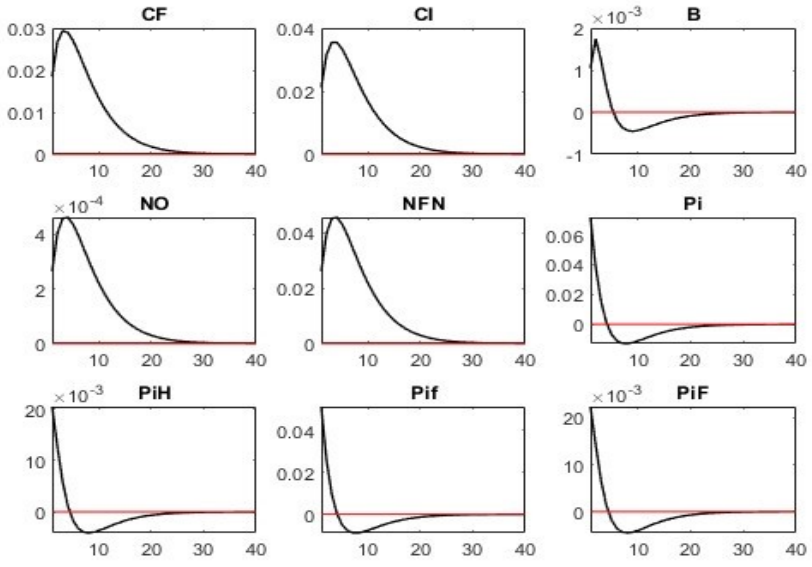
Figure 11: IRFs of the positive oil price shock (7)



Home prices PH decreased 2 percent which is considered as enhancing for the economy, specifically, formal prices declined 2 percent and informal prices decreased up to 2.5 percent.

Foreign imported goods for consumption CC decreased as the response to the cheap home prices in comparison to the foreign prices.

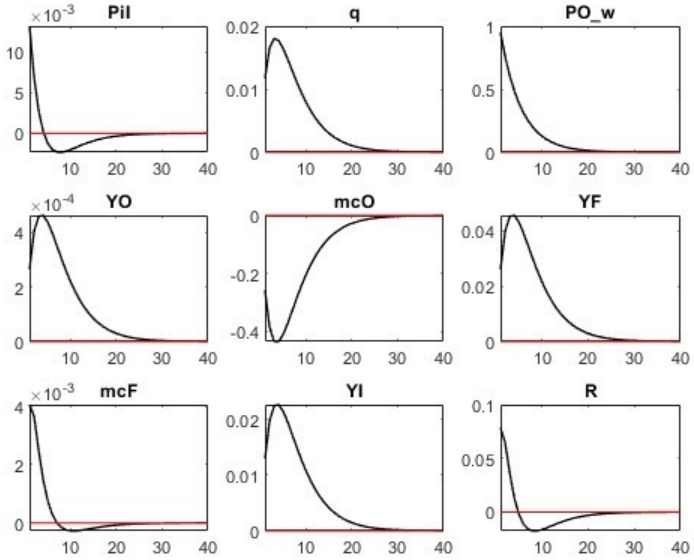
Figure 12: IRFs of the positive oil price shock (8)



Inflation, which is the main targeting goal of the Central Bank, has shown improvement with less economy sector. The total inflation, which combines home and forging inflations, improved by 4 percent, the home inflation PiH decreased by 1

percent, the formal inflation decreased by 2 percent, and the inflation from the informal production sector decreased by 3 percent.

Figure 13: IRFs of the positive oil price shock (9)



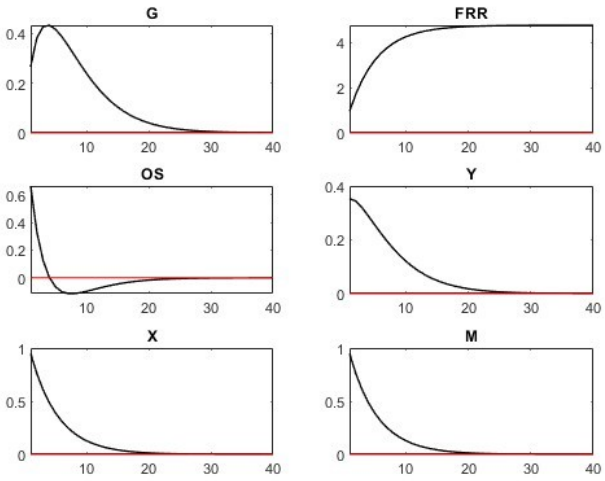
The real exchange rate also improved a little bit; it grew from 0.8 percent to 1.5 percent.

All production sectors improved with less informality; the formal non-tradable sector increased its production by 2.5 percent, while the oil sector has the ability to improve its production in terms of labor supply.

The marginal cost mcF of the formal production sector declined.

The nominal interest rate decreased a little bit as inflation and the real exchange rate improved.

Figure 14: IRFs of the positive oil price shock (10)



Since the Government spending is assumed that its policy regarding directly to the financial reserves revenues, it still the same, but Bonds issuing decrease with small percent.

5.2 - The main results of the model simulation:

1: Oil price shocks stimulate the economy in terms of production and consumption and improve the real exchange rate as well.

2: Dutch disease does not exist in the economy; since the oil shock improved the non-oil sector, the similarity with Dutch disease effects is the improvement of the real exchange rate. This is compatible with the argument mentioned before by Fattah, Z. (2020).

3: A Model simulation with a small size of the informal sector gives a lower inflation rate.

4: The Taylor rule, which represents CBI behavior as the monetary policy through the nominal exchange rate, is confined to changes in the variables related to the Monetary policy, such as MMD and R, and does not have real impacts on the macroeconomic variables. For this reason, the monetary policy in Iraq uses the foreign exchange window tool as the main tool of CBI instead of depending on the Taylor rule and the transmission mechanism of the interest rate.

As a result, the emerging mono-economy heavily dependent on oil should improve the reality of the economic situation by improving the non-oil production sectors and diversifying the sources of foreign reserves, because depending on one source makes the economy vulnerable to the economic shock that results from international markets that are not subjected to domestic factors.

6 - Conclusion:

We construct a new Keynesian model within the context of a Dynamic General Stochastic Equilibrium model, for which the parameters of the model are calibrated for the case of Iraq, and the model includes the household sector. In this thesis, we study a small open oil export economy where the oil export sector constitutes 95 percent of its exports and is considered to be the main source of its foreign revenues. In addition to the presence of a large informal sector for this purpose. The model is closed by two government authorities: the first is the monetary authority, which is represented by the Taylor rule, and the second is the fiscal policy, which is represented by government spending. All of the firms in the model are located within the country, and all of the oil produced is destined for export. The production of both formal and informal firms is consumed entirely within the country. The export and import markets are the primary channels through which the model communicates with the rest of the world.

The Impulse Response Functions (IRFs) that were generated as a result of the model simulation for positive oil price shocks were generated twice. The first group of IRFs showed the results of the simulation by assuming a large informal sector, while the second group showed the simulation by assuming a small shadow economy. In order to accomplish this, we decreased the informality parameters in the model.
The three main points that demonstrate the main findings of the thesis are as follows: first, there is no evidence of Dutch disease in the economy of Iraq, despite the fact that the real exchange rate has increased; second, non-oil output has increased in response to increases in international oil prices; and third, the positive oil price shock has improved the economy overall, as well as consumption and production output in all areas. Second, the impact of monetary policy, as reflected in the Taylor rule, is restricted to the variables that pertain to monetary policy and does not have any influence on the variables that pertain to the overall economy. Third, assuming that the size of the informal sector is relatively small, prices and domestic inflation will fall, which will lead to a reduction in the overall inflation rate.

7 - Log-linearized model:

Log-linearize around Steady State by applying Uhlig method:

Uhlig's method (Uhlig, H. 1999) is one of the most important stages that is common in DSGE models; it is used for converting non-linear models to linear form around their steady state. By this step, it is easier to find the approximation of the policy function by recursively solving the value function and get a deep understanding of the non-linear system behavior. Simply replacing a variable X_t with

$$X_t = X_{ss} e^{\hat{X}_t}$$

$$\hat{X}_t = logX - logX_{ss}$$

This is log of the deviation of variable to its steady state.

Euler equation

$$\hat{C}_t = E_t[\hat{C}_{t+1}] + \frac{1}{\sigma}(-\hat{R}_t + E_t[\widehat{\pi_{t+1}}])$$

Money demand

$$\widehat{MD_{t+1}} = \frac{\sigma}{\nu}\hat{C}_t - \left[\frac{\widehat{R_t}}{\nu(R\_ss - 1)}\right]$$

Labor supply

$$\widehat{N_t} = \widehat{N_t^I} + \widehat{N_t^F}$$

Formal labour supply

$$\widehat{N_t^F} = N_{H,t}^{FO} + \widehat{N_t^{FN}}$$

Formal non-oil labor supply

$$\widehat{N_t^{FN}} = \frac{1}{\varphi}(\widehat{W_t^F} - \widehat{W_t}) + \widehat{N_t}$$

Oil labour supply:

$$N_{H,t}^{FO} = 0.01\ (N_{H,t}^{FN})$$

Informal labor supply

$$\widehat{N_t^I} = \frac{1}{\varphi}(\widehat{W_t^I} - \widehat{W_t}) + \widehat{N_t}$$

Formal wage

$$\widehat{W_t^F} = \kappa(\widehat{W_t^I})$$

Informal wage

$$\widehat{W_t^I} = \varphi(\widehat{P_t^I} - \widehat{P_t}) + \widehat{W_t}$$

Non-tradable consumption

$$\hat{C}_{H,t} = -\psi(\hat{P}_{H,t} - \hat{P}_t) + \hat{C}_t$$

Formal non-tradable consumption

$$\hat{C}_{H,t}^F = -\mu(\hat{P}_{H,t}^F - \hat{P}_{H,t}) + \hat{C}_{H,t}$$

Informal non-tradable consumption

$$\hat{C}_{H,t}^I = -\mu(\hat{P}_{H,t}^I - \hat{P}_{H,t}) + \hat{C}_{H,t}$$

Foreign consumption

$$\hat{C}_{F,t} = -\psi(\hat{P}_{F,t} - \hat{P}_t) + \hat{C}_t$$

Foreign non-oil imported goods consumption

$$\hat{C}_{F,t}^{f} = -\varsigma\left(\hat{P}_{F,t}^{f} - \hat{P}_{F,t}\right) + \hat{C}_{F,t}$$

Oil tradable consumption

$$\hat{\mathrm{C}}_{F,\mathrm{t}}^{\mathrm{o}} = -\varsigma\left(\hat{\mathrm{P}}_{F,\mathrm{t}}^{\mathrm{o}} - \hat{\mathrm{P}}_{F,\mathrm{t}}\right) + \hat{\mathrm{C}}_{F,\mathrm{t}}$$

CPI (Total price)

$$\hat{\mathrm{P}}_{\mathrm{t}} = (1-\upsilon)\hat{\mathrm{P}}_{F,\mathrm{t}} + (\upsilon)\hat{\mathrm{P}}_{H,\mathrm{t}}$$

Non-tradable price consumption

$$\hat{\mathrm{P}}_{H,\mathrm{t}} = (1-\omega)\hat{\mathrm{P}}_{H,\mathrm{t}}^{\mathrm{F}} + (\omega)\hat{\mathrm{P}}_{H,\mathrm{t}}^{\mathrm{I}}$$

Foreign price

$$\hat{\mathrm{P}}_{F,\mathrm{t}} = (1-\alpha)\hat{\mathrm{P}}_{F,\mathrm{t}}^{\mathrm{o}} + (\alpha)\hat{\mathrm{P}}_{F,\mathrm{t}}^{\mathrm{f}}$$

Home formal non-tradable price

$$\hat{\mathrm{P}}_{H,\mathrm{t}}^{\mathrm{F}} = \hat{\mathrm{P}}_{H,\mathrm{t}-1}^{\mathrm{F}} + \pi_{H,t}^{F}$$

Foreign price of non-oil goods

$$p_{F,t}^{f} = e_t + p_t^{*}$$

Oil price in domestic markets

$$P_{F,t}^{o} = (1-x)P_{F,t-1}^{o} + xP_{F,t}^{OS_t}$$

International oil prices

$$P_{F,t}^{OS_t} = \rho_{P_{F,t}^{OS_t}} P_{F,t-1}^{OS_t} + \varepsilon_{\mathrm{t}}^{P_{F,t}^{OS_t}}$$

International non-oil imported goods

$$p_{F,t}^{f} = \rho_{p_{F,t}^{f}} p_{F,t-1}^{f} + \varepsilon_{t}^{p_{F,t}^{f}}$$

Total inflation

$$\pi_{t} = \pi_{F,t} + \pi_{H,t}$$

Tradable inflation

$$\pi_{F,t} = \hat{P}_{F,t} - \hat{P}_{F,t-1}$$

Non-tradable inflation

$$\pi_{H,t} = \hat{P}_{H,t} - \hat{P}_{H,t-1}$$

International Oil inflation

$$\pi_{F,t}^{o} = \rho_{\pi^{o}} \pi_{F,t-1}^{o} + \varepsilon_{t}^{\pi^{o}}$$

Imported inflation.

$$\pi_{F,t}^{f} = \rho_{\pi_{F,t}^{f}} \pi_{F,t-1}^{f} + \varepsilon_{t}^{\pi_{F,t}^{f}}$$

Informal inflation

$$\widehat{\pi_{t}^{I}} = \widehat{W_{t}^{I}} - \widehat{W_{t-1}^{I}}$$

Formal non -tradable NKPC

$$\pi_{t}^{F} = \beta E_{t}[\pi_{t+1}^{F}] + \lambda_{F}(mc_{F,t})$$

Real Exchange rate

$$q_t = p_t^f - p_t$$

Nominal exchange rate

$$e_t = \rho_e \hat{e}_{t-1} + \varepsilon_{e,t}$$

Oil production functio*n*

$$\hat{Y}_{T,t}^{o} = \hat{A}_{T,t}^{o} + \hat{N}_t^{O}$$

Real marginal cost of oil sector

$$\widehat{\mathrm{RMC}}_{\mathrm{t}}^{\mathrm{O}} = \widehat{\mathrm{W}}_{\mathrm{t}}^{\mathrm{F}} - (\widehat{\mathrm{A}}_{\mathrm{T,t}}^{\mathrm{o}} + \widehat{\mathrm{P}}_{\mathrm{T,t}}^{\mathrm{o}})$$

Oil productivity

$$\widehat{\mathrm{A}}_{\mathrm{T,t}}^{\mathrm{o}} = \rho_{\mathrm{A^o}} \widehat{\mathrm{A}}_{\mathrm{T,t-1}}^{\mathrm{o}} + \varepsilon_{\mathrm{t}}^{\mathrm{A^o}}$$

Formal non-tradable production function

$$\widehat{\mathrm{y}_{H,\mathrm{t}}^{\mathrm{F}}} = \widehat{\mathrm{A}_{\mathrm{F}}} + \widehat{\mathrm{N}_{\mathrm{F}}}$$

Formal productivity

$$\widehat{\mathrm{A}_{H,\mathrm{t}}^{\mathrm{F}}} = \mathrm{p}_{\mathrm{A}_{\mathrm{N,t}}^{\mathrm{F}}} \widehat{\mathrm{A}_{\mathrm{N,t-1}}^{\mathrm{F}}} + \varepsilon_{\mathrm{F,t}}^{\mathrm{a}}$$

Formal non-tradable marginal cost

$$\widehat{\mathrm{MC}}_{H,\mathrm{t}}^{\mathrm{F}} = \widehat{\mathrm{W}}_{\mathrm{t}}^{\mathrm{F}} - (\widehat{\mathrm{P}}_{H,\mathrm{t}}^{\mathrm{F}} + \widehat{\mathrm{A}}_{H,\mathrm{t}}^{\mathrm{F}})$$

Informal non-tradable production function

$$\widehat{y^{I}_{H,t}} = \widehat{N^{I}_{H,t}}$$

Taylor rule

$$\widehat{R_t} = \rho_{R_t}(\widehat{R}_{t-1}) + (1 - \rho_{R_t})(\phi_\pi \pi_t + \phi_Y \widehat{Y}_t + \phi_q q_t) + \varepsilon_R$$

Fiscal budget constraint

$$T_t + FRR_{t-1} + B_t = FRR_t + R_{t-1}B_{t-1} + G_t$$

Bonds

$$\hat{B}_t = R_{ss}\hat{B}_{t-1} + R_{ss}\frac{B_{ss}}{Y_{ss}}\hat{R}_{t-1} + R_{ss}\frac{B_{ss}}{Y_{ss}}\pi_t$$

Financial reserves revenues

$$FRR_t = FRR_{t-1} + P_t^{*o}C_t^{*o}$$

Oil price subsidy equation

$$OS_t = e(P_{F,t}^{OS_t}) - P_{F,t}^{o}$$

Government spending

$$\widehat{\boldsymbol{G_t}} = \boldsymbol{\rho}\widehat{\boldsymbol{G}}_{\boldsymbol{t-1}} + (\mathbf{1} - \boldsymbol{\rho})((\boldsymbol{B_t} - \boldsymbol{R_{t-1}B_{t-1}}) - \boldsymbol{FRR_t} - FRR_{t-1}) + \boldsymbol{\varepsilon_t^R}$$

GDP equation

$$\widehat{\boldsymbol{y_{GDP}}} = \hat{\boldsymbol{c}}\frac{\boldsymbol{c_{ss}}}{\boldsymbol{y_{ss}}} + \hat{\boldsymbol{g}}\frac{\boldsymbol{g_{ss}}}{\boldsymbol{y_{ss}}} + \hat{\boldsymbol{x}}\frac{\boldsymbol{x_{ss}}}{\boldsymbol{y_{ss}}} + \hat{\boldsymbol{m}}\frac{\boldsymbol{m_{ss}}}{\boldsymbol{y_{ss}}}$$

Oil output export

$$Y^{o}_{T,t} = C^{o}_{T,t}\frac{C^{o}_{T,ss}}{Y^{o}_{T,ss}} + C^{*}_{t}$$

Imports

$$\widehat{m} = \frac{cf_{ss}}{m_{ss}}(\widehat{cc} + \widehat{P^{f^{*}}_{F,t}}) + \frac{co_{ss}}{m_{ss}}(\widehat{co} + \widehat{P^{o^{*}}_{F,t}})$$

Export

$$\widehat{x} = \widehat{P^{o^{*}}_{F,t}} + \widehat{Y^{o}_{H}}$$

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Appendix:

FOC of household utility:

$$\frac{\partial \mathcal{L}}{\partial C} = 0 \qquad \lambda = \frac{\beta^t C^{-\sigma}}{P_t} \qquad 1$$

$$\frac{\partial \mathcal{L}}{\partial N_t} = 0 \qquad \lambda = \frac{\beta^t {N_t}^{\varphi}}{W_t} \qquad 2$$

$$\frac{\partial \mathcal{L}}{\partial m_{t+1}} = 0 \qquad \beta^t \frac{1}{P_t}\left(\frac{m_{t+1}}{P_t}\right)^{-v} + E\lambda_{t+1} = \lambda \qquad 3$$

$$\frac{\partial \mathcal{L}}{\partial B_{t+1}} = 0 \qquad \lambda_t Q_t = \lambda_{t+1} E_t \qquad 4$$

By combine 1 + 2 we get

$$-\frac{U_{n,t}}{U_{c,t}} = \frac{W_t}{P_t}$$

$which\ is\ the\ marginal\ rate\ of\ substitution\ between\ consumption\ and\ labor\ is\ equal\ to\ real\ wage$

$$\frac{N^{\varphi}}{{C_t}^{-\sigma}} = \frac{W_t}{P_t}$$

$(Labor\ \ equation)$

Combine 1 + 4

$$\frac{\beta^t C^{-\sigma} Q_{t+1}}{P_t} = \frac{\beta^t C^{-\sigma} E_t}{P_{t+1}}$$

$$Q_t = E_t\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{1}{\pi_{t+1}}\right)$$

Where:

$$\pi_{t+1} = \frac{P_{t+1}}{P_t} \quad Gross\ rate\ inflation$$

Now by combine (Euler equation and labor supply) we can rewrite labor equation as

$$N^{\varphi} C^{-\sigma} = \frac{W_t}{P_t}$$

$$\mathfrak{w}_t - \mathcal{P}_t = \sigma c_t + \varphi \mathfrak{n}_t$$

Which is the condition determining the quantity of labor supplied as a function of real wage.

And by log-linearize it we get

By combine 1 + 3 we derive demand money*:*

$$\frac{m_{t+1}}{p_t} = C_t^{\frac{\sigma}{v}} (1 - Q_t)^{-\frac{1}{v}}$$

Bonds yield

While Bonds pay out 1 the period after the purchase at price Q_{t+1}Bonds yield is derived as*:*

$$Yield = \frac{1 - Q_{t+1}}{Q_{t+1}}$$

$$1 + yield = (Q_{t+1})^{-1}$$

$$log(1 + yield) = -logQ_{t+1}$$

$$Yeild \cong -logQ_{t+1}$$

$$\cong \iota_t$$

To get demand of Formal and informal goods, we start from consumption expenditure to find equations for all kinds of goods in Iraqi economy:

How household allocate expenditure

, this problem solved by choosing the optimal level of $C_t(i), which\ this\ C\ willvary\ among\ all\ kinds$:

$$X_t = \int_0^1 P_t\,(i) C_t(i) di$$

$$X_t : household\ expenditure\ on\ good\ i$$

We have CES of C_t:

$$C_t = \left(\int_0^1 C_t(i)^{1-\frac{1}{\mathcal{E}_p}} di \right)^{\frac{\mathcal{E}_p}{\mathcal{E}_p - 1}}$$

$\mathcal{E}_p$: *elasticity of substitution among consumption goods variaties that are imperfect substitutes*

$$\mathcal{L}\left(\int_0^1 C_t(i)^{1-\frac{1}{\mathcal{E}_p}} di \right)^{\frac{\mathcal{E}_p}{\mathcal{E}_p - 1}} + \propto_t \left[X_t - \int_0^1 P_t(i) C_t(i) di \right]$$

$$\frac{\partial \mathcal{L}}{\partial C_t(i)} = 0$$

$$\frac{\mathcal{E}_p}{\mathcal{E}_p - 1} \left[\int_0^1 C_t(i)^{1-\frac{1}{\mathcal{E}_p}} di \right]^{\frac{\mathcal{E}_p}{\mathcal{E}_p - 1} - 1} \frac{\mathcal{E}_p}{\mathcal{E}_p - 1} C_t(i)^{\frac{\mathcal{E}_p}{\mathcal{E}_p - 1} - 1} - \propto_t P_t(i) = 0$$

$$\left[\int_0^1 C_t(i)^{1-\frac{1}{\mathcal{E}_p}} di \right]^{\frac{1}{\mathcal{E}_p - 1}} C_t(i)^{-\frac{1}{\mathcal{E}_p}} = \propto_t P_t(i)$$

$$\left[\left(\int_0^1 C_t(i)^{1-\frac{1}{\mathcal{E}_p}} di \right)^{\frac{\mathcal{E}_p}{\mathcal{E}_p - 1}} \right]^{\frac{1}{\epsilon_p}} C_t(i)^{-\frac{1}{\mathcal{E}_p}} = \propto_t P_t(i)$$

$$C_t^{\frac{1}{\mathcal{E}_p}} C_t(i)^{-\frac{1}{\mathcal{E}_p}} = \propto_t P_t(i)$$

This holds for each $(i) \in [0,1], for any pair (i,j), of different goods$:

$$\frac{C_t^{\frac{1}{\mathcal{E}_p}} C_t(i)^{-\frac{1}{\mathcal{E}_p}}}{C_t^{\frac{1}{\mathcal{E}_p}} C_t(j)^{-\frac{1}{\mathcal{E}_p}}} = \frac{\propto_t P_t(i)}{\propto_t P_t(j)}$$

$$\left(\frac{C_t(i)}{C_t(j)} \right)^{-\frac{1}{\mathcal{E}_p}} = \frac{P_t(i)}{P_t(j)}$$

Aggregate consumption $\boldsymbol{C_t(i) = C_t(j) \left(\frac{P_t(i)}{P_t(j)} \right)^{-\mathcal{E}}}$

By apply these steps to all kinds of goods, we get

To get Consumer Price Index, and total expenditure, we follow:

By inserting $C_t(i) = C_t(j)\left(\frac{P_t(i)}{P_t(j)}\right)^{-\mathcal{E}}$ *into* $X_t = \int_0^1 P_t\,(i)C_t(i)di$

$$X_t = \int_0^1 C_t(j)\left(\frac{P_t(i)}{P_t(j)}\right)^{-\mathcal{E}} C_t(i)di$$

$$X_t = P_t(j)C_t(j)\int_0^1 P_t(i)^{1-\mathcal{E}}\,di$$

$$C_t(j) = \frac{X_t P_t(i)^{-\mathcal{E}}}{\int_0^1 P_t(i)^{1-\mathcal{E}}\,di}$$

Assume i,j , we substitute this into

$$C_t = \left(\int_0^1 C_t(i)^{1--\frac{1}{\mathcal{E}_p}}\,di\right)^{\frac{\mathcal{E}_p}{\mathcal{E}_p-1}}$$

$$C_t = \int_0^1 \left[\left(\frac{X_t P_t(i)^{-\mathcal{E}}}{\int_0^1 P_t(i)^{1-\mathcal{E}}\,di}\right)^{1-\frac{1}{\mathcal{E}_p}}\right]^{\frac{\mathcal{E}_p}{\mathcal{E}_p-1}}$$

$$C_t = X_t\left[\int_0^1 \frac{X_t P_t(i)^{1-\mathcal{E}}}{\left(\int_0^1 P_t(i)^{1-\mathcal{E}}\,di\right)}\right]^{\frac{\mathcal{E}_p}{\mathcal{E}_p-1}}$$

$$C_t = X_t\left[\left(\int_0^1 P_t(i)^{1-\mathcal{E}}di\right)^{1-\frac{\mathcal{E}_p-1}{\mathcal{E}_p}}\right]^{\frac{\mathcal{E}_p}{\mathcal{E}_p-1}}$$

$$C_t = X_t \left(\int_0^1 P_t(i)^{1-\varepsilon} di \right)^{\frac{1}{\varepsilon_p - 1}}$$

Rewrite this as aggregate price index

$$1 = P_t \left(\int_0^1 P_t(i)^{1-\varepsilon} di \right)^{\frac{1}{\varepsilon_p - 1}}$$

$$P_t = \left(\int_0^1 P_t(i)^{1-\varepsilon} di \right)^{\frac{1}{\varepsilon_p - 1}}$$

Aggregate price dynamic

$$P_t = \left(\int_0^1 P_t(i)^{1-\varepsilon} di \right)^{\frac{1}{\varepsilon_p - 1}}$$

$$P_t = \left(\int_0^1 P_{t-1}(i)^{1-\varepsilon} di + \int_0^1 P_t^*(i)^{1-\varepsilon} di \right)^{\frac{1}{\varepsilon_p - 1}}$$

As all firms are identical, so they all set same price, then we can rewrite price index as

$$P_t = \left[\theta (P_{t-1})^{1-\varepsilon} + (1-\theta) {P_t^*}^{1-\varepsilon} \right]^{\frac{1}{\varepsilon_p - 1}}$$

$/P_{t-1}$

$$\left(\frac{P_t}{P_{t-1}} \right)^{1-\varepsilon} = \frac{\left[\theta (P_{t-1})^{1-\varepsilon} + (1-\theta) {P_t^*}^{1-\varepsilon} \right]}{{P_{t-1}}^{1-\varepsilon}}$$

$$\pi_t^{1-\varepsilon} = \theta + (1-\theta) \left(\frac{P_t^*}{P_{t-1}} \right)^{1-\varepsilon}$$

$\pi_t^{1-\varepsilon}$: *is gross inflation, and* P_t^* *is price set by firms in period* t.

The log linearization is

$$\widehat{\pi_t} = (1-\theta)(\widehat{P_t^*} - \widehat{P_{t-1}})$$

To derive expression for the expenditures in terms of aggregate variables:

$$X_t = P_t(j)C_t(j)\int_0^1 P_t(i)^{1-\varepsilon}\,di$$

$$X_t = P_t(j)C_t(j)\left[\left(\int_0^1 P_t(i)^{1-\varepsilon}\,di\right)^{\frac{1}{\varepsilon_p-1}}\right]^{1-\varepsilon}$$

$$X_t = C_t(j)P_t(j)^{\varepsilon}{P_t}^{1-\varepsilon}$$

This expression hold for any pair (i,j),

$$C_t(j) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon}\frac{X_t}{P_t}$$

Insert this into

$$C_t = \left(\int_0^1 C_t(i)^{1--\frac{1}{\varepsilon_p}}\,di\right)^{\frac{\varepsilon_p}{\varepsilon_p-1}}$$

$$C_t = \left(\int_0^1 \left(\left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon}\frac{X_t}{P_t}\right)^{1-\frac{1}{\varepsilon_p}} di\right)^{\frac{\varepsilon_p}{\varepsilon_p-1}}$$

$$C_t = X_t\,P_t^{-1}\left[\left(\int_0^1 P_t(i)^{1-\varepsilon}di\right)^{1-\frac{1}{\varepsilon_p}}\right]^{-\varepsilon}$$

$$C_t = X_t\,P_t^{\varepsilon-1}P_t^{-1}$$

$$C_t = X_t\,P_t^{-1}$$

$$\boldsymbol{X_t = \int_0^1 P_t(i)C_t(i)\,di = P_tC_t}$$

Which is Aggregate consumption expenditures of household, and by insert it into $C_t(j) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon}\frac{X_t}{P_t}$ *Gives household's demand for consumption goods*

$$C_t(j) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon}C_t$$

If the price of a good I increase relative to the overall price level, demand for a good i decreases, higher overall demand automatically increases demand for a good i.

$$\boldsymbol{insert} \quad \boldsymbol{X_t = \int_0^1 P_t(i)C_t(i)\,di = P_tC_t} \quad \boldsymbol{into\ Budget\ constriant}$$

Constant Elasticity of Substitution

CES of the consumption index of consumption of formal and informal goods. (Appendix)

$$\boldsymbol{C^F_{N,t} \equiv \left(\int_0^1 C^F_{N,t}(i)^{\frac{\varepsilon^F_N - 1}{\varepsilon^F_N}} di \right)^{\frac{\varepsilon^F_N}{\varepsilon^F_N - 1}}}$$

$\boldsymbol{C^F_{N,t}}$: *represents a CES index of formal consumption goods.*

$$\boldsymbol{C^I_{N,t} \equiv \left(\int_0^1 C^I_t(i)^{\frac{\varepsilon^I_N - 1}{\varepsilon^I_N}} di \right)^{\frac{\varepsilon^I_N}{\varepsilon^I_N - 1}}}$$

$\boldsymbol{C^I_{N,t}}$: *represents a CES index of informal consumption goods.*

$\varepsilon > 1$ *measures the elasticity of substitution between varieties of formal goods, and between informal goods, respectively.*

The Home oil consumption represents a CES index of domestic home oil tradable consumption goods.

$$\boldsymbol{C^o_{T,t} \equiv \left(\int_0^1 C^o_{T,t}(j)^{\frac{\varepsilon_o - 1}{\varepsilon_o}} di \right)^{\frac{\varepsilon_o}{\varepsilon_o - 1}}}$$

$\varepsilon > 1$ *measures the elasticity of substitution between varieties in any given country.*

$\boldsymbol{j}: \in [\mathbf{0}, \mathbf{1}]$ $\boldsymbol{denotes\ the\ goods}$ $variety$.

The foreign non-oil consumption goods $C^f_{T,t}$ *represent a CES index of imported consumption goods.*

$$\boldsymbol{C^f_{T,t} \equiv \left(\int_0^1 C^i_{T,t}(j)^{\frac{\varepsilon_f - 1}{\varepsilon_f}} di \right)^{\frac{\varepsilon_f}{\varepsilon_f - 1}}}$$

$\boldsymbol{\varepsilon_f}$: measures the degree of substitution between goods produced in different foreign countr

$$C_{T,t}^{i} \equiv \left(\int_0^1 C_{T,t}^{i}(j)^{\frac{\varepsilon_i - 1}{\varepsilon_i}} di \right)^{\frac{\varepsilon_i}{\varepsilon_i - 1}}$$

$C_{T,t}^{i}$: index of the goods imported from the foreign country i

Where $\boldsymbol{P_{T,t}^{o}}$ *is the price index of home oil tradable expressed as:*

$$P_{T,t}^{o} \equiv \left(\int_0^1 P_{T,t}^{o}(j)^{1-\varepsilon_o} di \right)^{\frac{1}{1-\varepsilon_o}}$$

Similarly, the optimal of expenditures on imports by country of origin is given by:

$$C_{T,t}^{i} = \left(\frac{P_{T,t}^{i}}{P_{T,t}^{f}} \right)^{-\varepsilon_i} C_{i,t}^{f}$$

Where $\boldsymbol{P_{i,t}}$ *is the price index in domestic currency for imports from country i defined as:*

$$P_{T,t}^{i} \equiv \left(\int_0^1 P_{T,t}^{i}(j)^{1-\varepsilon_o} di \right)^{\frac{1}{1-\varepsilon_o}}$$

And $\boldsymbol{P_{T,t}^{i}}$

$$P_{T,t}^{i} \equiv \left(\int_0^1 {P_{T,t}^{i}}^{1-\varepsilon_i} di \right)^{\frac{1}{1-\varepsilon_i}}$$

Price indexes of formal and informal: (Appendix)

$$P_{N,t}^{F} \equiv \left(\int_0^1 P_{N,t}^{F}(i)^{1-\varepsilon_N^F} di \right)^{\frac{1}{1-\varepsilon_N^F}}$$

$$P_{N,t}^{I} \equiv \left(\int_0^1 P_{N,t}^{I}(i)^{1-\varepsilon_N^I} di \right)^{\frac{1}{1-\varepsilon_N^I}}$$

Getting (New Keynesian Philips Curve):

We start from inserting demand function into max profits equation, by first order condition with respect to $P_{T,t}^{*H}$

$$\frac{\partial \boldsymbol{Y}^{\boldsymbol{F}}_{\boldsymbol{t,t+1}}(j)}{\partial P_t^{*F}} = -\mathcal{E}\left(\frac{\mathcal{P}_t^F(j)}{\mathcal{P}_t^F}\right)^{-\mathcal{E}-1}\left(\frac{1}{\mathcal{P}_t^F}\right)(C^F_{t+k})$$

$$-\mathcal{E}\left(\frac{\mathcal{P}_t^F(j)}{\mathcal{P}_t^F}\right)\left(\frac{C^F_{t+k}}{\mathcal{P}_t^F}\right)$$

$$= -\mathcal{E}\frac{\boldsymbol{Y}^{\boldsymbol{F}}_{\boldsymbol{t,t+1}}}{P_t^{*F}}$$

By inserting demand function equation into max profits

$$max_{P_t^{*F}} E_t \sum_{k=0}^{\infty} \theta_T^k \, E_t\left[Q_{t,t+k}\left(\boldsymbol{Y}^{\boldsymbol{F}}_{\boldsymbol{t,t+k}}\left(P_t^{*F}\frac{\partial \boldsymbol{Y}^{\boldsymbol{F}}_{\boldsymbol{t,t+k}}(j)}{\partial P_t^{*F}} - MC^n_{F,t+k}\frac{\partial \boldsymbol{Y}^{\boldsymbol{F}}_{\boldsymbol{t,t+k}}(j)}{\partial P_t^{*F}}\right)\right)\right]$$

The optimality condition (max profits) is

$$max_{P_t^{*F}} E_t \sum_{k=0}^{\infty} \theta_T^k \, E_t\left[Q_{t,t+k}\left(P_t^{*F}\left(P_t^{*F}(-\mathcal{E}\tfrac{\boldsymbol{Y}^{\boldsymbol{F}}_{\boldsymbol{t,t+k}}}{P_t^{*F}}) - MC^n_{F,t+k}(-\mathcal{E}\tfrac{\boldsymbol{Y}^{\boldsymbol{F}}_{\boldsymbol{t,t+k}}}{P_t^{*F}})\right)\right)\right]$$

$*P_t^{*F}$ *and then extract*

$$max_{P_t^{*F}} E_t \sum_{k=0}^{\infty} \theta_T^k \, E_t\left[Q_{t,t+k}\left(\boldsymbol{Y}^{\boldsymbol{F}}_{\boldsymbol{t,t+k}}\left(P_t^{*F} - \frac{\mathcal{E}}{\mathcal{E}-1} - MC^n_{F,t+k}\right)\right)\right] = 0$$

By replacing

$$Q_{t,t+k} = \beta^k E_t\left(\frac{C^F_{t+k}}{C^F_t}\right)^{-\sigma}\left(\frac{P^F_t}{P^F_{t+k}}\right)$$

$$max_{P_t^{*F}} E_t \sum_{k=0}^{\infty} \theta_T^k \, E_t\left[\beta^k E_t\left(\frac{C^F_{t+k}}{C^F_t}\right)^{-\sigma}\left(\frac{P^F_t}{P^F_{t+k}}\right)\left(\boldsymbol{Y}^{\boldsymbol{F}}_{\boldsymbol{t,t+k}}\left(P_t^{*F} - \frac{\mathcal{E}}{\mathcal{E}-1} - MC^n_{F,t+k}\right)\right)\right] = 0$$

$$max_{P_t^{*F}} E_t \sum_{k=0}^{\infty} \theta_T^k \, E_t\left[\left(\frac{{C^F_{t+k}}^{-\sigma}}{P^F_{t+k}}\boldsymbol{Y}^{\boldsymbol{F}}_{\boldsymbol{t,t+k}}\right)\left(P_t^{*F} - \frac{\mathcal{E}}{\mathcal{E}-1} - MC^n_{F,t+k}\right)\right] = 0$$

$$* \left(\frac{P^F_{t-1}}{P_{t-1}}\right)$$

$$max_{P_t^{*F}} E_t \sum_{k=0}^{\infty} \theta_T^k \, E_t\left[\left({C^F_{t+k}}^{-\sigma}\boldsymbol{Y}^{\boldsymbol{F}}_{\boldsymbol{t,t+k}} \;\; \frac{P^F_{t,t-1}}{P^F_{t,t-1}}\right)\left(\frac{P_t^{*F}}{P^F_{t,t-1}} - \frac{\mathcal{E}}{\mathcal{E}-1} - \frac{P^F_{t,t+1}}{P^F_{t,t-1}}MC^n_{F,t+k}\right)\right] = 0$$

$$\frac{P^F_{t,t+1}}{P^F_{t,t-1}} = \pi^F_{t-1,t+k}$$

$$\frac{MC^{n}_{F,t+k}}{P^{F}_{t,t+1}} = MC^{r}_{F,t+k}$$

$$max_{P^{*F}_t} E_t \sum_{k=0}^{\infty} \theta_T^k \, E_t \left[\left(C^{F}_{t+k}{}^{-\sigma} \boldsymbol{Y^{F}_{t,t+k}} \quad \frac{P^{F}_{t,t-1}}{P^{F}_{t,t-1}} \right) \left(\frac{P^{*F}_t}{P^{*F}_{t,t-1}} - \frac{\mathcal{E}}{\mathcal{E}-1} \pi^{HF}_{t-1,t+k} MC^{r}_{F,t+k} \right) \right] = 0$$

$$P^{*F}_t = P^{F}_t + \sum_{k=0}^{\infty} \theta_T^k \, \beta^k E_t \left(\pi^{F}_{t-1,t+k} \right) + \left(1 - \beta\theta_p \right) \sum_{k=0}^{\infty} \theta_T^k \left(mc_{F,t} - mc_F \right)$$

$$P^{*F}_t \; - \; P^{F}_t = \theta_T^k \beta^k E_t (P^{*F}_t \; - \; P^{F}_t) + \pi^{F}_t + \left(1 - \beta\theta_p \right) \left(mc_{F,t} - mc_F \right)$$

Under Calvo pricing, Home tradable price index is

$$P^{F}_t \equiv [\theta_T (P^{F}_t)^{1-\mathcal{E}} + (1-\theta_T)(P^{*F}_t)^{1-\mathcal{E}}]^{\frac{1}{1-\mathcal{E}}}$$

By logline arise it

$$\pi^{F}_t = (1-\theta_T)(P^{*F}_t - P^{F}_t)$$

Combine $P^{*F}_t \; - \; P^{F}_t = \theta_T^k \beta^k E_t (P^{*F}_t \; - \; P^{F}_t) + \pi^{F}_t + \left(1 - \beta\theta_p \right) \left(mc_{F,t} - mc_F \right)$ *with*

$$\pi^{F}_t = (1-\theta_T)(P^{*F}_t - P^{F}_t)$$

We get:

$$\frac{\pi^{F}_t}{(1-\theta_T)} = \theta_T^k \beta^k E_t \left(\frac{\pi^{F}_t}{1-\beta\theta_T} \right) + \pi^{F}_t \; + \; (1-\beta\theta_T) \left(mc_{F,t} - mc_F \right)$$

$$(1-\beta\theta_T) *$$

$$\pi^{F}_t \; = \theta_T^k \beta^k E_t \, \pi^{F}_t \; + \; (1-\theta_T)\pi^{F}_t + (1-\theta_T)(1-\beta\theta_T) \left(mc_{F,t} - mc_F \right)$$

$$\theta_T / \qquad \theta_T \pi^{F}_t = \; \theta_T^k \beta^k E_t \, [\pi^{F}_t] + (1-\theta_T)(1-\beta\theta_T) \left(mc_{F,t} - mc_F \right)$$

$$\pi^{F}_t \; = \beta^k E_t \, [\pi^{F}_t] \; + \; \frac{(1-\theta_T)(1-\beta\theta_T)}{\theta_T} \left(mc_{F,t} - mc_F \right)$$

$$\lambda_T = \frac{(1-\theta_T)(1-\beta\theta_T)}{\theta_T}$$

$$\pi^{F}_t \; = \beta^k E_t \, [\pi^{F}_t] \; + \; \lambda_T \left(mc_{F,t} - mc_F \right)$$

International risk sharing:

$$\frac{\boldsymbol{Q_t}}{\boldsymbol{Q_t}} = \frac{\beta^t \boldsymbol{E_t}\left[\left(\frac{\boldsymbol{C_{t+1}}}{\boldsymbol{C_t}}\right)^{-\sigma}\left(\frac{\boldsymbol{P_t}}{\boldsymbol{P_{t+1}}}\right)\right]}{\beta^t \boldsymbol{E_t}\left[\left(\frac{\boldsymbol{C^{*f}_{t+1}}}{\boldsymbol{C^{*f}_t}}\right)^{-\sigma}\left(\frac{\boldsymbol{P^{*f}_t}}{\boldsymbol{P^{*f}_{t+1}}}\right)\left(\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}\right)\right]}$$

$$1 = \frac{\boldsymbol{E_t}\left[\left(\frac{\boldsymbol{C_{t+1}}}{\boldsymbol{C_t}}\right)^{-\sigma}\left(\frac{\boldsymbol{P_t}}{\boldsymbol{P_{t+1}}}\right)\right]}{\boldsymbol{E_t}\left[\left(\frac{\boldsymbol{C^{*f}_{t+1}}}{\boldsymbol{C^{*f}_t}}\right)^{-\sigma}\left(\frac{\boldsymbol{P^{*f}_t}}{\boldsymbol{P^{*f}_{t+1}}}\right)\left(\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}\right)\right]}$$

$$1 = \boldsymbol{E_t}\left[\left(\frac{\boldsymbol{C_{t+1}}}{\boldsymbol{C_t}}\right)^{-\sigma}\left(\frac{\boldsymbol{C^{*f}_t}}{\boldsymbol{C^{*f}_{t+1}}}\right)^{-\sigma}\left(\frac{\boldsymbol{P_t P^{*f}_{t+1}}\mathcal{E}_{t+1}}{\boldsymbol{P_{t+1}}\mathcal{E}_t \boldsymbol{P^{*f}_t}}\right)\right]$$

$$1 = \boldsymbol{E_t}\left[\left(\frac{\boldsymbol{C_{t+1}}}{\boldsymbol{C_t}}\right)^{-\sigma}\left(\frac{\boldsymbol{C^{*f}_t}}{\boldsymbol{C^{*f}_{t+1}}}\right)^{-\sigma}\left(\frac{\mathcal{Q}_{t+1}}{\mathcal{Q}_t}\right)\right]$$

$$\boldsymbol{C_t} = \boldsymbol{E_t}\left[\left(\frac{\boldsymbol{C_{t+1}}}{\boldsymbol{C^{*f}_{t+1}}}\right)^{-\sigma}\boldsymbol{C^{*f}_t}\left(\frac{\mathcal{Q}_{t+1}}{\mathcal{Q}_t}\right)^{-\frac{1}{\sigma}}\right]$$

$$\boldsymbol{C_t} = \boldsymbol{E_t}\left[\left(\frac{\boldsymbol{C_{t+1}}}{\boldsymbol{C^{*f}_{t+1}}(\mathcal{Q}_{t+1})^{\frac{1}{\sigma}}}\right)\boldsymbol{C^{*f}_t}(\mathcal{Q}_t)^{\frac{1}{\sigma}}\right]$$

By set $\aleph = \boldsymbol{E_t}\left[\left(\frac{\boldsymbol{C_{t+1}}}{\boldsymbol{C^{f}_{t+1}}(\mathcal{Q}_{t+1})^{\frac{1}{\sigma}}}\right)(\mathcal{Q}_{t+1})^{\frac{1}{\sigma}}\right]$