Testing and Estimating a DSGE Model via Indirect Inference:

Tackling the Dutch Disease in Kuwait

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Abstract

The economy of Kuwait has very distinct features when compared to other oil endowed economies. As an oil producer, Kuwait's oil price volatility is a major determinant of the cyclical movements of macroeconomic aggregates in this economy. Thus, this thesis models a Real Business Cycle (RBC) model of Kuwait with an aim to match the cyclical movements of macroeconomic aggregates and describe the resource curse evident in the data. The Dynamic Stochastic General Equilibrium (DSGE) model of the economy is proposed and calibrated in Chapter 3. The model intuition showed that oil productivity shock is a major driver for aggregate fluctuations in this model. The results of model calibration showed that positive oil productivity shock expands oil and non-traded production whilst the non-oil sector declines. This RBC model can calibrate features of the data based on the assumptions it makes about the factor intensities across sectors and factor-price determination.

In Chapter 4 and 5, we bring data to bear by testing the validity of our proposed model via Indirect Inference. Our choice of testing is backed up by the limitations surrounding the various econometric techniques and the underlying assumptions they make, especially the Bayesian technique. The debates surrounding the assumptions made about the model and priors chosen makes the Bayesian technique a difficult choice. It is because of these controversies surrounding priors, how true they are and how they inform us about the validity of our model, that make the case for it to be rejected. Thus, the indirect inference is chosen as it provides us with a strong econometric framework to test the model against the data without claims of certainty about the priors. In other words, we can restrict our model and bring it as close as possible to the data, hence making us able to make policy suggestions to deal with the Dutch Disease in Kuwait's economy.

Finally, from our estimated model, suggestions for policy makers to tackle the Dutch Disease via labour market regulations are made in Chapter 6. More so, they are also extended to show optimal fiscal policy behaviour of the government to boom-bust output movements caused by oil price volatility. These have considerable welfare effects which are discussed for the variety of policies suggested.

Dedication

To God Almighty, for your endless grace.

To my family, for your love and support.

To my late grandma, Beatrice Osuji. I wish you had seen the end of this journey.

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If I had to say thank you to everyone who have helped me during the PhD, the list will go on for days. Thus, I say thank you to anyone who does not make it here, I am not oblivious of your help, and I appreciate you. Big Big Thank You.

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1 Introduction

"Curse or Blessing?"

That is the continuous roller-coaster question which faces many oil-endowed economies, of which Kuwait is no different. The question enquires into the welfare from resource endowment, and the answer to this question depends on the way you perceive oil endowment in these economies. On the path of blessing, the endowment of oil has been the greatest source of income for Kuwait's economy and largely influences all macroeconomic aggregates in the economy. In IMF's 2013 report on Kuwait, it showed that oil contributed about 85% of government revenue and 86% of exports in 2011. The growth in oil revenue is largely influenced by the volatility of oil prices. Hence, massive fluctuation in macroeconomic aggregates in this economy shows cycle movements strongly correlated with oil price movements. In support, the IMF reported in 2017 that during periods of persistently high oil prices between 2003-2007, per-capita income growth and private consumption growth were strongly correlated with the growth in oil prices. More so, from a fiscal standpoint, the growth of oil revenue in this economy is responsible for growth in the non-oil sectors within this period. However, we differentiate our results from some of the studies that have identified growth in both traded sectors because we identify that the general classification of the sectors as oil and non-oil does not tell the entire growth story in this economy. Therefore, we have classified the productive sectors into three sectors, oil, non-oil, and non-traded sector, which is common in open economy literature. So, just as in many open economy literature on the matter, we divide the gross domestic product by industry into these three sectors. In our classification, the oil sector is described by the oil and gas industry; whereas the non-oil sector comprises mining, agriculture, manufacturing, and refined products industries, and lastly, all other industries were classified as the nontraded sector. In every economy, there is a large domestic sector that includes the services industry and is classified as the nontraded sector. This comprises industries involved in hotels and restaurants, profession, transportation, and distribution among other activities. This sector is domestic and does not trade internationally. The nontraded sector is the second largest sector in Kuwait, accounting for about 40% of the aggregate activities whereas the oil and non-oil sector accounts for 50% and 10% respectively. It is on this basis that we have obtained the information for the figures below and we have maintained this classification all through the thesis.

The report from the figure below shows that during the periods of significant growth in oil output characterised by a rise in oil price, the non-traded sector grew whereas the non-oil traded sector declined during this boom. This summarizes the story of the Dutch disease in Kuwait with data sourced from the Central Bank of Kuwait (CBK) database.

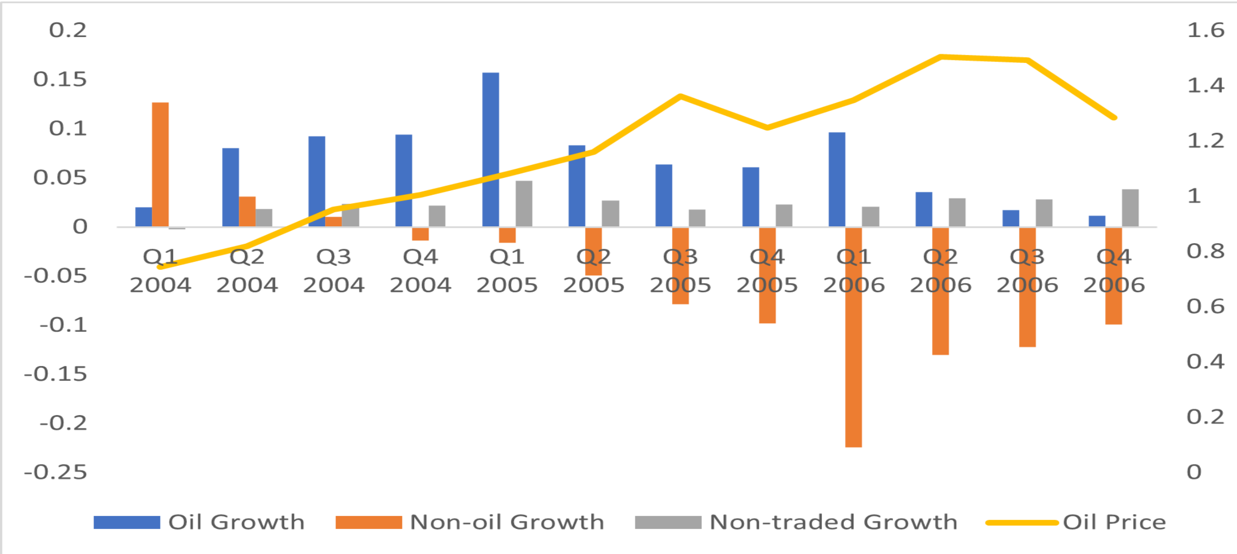

Figure 1: Quarterly Growth Rates of Kuwait's Sectors During Periods of Significant Oil Price Rise between 2004-2006(Sourced from CBK database)

This figure describes the *resource curse* in Kuwait which highlights the problem this thesis seeks to understand. However, what we observe from the figure which is contrary to many other oil endowed economies where a persistent growth in the oil sector causes all other sectors to decline, is that growth of the oil sector stimulated by persistent oil price rise causes a growth in the non-traded sector and a Dutch disease in the non-oil traded sector. This makes the problem in Kuwait to be unique. Having said that, the Dutch disease simply describes the adverse effects in the productive non-oil sector caused by the expansion of Kuwait oil productive sectors.

However, when we consider the other side of the coin when there is a persistent drop in oil price causing a contraction in the oil sector. The figure below shows that during periods of a massive decline in the oil sector, we observe that there is a massive decline in all the sectors.

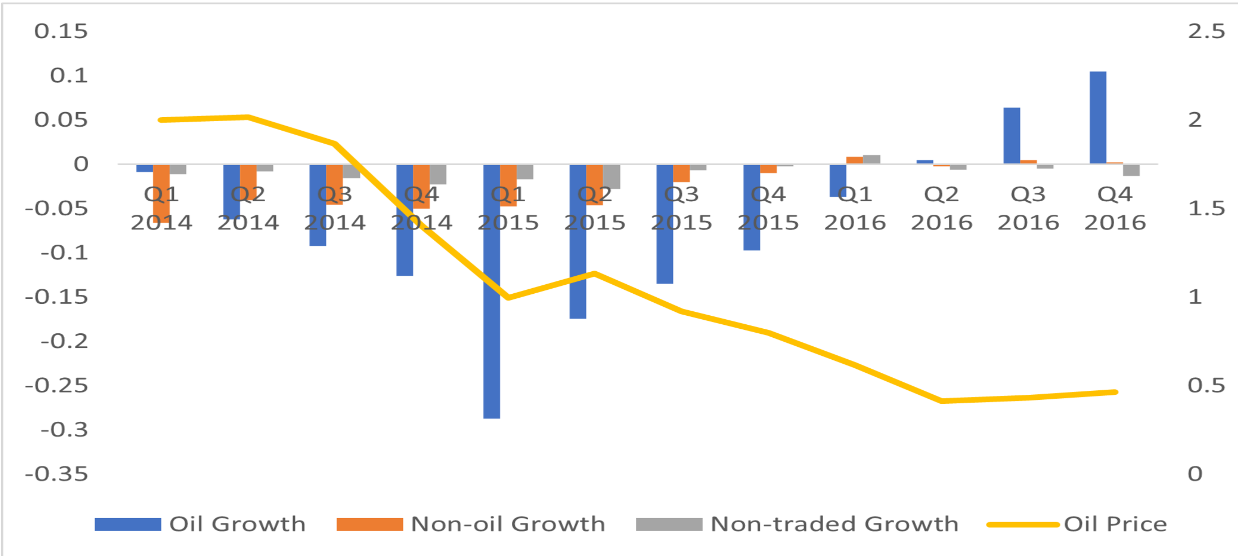

Figure 2: Quarterly Growth Rates of Kuwait's Sectors During Periods of Significant Oil Price Fall between 2014-2016(Sourced from CBK database)

Unlike the many others, Kuwait has ripped some benefits from the years of the oil boom. However, if we look closely, we are forced to ask if it has always been a blessing? With strong effects of oil revenue on the fiscal balance, private and public expenditure as well as being the driving force of cycles in this economy, it becomes necessary for this economy to be able to diversify from oil as the data suggest strong negative impacts in the cycle movements from the oil price drop. The most recent data as reported by the World Bank showed that in the first quarter of 2020, Kuwait's real GDP declined by 1.1% while the oil and non-oil sectors declined by 1.2% and 3.5% respectively. This was because of declining oil prices and Covid-19 shocks. More so, the data in recent years suggest that increased demand for alternative sources of energy is causing a decline in oil demand and may lead to a more persistent drop in oil price. This raises more questions for policymakers to answer what might happen in the face of a permanent drop in oil price. More so, oil endowments are limited and will one day run out, hence what will happen if they do not diversify effectively to other non-oil sectors. Therefore, it is very important to understand the driving features in the Kuwaiti economy and how best policymakers may handle these boom-bust moments caused by oil price volatility via macroeconomic modelling.

More so, the review of literature on Kuwait shows that it has largely been deficient in a structural model to understand the economy. Most of the models reviewed lacked micro-foundations and could be criticised based on Lucas' critique, nonetheless, we are still able to take some lessons from these reduced-form models on the story of the resource curse in Kuwait. On modelling the economy of Kuwait to understand the features of the economy, her Dutch disease and cyclical cointegrating movements, the closest models to a Dynamic

Stochastic General Equilibrium (DSGE) model for Kuwait were Computational General Equilibrium (CGE) models given in papers of Korshid (1990), Sirageldin and Khorshid (1995), Gelan (2018), Shehabi (2017, 2020) where the model was used to analyse the medium-term path of the Kuwaiti economy as oil grows in Korshid (1990) and the impact of Kuwait's energy price reforms and energy subsidy reforms on the economy in Shehabi (2017,2020). A detailed review of the literature of DSGE models, as well as models of Kuwait's economy, are contained in Chapter 2 of the thesis. Despite my review highlighting the shortfalls of the CGE models, I recognise that the popularity of these models may have been a way for researchers to cope with the data availability issues when implementing a model of Kuwait's economy.

Hence, the research aims which my thesis seeks to achieve are to:

1. Describe a DSGE model of Kuwait and determine how well this model matches the features of the Kuwait economy and the Dutch disease

2. Test and estimate the model via Indirect Inference

3. Determine the potential policy options for Kuwait to tackle her Dutch Disease

Thus in Chapter 3, we propose a real business cycle model for Kuwait which incorporates her distinct features. Our model extends the Neoclassical Real Business Cycle model of Kydland and Prescott (1982) model to include features of the open economy, expansion of the production technical possibilities with the inclusion of land as an input and the decomposition of the consumption and production options to comprise of oil, non-oil and non-traded goods. Having said that, our proposed model follows the model in Meenagh et al (2010), however, we extend their model to include multi-sector production and some features of specializations as implemented in Minford et al (2015, 2018). Hence, the model adopts the specialization assumptions of Heckscher-Ohlin-Samuelson (HOS) models which talks about specialization in certain sectors based on its factor intensity and relative factor supplies. In line with this, we obtain data of Kuwait's productive sector intensities from Kuwait's National Account Statistics Input and Output Table 2010 reported by the Central Statistical Bureau of Kuwait. The data showed that the oil sector is land-intensive given that all the natural endowments are extracted from the land and the non-oil sector which is involved in agriculture, manufacturing and mining is more labour-intensive. Thus, in our model factor supply and mobility determines the size of different sectors based on the factor intensity in respective production processes and sectors. In other words, the supply of land, that is market-clearing for land, and its sectoral intensity determines the supply of oil output; also, the market-clearing for labour and sector intensity determines the supply of non-oil output. Also, we assume that the supply of capital flows freely across sectors and borders, thus capital is thought to be a mobile factor whereas land and labour are assumed to be immobile factors.

Among the many distinct reasons for constructing a DSGE[1] model, our reason centres around explaining why the economy of Kuwait behaves the way it does and this plays a key role in determining the features which are included in our model. We describe the transmission of the Dutch disease as it is being transmitted from an oil technology shock[2]. The shock impact in the economy is described using a modified explanation of Johnson (1958) diagrams showing the importance of factor-price determination in the shock transmission and certain other underlying assumptions adopted in our model of Kuwait. Some of which included assumptions of perfect competition, the sectoral factor intensities and price taking in international markets, since Kuwait is a small open economy, among other assumptions. Using the modified Johnson's diagram in Chapter 3, we showed that a positive technology shock[3] would cause land rent to rise based on factor-price determination inherent in the model. This rise in land rent will cause a reallocation of labour to the oil sector to utilize land at the detriment of the non-oil sector. Thus, causing an expansion in the production of oil goods and a decline in the production of non-oil goods. We note that the positive productivity shock will cause the real exchange rate[4] to rise, hence a real depreciation of the real exchange rate. This causes a decline in domestic demand for traded goods and boosts the demand for non-traded goods, which causes the supply of non-tradeable goods to expand to fulfil this demand expansion. This explanation is consistent with the data evidence of Kuwait, where an expansion in oil output caused by a persistent oil rise would cause the nontraded sector to expand while there is a Dutch disease in the non-oil sector. There is a more detailed explanation of the economy-wide cyclical movement in Chapter 3.

Within our comprehensive yet not exhaustive review of the models on Kuwait, the closest models to DSGE models in the literature were Computational General Equilibrium (CGE) models, such as the ones in papers by Korshid (1990), Gelan (2018) amongst others. Despite the general criticism of CGE models in papers by Beckman et al (2011) with regards to how these models deal with future expectations, uncertainty and the priors assumed for the many parameters included in these models, I criticize these models further for not being tested against the data. Many studies on Kuwait lacked testing against the data evidence, therefore in my paper I fill the gap in the literature by proposing a DSGE model of Kuwait, and the validity of my proposed model is extended further by estimating and testing the model by indirect inference. The implication of using the Indirect Inference method is that, in comparison to other techniques in the literature, we use no prior distributions for the parameters when testing these models, rather we estimate them from the

[1]Dynamic Stochastic General Equilibrium

[2]In chapter 3, we show from our model why an increase in oil price is similar to a positive oil productivity shock. There is also more evidence on this in the calibrated and estimated impulse response functions shown in the appendix.

[3]We note that in our model setup, the effect of a positive oil technology shock would have the same effect as an exogenous rise in the price of oil which is shown in our Johnson(1958) figure and explanation.

[4]The real exchange rate is described as the ratio of traded to nontraded goods' price

proposed model and compare them on how closely they match those generated from the data. We recognise that in the literature, DSGE models have been criticised generally based on their specification, assumptions, and identification, hence there may be questions on why a DSGE model may be important here. Therefore, I begin my response to these criticisms by saying that the construction of the DSGE model is as much an art as it is science, and I recognise that it may not be a very accurate representation of an economy, and even if it is not, which model ever is? What matters is that it is the best way to obtain intuition into the workings of the economy. Besides, I increase the robustness of the model by estimating and testing the model against the data for Kuwait. To do this, I implement the Indirect Inference test in Dynare via Matlab to test the model against the data and determine how well the model matches the data. Put simply, the indirect inference procedure involves a process of comparing how much the data distribution and its moments generated by simulating an auxiliary model can match the data distribution and moments of the actual data for the economy. In the process of testing the model fit, the indirect inference method, creates a description of the data behaviour via the 'auxiliary model', usually using the moments as descriptors, and generating the implied distribution of the descriptors by simulating the model. Then to compare how well the model matches the data, the indirect inference test asks whether the probability of the data-based descriptors is greater than some confidence threshold, typically 5%. Hence, the indirect inference estimation technique involves searching over model parameters to find those parameters that best matches the data descriptors and its distribution most closely. This aim of testing and estimating the model is in line with pioneer ideas of Kydland and Prescott (1982) for dynamic stochastic general equilibrium models to test their theory and models by the ability of these models to match certain cross-sectional features, moments, of actual data for the economy and macro variables. Hence, the indirect inference method used is known as the simulated method of moments where the moments of the data simulated from the model is compared to the moments of the observed data. We note that as described in Meenagh et al (2019), that evaluation of the performance of the DSGE models via indirect inference can be done via the moments, IRFs or VAR coefficients, and regardless of which criteria being used, the indirect inference test statistic provides similar power and parameter estimates with a similar level of bias, provided that the selected data features are held constant. The estimation process involves the use of a Simulated Annealing Algorithm which was implemented via Dynare in Matlab and aimed at finding the minimum Wald statistics for the model. The result of this process is a set of parameters whose distributions set the model closest to the data. Chapter 4 contains the review of the indirect inference method and Chapter 5 reports the results from testing and estimating the proposed model of Kuwait.

We then proceed to use the intuition gained from our estimated and tested model to suggest policy options to revive, better diversify, and tackle the Dutch disease in the non-oil sector of Kuwait. In summary, these policies include two labour market regulations, and these are discussed extensively in Chapter 6. In the first policy, I suggest the use of subsidies to labour wages to influence the flow of labour in the traded sector. This is important because of the impact this policy has on the traded sector's labour demand and her reallocation thus a subsidy to labour would cause a reallocation of labour back into the non-oil sector. In Chapter 6, we illustrated this with the aid of the modified Johnson (1958) diagrams. More so, because the non-traded output supply is determined by demand factors and movement of the real exchange rate, and demand is sustained generally by aggregate income level, reallocation of input, particularly labour is effective in tackling the Dutch disease. In my analysis, I increased the robustness of this policy experiment by evaluating the welfare of these policies in terms of the resultant effect on output variance. Also, it may be necessary to note that in the policy experiment, I suggest that these policies must dominate the positive oil productivity shock to cause a reversal of labour flow from the oil to the non-oil traded sector, thus boosting production in the non-oil sector. This is true for all the labour market regulations suggested. In the second labour market regulation, I suggest policies that influence the supply of labour and preference to work relative to consumption or leisure. We find that this policy is also effective in reviving the lagging non-oil sector if it dominates the shocks caused by oil productivity.

In Chapter 7, we summarise the finding of our reviews and analysis. In addition to the gap in the literature which this thesis contributes to, I recognise that this study is the first for Kuwait to put these rigorous models through very reliable econometric processes and our results show that the model fits well and tells the story for Kuwait when shocked by positive oil technology. Furthermore, some regulations to the labour market via taxation and subsidy may reverse the adverse effects of oil shocks in the non-oil sector.

The rest of the thesis is structured thus: Chapter 2 reviews the literature on Neoclassical Real Business Cycle models. More so, we also review models in Kuwait and the Dutch Disease in the non-oil sector in this chapter. In Chapter 3, a dynamic stochastic general equilibrium model of Kuwait is proposed. The proposed model is calibrated and some intuition of the implications of oil productivity shocks in this economy are drawn based on the model's assumptions and calibrated impulse responses which are reported and interpreted. In Chapters 4 and 5, the indirect inference methodology is described and the results from the indirect inference estimation and test are also reported. In addition, to increase robustness in the method, a power test is conducted with results reported. In Chapter 6, some policy options to diversify Kuwait's economy and tackle the Dutch disease in the non-oil sector are suggested, experimented with, and reported. After which the thesis is concluded in Chapter 7.

2 Literature Review

... the process of formulating a model is as much an art as a science. It requires judgement and it will not result in a totally accurate representation of the economy. - Mike Wickens (2012), Macroeconomic Theory

2.1 Theoretical Literature on Real Business Cycle Models

2.1.1 Neoclassical Real Business Cycle Models

The question of what drives the economy may have once seemed to be the most popular question to be answered by economists. Even with decreasing popularity as time and era changed, its importance is never lost as the dynamics of our economies changes continuously and valuable insights into the economic structure and how it is modelled is unravelled. Even from the foundation works of the founding fathers of economics, Adam Smith (1937) and David Ricardo (1817), a variety of views which have today formed the start in the discussion of business cycle fluctuations answers this question and even raises more.

Some foundation works on real business cycle models commonly used today are found in Solow (1965), Cass (1965) and Koopmans (1965) models. However restrictive these models may have been in comparison to reality, they do form the genesis for our analysis on the aggregate economy. The details and conclusions from these models formed the basis upon which future models were built and many of these models still maintain the essential conclusions from these papers.

These models may differ in the details and composition of the driving force of the economy and the description of the technological process; however, they express a lot of similarities in the underlying structure of the economy. They describe a closed economy centrally planned economy with a single homogeneous commodity that is produced and consumed. One of the unique points contributed to this model is the confirmation of the idea of optimum output generated by a stable equilibrium growth path. Though the starting points of these models did not propose the ideas of an exogenous technological process that our model adopts, however, the fluctuations in this simple model were driven by fluctuations in the capital stock described in the underlying structure of the models. The technological process described in these papers is given by the description of the evolution of capital in this model. Hence, the driving force for output, production and growth is given by the cyclical movement of capital as earlier stated.

Without loss of intuition, we summarize the underlying structure of their models and the analysis which describes the driving force in this economy. To do this, I follow some descriptions of the equations as found in Wickens (2008). I express this representative agent model which produces a single homogeneous output Y_t. Output is produced with two homogeneous factors, labour N_t and capital K_t. Hence, the production function expressed in per capita terms can be given as:

$$y_t = f(k_t) \tag{2.1.1}$$

Their model generally assumes constant returns-to-scale in production, positive marginal productivity and diminishing marginal rate of substitution. The latter of these assumptions imply that an increase in the capital stock will increase the stock of output but it will increase at a diminishing rate. Hence, we obtain the condition below:

$$f(k_t) > 0; f'(k_t) > 0; f''(k_t) < 0; k > 0^5 \tag{2.1.2}$$

The terminal condition is given as:

$$\lim_{k \to 0} f'(k_t) = \infty; \lim_{k \to \infty} f'(k_t) = 0. \tag{2.1.3}$$

The above condition is the well-known Inada (1964) condition.

This closed economy model constrains the utility of output to consumption and investment only. The implication is that the output produced today can either be consumed today or saved up to be invested in the production of output tomorrow. For simplicity in this explanation, we do not assume extreme cases where all output today is all consumed, or all saved. Hence, consumption c_t and investment i_t is assumed to be non-zero in the discussion. Thus, the closed economy national identity is given as:

$$y_t = c_t + i_t; c_t, i_t > 0. \tag{2.1.4}$$

The above equation describes the resource constraint for the closed economy model described. We note that in this model, savings s_t is equal to investment i_t.

Lastly, the technological process in these models describes the rate of change of capital. Thus, the evolution of capital is given in the equation below:

$$\Delta k_{t+1} = i_t - \delta\, k_t \tag{2.1.5}$$

[5] You may want to note the mathematical implication of second and higher derivative as given in Chapter 9 of Wainwright(2005). Hence, capital is an increasing function of output and the slope of the curve (production function) or turning point in some other text tends to decrease in capital which is also a condition for maximization.

This describes how the capital accumulates over time. It shows that the change in the capital today is the investment less depreciated capital from the previous period. Another interpretation is that the capital available for production activities tomorrow is the investment or savings today plus today's undepreciated capital. Hence, the above equations of this model can be expressed in terms of capital. Thus the problem of the social planner in this simple model is to choose the level of consumption c_t and capital k_{t+1} which maximises social welfare given initial levels of capital, endowment and above constraints.

The social welfare problem is expressed via the utility index which is a function of per capita consumption. Hence, the social planner is faced with maximizing social welfare as expressed by the function below:

$$\max_{c_t} U(f(c_t)) \tag{2.1.6}$$

Alternatively, the problem can be expressed in terms of a reduced form function below:

$$\max_{k_{t+1}} U(f(k_t) - \Delta\, k_{t+1} - \delta\, k_t) \tag{2.1.7}$$

The optimal solution involves the maximization of the expected discounted capital in the social welfare problem. We observe that in this model, the equilibrium solution is the sequence of c_t, k_t, y_t such that social welfare is maximised with relevant Euler equations, constraints and terminal conditions being satisfied.

This early form simple dynamic general equilibrium (DGE) model has expressed some significant insight on the key drivers of the aggregate fluctuations in the model, it still raised many more questions for future researchers in the field. As Wickens (2008) rightly pointed out, business cycles are driven by shocks of various natures and lengths and policies designed to bring them back to equilibrium path, and the equilibrium of the economy is continuously disturbed by these shocks. Thus a few more questions that come out of the paper of Cass (1965), Koopmans (1965) and Solow (1965) ask: How realistic are the assumptions of the model? How do different shocks alter the equilibrium state of the economy? What happens in the fluctuations of macroeconomic aggregates when these shocks are temporary or permanent? Is there any chance for the efficiencies of the factors of production in explaining business cycles? Do we still maintain the same intuition when we move from a closed economy to an open economy model? What happens to the dynamics when there are exogenous shocks to the model? These are just a few amongst many more questions asked in future models, we may not answer all these questions in this review, but we shall show significant development from this basic model and the underlying ideas that bring to life the models which we may discuss in this paper.

The foundation works of Cass (1965), Koopmans (1965) and Solow (1965) act as pioneers of the neo-classical real business cycle (RBC) model. Although many economists refer to the works of King, Plosser and Rebelo (1988) as the foundation for modern neoclassical RBC models, we should not lose scope by attempting to assign these accomplishments, we focus on what we have learnt from them, and we recognise that they have all been significant in attempting to address the issues of her time. In criticism of the models of Cass (1965), Koopmans (1965) and Solow (1965), we agree with Kydland and Prescott (1982), that the assumption that the price of capital goods relative to consumption equals to unity is wrong in these early neoclassical models. This is evident in the price of capital, represented by the Tobin Q obtained from stock market data, which shows that the price is non-unity, $q \neq 1$. This is discussed in detail in the paper of Hayashi (1982) where the show that the optimal rate of investment is a function of optimal q[6] adjusted for tax. Also, the standard real business cycle models discussed above did not generate the hump-shaped impulse responses to shocks which is a feature of the data. In response to this, there have been improvements on the above technology with the introduction of convex adjustment costs to the stock of capital.[7] This is not the start of this idea as the paper by Lucas and Prescott (1971) had laid foundations for this with a key contribution on the idea of rational expectations [8] in these dynamic stochastic general equilibrium models. The adjustment cost technology describes some cost to adjusting the capital stock relative to what is normal. It is the cost of converting the level of investment or capital stock to stock that is useful for production. However, Kydland and Prescott (1982) contributed to the debate majorly with the proposition that fluctuations are mainly driven by real factors of productivity and taste via their dynamic stochastic general equilibrium (DSGE) model. Another major contribution of their work is in the methodology of DSGE models for macroeconomists. In their paper, they revolutionized solution techniques as they criticized prior models' failure to match the cross-sectional features of the data. Essentially, they discuss testing the theory by moving a step further to compare the moments between the data from simulated data generated from their model and the actual data for US post-war data. In addition, they calibrate their model as a source of explanation for their theorized model. Hence, through the addition of model calibration, it presents a microscope under which DSGE modelling and policy implications can be better carried out and analysed.

However, part of the concern of many economists surrounds the effect on the economy in the short run. This is because investment in new technology changes the productivity of factor inputs which may change capital in the next period as evident in the papers of Olley and Pakes (1996) and hence have a delayed response to demand. Also, the consumers and workers in this model will have to adjust their consumption in response to new income and interest rates movements. Thus, these exogenous technological shocks affect the equilibrium outcome in both consumer and producer optimization problems. Even more so, this potential

[6] q is defined as the ratio of marginal utility of an extra capital good to the marginal utility of an extra consumption good in Hayashi (1982)

[7] Pioneer ideas of this was discussed in the paper of Lucas (1967). However, this was discussed with the idea of static expectations which may be criticised for lacking realism. Nonetheless, the rational expectation discussions on this were discussed in the paper of Lucas and Prescott (1971).

[8] The idea of rational expectations are credited to the works of Muth (1961). This concept is key in the determination of prices in the models we have today as we assume that future prices are correctly anticipated.

effect may vary pending if the shock is perceived to be permanent or transitory. We examine how the paper of King, Plosser and Rebelo (1988) discuss these issues. In their paper, they raise some fundamental questions which all macroeconomists should always consider in their models, they include what analytical methods can be employed to study the time series implication of the neoclassical model? Also, does the neoclassical model - driven by technology shocks - replicate important features of macroeconomic times series. These are fundamental questions we try to answer with economic models and the model discussed in the next section will not be any different as we attempt to answer some of them. A major contribution in the paper of King, Plosser and Rebelo (1988) is that they compare the influence of temporary and permanent technology shocks and how much they can explain the aggregate fluctuations of the real business cycle model. The model presented in their paper is quite like the model described above, however, it differed where work effort was viewed as a choice. Thus, in the consumer problem, they choose between the consumption of goods and the amount of their hours supplied to labour or consumed as leisure. These form the composite utility for the representative agent. This composite utility is represented in the function below:

$$U(f(C_t, 1 - N_t)) \tag{2.1.8}$$

where c_t and N_t are consumption and labour respectively. Also, with the assumption of constant returns-to-scale, technological advancement was expressed in labour augmenting form, usually known as the Harrod-neutral technological progress. The underlying idea of labour augmenting progress is that higher technology increases output as the economy has more labour. We show the representation of this production function below, where K_t, Y_t, A_t and N_t represent capital, output, technology shock and labour respectively.

$$Y_t = f(K_t, A_t\, N_t) \tag{2.1.9}$$

This technological progress was chosen to be consistent with the balanced growth theory. Thus output, consumption, investment, and capital grow at a constant rate specified by the rate of change of technology. In their comparison of the persistence of shocks, they noted that to match the post-war data of the US business cycle, more persistent technological shocks were able to match the data better than temporary shocks. They noted that in the case of temporary shocks, the neoclassical RBC model shown above was not able to generate the serial correlation output and unemployment as shown in the data whereas in the case of more persistent shock it captures better the key features of the data. Macroeconomists have come to realise that to match cointegrating features of real business cycle data, one should consider the effect of permanent or more persistent technology shocks. Though the persistence of the shock is a step further for research in this area, yet King, Plosser and Rebelo (1988) highlighted the challenges of these closed economy neoclassical models to match certain features of the data moments.

2.2 Empirical Literature

2.2.1 Models of Kuwait's Economy

There have been a few attempts aimed at modelling the economy for Kuwait, however, none of these efforts so far have been able to attempt a dynamic stochastic general equilibrium (DSGE) model for Kuwait. Our literature review however comprehensive may not be exhaustive of all the models for Kuwait in the last few decades. Nonetheless, I am sure that they will reflect most of the modelling works on the Kuwaiti economy and how researchers have attempted to answer similar questions to what we have proposed to answer in this paper. Since DSGE models for Kuwait are scarce, we have also reviewed the models of similar economies in the Gulf region.

The closest models to a DSGE model for Kuwait are Computational General Equilibrium (CGE) models given in papers of Korshid (1990), Sirageldin and Khorshid (1995), Gelan (2018), Shehabi (2017, 2020) where they use their model to analyse the medium-term path of the Kuwaiti economy as oil grows in Korshid (1990) and the impact of Kuwait's energy price reforms and energy subsidy reforms on the economy in Shehabi (2017,2020). Even though their models are not able to describe the real business cycle features of the Kuwaiti economy, nonetheless they still attempt to answer the question of how the economy is impacted by an oil price shock. Korshid (1990) results for the scenario analysis under the assumption of high oil price, showed that gross output increased, both oil and non-oil, this was also accompanied by a rise in imports, private consumption, and exports; but there is a decline in household income, consumption per Kuwaiti, government consumption and the reserve fund per Kuwaiti. Most parts of the per capita (Kuwaiti) fall was ascribed to the rising Kuwaiti labour supply from the oil price impact. Quite similarly, in the case of a low oil price, the result showed slight growth in overall GDP, non-oil GDP, private consumption, import demand, household's income and household's consumption. However, the price of inputs to the non-oil sector and non-oil output price declined, alongside a drop in government expenditure and Kuwait's reserve. One point we take from the analysis of Korshid (1990) is that in periods of oil price boom and bust, non-oil sector growth continues, however, it slightly decreased in periods of a bust. This does not indicate the resource curse which the data suggests. We suggest that this difference may be because of the classification of the sectors broadly in their paper. More so, in more broad classifications of the economy into oil and non-oil sectors, the impact of non-oil traded sectors is not well identified as they may incorporate the impact of a domestic non-traded sector which responds slower to oil boom and bust.

Shehabi (2020) analysis from the CGE model showed that the impact of an oil price drop will contract all economic activities in the economy. The decline in oil price drives the real GDP down, declines oligopolistic markups as their model featured imperfect competition in the supply side, the real exchange rate depreciates, real disposable income drops, aggregate welfare drops, relative costs of inputs and intermediate goods falls, however, they suggest that government expenditure may rise as it is financed by the excess oil revenue reserve fund, and this is used to pay Kuwait citizens during this period of oil drop. More so, resulting from this is an expansion in non-oil sectors which may suggest a reversal of the Dutch disease. Shehabi (2020) suggests that this impact especially the impact on the non-oil sectors may be because these sectors can import intermediate goods for production and labour is also mobile, thus they can hire expatriates (non-Kuwaiti labour) which are cheaper to boost production in these sectors. However, we note that in the categorization of sectors, these non-petroleum (non-oil) sectors include some non-traded sectors which may decrease the accuracy and extent of the impact on the non-oil traded sector growth.

Despite the usefulness of the CGE model for the aims of Kuwait's economy, the literature on more developed economies which have had more expansive and rigorous research may suggest that CGE models are increasingly limited in their application in recent times. However, having had a look at the data availability issues posed in the estimation and testing of our proposed model, I may characterise the popularity of the CGE model for Kuwait as a convenient solution to deal with these data problems. Having said that, as we consider their findings to be quite informative on certain relationships and key features of the Kuwaiti economy, we recognise that it is impossible to overlook some of the general criticisms of the modelling technique as well as the other criticisms raised from the use of the technique on Kuwait-related research. Firstly, with regards to the papers on Kuwait, certain relationships which were regarded as static may have dynamic features which can be considered along with other variables which have some level of dynamism in the models. More so, the assumption that government expenditure behaviour is constant defeats the purpose of fiscal policy analysis as most of the ownership and resource control is the responsibility of the government in the Kuwaiti economy. We also recall some of the criticisms that may have put this modelling technique under the microscope from Bandara (1991) and Beckman et al (2011). Their survey of CGE models criticized its performance when dealing with future expectations as well as uncertainty, this is especially true in the case where models try to capture the business cycles with inherent intertemporal relationships. More so, Bandara (1991) criticizes the data and parameter values of many CGE models of which they describe these parameters used in the model as *little more than best guess*. This is because these values are calibrated and are not usually estimated. Finally, we criticize these CGE models in a similar light as many of these models are not subjected to rigorous statistical tests to prove their validity. Our proposed model in this paper is calibrated and the model parameters are later estimated and tested via indirect inference technique. This gives our model a lot of superiority and reliability when compared alongside these CGE counterparts for

Kuwait.

Other models on Kuwait includes an estimated Vector Auto-Regressive (VAR) and Vector Error Correction Model (VECM) in papers by Eltony and Al-Awadi (2001), Al-Shammari et al (2018), Merza (2007), Saaed (2007), Saaed and Hussain (2015) amongst others. We find in these papers that in some cases, the motivation for a method being used may be lacking and, in many cases, used based on its simplicity. Nonetheless, the results in some of the empirical literature support the resource curse arguments or give evidence for inherent relationships between key variables and oil price which indicates just a bit of their usefulness with regards to the objectives of this paper. However, we criticize these models more generally because they lacked the underlying structural model, the Lucas' Critique.

2.3 Literature on Dutch Disease in Kuwait

In the literature reviewed in this section, we try to understand how the problem of the Dutch disease is caused and how it affects the non-oil sector in this economy.

The term "Dutch Disease" was coined in 1977 by the Economist after the discovery of oil reserves in the North Sea. Originally, it was used to describe the use of booming sector's revenues for social service levels which were not sustainable but politically difficult to reduce. However, the definition has received a lot of revision as research on the topic progressed. In Corden (1984), Dutch disease was used to describe the adverse effects of the expansion of Dutch oil manufacturing in the nineteen sixties, which was explored through the appreciation of the Dutch real exchange rate causing negative effects on the non-oil sector. This is the most dominant definition as used in a lot of research, nonetheless, this definition keeps having a facelift as more research continues to be done in the area and on a vast variety of economies with different endowments, explored across a variety of multi-sector macroeconomic models.

Our model explores a similar definition as that of Neary and Corden (1982) and Corden (1984) which described this effect within a similar model setup in sectoral characteristics. Mainly, we explore this phenomenon within a sectoral division described in Neary and Corden (1982) as booming sector (oil sector), lagging sector (non-oil sector) and non-traded sector. However, the explanation of the problem and causation of the problem of the lagged sector, which explores the Dutch disease, differs between both papers. More generally, Neary and Corden (1982), Corden (1984), explained the problem of the lagged sector within their model for the Dutch and Australian economy as coming from the factor mobility within their framework. They explored this under a 3-sector 2-factor model exploring features of the Heckscher-Ohlin model, thus experimenting on the effects of the lagging sector when factor mobility varied. In Neary and Corden (1982), they find that when labour was mobile, the lagging sector experienced a decline in output and employment.

In addition to this effect, the balance of trade worsened and real exchange rate[9] appreciated, which is equivalent to a depreciation in our model where the definition of the real exchange rate is the inverse of theirs. To aid policy recommendations, they point out that the way government spends its extra income is a crucial factor to determine the impact of the spending effect from the extra income coming from the booming sector. More specifically, they point out that the manner of effect on the economy depends on whether the effect is because of resource movement effect or spending effect from the boom. The spending effect describes the effect on the lagging sector resulting when some part of the extra income from the booming sector was spent by the government, thus causing a rise in the price of non-tradeable relative to tradeable. Whereas the resource movement effect comes from the marginal product of labour rising in the booming sector such that at a constant wage in terms of tradeable, more labour is demanded in the booming sector causing movements of the factor from the lagging sector into the booming sector.

More so, after the paper of Neary and Corden (1982) and Corden (1984) who explored this problem within a variety of model frameworks, more research has been done specifically to understand the Dutch disease within Kuwait's economy. These contributions include Shah (1986), Al-Sabah (1988), Looney (1991, 1992), Eltony (2007), Nosova (2018), Aljarallah and Angus (2020), Faheem et al (2020), Shehabi (2017, 2019, 2020) among others. Below we review some of their contributions relevant to the topic.

Looney (1992) aligns strongly with the earlier works of Neary and Corden (1982) that the government's expenditure can set off a chain of price effects that affect the real exchange rate and makes internationally traded goods fall relative to non-traded goods. Similarly, they posit that these government expenditures drive factor inputs to flow from traded towards non-traded sectors. In addition, Shehabi (2019) highlights the pricing behaviours of domestic oligopolies, the flexibility in the contracts of foreign workers as well as access to assets invested in the SWFs as some of the reasons for the asymmetry between petroleum prices and economic performance in this economy. Some other perspective on the matter comes from Aljarallah and Angus (2020) in their paper which points out economic, political, and social drivers as the main modes of resource curse transmission in Kuwait. The economic transmission comes from the impact of resource rent on total factor productivity (TFP), whereas the social and political drivers come from the adverse effects to human capital within the state and institutional quality.

In conclusion, these views on Kuwait's resource curse and modes of transmission may seem diverse, we had pointed out from the start that their explanations and the policy recommendations will differ based on their understanding of the problem via well-structured empirical processes, models and otherwise. Thus, we do not take away from their investigations but rather gain lessons and reasons for such findings.

[9] we may note that in Neary and Corden (1982), the real exchange rate was described as the ratio of non-traded price to traded price in that economy, whereas in our model, it is specified as the ratio of traded to non-traded price. Thus, an appreciation recorded in their result will be equivalent to depreciation in ours.

3 A DSGE Model of Kuwait

In this section, we propose and formulate a small open economy DSGE model with three sectors to capture fluctuations in Kuwait's economy. Our proposed model follows the model in Meenagh et al (2010), however, we extend their model to include multi-sector production and some features of specializations as implemented in Minford et al (2015, 2018). In our model, we describe the activities of the firm to cut between two major sectors, traded sector and non-traded sector. Within this classification, we go further to divide the traded goods sector into two sectors, oil and non-oil sectors. In summary, the productive sectors in this model are broadly classified into three, oil, non-oil and non-traded sector. In addition, this model comprises of welfare optimizing agents with representative households who optimize expected discounted utility, 3-sector firm which maximizes expected discounted streams of profit under perfect competition by setting price equal to marginal cost, a government sector that owns and regulates land as its source of finance for expenditure and a foreign sector which trades internationally as well as supplies the domestic needs for traded goods. Lastly, we have a non-traded sector that contains goods and services consumed domestically and the supply of output in this sector is driven by domestic non-traded demand needs.

The model's formulations stem from some real business cycle and trade theories; one may track the discussions of such formulations to go as far back as Ricardo (1817) - theory of comparative advantage. Thus, just as in the theory, we assume that countries should specialize in sectors where they have a relative comparative advantage. This determines the path for specialization and the trade story in this model. Also, it adopts the specialization assumptions of Heckscher-Ohlin-Samuelson (HOS) models which talks about specialization in certain sectors based on its factor intensity and relative factor supplies. Thus, factor supply and mobility determine the size of different sectors based on the factor intensity in respective production processes. In line with this, we obtain data of Kuwait's productive sector intensities from Kuwait's National Account Statistics Input and Output Table 2010 reported by the Central Statistical Bureau of Kuwait. The detailed report of the factor shares of each productive sector in Kuwait is given in the figure 12 figure below. From the data of Kuwait's factor shares, we have determined that the oil sector is land-intensive and the non-oil sector is labour-intensive. In other words, the supply of land, that is market-clearing for land, and its sectoral intensity determines the supply of oil output; also, the market-clearing for labour and sector intensity determines the supply of non-oil output. In addition, we assume that the supply of capital flows freely across sectors and borders, thus capital is thought to be a mobile factor whereas land and labour are assumed to be immobile factors.

In our dynamic stochastic general equilibrium (DSGE) model, the underlying structural model is a representative agent model where the home economy is composed of identical and infinitely lived agents who produce non-traded, oil and non-oil products which are consumed domestically and exported abroad. The home economy coexists with another foreign economy, "the rest of the world", which is larger than the home economy. Thus, the home economy is a small open economy which implies that it cannot influence world prices and interest rates whereas the foreign economy is independent of choices of the home country but is large enough to affect international prices and interest rates. The home economy produces non-traded products which are strictly for domestic consumption and tradeable goods in the form of oil and non-oil goods which can be consumed domestically and exported abroad. Therefore, the composition of consumption of tradeable goods is a weighted ratio of domestic and foreign consumption. We note that the goods are traded with the foreign country at prices and interest rates which are exogenously determined in world markets due to perfect competition assumption and the relative size of this economy in this model. We assume that these prices incorporate transport and border costs which makes the case for factor-price determination which we shall see in some subsections below, also the home economy can borrow internationally at predetermined interest rates, and this concludes the model's structure.

In the following subsections, we discuss the optimization problems of the representative agents, the conditions that complete the model, some discussions surrounding the dynamics of the model in the presence of shocks and lastly, we discuss the model's calibration result. We shall start with the representative household's problem below.

3.1 Representative Household

In the household's dynamic problem, he chooses the commodity bundle to consume C_t as well as the total amount of leisure l_t that he would like to enjoy. The representative household maximizes the present discounted utility subject to the budget constraint and time availability constraints. The household's preferences are described by the utility function shown below.

$$E_0 \sum_{t=0}^{\infty} \beta^t \, U(C_t, l_t) \tag{3.1.1}$$

At every period, the household faces a static problem of choosing consumption by product origin for each sector. Thus, the household is faced with the consumption of oil, non-oil and non-traded products. Based on the assumption of a perfect market, we assume that countries produce homogeneous traded commodities. Therefore, any needs for traded consumption goods that cannot be satisfied domestically are supplemented by imported goods. Similarly, all the excess traded goods are exported to the foreign country at world predetermined prices.

The static problem of the consumer is to maximize the composite utility index $\tilde{C}_t$, subject to the expenditure function. The composite utility index comprises of non-traded goods consumption, C_t^{NT}, and traded goods consumption, C_t^T. This composite utility index is predetermined, meaning that for every level of consumption chosen, there is a combination of traded and nontraded goods that gives that level of consumption. The composite consumption utility index as represented via the Armington (1969) aggregator is formed below:

$$C_t = [\omega_{NT}\,(C_t^{NT})^{-\varsigma} + (1-\omega_{NT})\,(C_t^T)^{-\varsigma}]^{\frac{-1}{\varsigma}} \tag{3.1.2}$$

where ω_{NT} is the weight of the non-traded good in the consumption function, ς is the elasticity of substitution between traded and non-traded goods. The consumption bundle is treated as numeraire thus we express prices of the components of the consumption bundle in terms of the general price level, P_t. The household maximizes the composite utility index subject to the expenditure function expressed in real terms.

$$C_t = P_t^T\,C_t^T + P_t^{NT}\,C_t^{NT} \tag{3.1.3}$$

This yields the following

$$C_t^T = P_t^{T\,\frac{-1}{1+\varsigma}}\,[(1-\omega_{NT})]^{\frac{1}{1+\varsigma}}\,C_t \tag{3.1.4}$$

$$C_t^{NT} = P_t^{NT\,\frac{-1}{1+\varsigma}}\,\omega_{NT}^{\frac{1}{1+\varsigma}}\,C_t \tag{3.1.5}$$

We note that all prices are expressed in real terms hence, P_t^T and P_t^{NT} are the real price [10] of traded and nontraded goods. Also, let $\frac{1}{1+\varsigma} = \sigma$ for simplicity.

Similarly, traded goods consumed is a bundle comprising of oil and non-oil goods. Hence, the composite utility index for the traded goods is aggregated using the Armington (1969) aggregator as shown below:

$$C_t^T = [\omega_O\,(C_t^O)^{-\varsigma^T} + (1-\omega_O)\,(C_t^{NO})^{-\varsigma^T}]^{\frac{-1}{\varsigma^T}} \tag{3.1.6}$$

where ω_O is the weight of the oil good in the bundle of traded consumption, ς_T is the elasticity of substitution between traded and non-traded goods. The traded consumption bundle is treated as numeraire thus we express prices of the components of the consumption bundle in terms of the general price level, P_t. The household maximizes the traded goods composite utility index subject to the expenditure function of traded goods expressed in real terms.

[10] where $P_t^T = \frac{P_t^T}{P_t}$ and $P_t^{NT} = \frac{P_t^{NT}}{P_t}$.

$$C_t^T = P_t^O\, C_t^O + P_t^{NO}\, C_t^{NO} \tag{3.1.7}$$

This yields the following

$$C_t^O = P_t^{O\,\frac{-1}{1+\varsigma^T}}\,[(1-\omega_O)]^{\frac{1}{1+\varsigma^T}}\, C_t^T \tag{3.1.8}$$

$$C_t^{NO} = P_t^{NO\,\frac{-1}{1+\varsigma^T}}\,\omega_{NO}^{\frac{1}{1+\varsigma^T}}\, C_t^T \tag{3.1.9}$$

We note that all prices are expressed in real terms hence, P_t^T and P_t^{NT} are the real price [11] of traded and nontraded goods. It may be important to note that the traded price is a weighted price of both oil and non-oil goods. Thus, we have that:

$$P_t^T = w_o\, P_t^O + (1-w_o)\, P_t^{NO} \tag{3.1.10}$$

Also, let $\frac{1}{1+\varsigma^T} = \sigma^T$ for simplicity.

In the household's dynamic problem, we specify the utility function as a time separable utility function, therefore the utility function can be expressed as:

$$U(C_t, 1-N_t) = \frac{\theta_0\, \epsilon_t^C\, {C_t}^{1-\rho_0}}{1-\rho_0} + \frac{(1-\theta_0)\, \epsilon_t^{NS}\, (1-N_t)^{1-\rho_0}}{1-\rho_2} \tag{3.1.11}$$

where θ_0 is the weight of consumption relative to leisure, ρ_0 and ρ_2 are elasticity of substitution parameters and ϵ_t^C,ϵ_t^{NS} are preference shocks, in particular consumption and leisure shocks respectively, E_0 is the mathematical expectation operator, β is the discount factor, C_t is consumption in period t, l_t is the amount of leisure time consumed in period t, N_t is the number of hours supplied for labour in period t.

The time endowment is normalized to one, thus the representative agent splits his time between hours supplied for labour and an amount consumed for leisure. Hence, we have that

$$N_t + l_t = 1 \tag{3.1.12}$$

The representative household or consumer maximizes the expected discounted utility subject to the

[11] where $P_t^O = \frac{P_t^O}{P_t}$ and $P_t^{NO} = \frac{P_t^{NO}}{P_t}$.

budget constraint. The representative household's budget constraint is

$$C_t + \frac{B_{t+1}}{1+r_t} + \frac{Q_t\, B^f_{t+1}}{1+r^f_t} = w_t\, N_t + B_t + Q_t\, B^f_t + \pi_t \tag{3.1.13}$$

where B_t and B^f_t is the home and foreign bonds respectively. Also, w_t is the wage earned by the household for the number of hours worked. They both compose the sources of income for the household. Also, r_t and r^f_t is the home and foreign interest rates for the debt borrowed.

The Lagrangian is

$$\begin{aligned} L_0 \quad = \quad & E_0 \sum_{t=0}^{\infty} \beta^t \, [\frac{\theta_0\, \epsilon^C_t\, {C_t}^{1-\rho_0}}{1-\rho_0} + \frac{(1-\theta_0)\, \epsilon^{NS}_t\, (1-N_t)^{1-\rho_0}}{1-\rho_2} \\ & + \lambda_t\, (w_t\, N_t + \pi_t + B_t + Q_t\, B^f_t - C_t - \frac{B_{t+1}}{1+r_t} - \frac{Q_t\, B^f_{t+1}}{1+r^f_t})] \end{aligned} \tag{3.1.14}$$

the first order condition with respect to C_t, N_t, B_{t+1}, B^f_{t+1},π_t and λ_t are given below

$$\frac{\delta\, L_0}{\delta\, C_t} = \theta_0\, \epsilon^C_t\, {C_t}^{-\rho_0} - \lambda_t = 0 \tag{3.1.15}$$

$$\frac{\delta\, L_0}{\delta\, N_t} = (1-\theta_0)\, \epsilon^{NS}_t\, (1-N_t)^{-\rho_2} - \lambda_t\, w_t = 0 \tag{3.1.16}$$

$$\frac{\delta\, L_0}{\delta\, B_{t+1}} = \frac{-\lambda_t}{1+r_t} + \beta\, E_t\, \lambda_{t+1} = 0 \tag{3.1.17}$$

$$\frac{\delta\, L_0}{\delta\, B^f_{t+1}} = \beta\, E_t\, \lambda_{t+1}\, Q_{t+1} - \frac{\lambda_t\, Q_t}{1+r^f_t} = 0 \tag{3.1.18}$$

$$\frac{\delta\, L_0}{\delta\, \pi_t} = 0 \tag{3.1.19}$$

$$\frac{\delta\, L_0}{\delta\, \lambda_t} = w_t\, N_t + T_t + B_t + Q_t\, B^f_t + (P_t + d_t) S_{t-1} - C_t - \frac{B_{t+1}}{1+r_t} - \frac{Q_t\, B^f_{t+1}}{1+r^f_t} - P_t\, S_t = 0 \tag{3.1.20}$$

Substituting (3.1.15) into (3.1.17) we obtain the Euler equation describing the intertemporal substitution of consumption as,

$$1 + r_t = \frac{1}{\beta}\, E_t\, \frac{\epsilon_t^C}{\epsilon_{t+1}^c} (\frac{C_t}{C_{t+1}})^{-\rho_0} \tag{3.1.21}$$

substituting (3.1.15) and (3.1.17) into (3.1.16) gives the intratemporal consumption as shown below describing the labour supply equation

$$1 - N_t = [\frac{\theta_0\, \epsilon_t^C\, w_t\, C_t^{-\rho_0}}{(1-\theta_0)\, \epsilon_t^{NS}}]^{\frac{-1}{\rho_2}} \tag{3.1.22}$$

Given that agents have access to a foreign bond that has the rate of return r_t^f determined in foreign markets, makes the steady state of the model depend on the initial foreign debt position. Hence, any difference between foreign rates of return and discount rates will display never-ending growths or recession when a shock occurs in the model as discussed in Schmitt-Grohe and Uribe (2003). Thus, the non-stationarity generated by the foreign bond is eliminated by the debt-elastic interest rate condition in this model. This is given below:

$$r_t = r_t^f + Q_{t+1} - Q_t + p(B_t^f) \tag{3.1.23}$$

Thus, stationarity is induced under the assumption that the interest rate at which domestic agents borrow is increasing in the aggregate level of debt. Where $p(.)$ is a country-specific interest rate premium and this risk premium $p(B_t^f) = \phi\,(e^{B_f - \bar{b^f}})$. ϕ and $\bar{b^f}$ are constant parameters. In this model, we use the debt elastic interest rate in place of the uncovered interest parity (UIP) condition. Lastly, for simplicity, we assume that the household can only borrow from abroad hence we set domestic bonds equal to zero, $B_t = 0$.

3.2 Representative Firm

Firms combine factor inputs of labour, capital, and land, in the production process to create output in each of the three sectors. They produce non-tradeable and tradeable goods - oil and non-oil goods. The non-traded goods are all consumed domestically whereas the traded goods - oil and non-oil goods are consumed domestically as well as traded internationally. Also, we assume that domestic output can be converted into capital at no extra cost, hence the outputs can be consumed or used up as capital for production. The firms sell their output to be used as consumption goods to representative consumers and government or converted to capital goods for use by other firms in the production process.

The representative firm under perfect competition maximizes profit subject to production and capital accumulation by setting its price equals to marginal cost and average cost[12]. Hence, the exogenously deter-

[12]Recall the long-run conditions for equilibrium under perfect competition, it says that for equilibrium, in the long run, the

mined price of traded goods, price of oil goods P_t^O and price of non-oil goods P_t^{NO}, as well as the price of non-traded goods P_t^{NT} are set equal to marginal cost in each of the sectors. The marginal cost and average cost are the weighted averages of the factor costs and their residual is the inverse productivity shock in each sector. Also, we assume that the functional form for marginal cost in each sector is a Cobb-Douglas functional form and the weights assigned to each factor price is the relative factor share in that sector. The aggregate factor share from all the sectors sums to numeraire in each factor. The prices expressed in the Cobb-Douglas setup are given below.

$$P_t^O = w_t^{\alpha_o} \, r_t^{k^{\beta_o}} \, s_t^{1-\alpha_o-\beta_o} \, \epsilon_t^{o-1} \tag{3.2.1}$$

$$P_t^{NO} = w_t^{\alpha_{no}} \, r_t^{k^{\beta_{no}}} \, s_t^{1-\alpha_{no}-\beta_{no}} \, \epsilon_t^{no-1} \tag{3.2.2}$$

$$P_t^{NT} = w_t^{\alpha_{nt}} \, r_t^{k^{\beta_{nt}}} \, s_t^{1-\alpha_{nt}-\beta_{nt}} \, \epsilon_t^{nt-1} \tag{3.2.3}$$

Where w_t, r_t^k and s_t are the wage rate, rental rate of capital and the land rental rate respectively; factor prices for labour N_t, capital K_t and land L_t factor inputs used up in the production process. All prices are expressed in real terms as earlier stated. Hence, the output produced is a combination of all factor inputs for production in each sector.

$$Y_t^i = f(N_t^i, K_t^i, L_t^i) \tag{3.2.4}$$

where $i = \text{oil, nonoil and nontraded specifications}$

Also, ϵ_t^o, ϵ_t^{no}, and ϵ_t^{nt} are productivity shocks (technology shocks) to output in the oil, non-oil and non-traded sectors respectively. α_o, α_{no} and α_{nt} are factor shares of labour used up for production in the oil, non-oil and non-traded sectors respectively. Similarly, β_o, β_{no} and β_{nt} are capital shares in the production process in each sector as listed above, whereas, $1 - \alpha_o - \beta_o$, $1 - \alpha_{no} - \beta_{no}$ and $1 - \alpha_{nt} - \beta_{nt}$ are land shares in the production process in oil, non-oil and non-traded sector respectively.

As earlier noted, the data of factor share distribution across the three productive sectors has enabled us to determine that the oil sector is land-intensive given that all natural endowments are extracted from the land and the non-oil sector which is involved in agriculture, manufacturing and distribution is more labour intensive. Hence, from equations (3.2.1) and (3.2.2), the price of oil and non-oil goods, we can solve for the

price should be equal to marginal and average cost otherwise the firm may be able to make abnormal profits. This is the case where the price or marginal revenue is greater than the average cost, thus yielding super-normal profits or price less than average cost which will yield losses equilibrium factor prices for the immobile factors in which the traded sectors have their production intensity, wage rate w_t and land rent s_t via factor-price determination[13].

$$s_t = [\frac{P_t^o \, \epsilon_t^o}{w_t^{\alpha_o} \, r_t^{k\,\beta_o}}]^{\frac{1}{1-\alpha_o-\beta_o}} \tag{3.2.5}$$

$$w_t = [\frac{P_t^{NO} \, \epsilon_t^{no}}{s_t^{1-\alpha_{no}-\beta_{no}} \, r_t^{k\,\beta_{no}}}]^{\frac{1}{\alpha_{no}}} \tag{3.2.6}$$

The above prices for land rent and wage rate are the market-clearing factor prices that make output price equal to marginal cost.

A summary of Kuwait's factor shares as obtained from Kuwait's National Account Statistics Input and Output Table 2010 reported by the Central Statistical Bureau of Kuwait is given in the table below.

Parameter	Role	Value
α_o	labour share in oil sector	0.1
α_{no}	labour share in non-oil sector	0.3
α_{nt}	labour share in non-traded sector	0.6
β_o	capital share in oil sector	0.2
β_{no}	capital share in non-oil sector	0.6
β_{nt}	capital share in non-traded sector	0.2
$1-\alpha_o-\beta_o$	land share in oil sector	0.7
$1-\alpha_{no}-\beta_{no}$	land share in non-oil sector	0.1
$1-\alpha_{nt}-\beta_{nt}$	land share in non-traded sector	0.2
$\frac{y^o}{y}$	size of oil sector in aggregate	0.5
$\frac{y^{no}}{y}$	size of non-oil sector	0.1
$\frac{y^{NT}}{y}$	size of non-traded sector	0.4

Table 1: Fixed Parameters

3.3 The Production Process and Sector Characteristics

The technological process available to the economy as given in the production function is a Cobb-Douglas production function with constant returns-to-scale. This is shown below:

$$Y_t^i = N_t^{i\,\alpha_i} \, K_t^{i\,\beta_i} \, L_t^{i\,1-\alpha_i-\beta_i} \tag{3.3.1}$$

[13]That is, price equals marginal cost

where $0 < \alpha, \beta < 1$, i denotes the sectors; oil O, non-oil NO and non-tradeable sector NT. Y_t is the aggregate output per capita, K_t is the capital carried over from previous period, N_t is the labour hours supplied by the household in the current period and L_t is the land rented for production in time t.

Labour, land, and capital are assumed to be subject to diminishing marginal products. Also, the production function $f(N, K, L)$ is smooth and concave and satisfies the appropriate inada conditions.

The stock of capital evolves following the equation shown below:

$$I_t = \Phi(K_t^* - K_{t-1}) + \delta\, K_{t-1} \tag{3.3.2}$$

where I_t is gross investment, Φ is the partial adjustment parameter describing that there is a cost to adjusting capital, thus the firm's close only a fraction of the gap between actual and desired capital levels each year. Hence, the parameter also describes the speed at which firms reach the optimal target values. K_t^* describes the desired capital stock level and K_t is the actual capital stock level for a given period t.

The firm's profit, π_t is given by total output from production less the total cost of capital, land and labour. The cost of capital covers the rental rate of capital, r_t^k and ϵ_t^k an error term that captures the impact of excluded imposts or regulations on a firm's use of capital. The cost of labour is given as the wage rate w_t plus ϵ_t^n an error term that captures the impact of excluded imposts or regulation on a firm's use of labour. The cost of land covers the rent paid on the hire of land s_t and ϵ_t^l an error term capturing the effect of regulations on a firm's use of land. The profit function is shown below:

$$\pi_t = P_t\, Y_t - K_t(r_t^k + \epsilon_t^k) - N_t(w_t + \epsilon_t^n) - L_t(s_t + \epsilon_t^l) \tag{3.3.3}$$

Hence, the optimization problem of the firm is to maximize the present discounted stream of cash flow. The representative firm maximizes the present discounted stream of cash flow, V, subject to constraints of the production technology. The firm's problem is summarized in the following equation:

$$\begin{aligned} \max_{K_t, N_t, L_t} V \quad &= \quad E_t \sum_{j=0}^{T} d_t^j \,[P_{t+j}\, Y_{t+j} - K_t(r_t^k + \epsilon_t^k) \\ &\quad -N_t(w_t + \epsilon_t^n) - L_t(s_t + \epsilon_t^l)] \end{aligned} \tag{3.3.4}$$

Thus, the firm chooses capital, labour and land to maximize their present discounted stream of cash flow. The first-order conditions yield the following

$$\frac{\delta V}{\delta K_t} = 0 : K_t = \frac{\beta \, P_t \, Y_t}{r_t^k + \epsilon_t^k} \tag{3.3.5}$$

$$\frac{\delta V}{\delta N_t} = 0 : N_t = \frac{\alpha \, P_t \, Y_t}{w_t + \epsilon_t^n} \tag{3.3.6}$$

$$\frac{\delta V}{\delta L_t} = 0 : L_t = \frac{(1 - \alpha - \beta) \, P_t \, Y_t}{s_t + \epsilon_t^l} \tag{3.3.7}$$

It is important to note that the above optimizations in equations (3.3.5), (3.3.6) and (3.3.7) differs across the different sectors - oil, non-oil and non-tradeable - due to varying characteristics of the sectors in terms of and intensity which we shall discuss in the following subsections.

3.3.1 Non-Oil Sector

Non-oil firms are assumed to use labour, capital and land inputs in the production of traded non-oil goods. Labour use is intensive in this sector. Output prices are exogenously set in the world markets; thus the firms have no monopoly power over the output prices. The non-oil firms are characteristically perfectly competitive firms. Hence the production function of the non-oil firms is given below

$$Y_t^{NO} = N_t^{NO^{\alpha_{no}}} \, K_t^{NO^{\beta_{no}}} \, L_t^{NO^{1-\alpha_{no}-\beta_{no}}} \tag{3.3.8}$$

The corresponding first order condition for this sector yields the following factor demand properties for the non-oil sector:

$$K_t^{NO} = \frac{\beta_{no} \, P_t^{NO} \, Y_t^{NO}}{r_t^k + \epsilon_t^k} \tag{3.3.9}$$

$$N_t^{NO} = \frac{\alpha_{no} \, P_t^{NO} \, Y_t^{NO}}{w_t + \epsilon_t^n} \tag{3.3.10}$$

$$L_t^{NO} = \frac{(1 - \alpha_{no} - \beta_{no}) \, P_t^{NO} \, Y_t^{NO}}{s_t + \epsilon_t^l} \tag{3.3.11}$$

3.3.2 Oil Sector

Relative to the other sectors, the oil sector is the main user of land in the model because production in this sector is land-intensive. They use land, labour, and capital in the production of oil traded output. Just as in the non-oil sector, the oil firms have no monopoly power over input and output prices. Hence the input and output prices are set in international markets. It is necessary to note that all land is owned by the government and the rent generated from land use serves as revenue to the government. Thus, the production function of the oil sector is

$$Y_t^O = N_t^{O^{\alpha_o}} \, K_t^{O^{\beta_o}} \, L_t^{O^{1-\alpha_o-\beta_o}} \tag{3.3.12}$$

Therefore, the corresponding first-order conditions (FOC) yields the same result as the general FOC obtained above. This is summarized below

$$K_t^O = \frac{\beta_o \, P_t^O \, Y_t^O}{r_t^k + \epsilon_t^k} \tag{3.3.13}$$

$$N_t^O = \frac{\alpha_o \, P_t^O \, Y_t^O}{w_t + \epsilon_t^n} \tag{3.3.14}$$

$$L_t^O = \frac{(1-\alpha_o-\beta_o) \, P_t^O \, Y_t^O}{s_t + \epsilon_t^l} \tag{3.3.15}$$

3.3.3 Non-Traded Sector

This sector comprises goods and services which are not produced in any other sector. They include services such as distribution, tourism, hotels, restaurants, transport services among others. One key feature of the output in this sector is that it is not traded internationally, hence is consumed domestically. Therefore, there is a chance for output prices to be set domestically. However, for simplicity, we assume perfect competition and prices of nontraded goods are already set in the previous section equals its marginal cost. On the input side, we note that just as in the above sectors, land, as well as capital and labour, are all used in the production of non-traded output.

Similarly, the production function is given as

$$Y_t^{NT} = N_t^{NT^{\alpha_{nt}}} \, K_t^{NT^{\beta_{nt}}} \, L_t^{NT^{1-\alpha_{nt}-\beta_{nt}}} \tag{3.3.16}$$

The first-order conditions yield the following

$$K_t^{NT} = \frac{\beta_{nt} \, P_t^{NT} \, Y_t^{NT}}{r_t^k + \epsilon_t^k} \tag{3.3.17}$$

$$N_t^{NT} = \frac{\alpha_{nt}\, P_t^{NT}\, Y_t^{NT}}{w_t + \epsilon_t^n} \tag{3.3.18}$$

$$L_t^{NT} = \frac{(1 - \alpha_{nt} - \beta_{nt})\, P_t^{NT}\, Y_t^{NT}}{s_t + \epsilon_t^l} \tag{3.3.19}$$

3.4 Government

We had mentioned in subsections above that the land is owned by the government, hence the revenue generated from renting the fixed supply of land to the firms is the biggest source of revenue to the government. By extension, the land rental rate is just a cost of output in the production process, hence we model the government's expenditure as financed by a proportion of aggregate output. We thus represent the government's expenditure as a function of aggregate output which is shown below:

$$G_t = \frac{g}{y}\, Y_t + \epsilon_t^g \tag{3.4.1}$$

Where $\frac{g}{y}$ represents the government's expenditure as a proportion of aggregate output and ϵ_t^g represents the government's expenditure shock.

3.5 Completing the Model

3.5.1 The Nontraded Goods Market Clearing

Contrary to the traded sector which comprises of oil and non-oil goods which is consumed domestically as well as traded internationally via imports, when non-oil demand exceeds domestic supply, and exports, when oil supply exceeds domestic oil demand; the nontraded sector is only consumed domestically. Thus, supply in this sector rises or falls to fulfil all non-traded demand needs. Although we assume that there is no cost in the conversion of output into capital inputs, we assume that all capital needs are supplied from outputs in non-oil and nontraded sectors. Technically, we assume that the nontraded sector can supply all the nontraded capital demand in the production process. As nontraded supply is determined by the demand for nontraded goods, the nontraded demand comprises the consumption of nontraded goods by the private household, the supply of nontraded capital and government expenditure. We had modelled government expenditure to be financed by a proportion of aggregate output; we note that the output proportion comes from the nontraded output. Thus, the market-clearing condition for nontraded goods is given below:

$$Y_t^{NT} = C_t^{NT} + G_t + \beta_{nt}\left(\Phi(K_t^* - K_{t-1}) + \delta\, K_{t-1}\right) + \epsilon_t^{YNT} \tag{3.5.1}$$

where ϵ_t^{YNT} is a shock to nontraded demand output.

In the subsections below, we discuss the contrary which describes the market-clearing for the traded sector.

3.5.2 The Foreign Sector

To further complete the model, we assume that the consumption decisions of the small open economy are not restricted to its production. Thus, we describe a foreign sector, just like a country to represent the rest of the world trading with the domestic economy. We describe the sources of imports and the market for exports for the home economy. Since the production comprises of the production of tradeable and non-tradeable goods, the imports and exports will only constitute traded goods - oil and non-oil goods. Also, to understand the export in this economy, we must be able to define the demand sources for the traded goods. As mentioned in sections above, we assume that it is costless for output to be converted into capital for production, however, we assume that only non-oil output is converted into capital for production in the traded sector, thus all domestic capital supply comes from the demand in non-oil goods for capital production. This means that the supply of capital to the oil and non-oil sector comes from the demand for non-oil goods. In other words, all capital accumulation and investment decisions constitute a demand source for non-oil output.

Therefore, the domestic economy will supplement any gap in consumption of non-oil goods C_t^{NO} and proportions of investment I_t, describing the proportions of capital supplied by the non-oil demand, by importing from the foreign country. Thus, non-oil goods constitute most imports as is the case for Kuwait. Also, the excess after domestic consumption of oil goods in the traded sector constitutes most exports in this economy. Since households are the main consumers of the output from the sectors, we argue that imports are the excess between demand and supply for non-oil goods and exports is the gap between demand and supply for oil goods. We express these below:

$$IM_t = C_t^{NO} + (1 - \beta_{nt})\,(\Phi(K_t^* - K_{t-1}) + \delta\, K_{t-1}) - Y_t^{NO} \tag{3.5.2}$$

and

$$EX_t = Y_t^O - C_t^O \tag{3.5.3}$$

We obtain the net export from the market clearing condition in the goods market as shown below:

$$NX_t = Y_t - C_t - (\Phi(K_t^* - K_{t-1}) + \delta\, K_{t-1}) - G_t \tag{3.5.4}$$

Recall from the nontraded sector that Walras' law applies and if the non-traded market clears, the traded market will also clear. Hence, in the traded sector, the net export is equivalent to the gap in the market-clearing for traded goods. Hence,

$$NX_t = EX_t - IM_t \tag{3.5.5}$$

If $NX_t < 0$ this implies a trade balance deficit, whereas if $NX_t > 0$ this indicates a trade balance surplus. The above equation implies that the current account surplus which is the sum of trade balance plus net income flows from foreign assets is equal to the capital account deficit which is the decrease in the countries net foreign assets. Hence the foreign bonds valued at constant foreign prices evolve over time to balance payments according to the following equation

$$B_t^f = (1 + r_t^f)\, B_{t-1}^f + NX_t \tag{3.5.6}$$

3.5.3 Market Clearing Conditions

To describe the stochastic processes that define the equilibrium path under this framework, we need to define the market clearing conditions.

- Goods market clearing

$$Y_t = C_t + I_t + G_t + NX_t \tag{3.5.7}$$

- Labour market clearing

$$N_t = N_t^{NT} + N_t^{NO} + N_t^{O} \tag{3.5.8}$$

- Capital Market Clearing

$$K_t = K_t^{NT} + K_t^{NO} + K_t^{O} \tag{3.5.9}$$

- Land Market Clearing

$$\bar{L} = L_t^{NT} + L_t^{NO} + L_t^{O} \tag{3.5.10}$$

Hence from (3.5.8), we have that

$$N_t = \frac{\alpha_{NT}\, P_t^{NT}\, Y_t^{NT}}{w_t + \epsilon_t^n} + \frac{\alpha_{NO}\, P_t^{NO}\, Y_t^{NO}}{w_t + \epsilon_t^n} + \frac{\alpha_{O}\, P_t^{O}\, Y_t^{O}}{w_t + \epsilon_t^n} \tag{3.5.11}$$

Thus

$$N_t = \frac{1}{w_t + \epsilon_t^n} \left(\alpha_{nt}\, P_t^{NT}\, Y_t^{NT} + \alpha_{no}\, P_t^{NO}\, Y_t^{NO} + \alpha_o\, P_t^O\, Y_t^O\right) \tag{3.5.12}$$

Since labour is intensive in the non-oil sector, we can solve for equilibrium output in the non-oil sector which is given below

$$Y_t^{NO} = \frac{1}{\alpha_{no}\, P_t^{NO}} \left[N_t \left(w_t + \epsilon_t^n\right) - \alpha_o\, P_t^o\, Y_t^O - \alpha_{nt}\, P_t^{NT}\, Y_t^{NT}\right] \tag{3.5.13}$$

Similarly, from (2.5.10), we have that

$$L_t = \frac{(1 - \alpha_{nt} - \beta_{nt})\, P_t^{NT}\, Y_t^{NT}}{s_t + \epsilon_t^l} + \frac{(1 - \alpha_{no} - \beta_{no})\, P_t^O\, Y_t^O}{s_t + \epsilon_t^l} + \frac{(1 - \alpha_o - \beta_o)\, P_t^O\, Y_t^O}{s_t + \epsilon_t^l} \tag{3.5.14}$$

Similarly, the oil sector which is land-intensive and generates the equilibrium oil output. This is given below

$$Y_t^O = \frac{1}{(1 - \alpha_o - \beta_o)\, P_t^o} \left[L_t \left(s_t + \epsilon_t^l\right) - (1 - \alpha_{no} - \beta_{no})\, P_t^{NO}\, Y_t^{NO} - (1 - \alpha_{nt} - \beta_{nt})\, P_t^{NT}\, Y_t^{NT}\right] \tag{3.5.15}$$

In the capital story, capital is mobile and flows freely from abroad and across sectors. Recall from the previous section that non-oil output can be converted into capital input at no cost. Thus we assume that the rental rate of capital is given as

$$r_t^k = P_t^{NO}\, (r_t + \delta) \tag{3.5.16}$$

where δ is the depreciation rate of capital. The rental rate of capital adjusts to ensure that capital flows in to meet all domestic demand needs for capital, thus making demand equal supply for capital in (3.5.9) above.

In summary, aggregate output is given as:

$$Y_t = Y_t^{NT} + Y_t^o + Y_t^{NO} \tag{3.5.17}$$

The competitive equilibrium is thus defined as a set of stochastic processes of the variables satisfying the constraints, first-order conditions and market clearing conditions in the model framework and they hold for any time $t > 0$.

3.6 Model Listing

1. Nontraded consumption C_t^{NT}

$$C_t^{NT} = -\sigma^{nt}\, P_t^{NT} + C_t \tag{3.6.1}$$

2. Oil consumption C_t^{O}

$$C_t^{O} = -\sigma^{o}\, P_t^{O} + C_t \tag{3.6.2}$$

3. Non-oil consumption C_t^{NO}

$$C_t^{NO} = -\sigma^{no}\, P_t^{NO} + C_t \tag{3.6.3}$$

4. Consumption C_t

$$C_t = E_t\, C_{t+1} - \frac{1}{\rho_0}\, r_t + \frac{1}{\rho_0}\, \epsilon_t^C \tag{3.6.4}$$

5. Labour Supply N_t

$$N_t = \frac{1}{\rho_2}\, \frac{\theta_0}{1-\theta_0} + \frac{1}{\rho_2}\, \epsilon_t^C - \frac{\rho_0}{\rho_2}\, C_t + \frac{1}{\rho_2}\, w_t - \frac{1}{\rho_2} \epsilon_t^{NS} \tag{3.6.5}$$

6. Debt-elastic interest rate

$$r_t = r_t^f + Q_{t+1} - Q_t + \Phi\,(B_t^f) \tag{3.6.6}$$

7. Land rent s_t

$$s_t = \frac{1}{1-\alpha_o-\beta_o}\,[P_t^o - \alpha_o\, w_t - \beta_o\, r_t^k + \epsilon_t^o] \tag{3.6.7}$$

8. Wage rate w_t

$$w_t = \frac{1}{\alpha_{no}}\,[P_t^{NO} - \beta_{no}\, r_t^k - (1-\alpha_{no}-\beta_{no})\, s_t + \epsilon_t^{no}] \tag{3.6.8}$$

9. Non-traded goods price P_t^{NT}

$$P_t^{NT} = \alpha_{nt}\, w_t + \beta_{nt}\, r_t^k + (1-\alpha_{nt}-\beta_{nt})\, s_t - \epsilon_t^{nt} \tag{3.6.9}$$

10. Land supply

$$L_t = \bar{L} \tag{3.6.10}$$

11. Government expenditure G_t

$$G_t = \frac{g}{y}\, Y_t + \epsilon_t^G \tag{3.6.11}$$

12. Foreign bonds B_t^f

$$B_t^f = (1 + r_t^f)\, B_{t-1}^f + NX_t \tag{3.6.12}$$

13. Non-oil output Y_t^{NO}

$$Y_t^{NO} = \frac{1}{\alpha_{no}}\left[N_t + w_t - \alpha_o\,(P_t^o + Y_t^O) - \alpha_{nt}\,(P_t^{NT} + Y_t^{NT}) - \alpha_{no}\,P_t^{NO} + \epsilon_t^n\right] \tag{3.6.13}$$

14. Oil output Y_t^O

$$Y_t^O = \frac{1}{1 - \alpha_o - \beta_o}\left[L_t + s_t - (1 - \alpha_{no} - \beta_{no})\,(P_t^{NO} + Y_t^{NO}) - (1 - \alpha_{nt} - \beta_{nt})\,(P_t^{NT} + Y_t^{NT}) - (1 - \alpha_o - \beta_o)\,P_t^o + \epsilon_t^l\right] \tag{3.6.14}$$

15. Nontraded capital demand

$$K_t^{NT} = \beta_{nt}\,(P_t^{NT} + Y_t^{NT}) - r_t^k + \epsilon_t^{KNT} \tag{3.6.15}$$

16. Non-oil capital demand

$$K_t^{NO} = \beta_{no}\,(P_t^{NO} + Y_t^{NO}) - r_t^k + \epsilon_t^{KNO} \tag{3.6.16}$$

17. Oil capital demand

$$K_t^O = \beta_o\,(P_t^O + Y_t^O) - r_t^k + \epsilon_t^{KO} \tag{3.6.17}$$

18. Desired capital (Aggregate Demand for Capital)

$$K_t = \beta_{nt}\,K_t^{NT} + \beta_{no}\,K_t^{NO} + \beta_o\,K_t^O \tag{3.6.18}$$

19. Nontraded Output Y_t^{NT}

$$Y_t^{NT} = \frac{c^{NT}}{y^{NT}}\,C_t^{NT} + \frac{g}{y}\,G_t + \frac{k}{y}\,(\beta_{nt}\,(\phi\,(k_t - k_{t-1}) + \delta\,k_{t-1})) + \epsilon_t^{YNT} \tag{3.6.19}$$

where β_{NT} is the proportion of investment supplied by nontraded goods.

20. Aggregate output Y_t

$$Y_t = \frac{y^{NT}}{y}\,Y_t^{NT} + \frac{y^o}{y}\,Y_t^o + \frac{y^{NO}}{y}\,Y_t^{NO} \tag{3.6.20}$$

21. Net Export

$$\frac{NX_t}{Y_t} = Y_t - \frac{c}{y}\,C_t - \frac{k}{y}\,(\phi\,(k_t - k_{t-1}) + \delta\,k_{t-1}) - \frac{g}{y}\,G_t \tag{3.6.21}$$

22. Rental rate of Capital

$$r_t^k = P_t^{NO} + r_t \tag{3.6.22}$$

23. Price of Traded goods P_t^T

$$P_t^T = 0.9\,P_t^O + 0.1\,P_t^{NO} \tag{3.6.23}$$

24. Real Exchange Rate Q_t

$$Q_t = P_t^T - P_t^{nt} \tag{3.6.24}$$

3.7 Transmission Mechanism of Shocks in the Model

We summarize the implication of the shocks, which we vastly divide into price shocks and demand shocks, on economic activity in this model. This is necessary as it increases the tractability of the shocks and helps us understand the transmission mechanism and how the shocks impact most of the variables in the model. More so, open economy models with just two sectors can be quite demanding in their tractability and we assume greater complications in understanding the mediums of transmission in this model with three sectors. Before understanding the shock mechanism in the model, we attempt to describe the price relationships and sectoral interactions inherent within this model framework. These interactions are described in the subsections below.

3.7.1 Output price and Factor price Relationship Dynamics

In this subsection, we adopt the Johnson (1958) diagrams to explain how the nature of technology or the range of variation in factor endowments within certain restrictions determines the nature of trade and extent of production in this model. This explanation is in tandem with our earlier assumptions about the factor intensities and factor supply restrictions for the productive sectors in this model.

Recall that, we had determined in earlier subsections that the oil sector is land-intensive and the non-oil sector is labour-intensive. This information is important in determining the technical possibilities and factor reallocation in this model. In line with other models of international trade, we begin by assuming that the taste and the distribution of the means of satisfying wants which make up the consumption side are given. Also, on the production side, we assume that the technology and the supply of the factors of production are given. Hence, factors are immobile, meaning that they cannot flow from the domestic economy to a foreign country in this model. Furthermore, we assume that both the domestic economy and foreign economy have identical factors of production and output after production, hence factors and products are homogeneous. Lastly, we also note that there is perfect competition and trade barriers are absent, meaning that we may assume that tariffs and transport cost goes into the final price of traded goods which are exogenously determined in this model.

For the analysis that follows, it is necessary to simplify our arguments by pointing out that in addition to having two countries, domestic and foreign, as assumed in earlier subsections and within our model, we have also simplified the argument to cover two goods, oil and non-oil, and two factors, land and labour, which are immobile factors. Hence, based on the factor intensities and factor supply to the oil (land-intensive) sector and non-oil (labour-intensive) sector, output from these sectors is determined by both factor intensity and factor supply. More so, we also assume that there is difficulty in substituting one factor for another in the production process. Therefore, there is no factor substitutability land cannot easily be substituted for labour or in reverse to boost production in any of the traded sectors, which by implication means that the oil sector cannot then become labour-intensive, or the non-oil sector become land-intensive. Thus, our analysis begins by summarizing the assumed sectoral technical possibilities, given in the production function. The production function defines the relationship between the optimum land-labour ratios in both sectors, the relative factor prices and the relative output prices [14] of both sectors -oil and non-oil sector. This relationship is explained via the figure below and we analyse this by examining output price changes or their movement along the factor-price curves. It may be necessary to note that our discussions surround the traded sector which is where specialization occurs within the production process.

Firstly, the factor endowment of the traded sector sets an overall land-labour ratio, to which the land-labour ratios in the oil and non-oil sector weighted by the proportions of the total labour force employed must average out. The overall land-labour ratio in the figure below is set by the long-run supply curve and the ratio is given by $\frac{\bar{L}}{\bar{N}}_T$, as shown in the second quadrant. Thus, the extreme case or corner solution is the point where the traded sector's resources may be used entirely in the land-intensive sector (oil sector). Conversely, the case where all the resources may be used in the labour-intensive sector, non-oil sector. Also, we note that the relative price of land, given by the ratio of land rent to wage rate $\frac{s}{w}$ and the relative price of oil, given as the ratio of oil price to non-oil price $\frac{P^O}{P^{NO}}$, must lie within the limits of these two extremes.

By implication of these extremes, the traded sector is completely specialized in oil production as in the first case or non-oil as in the latter of the extremes. Therefore, there would be no exchange ratio between commodities, though the non-produced commodity might have a virtual price equal to the exogenous world price of the traded output which is equal to marginal cost in this model, thereby setting the price of either

[14] or the relative costs of the output as stated in Johnson (1958)

labour or capital as the case may be. Therefore, the resource restriction of the traded sector is shown below.

$$\omega_o \frac{L}{N}_o + (1 - \omega_o) \frac{L}{N}_{no} = \frac{\bar{L}}{\bar{N}}_T \tag{3.7.1}$$

At the extremes, $\omega_o = 0$ or $\omega_o = 1$, indicating all resources used up in the non-oil and oil sector respectively, where $\frac{L}{N}_o$ and $\frac{L}{N}_{no}$ in the equation above represents the optimum land-labour ratio in the oil and non-oil sector respectively. Given the technical restrictions on the traded sectors by factor endowment given by $\frac{\bar{L}}{\bar{N}}_T$ in the figure above, the implication is a restriction on the possible variations of factor prices and relative costs of production. Hence at the overall land-labour ratio given by $\frac{\bar{L}}{\bar{N}}_T$, if all resources are used up in the production of oil goods, then the relative price of land will be a_o, conversely if it were used up in the production of non-oil goods, it will be given as a_{no}, this is shown in the figure below at the points of intersection between the factor demand curves of the oil (*oo*) and non-oil (*nono*) sectors, and the factor supply curve s in the second quadrant. From these extreme factor prices, the corresponding output price will be at p_{no} and p_o[15] for a_{no} and a_o[16] respectively.

[15]Please note that p_{no} and p_o are price ratios, that is being expressed in a ratio of oil to non-oil prices, however, we express them like this to signify the extreme case where all the overall traded sector factor inputs are invested into the production of either oil or non-oil goods

[16]similarly, this price is expressed in the ratio of land rent to wage rate

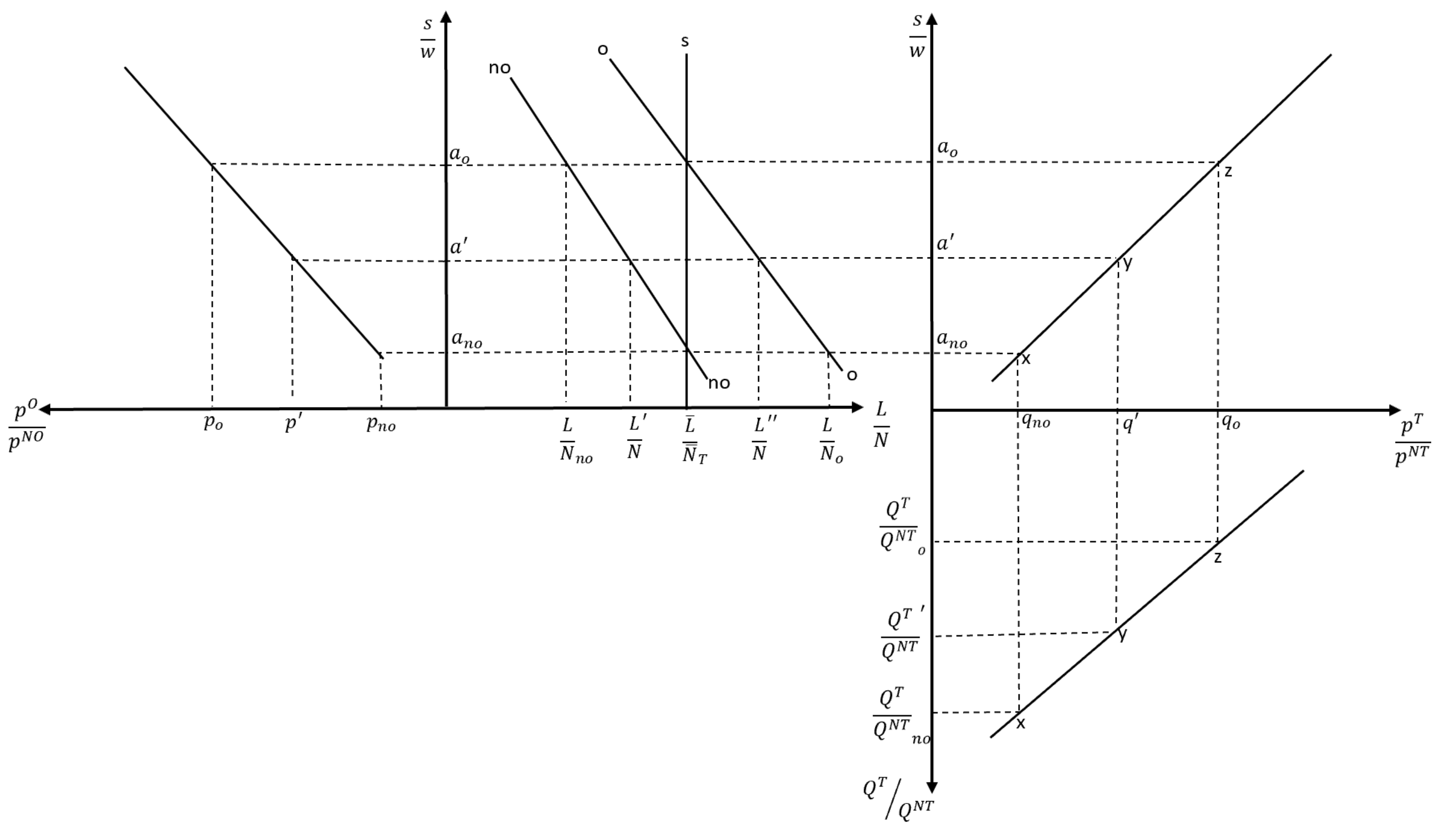

Figure 3: Factor-Price Interaction in the Traded Sector

Next we discuss the factor-price determination describing the relationship between output price or relative price of oil $\frac{P^O}{P^{NO}}$ and the factor input price or relative price of land $\frac{s}{w}$ as used severally in this discussion. As a result of factor-price determination adopted in this perfect competition model, there is inherent interaction between factor prices and output prices in this model. In the figure above, factor-price determination relates equilibrium traded output prices with equilibrium factor prices for the immobile factors in which the traded sectors have their production intensity, which is in tandem with the assumptions of our model discussed above. This implies from our model that the exogenously determined traded output price causes equilibrium factor price for the immobile factors in which the traded sectors have their production intensity. More so, this factor-price determination[17] relationship is described in the first quadrant. At this point, it is necessary to note that in line with our model, the output prices given as the relative price of oil is exogenously determined, hence the corresponding determinants in terms of the relative price of land is also taken as given hence can only be affected by a technology shock, which would cause the same effect as a shock to the relative price of oil. Thus in the first quadrant, the relative price of land would rise or fall depending on if the relative price of oil rises or falls respectively.

Therefore, we can combine the intuition from the first and second quadrant to highlight the relationship between output and input price with the optimum level of land and labour demanded in the sectors. In the extreme case already described above, as the relative price of land rises from a_{no} to a_o, the corresponding land-labour ratio in individual sectors decreases from $\frac{L}{N}_o$ to $\frac{\bar{L}}{\bar{N}}_T$ in the oil sector and $\frac{\bar{L}}{\bar{N}}_T$ to $\frac{L}{N}_{no}$ in the non-oil sector. It is necessary to note that the decrease in these ratios is consistent and reconciled with the constancy of the overall land-labour ratio by shifting resources from the production of non-oil goods to the production of oil goods as the land price increases. The implication means that it frees up the labour required to increase the utility on the fixed factor of land in the optimum land-labour ratio for the oil sector. Hence for any relative price of land between the extremes, the proportions of the total land ratio demanded in one sector is equal to the ratio of the difference between the other sector's land-labour ratio and the overall land-labour ratio for the traded sector, to the difference between the overall land-labour ratio and optimum land labour ratio is the other sector. In other words, the proportions of land used up in the production of non-oil goods when price moves to p' is given as :

$$\frac{\frac{L}{N}'' - \frac{\bar{L}}{\bar{N}}_T}{\frac{\bar{L}}{\bar{N}}_T - \frac{L}{N}'} \tag{3.7.2}$$

Thus, from the first and second quadrant, given our technical specification in the traded sector, the spread between the optimum land-labour ratios in the two sectors and the difficulty of substituting land for

[17] This is the standard price equals marginal cost relationship $P = MC$

labour determines the range of variation of relative factor prices and commodity costs possible in the traded sector. As is the case in this Kuwait model, since factor shares are fixed, by extension the weights of sectoral proportions are in equation (3.7.1) above are also fixed. Thus, only the optimum proportions of land-labour ratio in each sector can move to balance the supply of overall land-labour to the traded sector. Hence, we may conclude that in this model, within the range of variation permitted by the production possibilities and factor endowment as shown between the extreme cases above, a certain given price of output (relative price of oil) would correspond to a certain price of input (relative price of land) which would correspond to a pattern of production given by technical possibilities and resource(factor) allocation which would correspond to a certain proportion of output produced, which would correspond to a certain distribution of income and the consumers would be willing to consume these commodities at the given output and input prices given. This summarizes the relationship between output price, factor price and optimum factor inputs in the traded sector, given by the first and second quadrants.

We extend our discussion to understand the implication of output price changes and factor price changes on the real exchange rate [18] and the demand for traded and non-traded output in this model. The third quadrant describes the relationship between the relative price of land and the real exchange rate, defined as the ratio of traded to nontraded price in this model. Whereas the fourth quadrant describes how the real exchange rate determines the demand of traded and nontraded output in this model. Contrary to the discussions of the first and second quadrants, where we set boundaries for technical operation in the traded sector, our discussion mainly focuses on the impact of price changes and real exchange rate changes in this model.

From the third quadrant, a rise in the relative price of land from a_{no} to a' will cause the real exchange rate to rise from q_{no} to q', that is a real depreciation[19], thus showing a positive relationship between the relative price of land and the real exchange rate. We may recall that the traded price is the weighted price of oil and non-oil goods, hence as explained in the paragraphs above, the relative price of land will rise in response to an exogenous rise in the relative price of oil and by extension, the traded price in this economy also rises. On the other hand, the impact on the domestic nontraded price would be a decline due to factor-price determination. Recall that the nontraded sector in Kuwait is more labour intensive relative to the traded sector, thus as the relative price of land rises, the nontraded price would decline, thus causing the real exchange rate defined as the ratio of traded to nontraded price to rise as shown in the movement from q_{no} to q'. This relationship is

[18] Recall that in previous subsections above, we had described the real exchange rate as the ratio of traded to nontraded price and this definition is still being maintained here

[19] This impact is in tandem with other literature such as Shehabi (2020) where the real exchange rate is described as the ratio of nontraded price to traded goods price $\frac{P^{NT}}{P^{T}}$, therefore the interpretation as a rise in this analysis corresponds to this interpretation because the real exchange rate is described here as $\frac{P^{T}}{P^{NT}}$, which is the inverse to the definitions given in Shehabi (2020) and other similar literature.

maintained as the factor price increases from a' to a_o and the corresponding real exchange rate from q' to q_o. In the fourth quadrant, the demand of traded and nontraded goods is described by the ratio of traded to non-traded output, $\frac{Q^T}{Q^{NT}}$. Hence, there is an inverse relationship between the relative price of traded goods, the real exchange rate, and the relative demand of traded goods given by the ratio $\frac{Q^T}{Q^{NT}}$. Therefore, the real exchange rate determines the demand for traded and nontraded goods. Also, we note that this demand ratio is the optimum ratio of traded to nontraded goods that clears the goods market for any given supply of traded and nontraded goods. Recall from our model that the nontraded demand determines supply, thus the supply for nontraded goods rises or falls to meet the demand needs in the nontraded sector; whereas the traded sector's price is exogenous, and it sets factor prices which determines factor supply to the sector and by extension output supply in the traded sector.

In other words, market-clearing in goods and factor markets can be linked to the movements in the real exchange rate, also known as the relative price of tradeable. This is because as explained above, the nontraded sector demand determines supply. However, the nontraded demand is also determined by the movements in the real exchange rate, which we recall determines factor prices, given by the relative price of land in this economy. Thus, these movements in real exchange rate via movements in the traded goods price (relative price of oil) determines factor prices (the relative price of land), which in turn determines the optimum factor proportions and the flow of factors supplied for output production within the traded and nontraded sectors. Conclusively, the optimum factors are supplied at a set factor price to clear the demand needs in the nontraded sector. By extension, the land-labour ratio available for production in the traded sector is the fixed supply of land-labour ratio in the aggregate economy less that supplied to clear demand in the nontraded sector. Thus, the supply curve set in the second quadrant shifts to the left or right depending on the proportion of aggregate factors supplied to the nontraded sector. These factors supplied to the traded sector determines the traded sector's output and this traded goods market is cleared by the goods market-clearing, shown in equation (3.5.7). Otherwise stated, the supply of traded goods is cleared by the demand for traded goods and net exports[20]. In summary, the movement in the real exchange rate ensures market-clearing; demand equals supply in both[21] markets and both sectors[22]. Thus as the real exchange rate rises from q_{no} to q', resulting from the rise in traded price, there is a contraction in the relative demand for traded goods shown in the movement from ${\frac{Q^T}{Q^{NT}}}_{no}$ to ${\frac{Q^T}{Q^{NT}}}'$ in the fourth quadrant. Hence less traded goods are demanded in the economy relative to nontraded goods.

To summarise the relationship between the output price, factor price, optimum factor utilization, real

[20]which captures the foreign demand and supply of traded goods from and to the domestic economy. This mops up all the surpluses or deficits between demand and supply of traded goods

[21]goods and factor markets

[22]both traded and nontraded sector

exchange rate and output demand in the economy, we discuss what happens when the relative price of land moves along its curve. If the relative price of land rises, factor inputs are reallocated, thus changing the optimum factor ratios by sector. As a result, labour is relocated from the non-oil sector to the oil sector to increase land utility thus reducing land utility in the non-oil sector. In the same light, this is caused by a rise in the relative price of oil which raises the traded price and by extension raises the real exchange rate or real depreciation in the real exchange rate. Consequently, lesser traded goods are demanded relative to the nontraded goods in this economy.

We discuss further dynamics to the relationships and interactions discussed above by analysing the impact of an exogenous technology shock in this economy.

3.7.2 Oil Productivity Shock Transmission

The tractability of the shock transmission in this model is very important because it gives us valuable insight into the impact of oil technology shock on key variables and equilibrium in this model. Also, it helps us in understanding the impulse response functions in our calibration and estimation subsections below. More so, it is also important because we had suggested that the main sources of shock in this model are based on price shocks - input and output price, and demand shocks in our earlier premise, hence understanding the different mediums of transmission is critical. Therefore, we analyse the impact of a positive oil technology shock in the model, and we try to track the potential sources of variation to the existing relationships already described. In this model, the oil technology shock causes the same effect as an exogenous rise in oil price, which we show through our model equations stated above. Recall from the representative firm's section, just as assumed in these adapted Johnson (1958) figures, the firm operates under perfect competition, thus price is set equal to marginal cost in each of the sectors. Hence, we modelled our Cobb-Douglas style price in each sector as shown below:

$$P_t^O = w_t^{\alpha_o}\, r_t^{k\,\beta_o}\, s_t^{1-\alpha_o-\beta_o}\, \epsilon_t^{o-1} \tag{3.7.3}$$

$$P_t^{NO} = w_t^{\alpha_{no}}\, r_t^{k\,\beta_{no}}\, s_t^{1-\alpha_{no}-\beta_{no}}\, \epsilon_t^{no-1} \tag{3.7.4}$$

Where ϵ_t^o and ϵ_t^{no} are productivity shocks (technology shocks) to output in the oil, non-oil and non-traded sectors respectively and all other terms maintain their usual meaning.

Furthermore, to show how this relates to a shock to the relative price of land in the case of an oil shock, we recall that in modelling the firm, we had determined that the oil sector is land-intensive while the non-oil sector is labour-intensive. Hence, from equations (3.7.3) and (3.7.4), the price of oil and non-oil goods, we can solve for the equilibrium factor prices for the immobile factors in which the traded sectors have their production intensity, wage rate w_t and land rent s_t via factor-price determination.

$$s_t = [\frac{P_t^o \, \epsilon_t^o}{w_t^{\alpha_o} \, r_t^{k\beta_o}}]^{\frac{1}{1-\alpha_o-\beta_o}} \tag{3.7.5}$$

$$w_t = [\frac{P_t^{NO} \, \epsilon_t^{no}}{s_t^{1-\alpha_{no}-\beta_{no}} \, r_t^{k\beta_{no}}}]^{\frac{1}{\alpha_{no}}} \tag{3.7.6}$$

The above prices for land rent and wage rate are the market-clearing factor prices that make output price equal to marginal cost.

Therefore, in the figure described below, a positive oil technology shock which is exogenous in this model causes a shift upwards in the price curve as shown in the first quadrant. In line with the discussions of our reduced-form model, a positive technology shock is also a shock to the rental rate of land, s_t, as depicted in the first quadrant of the figure below.

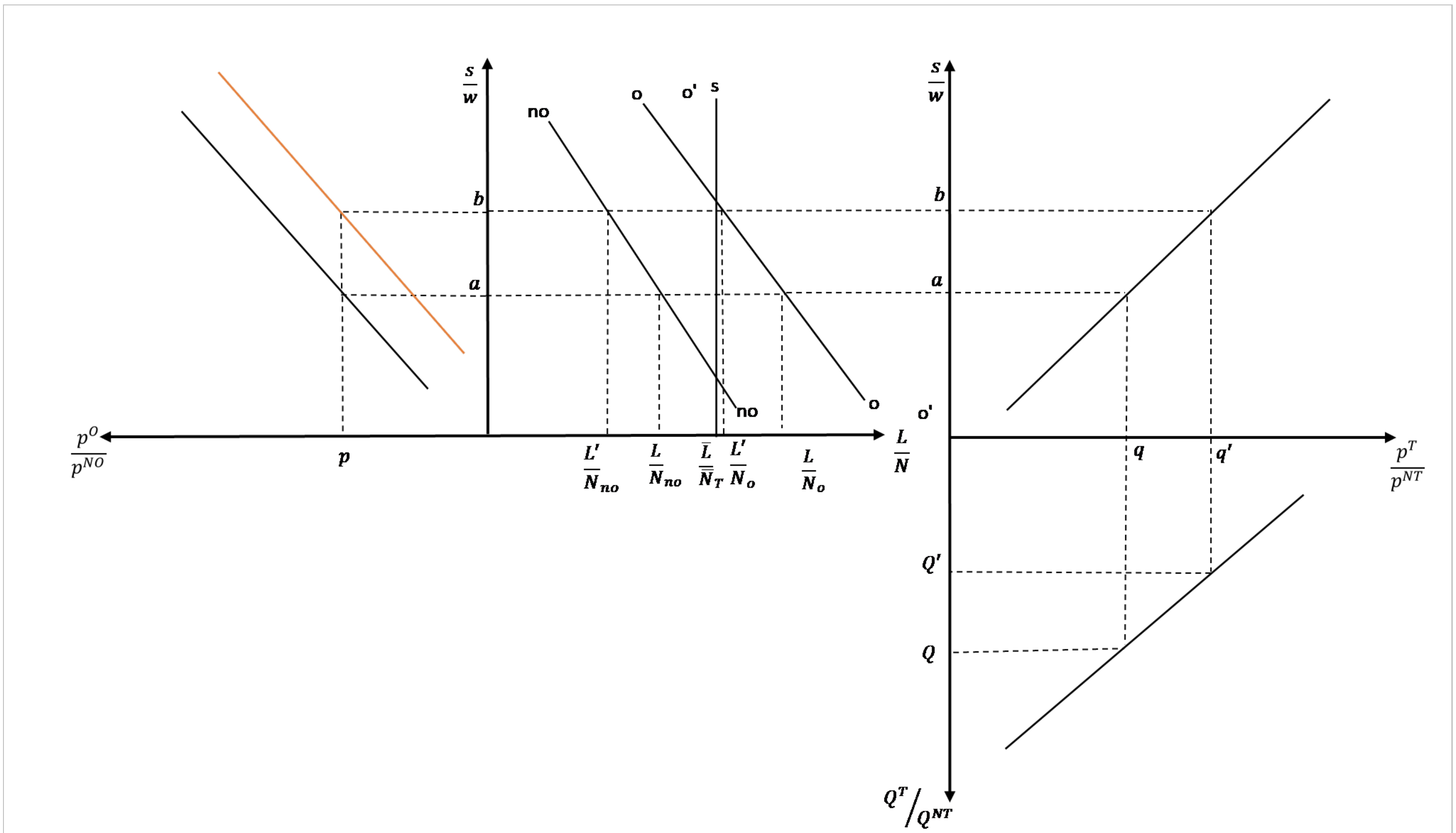

Figure 4: Oil Productivity Shock on Output-Factor Prices Relationships in the Model

In this model, the positive technology shock causes the same effect as a price shock. Hence, as shown in the figure above, the result from the positive technology shock is a rightward shift of the curve in the first quadrant, output price - factor price curve, indicating that at the same equilibrium price level p, same output price will cause higher factor price. If we track the impact of the shock across the second, third and fourth quadrants, we shall be able to examine the effects on input demand, output demand and the real exchange rate. Thus, as the exogenous technology shock hits the economy, it raises the relative price of land in the first quadrant as shown in the movement from a to b.

Before we continue with the oil technology shock transmission, it is necessary to recall that the fixed factor endowment sets the overall land-labour ratio supplied to the traded sector and this is given by the long-run supply curve shown in the second quadrant below which has remained constant. We recall this because this sets the technical restriction in terms of resources for production in the traded sector. The overall land-labour ratio is given by $\frac{\bar{L}}{N}_T$ as shown in the second quadrant above.

At the higher relative price of land shown in b, lesser factors are demanded in both the oil and non-oil sectors. This is shown by the contraction from $\frac{L}{N}_{no}$ to $\frac{L}{N}'_{no}$ in the non-oil sector and the contraction from $\frac{L}{N}_o$ to $\frac{L}{N}'_o$ in the oil sector. As we had emphasized in the subsection above, we reiterate that changes in the optimum proportions of land-labour ratios in both the oil and non-oil sector are consistent and reconciled with the constancy of the overall land-labour ratio which is fixed in supply. However, we discuss a potential traded input supply variability as is the case here in the paragraphs below which discusses how the nontraded sector activities create a balance and clear the input market in this economy[23]. More so, just as in the factor-price determination mechanism above, a rise in factor price from a to b would cause the labour required to utilize land and boost production in the oil sector to be freed up from non-oil sector. This is to increase the utility on the fixed factor of land in the optimum land-labour ratio for the oil sector. Furthermore, to measure the effectiveness of the positive productivity shock on the real exchange rate and demand for output in this model, we examine the corresponding output price-factor price impact in the third and fourth quadrant.

As the relative price of land rises to b, the real exchange rate that corresponds to the new price is given by an increase from q to q' in the third quadrant, which is a real depreciation. The effect on the demand for traded and nontraded goods is determined by the real exchange rate and we can determine this from the fourth quadrant. The ratio of traded to nontraded goods demanded because of real exchange rate movement from q to q' is given by a corresponding move from Q to Q' in the fourth quadrant. Thus, at the new real exchange rate at q', more nontraded goods will be demanded relative to traded goods domestically and the

[23]We recall from the model formulation of the nontraded sector, that nontraded supply moves up or down to satisfy demand as determined by movements in the real exchange rate. Therefore, a clearer understanding of the role of nontraded demand in clearing factor supply in the second quadrant should be considered alongside the real exchange rate impact in the third and fourth quadrant.

excess tradeable, are moped up by net exports to the international market.

We recall the decreasing demand for factor inputs in the traded sector as shown in the second quadrant and consider the resource constraint given in equation 3.7.1 given in subsections above simultaneously. We note that the equation balances for the factor inputs in the traded sector because the rising real exchange rate in q' raises the nontraded demand which causes more factor inputs to be supplied to the nontraded sector to meet the increased demand. Thus, there is a leftward shift in the fixed input supply curve to the left in the second quadrant, hence balancing the equation.

3.8 Calibration and Impulse Response Functions

3.8.1 Calibration

To gain intuition about the model and generate impulse response functions (IRFs) for the model, we chose to calibrate the model. The model is calibrated by choosing parameters either as supplied by the data or as commonly identified or assumed in similar literature. In this paper, the chosen parameters are calibrated based on the actual data for Kuwait, estimates from the literature on Kuwait or literature for economies with similar structure to Kuwait. For our data, we used quarterly data of Kuwait from 1990Q1 to 2016Q4. The parameters obtained from the literature on similar economies are summarised in the table below

Parameter	Role	Value
ρ_0	CRRA coefficient for c_t	1.0
ρ_2	CRRA coefficient for N_t	1.2
θ_0	home bias in consumption	0.5
ϕ	risk premium on foreign bond	0.2
$\frac{g}{y}$	government expenditure share in output	0.23
$\frac{C}{y}$	mean consumption to output ratio	0.36
$\frac{k}{y}$	mean capital to output ratio	1.5
σ	partial adjustment parameter	0.25
δ	depreciation rate	0.051
σ^{no}	marginal effect of non-oil price on non-oil consumption	0.01
σ^{o}	marginal effect of oil price on oil consumption	0.01
σ^{nt}	marginal effect of non-traded price on non-traded consumption	0.01
$\frac{cnt}{ynt}$	nontraded consumption share in nontraded output	0.69

Table 2: Calibrated parameters from Literature

The next set of fixed parameters shown in the table below shows fixed parameters which will remain unchanged throughout our calibration experiment because they represent very strong features of the Kuwait economy and on average does not change through time. The reason they remain fixed is because they define the sectoral intensities which is a key factor in understanding the model and for all the implications explained in oil shock transmission subsections below. When we consider the sectoral factor shares of fixed factors in this economy, we observe that within the traded sector, the oil sector is land intensive while the non-oil sector is labour intensive which fits the facts of the model which we sort to explain. Whereas, the nontraded sector's production function depends on all three factors, however its intensity does not matter too much since its output is not traded internationally. Still, we recognise that its high labour intensity is a representation of Kuwait's high employment of its citizens in its governmental and service industries which matches the data strongly. These fixed factor shares are derived from the data for Kuwait as obtained in the National Accounts Statistics Input and Output 2010 Tables reported by the Central Statistical Bureau of Kuwait. These fixed parameters are summarized in the table below.

Parameter	Role	Value
α_o	labour share in oil sector	0.1
α_{no}	labour share in non-oil sector	0.3
α_{nt}	labour share in non-traded sector	0.6
β_o	capital share in oil sector	0.2
β_{no}	capital share in non-oil sector	0.6
β_{nt}	capital share in non-traded sector	0.2
$1-\alpha_o-\beta_o$	land share in oil sector	0.7
$1-\alpha_{no}-\beta_{no}$	land share in non-oil sector	0.1
$1-\alpha_{nt}-\beta_{nt}$	land share in non-traded sector	0.2
$\frac{y^o}{y}$	size of oil sector in aggregate	0.5
$\frac{y^{no}}{y}$	size of non-oil sector	0.1
$\frac{y^{NT}}{y}$	size of non-traded sector	0.4

Table 3: Fixed Parameters

The Impulse Response Functions (IRFs) interpretation that follows describes the internal dynamics implied by the model's shocks. In the calibration analysis, it mainly presents the effects of a one-off permanent positive oil productivity shock. Even though the IRFs of all the variables behaves as expected, however, only the variables of interest in this paper are presented and discussed in the next subsection.

3.8.2 Oil Productivity Shock IRF Explanation

From our reduced-form model, the impact of a positive productivity shock in the oil sector will have a direct impact on land rent. This was illustrated in our adaptation of the Johnson (1958) diagram above, hence factor-price determination inherent in the model would cause a positive technological shock, which has the same effect as an exogenous rise in the price of oil, to raise the price of land. Hence, a positive technological shock will raise the rental rate of land as shown in the impulse response function (IRF) below.

This rise in land rent will cause a reallocation of labour to the oil sector to utilize land at the detriment of the non-oil sector. This is evident from the rise in oil output and the decline in non-oil output in the IRF below. This is explained in our Johnson diagram above by the movements in the second and third quadrants. Recall from the chart above, the factor price ratio, $\frac{s_t}{w_t}$, the ratio of land rent to the wage rate, drives the supply of immobile factors to the traded sector. Hence, with land rent rising from productivity shock, the ratio of factor cost rises, and more labour is supplied to the sector to utilize land since land is a fixed factor. Hence, this raises land use in the oil sector. Since the oil sector is land-intensive, the increase in land use in the sector will stimulate the production of oil output. Thus, by extension, land use in the non-oil sector falls. By extension, the ratio of oil to non-oil price determines the ratio of land rent to wage rate which in turn determines the production of oil to non-oil output in the traded sector as seen in the impulse response function below.

Just as in the third quadrant of the Johnson diagram above, the exogenous technology shock causes a depreciation[24] of the real exchange rate. This causes a decline in domestic demand for traded goods and boosts the demand for non-traded goods. Therefore, just as the market-clearing condition for non-traded goods, the supply rises to meet demand and non-traded prices[25] also rises to clear the market.

On the demand side, with a rise in the aggregate income resulting from both oil and nontraded output growth, there is a significant boost to domestic consumption, both private and public consumption represented in the government's expenditure. Hence, there is a corresponding rise in the demand for consumption composites, consumption of oil, non-oil, and non-traded goods. Also, with the contraction in the non-oil sector, the demand for non-oil goods via imports increases and import expands to meet this demand. Also, there is an expansion in exports resulting from oil output expansion. Thus, there is a positive net export which causes the real interest rate to be lowered to balance payments in the economy. By extension, there

[24]We note that the rise in oil price similar to the effect from the positive productivity shock, in addition to a decline in the price of nontraded goods, will cause the real exchange rate; $Q_t = \frac{P_t^T}{P_t^{NT}}$, to rise (real depreciation).

[25]Recall that the price of non-traded goods is also defined by features of the perfect condition, thus price equals marginal cost. From the allocation of factors in the sector, the non-traded sector is more labour intensive, though malleable in its input combinations. Therefore, the non-traded sector's highest cost by ratio is the cost of labour. Thus, as the cost of land rises, the input cost ratio is given by the ratio of land rent to wage rate rises. In line with this rise is a fall in the price of nontraded goods which is more labour intensive.

is a decline in foreign debt given by expansion in aggregate income and the interest rate adjusts to balance the current and capital accounts.

Lastly, capital which is the only mobile and flexible factor in this economy flow freely into more productive sectors. This is shown by the capital flowing into the oil and nontraded sector and flowing out of the non-oil sector in the IRF below.

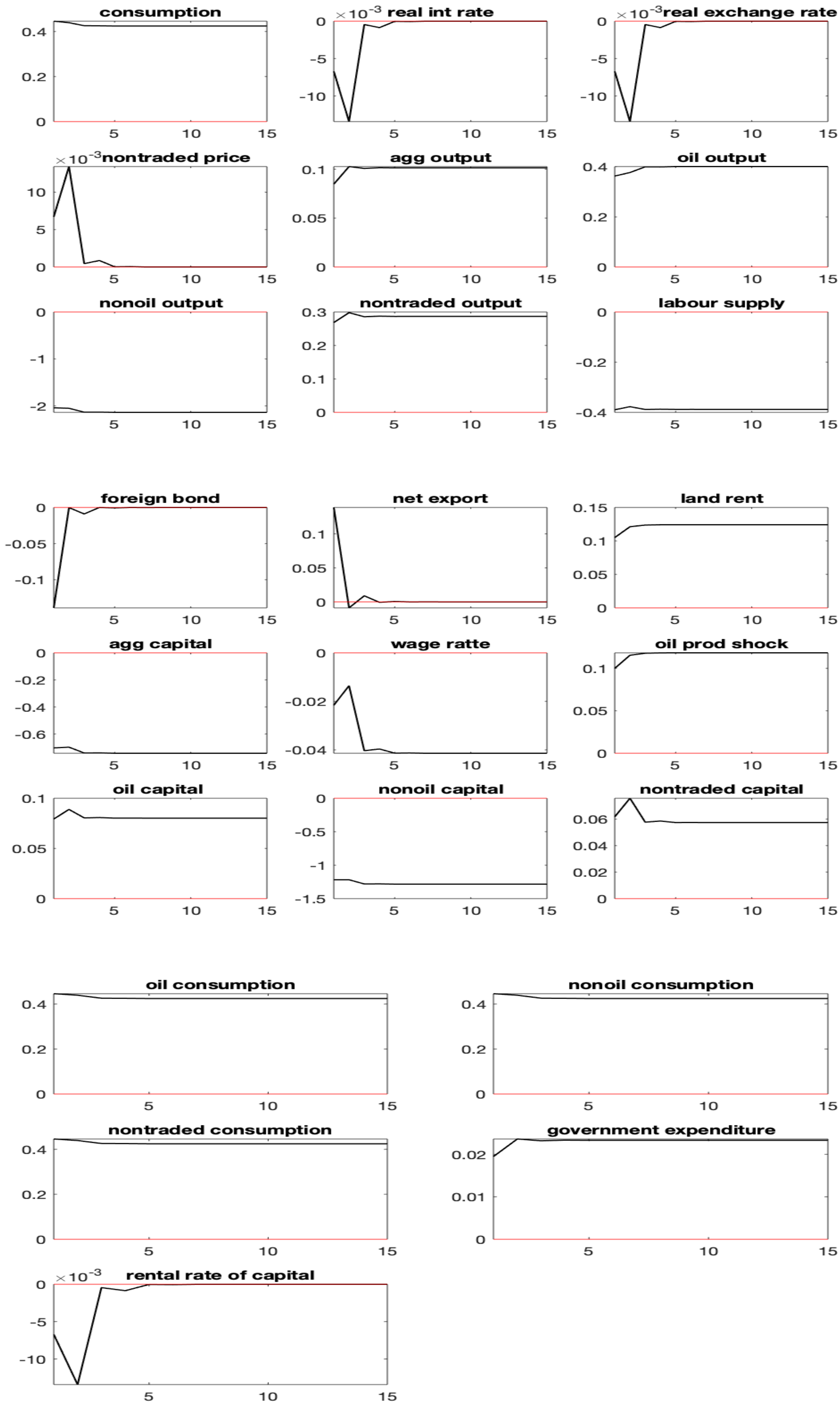

Figure 5: Oil Technology shock

3.9 Summary

In the chapter above, a DSGE model of Kuwait is proposed. In this model, we have a firm that is divided into two major sectors, traded sector and the nontraded sector, however, we go further to divide the traded goods sector into two sectors, oil and non-oil sectors. In summary, this model comprises of welfare optimizing agents with households who optimize expected discounted utility, 3-sector firm which maximizes expected discounted streams of profit under perfect competition by setting price equal to marginal cost, a government sector that owns and regulates land as its source of finance for expenditure and a foreign sector which trades internationally as well as supplies the domestic needs for traded goods. Lastly, we have a non-traded sector that contains goods and services consumed domestically and the supply of output in this sector is driven by domestic non-traded demand needs. This model features a home economy that is composed of identical and infinitely lived agents who produce non-traded, oil and non-oil products which are consumed domestically and exported abroad. The home economy coexists with another foreign economy, "the rest of the world", which is larger than the home economy. Thus, the home economy is a small open economy which implies that it cannot influence world prices and interest rates whereas the foreign economy is independent of choices of the home country but is large enough to affect international prices and interest rates. The home economy produces non-traded products which are strictly for domestic consumption and tradeable goods in the form of oil and non-oil goods which can be consumed domestically and exported abroad. Therefore, the composition of consumption of tradeable goods is a weighted ratio of domestic and foreign consumption. We note that the goods are traded with the foreign country at prices and interest rates which are exogenously determined in world markets due to perfect competition assumption and the relative size of this economy in this model. We assume that these prices incorporate transport and border costs which makes the case for factor-price determination featured above, also the home economy can borrow internationally at predetermined interest rates. This summarizes the model's structure. The model is bounded by the assumption that land and labour are immobile factors, whereas capital is mobile. Also, the factor intensities play a vital role in the productivity of the sectors. Lastly, we conclude the chapter with diagrams modified from Johnson (1958) and calibration results that show oil productivity shock as the major driver for aggregate fluctuations in this model.

4 Methodology: Indirect Inference Method

4.1 The Empirical Evaluation of DSGE Models

Macroeconomic models have often been criticised based on inherent identification issues. Even though the solution of the DSGE model takes the form of a VAR model, many of the VAR models pre-existing before DSGE models were heavily criticised because they could not deduce the parameters of the underlying structural model from these reduced-form VAR models. This is in line with the famous Lucas critique and the structural nature of the DSGE model solves this problem. Part of the criticism of those pre-DSGE VAR models was because most of those models had some constancy and were mostly policy invariant. However, Lucas (1976) pointed out that that argument does not hold strongly because if expectations are formed rationally, then macro models parameters, mostly reduced-form model parameters, would respond to changing monetary and fiscal policy. The reason is that these policies affect the parameters of the underlying structural models which are used in the derivation of these reduced form macroeconomic models. In other words, Lucas suggests that when expectations are formed rationally, then economic agents will react to policy changes because they affect the underlying micro-founded structures built from the agent's optimization problems as in the DSGE models. Thus, this argument by Lucas (1976) has led economists to solve this inherent problem by deriving macroeconomic models based on microeconomic foundations which implies that building these models is based on preferences and technology. The structural nature of the DSGE model answers this, then the question which this modelling technique faces is on how it evaluates the reduced form VAR model.

How DSGE models have brought evidence to bear has had to involve a variety of processes through decades of research and learning. Some of these procedures may have involved using a VAR model, generalised method of moments (GMM) estimation, single equation rational expectation estimation, maximum likelihood estimation, Bayesian estimation as well as indirect estimation. Thus, the decision of which method to adopt and how well the chosen method highlights, explains or discusses the problem inherent in an auxiliary model, can be a tough decision for economic researchers to make.

One might then ask why this is a challenge for many economists and what influences the choice of estimation procedures. The answer to these questions has been a source of active debates for decades and to shed light on the issue, we bring light to the path in which these different procedures have taken and the challenges and criticisms they may have faced and the reason for our chosen method. This may involve comparing in some cases, but we do make the necessary points to evaluate the DSGE estimation techniques fairly.

Since the suggestion of Kydland and Prescott (1982) for models to be calibrated and estimated under rational expectation, they observed that their likelihood ratio test which was their method of model evaluation was rejecting too many good models. Thus, this further raised questions on the ability to fairly test DSGE models and the increasing criticism under this method. Before I dive into the criticism of the indirect inference, I shall first discuss some evidence of the empirical techniques involved in DSGE estimation.

In addition to the VAR analysis discussed above, the generalised method of moments (GMM), also known as the instrumental variable technique, can also be used in the estimation of DSGE models. In the solution of DSGE models, a key set of equations that stabilizes and defines the solution and equilibrium in the model is the set of Euler equations. These are set of equations derived from the combination of first-order conditions from the dynamic optimization process of the structural model. The GMM estimation is a natural way of estimating the underlying Euler equations by exploiting the moment condition. The Hansen (1982) GMM estimation involves the estimation of the θ, a set of parameters that defines the moment conditions defined within a DSGE model. In other words, assuming the moment condition is defined in the below as:

$$E[f(x_t, \theta_0)] = 0 \tag{4.1.1}$$

where $E(.)$ represents expectation, $f(.)$ is a vector of functions, x_t is a vector of variables and θ_0 is a vector of parameters. Thus, the GMM estimation involves the estimation of θ_0 for which the above moment condition holds, that is equal to 0 as above. We note that the condition holds for $\theta = \theta_0$. It may be necessary to note that we do not go into details to illustrate the moment condition for a sample size of T. We assume in our discussions that for such samples, the appropriate moment condition is defined and the estimated $\tilde{\theta}$ satisfies the relevant identification conditions [26] and distribution of θ. The sample moment conditions from the solution to a DSGE model may be defined as a vector of reduced-form equations summarized below as

$$E[f(x_t, \theta_0)] = E_t\left[Z_t' X_t(\theta)\right] = 0 \tag{4.1.2}$$

where X_t is a $T * N$ vector with t rows of defined or reduced-form equations, θ is the vector of relevant parameters and Z_t is a vector of $q \geq N$ instrumental variables.[27] Recall that the linear rational expectations model can be defined by a VARX or VARMAX equation, then we can use lagged values of the VAR model as our instruments in the condition above. Nonetheless, with all these to improve the estimation technique under rational expectation, there is still a problem of errors in the specification as noted by Lucas and Prescott. Also, another challenge of the GMM estimation is that a large set of moment conditions may

[26] We note that in a sample, if the dimensions of θ are greater than or equal to the dimensions of $f(.)$, then it can meet the relevant moment condition because it is either over-identified or exactly identified in the relevant case. In the case where the dimension of θ is less than $f(.)$, $\tilde{\theta}$ is chosen to minimize the weighted quadratic function of the sample moment condition. That is the $\tilde{\theta}$ that minimizes the sum of squared residual in moment condition

[27] We also note that the relevant restrictions are met in the system of simultaneous equations under the moment conditions

improve asymptotic efficiency but may also increase the sample bias if instrumental variables are weakly correlated with the predicted variable. This is the case, especially in small samples. Thus, the asymptotic distribution may be a poor approximation in small samples. More so, in the case of non-linear conditions, the moment conditions may be poor estimates, and this may have increased inaccuracy if the data is non-stationary.

Relative to the GMM estimation technique described above, the maximum likelihood involves the estimation of the mean of the conditional distribution of the linear function of the DSGE model, given all the available information up to time t. That is, if $f(.)$ is a linear function of the DSGE, then the problem involves the estimation of the conditional mean shown below:

$$E_t\left[f(y_t, y_{t+1}, x_t; \theta\right] = 0 \tag{4.1.3}$$

The relative advantage of the maximum likelihood (ML) over the GMM is that we may obtain fully efficient estimates of the model. However, the disadvantage is that we must specify the distribution of the disturbances, specify the full model of which any error in the specification of the underlying equations in the model may cause biases and lack robustness in the estimates of the whole economy. Thus, instead of $\tilde{\theta}$ as in the GMM estimation, the ML estimates the full sample θ.

In recent times, one of the most popular debates in DSGE evaluation is the "Bayesian vs Indirect Inference" debate. Still, there is no clear winner across economic departments in various schools as some schools widely adopt one over the other. Bayesian estimation technique involves extending the sample information on the observations of variables contained in the likelihood function by obtaining prior information about the parameters of interest. One may then ask, what is the difference between the model calibration and Bayesian estimation? Good question! Calibration can be seen as a Bayesian estimation as it assumes that its chosen priors are correct and certain, thus the model calibration is just an extreme calibration. Whereas the Bayesian technique assumes that it has prior distribution, based on some similar information as the calibration techniques and the actual data, however, it does not believe that these priors are certain but rather estimated parameters follow a certain distribution. Thus, allowing the parameters to vary within certain limits set by the prior distribution.

In other words, a lot of econometricians will say that the Bayesian estimation method is between the extremes of calibration and the maximum likelihood method. In Bayesian estimation, the information is expressed in terms of the prior probability distributions of the values that parameters can take, which is then combined with the information obtained from the sample about the variables to obtain a joint distribution of both parameters and variables. Then, the distribution of the parameters conditional on the observed sample is obtained by dividing the joint distribution by the marginal distribution of the data obtained. The marginal distribution of the data is obtained by integrating over all possible values of the parameters. Hence, the Bayesian technique obtains estimates of the parameters which are just measures of central tendency[28] of these posterior distributions. Hence, in comparison to the maximum likelihood method[29], the Bayesian technique infers that θ is either estimated using the mean or mode of the posterior distribution whereas the maximum likelihood chooses the parameters that maximize the mode of the likelihood function.

The main criticisms of the Bayesian estimation method include that the prior information is subjective as we do not know definitively the distribution of the priors and if the subjective information of the priors is incorrect, then it leads to a bias of the parameter estimates. Also, there is the big question of whether prior information can be expressed in terms of probability distributions. Lastly, in scenarios where the parameters are constants, how valid is it to treat them as random variables and assign distributions to them? Questions such as them have been used to question the validity of the Bayesian technique in DSGE evaluation. At this junction, it then is necessary to ask whether the indirect inference method deals with these problems better than the Bayesian technique.

4.2 Model Evaluation of the DSGE Model

The performance of a DSGE model can be evaluated by either comparing moments, that is the comparing the properties of the auxiliary model or by the impulse response functions, which is a method of visual inspection of the model's performance. Below are the descriptions of both methods.

4.2.1 Tests Based on the Properties of Structural Parameters

We assume that the parameters to be evaluated are given, either estimated or calibrated, then the process of evaluating based on the properties of the structural parameters is a process of evaluating this model by testing of the structural parameters of the model passes the test of significance. In other words, it tests if the difference between the estimated or calibrated coefficient from the auxiliary model is significantly different from those observed in the data. Thus, this is a hypothesis test. By implication, if we do not reject the null hypothesis, it means that the economic model is not significantly different from the observed data whereas a rejection implies that the auxiliary model is incorrectly specified, thus parameters are significantly different from that generated from the data. Using asymptotic theory, we shall explain the test statistic, in this case, the Wald statistic, and the decision rule under this method of evaluation.

We explain how the Wald's test statistic is obtained. Just as in subsections above, assume that θ

[28]The central tendency measures may be the mean, median or mode of the posterior distribution
[29]The maximum likelihood is a classical estimation technique

represents a set of parameters that defines the moment conditions defined within a DSGE model and we have a definitive value for θ given by θ_0 such that the observed data y_t and simulated time series generated from the auxiliary model x_t share same distribution, by implication $x_t(\theta)_{s=1}^{S}$ and ${y_t}^{T}{}_{t=1}$ where $s = cT$ and $c \geq 1$. Also, we assume that $[]x_t(\theta)]$ and $[y_t]$ are stationary and ergodic. Thus, if $\hat{\theta}$ represents the estimated or calibrated value of θ, we can express the null hypothesis as shown below.

$H_o : \hat{\theta} \Longrightarrow \theta$

The if we consider the continuous $p \times 1$ vector of functions $g(\alpha_T(\theta))$ and $g(\alpha_S(\theta))$ which could be described as moments, then $G_T\left(\alpha_T\right) = \frac{1}{T}\sum_{s=1}^{T} g(\alpha_T(\theta))$ and $G_S\left(\alpha_S\right) = \frac{1}{S}\sum_{s=1}^{S} g(\alpha_S(\theta))$. Thus the Wald statistic is given as

$$[G_T(\alpha_T) - G_S(\alpha_S(\hat{\theta}))]'\, W(\hat{\theta})\, [G_T(\alpha_T) - G_S(\alpha_S(\hat{\theta}))] \tag{4.2.1}$$

where the weight of the optimal weighting matrix is

$$W(\hat{\theta}) = [[\frac{\delta\, G(\alpha(\hat{\theta}))}{\delta\alpha}]\, \Omega(\hat{\theta})\, [\frac{\delta\, G(\alpha(\hat{\theta}))}{\delta\alpha}]']^{-1} \tag{4.2.2}$$

Just as noted above, we reiterate that this expression is obtained under asymptotic theory. Thus, we recognise as obtained in the next chapter that the Wald statistic can also be obtained by simulation, which involves bootstrapping the Wald statistic from simulated data. The process of doing this begins by determining the errors of the model conditional on the observed data and $\hat{\theta}$, next we construct the empirical distribution of the structural errors, and lastly, we compute the Wald statistic from the simulated data. The simulated data is the data obtained by either taking a random distribution of the structural disturbance or generated from actual residuals (or a similar distribution). Thus, the Wald statistic from the simulation is given as:

$$g(\alpha_T) - g(\alpha_S) = \alpha_T - \alpha_S(\theta) \tag{4.2.3}$$

Thus by implication,

$$G_T(\alpha_T) - G_S(\alpha_S(\hat{\alpha})) = \alpha_T - \alpha_S(\hat{\theta}) \tag{4.2.4}$$

In the next section, where we report our estimation result under the indirect inference method, we have also reported results of the Wald statistic calculated by the simulation technique described above.

4.2.2 Test Based on the Impulse Response Function

Let us assume that the economic model is represented as a VAR. Thus, for the observed data y_t,

$y_t = A(L)\, y_{t-1} + e_t$

and for the simulated data $x_t(\theta)$

$x_t(\theta) = A(L;\theta)\, x_{t-1}\,(\theta) + e_t(\theta)$

Therefore, the IRFs are then given as

$$y_t = C(L)e_t \tag{4.2.5}$$

$$x_t(\theta) = C(L;\theta)e_t(\theta) \tag{4.2.6}$$

If the estimated IRF coefficients are represented as vectors of γ and $\gamma(\hat{\theta})$, that is IRF for data and model, then we can check if there is a significant difference between them via the Wald statistic shown below:

$$[\gamma - \gamma(\hat{\theta})]'\, V^{-1}\, [\gamma - \gamma(\hat{\theta})] \tag{4.2.7}$$

where V is the variance-covariance matrix which is obtained by simulation techniques.

4.3 What is the Indirect Inference method?

The indirect inference method is a classical statistical framework that aims to compare the performance of the auxiliary model based on simulated data generated from the model, with the performance of the auxiliary model based on the actual data of the economy or variables within the said model. Essentially, the indirect inference procedure involves a process of comparing how much the data distribution and its moments generated by simulating an auxiliary model can match the data distribution and moments of the actual data for the economy. This is in line with the pioneer ideas of Kydland and Prescott (1982) for dynamic stochastic general equilibrium models to test their theory and models by the ability of these models to match certain cross-sectional features, moments, of actual data for the economy and macro variables. Hence, the indirect inference method used is also known as the method of simulated moments. We note that as described in Meenagh et al (2019), that evaluation of the performance of the DSGE models via indirect inference can be done via the moments, IRFs or VAR coefficients, and regardless of which criteria being used, the indirect inference test statistic provides similar power and parameter estimates with a similar level of bias, provided that the selected data features are held constant. The procedure of estimation and testing under indirect inference is discussed in detail in the paper of Le et al (2016) survey for users. Hence, in the following subsections, I discuss the procedures of indirect inference estimation and test, and the advantages this method provides relative to the alternatives for RBC and DSGE modelling.

4.4 Indirect Inference Testing and Estimation

Under this subsection, we start by noting that there is a difference between the indirect inference test and the indirect estimation of structural parameters. Thus, we set out to create clarity on the matter by discussing both individually.

4.4.1 Indirect Estimation of Structural Parameters

The indirect estimation process has been a useful estimation procedure and is not as new as many researchers may think it is. This procedure is evident in papers of Smith (1993), Gourieroux et al (1993), Meenagh et al (2012), Le et al (2011) amongst others[30]. Minford et al. (2009) proposed the use of the indirect inference method in the evaluation of a model's ability to match the properties of the data and more work and more laid out process was shown in the papers of Le et al (2011,2015). In their paper, they described the indirect estimation technique as a technique of estimation where the parameters of the structural model are chosen so that when the model is simulated, it generates estimates of the auxiliary model which are like the actual data. Then the optimal choice of parameters for the structural model are those that minimise the distance between both sets of parameters and Le et al (2015) show that the properties of the estimates are like the properties of the estimates under direct inference techniques such as the maximum likelihood (ML). Hence, estimates of the indirect estimation are asymptotically normal and consistent. Usually, in DSGE modelling, common choices of auxiliary models include the VAR model, moment of the data among others. However, in our paper, the auxiliary model representation is chosen to be VARMA since we use non-stationary data, and we follow papers by Meenagh et al (2012) and Le et al (2016) to approximate this into a VECM. Following Meenagh et al (2012), the VECM is used as the auxiliary model which is later expressed as a VAR for the selected variables of interest used in the computation of the directed Wald. Thus, the VAR coefficients and the VAR error variances are used to describe the data and compute the Wald statistics for the indirect inference test on the estimated parameters.

The estimation process involves the use of the Simulated Annealing Algorithm aimed at finding the minimum Wald statistics for the model. The result is a set of parameters whose distributions set the model closest to the data. One key thing to note under the indirect estimation is that these properties of the parameters do not only depend on the precise nature of the auxiliary model chosen but also the criterion

[30]More literature to review may include Gregory and Smith(1991,1993), Gourieroux and Monfort (1995) and many more as reviewed in the survey by Le et al (2015)

for the estimation is based on the unique mapping of the model's parameters. However, this does not mean that the model's ability to capture features of the data and pass the test is not important, but these two objectives are necessary for each other within the process.

4.4.2 Indirect Inference Test

Now that we have been able to describe the indirect estimation of the structural parameters, it is also important to describe the process of testing whether the model's features match that of the data. In other words, this is a test that answers the question, "Is the auxiliary model a true model of the economy?", "Does the features of the auxiliary model match the features of the data?". Thus assuming that the structural parameters are given from indirect inference estimations, the choice of auxiliary model is a VAR[31]. In Le et al (2015), they were able to show that the structural restrictions of the DSGE model are reflected in the data simulated from the model and will be consistent with the restricted version of the VAR, given that the model is identified. Thus, the II test involves comparing the unrestricted VAR estimates obtained from simulated data, or some function of the estimates such as the Wald statistic, with unrestricted VAR estimates obtained from the data. It is necessary to note, as in Le et al (2015) that rather than relying on the asymptotic distribution of the test statistic, its small sample distribution is estimated. We describe the steps of the indirect inference test below:

4.4.3 Indirect Inference Test Procedure

For simplicity, suppose that the DSGE model is given as

$$A_0 \, E_t \, Y_{t+1} = A_1 \, Y_t \, + z_t \tag{4.4.1}$$

$$z_t = D \, z_{t-1} + F \, \epsilon_t \tag{4.4.2}$$

then the reduced form of our DSGE model is given as

$$x_t = A \, x_{t-1} + B \, \epsilon_t \tag{4.4.3}$$

where $x_t = (y_t, z_t, a_t)$, and a_t are auxiliary variables, A and B are reduced form parameters of the model's structural parameters.

The steps to indirect inference testing are summarised thus:

[31]We do recognise that solution to a DSGE model is represented as VARMA, or VECM since the model's shocks are non-stationary as explained in the subsection above following papers by Meenagh et al (2012) and Le et al (2016)

1. Calculate the residuals and innovations of the economic model conditional on the data and parameters

   Given that we have been able to solve the model and it is represented as a VAR just as above, then the first step involves extracting the residuals ϵ_t from the VAR and then given the stationarity of the shocks, the innovations are also extracted. Assuming, that the VAR model is identified, the number of independent structural residuals is taken to be less than or equal to the number of endogenous variables. Thus we can extract the residuals given the parameters[32] and data. If the VAR has no expectations, we simply extract the residuals from the VAR model straight away, however, if there are expectation variables in our model, just as in our DSGE model above, we must estimate these variables via the instrumental variable method described in McCallum (1976) and Wickens (1982), with the lagged endogenous data as instruments. After the estimation, we can then extract the residuals. If we assume that these residuals are autoregressive, just as is the case in many DSGE models, we can then estimate the autoregressive coefficients and extract the model's innovations. This is called the limited information maximum likelihood (LIML) method. However, these can also be extracted directly where the AR coefficients and known. This is called the exact method.

2. Derive the simulated data by bootstrapping

   Bootstrapping is used to find small sample distributions[33] produced by the actual errors implied by the model and data. After obtaining the model innovations in *Step 1*, we can simulate the data by bootstrapping these innovations and we bootstrap by time vector to preserve any simultaneity between them. To obtain the N bootstrapped simulations, we need we repeat this process by drawing each sample independently.

3. Compute the Wald statistic.

   The decision rule which involves rejecting or not rejecting the null hypothesis that the model is true requires the estimation of an auxiliary model using the actual and simulated data and then calculating the Wald statistic. The Wald statistic is calculated from the equation below as given from the subsection above

$$[\gamma - \gamma(\hat{\theta})]' \, V^{-1} \, [\gamma - \gamma(\hat{\theta})] \tag{4.4.4}$$

   where V is the variance-covariance matrix which is obtained by simulation techniques. Similar to

[32] This can be gotten either by estimation or calibration of the structural parameters

[33] This is because the large sample (asymptotic) distribution is assumed to be normally distributed and we won't want to assume that all model errors follow the normal distribution. Thus, this enables a more accurate description of the error's distribution.

the description above, γ and $\gamma(\hat{\theta})$ are from the simulated data and model respectively. Thus, by substituting each set of simulated data up to N the number of bootstrapped simulations, we obtain the distribution of the Wald statistic. Note that, the choice of variables and the order of the VAR is up to you. Since the Wald test is strict, increasing the VAR order makes the test more stringent; hence in practice, we use a VAR (1). You can use all the variables in the VAR, or a subset of variables to see what combinations of parameters the model can fit.

For the model to fit the data at the 95% confidence level we want the Wald statistic for the actual data to be less than the 95th percentile of the Wald statistics from the simulated data. The Wald statistics from the simulated data comes from χ^2 distribution with degrees of freedom equal to $k-1$, where k is the number of parameters. Therefore, to make it easier to understand, the Mahalanobis distance can be used to transform the Wald for the actual data into a t-statistic. This is given as the square root of the Wald value. As it is the square root of a chi-squared distribution, it is possible to convert it to a t-statistic by adjusting the mean and the size and normalising it to ensure that the resulting t-statistic is 1.645 at the 95% point of distribution. Thus, the null hypothesis can be rejected if this t-value takes a value that is greater than 1.645. The formula that converts the Wald value into a t-statistic is given below

$$T = 1.648\,(\frac{\sqrt{2w^{a}} - \sqrt{2k-1}}{\sqrt{2w^{0.95}} - \sqrt{2k-1}}) \tag{4.4.5}$$

where w^a is the Wald statistic of the actual data and $w^0.95$ is the Wald statistic of the 95th percentile of the simulated data

4.5 Power of Indirect Inference Test

One of the advantages of the indirect inference test which sets it apart from the other methods is how powerful the method is. The power of the test refers to the probability of rejecting a hypothesis when it is false. In other words, this is the probability of rejecting a false null hypothesis. To inform us of the power of the indirect inference (II) test, just as in Le et al (2011, 2016), we compare the II test method's power with that of other direct inference methods.

In Le et al (2016) survey, they describe the procedure of evaluating the power of the indirect inference test. This involves using a Monte Carlo simulation procedure to generate samples from some true model, say 1000 samples based on the properties of the model's distribution, such as its moments. Then the distribution of the Wald is then calculated from the sample of the true model generated. Then another set of samples, say

1000 samples, are generated from a false model. Similarly, Wald's distribution for this false set of parameters θ is also calculated. The rejection rate of the true model at a particular degree of false (+ or - a certain degree of falseness) is obtained by calculating how many of the samples of the true model would reject the false model on this calculated distribution at 95%confidence. The degree of falseness is spread evenly across the sample and a sample size of 1000 or more ensures that it is large enough to replicate the distribution especially in models with many variables. Le et al (2011) evaluate the accuracy of the bootstrap to replicate the Wald distribution and they found that the accuracy level to be reasonably high.

To show the comparative superior power of the II test, Le et al (2015) examine the performance of the II test on the Sargent-Wallace (SW) model of the US for a sample period spanning from 1947Q1 to 2004Q4. They compare this against the power of the direct inference method, where the Likelihood Ratio (LR) is used as a benchmark. The power of the direct inference is determined by how well the DSGE model is forecasting the simulated data generated by the true model when compared to the VAR model fitted to the data. In other words, the difference between the direct and indirect power test is that the former asks how close does the model forecast the data? Whereas the latter asks, how close does the model replicate the properties of the auxiliary model estimated with the actual data? Thus to calculate the power of the LR test, the model's set of parameters θ, as well as its residuals and autoregressive parameters ρ are extracted via LIML [34] (Wickens,1982) for the first set of samples obtained from the true model. Thus, these residuals are then used to forecast the simulated data and distribution. From this, the distribution of the LR is obtained. The rejection rate is then obtained at 95% confidence.

The comparison of the power shows that at an increased level of falseness from the true model, the indirect inference test rejects more models which show its accuracy and greater power relative to the LR test. We show the results of the comparison as given in Le et al (2015) for a 3-variable VAR model.

[34] The instrumental variable procedure is used to forecast future variables and implement rational expectations on the structural equations. Using a VAR representation, the autoregressive parameters and residuals are then extracted

Percent Mis-specified	Indirect Inference	Direct Inference
0	5.0	5.0
1	19.8	6.3
3	52.1	8.8
5	82.3	13.1
7	99.4	21.6
10	100	53.4
15	100	99.3
20	100	99.7

Table 4: Rejection Rates for Wald and Likelihood Ratio for 3 Variable VAR(1)

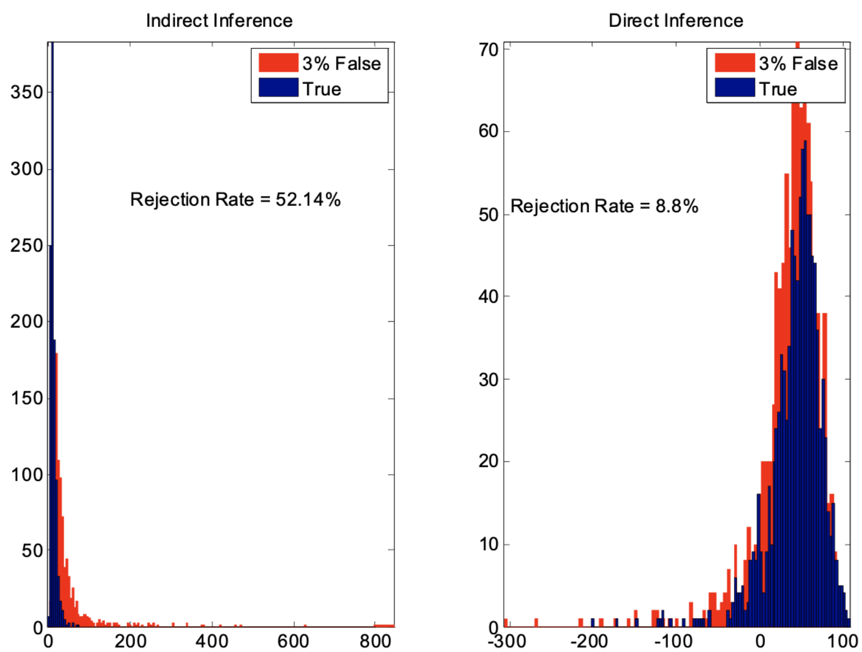

Figure 6: Histograms of true and 3% false models for Indirect and Direct Inference (some outliers deleted from Indirect for the chart) sourced from Le et al (2015)

35

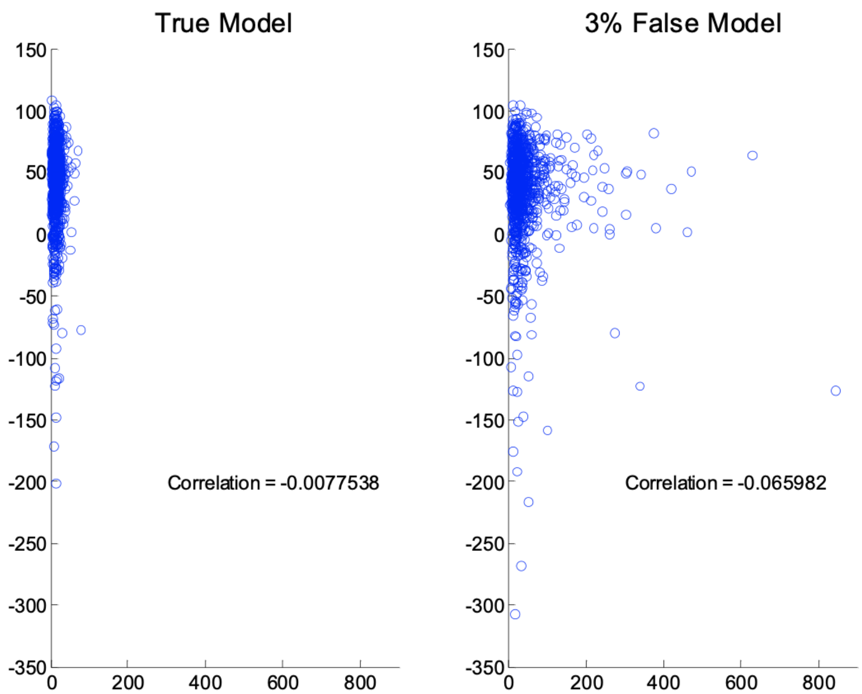

Figure 7: Scatter Plots of Indirect Inference (Wald) v. Direct Inference (LR) for 1000 samples of True Model (3 Variable VAR(1)) sourced from Le et al (2015) 36

The charts above sourced from Le et al (2015) shows the histograms of the two test statistics for the true and false (at 3% falseness) models in figure 5; this is more evidence showing the accuracy and power of the II test. Also, figure 6 shows the correlation coefficients between the two tests for the true and 3% false models; this illustrates that there is little or no correlation between the two tests across samples. These figures express the superior power of the indirect inference method over the direct inference (LR) method.

5 Testing and Estimating a DSGE Model of Kuwait via Indirect Inference

This section presents the results from the process of testing and estimating the DSGE model of Kuwait outlined and discussed in Chapter 3 of this paper. The results also infer about the method of Indirect inference as described in Chapter 4. This testing aims to verify the impact of the oil productivity shock calibrated in Chapter 3. Lastly, the report in this chapter infers the power of the method and its implication for the proposed model. We start this report by describing the characteristics of the data.

5.1 Data Description

The figure below displays the time paths for the data series that used in the evaluation and estimation of the model. The scope of the data covers a quarterly time that spans from 1991Q1 to 2016Q4. The data is expressed in real per capita terms, and they are also transformed to logarithmic form. Hence, the data contained in figure 8 is a logarithmic expression of the unfiltered data of Kuwait expressed in real per capita terms. Please note that horizontal axes describe the quarters with the first quarter being 1991Q1 and the last being 2016Q4. The data for Kuwait was obtained from multiple sources which include the Central Statistical Bureau (CSB) Kuwait, Central Bank of Kuwait (CBK) statistics and publications, the International Monetary Fund (IMF)database, Bureau of Labour Statistics (BLS) series, World Bank Database and United Nations (UN) database. We have used quite a variety of sources[37] because obtaining certain data proved difficult and some variables had to be cross-checked with the data presented in other databases to ensure consistency. The data is also expressed in Kuwait dinar and any data expressed in U.S. dollars were converted into Kuwait dinar at the exchange rate obtained from the IMF database. The table below describes the data used and this data is not filtered and some of the data series are nonstationary.

We note that data for land rent[38] was not available from data sources, hence we backed this out from the zero profit equation [39] and it is also expressed per unit land available, which is fixed in supply.

[37]To obtain more details of the individual sources for the data used, this can be seen in the data appendix section of this thesis.

[38]The rent is defined as the excess profits or loss per unit land after payments for labour and capital have been compensated.

[39]This is under the assumption of perfect competition, hence the rent contains the payments or reward paid for land as well as any excess profits or losses that may exist after cost.

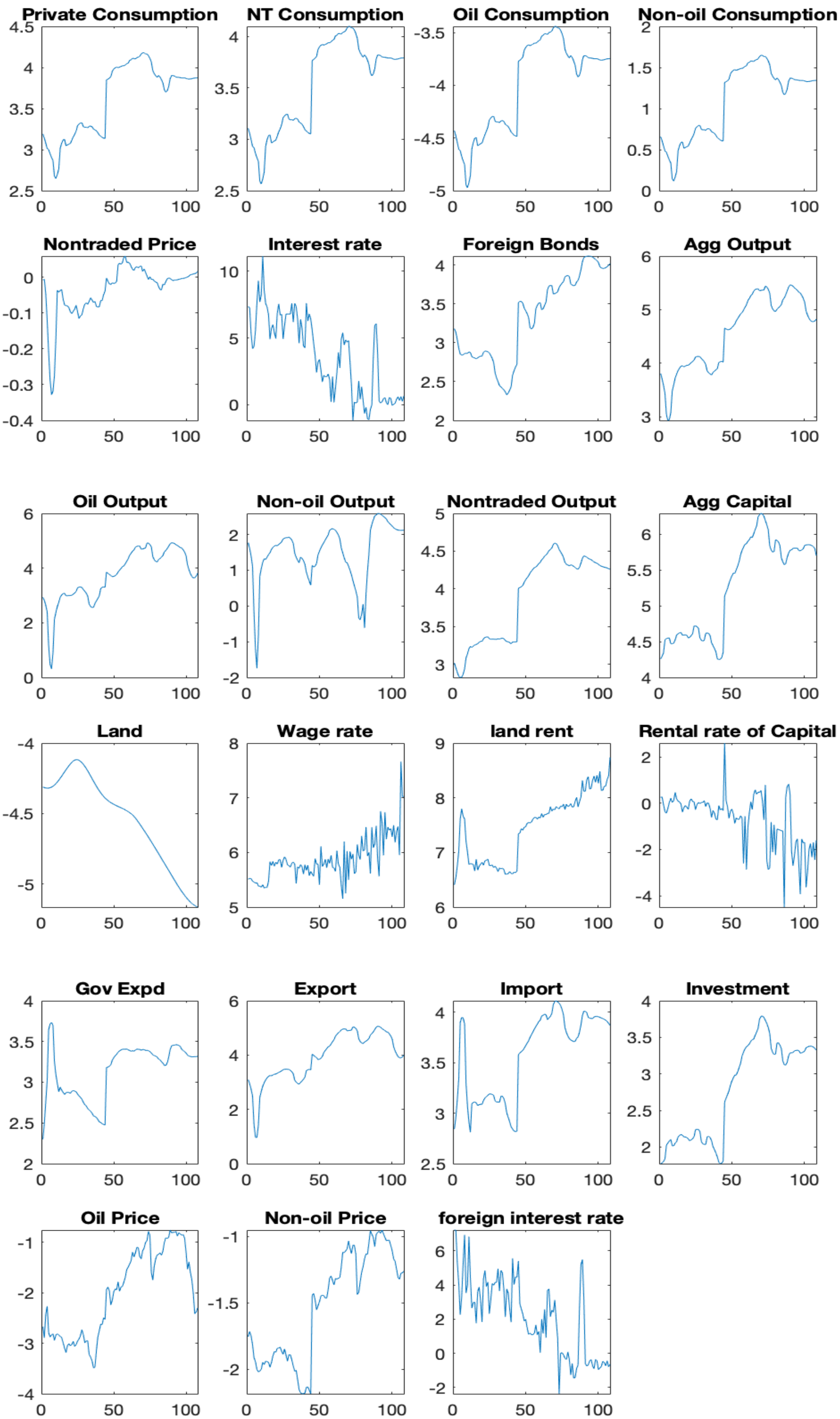

Figure 8: Unfiltered data for Kuwait Expressed in Logarithmic Form

Note: NT, Agg in the chart above, denotes non-traded and aggregate respectively.

More so, we summarize the raw data obtained for the series in the table below. The table briefly describes the variables and where the data is sourced from. For some variables, data was unavailable, hence I have constructed the series based on the model or used appropriate proxies for them. In the notes that follow after the table, I report the data constructed and some filtering done to it as well as any means used to make up missing data. For a more detailed outlook of the data, we have expanded this report in the appendix section to elaborate more on it.

Symbol	Variables	Data Definition
Y	Output	Gross Domestic Product (GDP) at current prices
Y^o	Oil Output	Gross Domestic Product (GDP) by industry (oil and gas), Current prices
Y^{no}	Non-oil Output	Gross Domestic Product (GDP) by industry (non-oil classification), Current prices
Y^{nt}	Non-traded Output	Gross Domestic Product (GDP) by industry (nontraded classification), Current prices
C	Consumption	Final Consumption in GDP by Expenditure, Private, Current prices
C^o	Oil Consumption	weighted portion of Final consumption, Private, Current prices
C^{no}	Non-oil Consumption	weighted portion of Final consumption, Private, Current prices
C^{nt}	Nontraded Consumption	weighted portion of Final consumption, Private, Current prices
I	Investment	Gross Fixed Capital Formation (GFCF) plus changes in stock in GDP by Expenditure, Current prices
K	Capital	calculated from perpetual inventory equation, Current prices
r	Interest rate	three-month treasury bill rate, nominal
s	Land Rent	Calculated from zero profit equation, current prices
w	Wage Rate	expenditure on wages and salaries divided by working population
G	Government Expenditure	Government expenditure in GDP by expenditure, Current prices
P^o	Oil Price	Brent Spot Price, Nominal
P^{NO}	Non-oil Price	World Commodity Price Index, Nominal
P^{nt}	Nontraded Price	weighted average of the chain-type price indexes for value-added from all industries classed as nontraded
r^f	Foreign Interest Rate	weighted average of three-month treasury bill rate from EU, Japan and US, Nominal
B^f	Foreign Bond	Ratio of Net Foreign Assets to GDP, Current Prices
Q	Real exchange rate	ratio of traded to nontraded price
N	Labour supply	persons aged between 18 and 54 in the population
NX	Net Export	Net Export from GDP by expenditure, Current prices

Table 5: Summary of Data Description

Data note:

1. All prices are expressed in Kuwaiti dinar

2. In the classification, the industry that makes up the oil sector is the Oil and Gas industry; whereas the non-oil sector comprises mining, agriculture, manufacturing and refined products industries; then all other industries were classified as the non-traded sector. More details on the data can be found in

the Data Appendix.

3. After obtaining the quarterly series from interpolation, I scale them properly and I adjust them for seasonal effects. Next, I express the nominal variables in real terms by dividing them by the price index, taking 2000 as the base year. After which, I have converted the data where appropriate into logarithmic form.

4. In scenarios where I had some missing data especially in 1990 where there was a Gulf war, I make up the incomplete series by applying some interpolation techniques as I had data before 1990. Also, I applied some techniques available on Eviews statistical package to convert frequency from annual to quarterly. More details on the methods employed can be seen in the Data Appendix.

5. Due to the lack of data, I have constructed some data for consumption by different products to obtain the weights assigned to oil consumption C^{o}, non-oil consumption C^{no}, and non-traded consumption C^{nt}. There is a detailed explanation of the extraction of these weights in the Data appendix section.

6. The capital is created following Caselli (2005) using the capital accumulation equation stated below.

$$K_t = I_t + (1-\delta)\, K_{t-1} \tag{5.1.1}$$

More so, the initial level of capital is calculated from the equation below

$$K_0 = \frac{I_0}{(g+\delta)} \tag{5.1.2}$$

where g is the growth rate of output and δ is the depreciation rate

For the composition of capital that is allocated to oil K^{o}, non-oil K^{no} and non-traded K^{nt} sectors, I made a few manipulations of the data to get these proportions. Since there is no data for these proportions, I have obtained them from the data reported on public investment expenditure of ministries and departments as reported in the quarterly special edition of Central Bank of Kuwait (CBK) Statistics and Publications. The proportions are defined by the proportion of current public investment expenditure of ministries and departments, which I then grouped into sectors like the classification of industries in the output described above.

7. Land rent is defined as the reward paid for using land in the productive process. This dataset is derived from our zero-profit equation which follows from our model assumptions. Hence, land rent covers all

the rental rates of land, application and other charges associated with renting land as well as profits accumulated.

From our model, we extract land rent from the equation shown below:

$$\pi_t = P_t Y_t - K_t(r_t^k + \epsilon_t^k) - N_t(w_t + \epsilon_t^n) - L_t(s_t + \epsilon_t^l) \tag{5.1.3}$$

All variables and parameters maintain their initial definitions.

8. Foreign interest rate is calculated as the weighted average of three-month treasury bill rate of the following countries and in the given proportions - EU(19%), US(60%), Japan (21%).

9. The wage rate is the reward per unit labour used up in production processes. As is the case with a few data in the series, getting the wage rate paid to domestic workers was unavailable. Thus, I was forced to extract this data from a close proxy sourced from the quarterly special edition of Central Bank of Kuwait (CBK) Statistics and Publication. The series used was the government's expenditure on wages and salaries reported in the economic classification of current expenditure. This quarterly series obtained was then divided by working population to obtain the wage rate in Kuwaiti dinar.

10. From the ILO series, we take labour supplied to the oil sector N^o as labour distributed to industry sector; for the non-oil sector N^{no}, we use labour distribution to the agriculture sector and lastly the non-traded labour N^{nt} as labour distributed to the services sector.

11. Traded price P^T is defined as a weighted sum of oil and non-oil price to make the price of traded goods in the economy. This ratio is fixed in the proportion shown in the equation below.

$$P_t^T = 0.9\, P_t^O + 0.1\, P_t^{NO} \tag{5.1.4}$$

All terms remain as initially defined.

From the data sourced and the series reported above, one may say that one of the limitations of this study stems from the availability of data. Nonetheless, we have used some proxies as well as statistical techniques to bridge some parts of this gap. However, we recognise that some measurement errors may still arise from these data issues.

5.2 Non-Stationarity Data and the Indirect Inference method

The choice not to filter the data aligns with the works of Meenagh et al (2012) and we give reasons because filtration as suggested in many papers have unknown effects on the data and moments thereof, particularly they may distort the dynamic properties of the model in ways that are not easy to uncover. Also, since we aim to test the theories of growth in this model and our model has nonstationary technology shocks, we shall preserve the non-stationarity of the data series. In Davidson et al (2010) examination of the indirect inference method extended to nonstationary data on an RBC model of the UK, they showed that the model can explain the behaviour of main variables of the UK economy irrespective of the non-stationarity. The problem usually associated with non-stationary series is that statistically, errors and shocks should be stationary otherwise their second moment(variance) will be asymptotically infinite. Thus, to solve this problem, Davidson et al (2010) dealt with the non-stationarity by using a vector error correction model (VECM) whereas a VAR was used on the series which were stationary. Under the VECM, the data are differenced and related to the lagged deviation of the data from its trend. They even find that the indirect inference method is more accurate in the non-stationary case relative to the stationary case. Building on the idea of Davidson et al (2010), Meenagh et al (2012) better outlined the steps for handling non-stationary series which we have implemented in this paper. They show that the assumption that a solution to a DSGE model can be expressed as a VECM allows the non-stationary residuals to appear as observable variables, thus an unrestricted version of this VECM is used as our auxiliary model. Thus, for this to be done, we must include in the auxiliary model these nonstationary residuals derived from the DSGE model. The implication is that the auxiliary model contains key variables to define the cointegrating relationships which guarantee that the VECM achieves cointegration under the null, that is the DSGE model. They further conclude under that experiment for the indirect inference test method, that there is higher accuracy and power with non-stationary data relative to stationary data.

5.3 Indirect Inference Estimation Results

In this section, we summarize the results of our indirect inference estimation of the structural parameters of our model. Within the estimation framework, we have some parameters which are fixed and some which are allowed to vary in the process of minimizing the distance between the data and the true model. Hence, this result reports a set of parameters that best fits this process. The choice of parameters to leave fixed are the parameters extracted from the data which reflect certain structural and con-integrating features of the Kuwait economy. Recall from subsection 4.3.1, we aim to minimize these parameters and still obtain features as predicted from our model on the effect of the oil traded sector on the economy of Kuwait. Hence, maintaining these parameters are necessary and we summarize the two sets of parameters below. The fixed parameters below represent the fixed factor by sector in the model.

Parameter	Role	Value
α_o	labour share in oil sector	0.1
α_{no}	labour share in non-oil sector	0.3
α_{nt}	labour share in non-traded sector	0.6
β_o	capital share in oil sector	0.2
β_{no}	capital share in non-oil sector	0.6
β_{nt}	capital share in non-traded sector	0.2
$1-\alpha_o-\beta_o$	land share in oil sector	0.7
$1-\alpha_{no}-\beta_{no}$	land share in non-oil sector	0.1
$1-\alpha_{nt}-\beta_{nt}$	land share in non-traded sector	0.2
$\frac{y^o}{y}$	size of oil sector in aggregate	0.5
$\frac{y^{no}}{y}$	size of non-oil sector	0.1
$\frac{y^{NT}}{y}$	size of non-traded sector	0.4

Table 6: Fixed Parameters

These parameters held fixed above represent features of Kuwait as obtained from the data which describes some unique sectoral features of the economy. The factor intensities are calculated from the average sectoral allocation of factor inputs to each sector and the size of each sector is calculated from the average proportion of sectoral output to aggregate output.

As we can see from above, when we consider the traded sector, oil and non-oil sector and the fixed factors, land and labour, the oil sector is intensive in the land as given by the share of land 0.7, $1-\alpha_o-\beta_o$, relative to the share of the other input of labour in the sector, 0.1. Thus, with the oil sector intensive in land relative to labour, the non-oil sector is intensive in labour given by α_{no}, 0.3 relative to land share, $1-\alpha_{no}-\beta_{no}$, 0.1 in the sector. This follows our theoretical framework described in the model for Kuwait in section 3, where the traded sectors are intensive in the fixed factors in this economy, land and labour. Also, within the estimation framework, we maintain that the size of the three sectors given by ω_o, ω_{no} and ω_{nt} for the oil, non-oil and non-traded sector respectively are constant through time.

As already described, the indirect inference estimation procedure starts from the optimally calibrated specification of the model which we had initially calibrated and reported in subsection 3.8. Then for the set of parameters that are allowed to vary, we search across the variant set of parameters within a limit of ± 0.5 until they satisfy the criteria of being close to the actual model. This indirect inference estimation process searches by simulated annealing - assisted grid search algorithm across a range of parameters. The whole idea of the process is to move the parameters of the structural model around until the model implies a VAR representation as close as possible to the VAR estimated on the actual data. Thus, the parameters are chosen indirectly based on the model's implied closeness to the VAR fitted to the data. Just as described in subsections above, the implied closeness is accessed from the VAR coefficients.

5.4 Results of Estimated Model's Parameters

From the indirect inference test on the initially calibrated DSGE model shown in section 3, the indirect estimation suggests searching for the best parameter set by varying the parameters in the initial calibration by ± 0.5 and within economic reality to ensure that they maintain their micro-founded structures and interpretations. The indirect inference estimated model was tested and the result is reported in the next subsection shows that it passes the test with a t-statistic of 1.54 which is less than 1.645 critical value. Hence, we do not reject our estimated model. The indirect inference estimation aims to minimise the Wald statistic, also the t-statistic, by randomly choosing values of the estimated parameters with a predetermined interval usually chosen to maintain model structure and economic consistency. This indirect inference estimation process searches by simulated annealing - assisted grid search algorithm across a range of structural parameters. This process aims to search for the set of parameters that makes our DSGE model variable moments best match the moments generated from the data for Kuwait. However, it is the responsibility of the researcher to ensure that the magnitude of the estimated parameters are reconcilable economically and that is why we have allowed the estimated parameters to vary within ± 0.5 to ensure this goal.

The results of the estimation process showed over 100 sets of parameters that were able to pass the test (that is, yielding a T-statistic which is less than 1.645). Hence, to find the set that best fits, we kept restricting the model by reducing the range in which each parameter is allowed to vary and in some cases limiting the search to a single numerical point. This was conducted severally and we report the set of parameters for the best fit estimates in the table below.

Parameter	Role	Value
ρ_0	CRRA coefficient for c_t	1.2
ρ_2	CRRA coefficient for N_t	1.1
θ_0	home bias in consumption	0.32
ϕ	risk premium on foreign bond	0.13
$\frac{g}{y}$	government expenditure share in output	0.21
$\frac{C}{y}$	mean consumption to output ratio	0.29
$\frac{k}{y}$	mean capital to output ratio	0.86
σ	partial adjustment parameter	0.13
δ	depreciation rate	0.053
σ^{no}	marginal effect of nonoil price on nonoil consumption	0.014
σ^{o}	marginal effect of oil price on oil consumption	0.013
σ^{nt}	marginal effect of non-traded price on non-traded consumption	0.0068
$\frac{cnt}{ynt}$	nontraded consumption share in nontraded output	0.66

Table 7: Indirect Estimated Parameters

The parameters reported above are estimated by Indirect Inference estimation. These estimated parameters are significantly different from the calibrated parameters, and this difference affects the estimated error processes, innovations, and persistence. The estimated model contains 12 shock processes and 3 of these shocks are treated as non-stationary data based on the theory. These non-stationary shocks are the productivity shocks, and they are modelled as ARIMA (1,1,0) processes. These shocks are tested by a variety of methods which includes the Augmented Dickey-Fuller (ADF) test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, and the result of the latter is summarised in the table below. From the table, only the productivity shocks are non-stationary, or first-difference stationary, hence the ARIMA (1,1,0) specification. Whereas, all other shocks are either level or trend stationary, which we summarise as stationary. These stationary shocks are modelled as AR (1) processes. The specification of the KPSS is summarised in the equations summarized below. Within the KPSS test, the appropriate test depends on the nature of non-stationarity characterised by the shock process and this test is done in sequential order. In the sequence, we start by testing if the shock process is a trend or level stationary, if we conclude that it is non-stationary in this test, then we proceed to test the shock process in first difference.

The decision rule for the hypothesis test can be made using either the KPSS test statistic, also LM statistic. If the *test statistic* is greater than the asymptotic *Critical Value* reported at 1% significance level, then we reject the null hypothesis and conclude that the shock being tested is a unit root. More details of the test process are contained in the Data Appendix. In this explanation, I use ϵ_t to define the shock residual, T denotes the linear time trend,β_2 to denote the parameter estimates describing the AR coefficient, and ξ_t for the shock innovations. In the part that follows, I summarise the test procedure:

The corresponding hypothesis test described above is:

H_0:$\beta_2 < 0$: ϵ_t is a level/trend/first-difference stationary process

H_1:$\beta_2 = 0$: ϵ_t is a unit root process

- Stationarity Test Specifications

  For trend stationary test;

$$\epsilon_t = \beta_1 T + \beta_2 \epsilon_{t-1} + \xi_t \tag{5.4.1}$$

  For level stationary test;

$$\epsilon_t = \beta_2 \epsilon_{t-1} + \xi_t \tag{5.4.2}$$

  For first-difference test;

$$\epsilon_t = \epsilon_{t-1} + \beta_2(\epsilon_{t-1} - \epsilon_{t-2}) + \xi_t \tag{5.4.3}$$

The table below summarises the result from the stationarity test and the estimated shock process below. The properties of the shocks and its innovations are reported, that is the mean μ and standard deviation σ of the I(0) shock innovation $\xi_t \sim (\mu, \sigma)$. More details of other properties of the shocks are reported in the appendix.

Shocks	Description	Decision Rule	Stationarity	AR Coef
ϵ_t^o	oil productivity shock	0.194<0.739	non-stationary	-0.38
ϵ_t^{NO}	non-oil prod. shock	0.0908<0.739	non-stationary	-0.41
ϵ_t^{NT}	non-traded prod. shock	0.0435<0.216	non-stationary	-0.44
ϵ_t^{YNT}	non-traded demand shock	0.1203<0.739	trend stationary	0.92
ϵ_t^{NS}	labour supply shock	0.2253<0.739	level stationary	0.14
ϵ_t^n	labour demand shock	0.059<0.739	level stationary	0.29
ϵ_t^l	land demand shock	0.303<0.739	level stationary	0.97
ϵ_t^{KNO}	capital demand shock	0.365<0.739	level stationary	0.95
ϵ_t^{KO}	capital demand shock	0.0939<0.216	trend stationary	0.87
ϵ_t^{KNT}	capital demand shock	0.561<0.739	level stationary	0.94
ϵ_t^C	consumption shock	0.058 <0.216	trend stationary	0.95
ϵ_t^G	government shock	0.673<0.739	level stationary	0.99

Table 8: KPSS Stationarity Test Result with AR coefficient Reported at 1% Significance Level

The properties of the shocks are summarised in the equations below:

- Oil Productivity Shock

$$\epsilon_t^o = \epsilon_{t-1}^o - 0.38\,(\epsilon_{t-1}^o - \epsilon_{t-2}^o) + \xi_t^o; \xi_t^o \sim (0.04, 1.15) \tag{5.4.4}$$

- Non-oil Productivity Shock

$$\epsilon_t^{NO} = \epsilon_{t-1}^{NO} - 0.41\,(\epsilon_{t-1}^{NO} - \epsilon_{t-2}^{NO}) + \xi_t^{NO}; \xi_t^{NO} \sim (0.05, 0.72) \tag{5.4.5}$$

- Nontraded Productivity Shock

$$\epsilon_t^{NT} = \epsilon_{t-1}^{NT} - 0.44\,(\epsilon_{t-1}^{NT} - \epsilon_{t-2}^{NT}) + \xi_t^{NT}; \xi_t^{NT} \sim (-0.03, 0.39) \tag{5.4.6}$$

- Nontraded Demand Shock

$$\epsilon_t^{YNT} = 0.92\,\epsilon_{t-1}^{YNT} + \xi_t^{YNT}; \xi_t^{YNT} \sim (0.002, 0.049) \tag{5.4.7}$$

- Labour Supply Preference Shock

$$\epsilon_t^{NS} = 0.14\,\epsilon_{t-1}^{NS} + \xi_t^{NS}; \xi_t^{NS} \sim (0.04, 0.55) \tag{5.4.8}$$

- Labour Demand Shock

$$\epsilon_t^{N} = 0.29\,\epsilon_{t-1}^{N} + \xi_t^{N}; \xi_t^{N} \sim (0.18, 2.08) \tag{5.4.9}$$

- Land Demand Shock

$$\epsilon_t^{l} = 0.97\,\epsilon_{t-1}^{l} + \xi_t^{l}; \xi_t^{l} \sim (-0.45, 1.51) \tag{5.4.10}$$

- Non-oil Capital Demand Shock

$$\epsilon_t^{KNO} = 0.95\,\epsilon_{t-1}^{KNO} + \xi_t^{KNO}; \xi_t^{KNO} \sim (0.007, 0.24) \tag{5.4.11}$$

- Oil Capital Demand Shock

$$\epsilon_t^{KO} = 0.87\,\epsilon_{t-1}^{KO} + \xi_t^{KO}; \xi_t^{KO} \sim (0.003, 0.15) \tag{5.4.12}$$

- Nontraded Capital Demand Shock

$$\epsilon_t^{KNT} = 0.94\,\epsilon_{t-1}^{KNT} + \xi_t^{KNT}; \xi_t^{KNT} \sim (0.003, 0.14) \quad (5.4.13)$$

- Consumption Preference Shock

$$\epsilon_t^{C} = 0.95\,\epsilon_{t-1}^{C} + \xi_t^{C}; \xi_t^{C} \sim (-0.012, 0.18) \quad (5.4.14)$$

- Government Expenditure Shock

$$\epsilon_t^{G} = 0.99\,\epsilon_{t-1}^{G} + \xi_t^{G}; \xi_t^{G} \sim (0.0017, 0.108) \quad (5.4.15)$$

In the shock processes reported above, I have also reported some properties of the shock's innovation, particularly the mean and standard deviation of the innovations. From the report, we can infer that in this economy, labour and land demand shocks and oil productivity shocks yields the highest volatility relative to other shocks in this model.

5.5 Indirect Inference Test Results

It is necessary to note that the indirect inference test is a test of fitness of the DSGE model against the data for Kuwait. Thus this test is based on the statistical distribution of the VAR parameters. Here, we measure the level of fitness based on certain statistical criteria of which we have used the first and second moments to describe them. In order words, this test enables us to test the underlying hypothesis;

H_o: The auxiliary model is a true model of Kuwait.

The decision rule of this test is based on the Wald statistic which is calculated on the bootstrapped distribution of sample coefficients as implied from our model for Kuwait. The calculation of this has already been discussed in section 4.4, hence I shall proceed to report the test result and its interpretation.

Also, note that here the model parameters have already been estimated and they were reported in the subsection above. Thus what this report shows is how the VAR estimated from the simulation of the DSGE model compares against the VAR estimated from the data. Therefore as earlier described, the test is based on the statistical distribution of the VAR parameters which are implied by the structural parameters of the DSGE model. Thus 1000 OLS estimates[40] of the VAR coefficients are simulated, after which the Wald

[40]It may be necessary to note that in each simulation, the VAR is estimated on each sample and we restrict these parameters until we can pick the closest to the VAR generated from the data.

statistic is extracted from the bootstrapped distribution obtained from each sample simulated. Thus, our decision rule involves comparing the T-statistic with the critical value and this is reported in the table below.

Model	Included variables	T-statistic	P-value
Estimated	Y_t,r_t	1.54	0.054

Table 9: Indirect inference test on models

Just as discussed in subsection 4.4, the models are not evaluated based on a full set of variables as this will cause all models to be rejected under the indirect inference[41]. When models are evaluated based on all the variables, this is called the *Full Wald* whereas the case where the Wald is calculated for a group of variables, this is called the *Directed Wald*. Thus just as described under the Directed Wald, the models are tested based on a selection of variables, in this case, aggregate output and interest rate(Y_t and r_t). In addition, the test also considers the first and second moments which increases the accuracy of the model and how well it can match the data. The above model of the indirect inference test of the estimated model passes the test with a t-statistic of 1.54, which suggests non-rejection of the model at a 5 % level of significance. In other words, our model described for Kuwait's economy is the true model.

5.6 Impulse Response Functions for Estimated Model

We analyse the impact of a positive 10 percent shock on macro variables and our findings from the estimated model are discussed in the subsections below.

5.6.1 Oil Technology shock

In our reduced-form model, the impact of a positive productivity shock in the oil sector will have a direct impact on land supplied to the traded sector. From section 3, we had described factor-price determination inherent in the model. Thus, a positive technological shock can be translated as similar to the effect of a rise in the price of oil which is exogenous in the model. Hence, a positive technological shock will raise the rental rate of land, land cost. This rise in the land rent will cause the supply of factors to the traded sector to rise. Recall from the chart above, the factor price ratio, $\frac{s_t}{w_t}$, the ratio of land rent to the wage rate, drives the supply of immobile factors to the traded sector. Hence, with land rent rising from productivity shock, the ratio of factor cost rises, and more labour is supplied to the sector to utilize land since land is a fixed factor. Hence, this raises land use in the traded sector. Since the oil sector is land-intensive, this rises in land use in the sector will stimulate the production of oil output. Thus, by extension, land use in the non-oil

[41] It is necessary to note that the choice of variables and the order of the VAR is up to you. Since the Wald test is strict, increasing the VAR order makes the test more stringent; hence in practice, we use a VAR(1). You can use all the variables in the VAR, or a subset of variables to see what combinations of parameters the model can fit

sector falls. In summary, the proportion of land to labour, $\frac{L_t}{N_t}$, supplied to the traded sector rises relative to the non-traded sector and the oil sector, which is land-intensive, expands its optimum land-labour ratio to clear all the land and use it up in the sector. By extension, the ratio of oil to non-oil price determines the ratio of land rent to wage rate which in turn determines the extension of oil to non-oil output in the traded sector.

To determine the movement of the only endogenous commodity price in the economy, the price of non-traded goods is also defined by the features of perfect condition, thus price equals marginal cost. From the allocation of factors in the sector, the non-traded sector is more labour intensive, though malleable in its input combinations. Therefore, the non-traded sector's highest cost by ratio is the cost of labour. Thus, as the cost of land rises, the input cost ratio is given by the ratio of land rent to wage rate rises. In line with this rise is a fall in the price of nontraded goods which is more labour intensive. This causes the demand for nontraded goods to go up and the supply of nontraded goods rises to clear the demand. We note that the impact on the real exchange rate would be a depreciation; $Q_t = \frac{P_t^T}{P_t^{NT}}$, to rise (real depreciation).

On the demand side, with a rise in the aggregate income resulting from both oil and nontraded output growth, there is a significant boost to domestic consumption, particularly private consumption. Hence, there is corresponding rise in the demand for consumption composites, consumption of oil, non-oil and non-traded goods. Also, with the contraction in the non-oil sector, the demand for non-oil goods via imports increases and import expands to meet this demand. Also, there is an expansion in exports resulting from oil output expansion. Thus, there is a positive net export which causes the real interest rate to be lowered to balance payments in the economy. By extension, there is a decline in foreign debt given by expansion in aggregate income and the interest rate adjusts to balance the current and capital accounts.

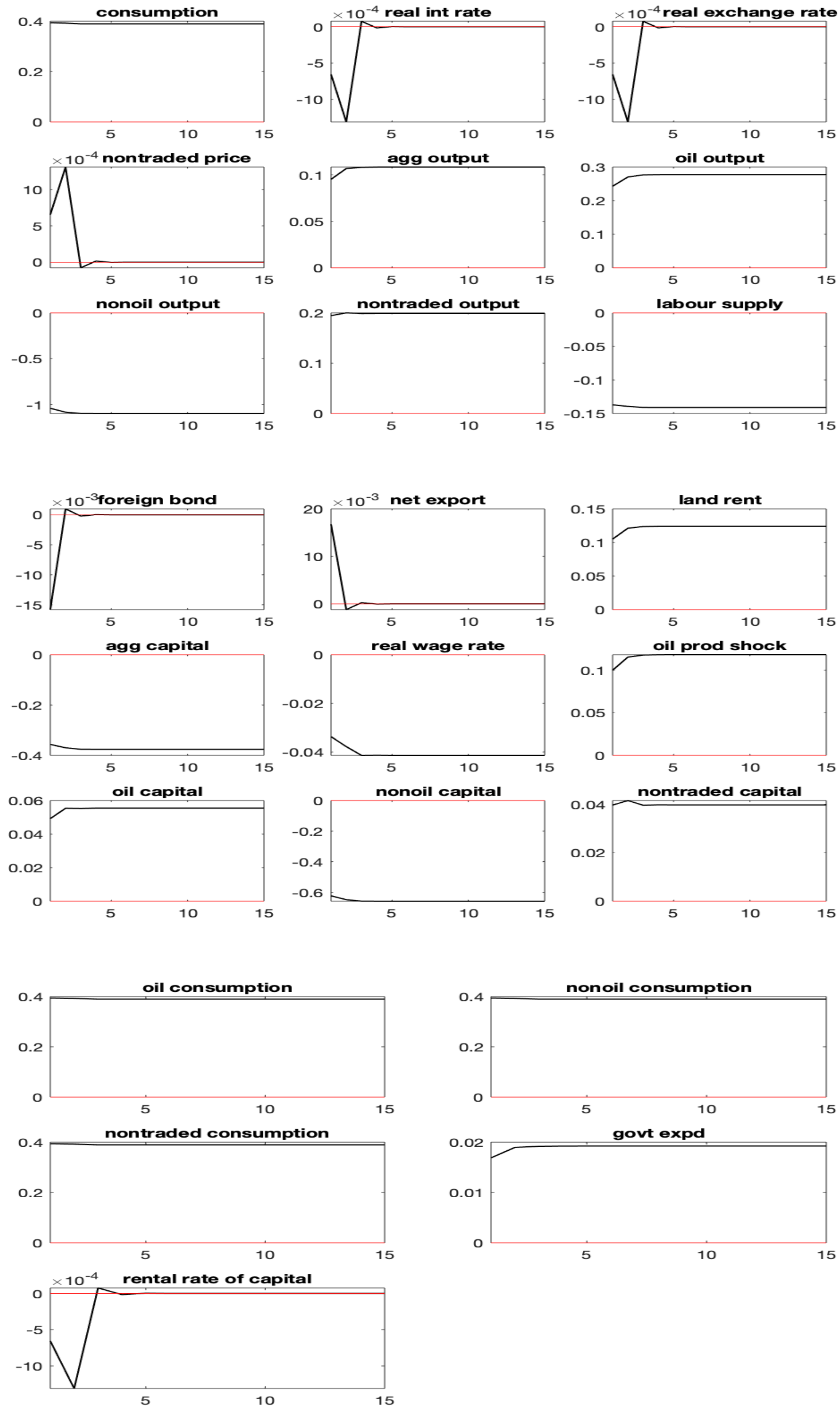

Figure 9: Impulse Response Function of a 10% Oil Technology shock in the Estimated Model (15 Quarters)

5.7 The Power of the Test

To obtain the power of the estimated model, we generate 1000 Monte Carlo samples from the residuals of the data. We then create nulls that falsify the parameters by ± the chosen level of falseness. By falsifying the model parameters, we have been able to construct a False DSGE model whose parameters were moved $x\%$ away from their true values in both directions in an alternating manner, thereby alternating the higher moments of the error processes by the same level of falseness. In this experiment, we consider this false model as if it were *true* because we want to be able to calculate the estimated Wald and test the number of samples that are rejected for a certain level of falseness. Thus the power of the test is given by the proportion of samples rejected. We continue this process by increasing the level of falseness until we have 100 percent rejection of the estimated model. The result of the power test is reported for the calibrated and estimated model in the table below.

Model Null(Falseness %)	Estimated model Rejection %
0	5
3	5.2
5	5.8
7	10
10	21.2
15	49.6
20	91.2
30	100
40	100
50	100
60	100

Table 10: Indirect Inference Power test

What we find from the table above is that for a sample size of 1000, the false model is rejected 100 % of the time when the model is 30 % false, that is if the model parameters are falsified by ±0.3. This just speaks a lot about the strictness, accuracy, and power of the indirect inference test. Recall the evidence provided in Le et al (2015, 2016) on the power of the II method in comparison to direct inference and this experiment above speaks volumes in support of the indirect inference power and accuracy.

5.8 Summary of Estimations Results

In summary, the chapter is an estimation of the DSGE model described and calibrated in Chapter 3. Thus, in this chapter, we bring data to bear on the proposed model. We start by sourcing our data from Kuwait statistical houses as reported above and we also described the cleaning done to this data as well as the construction of certain datasets from the available data. This data ranged from 1991Q1 to 2016Q4, Kuwait post-war era and the data gathered were non-stationary. We noted that this does not matter much in indirect inference estimation as studies in Davidson et al (2010), Meenagh et al (2012) among others have shown that there is increased accuracy in the non-stationary data relative to stationary data under indirect inference.

From the data on value added by sector, we can define the sectoral characteristics of the three sectors. These average values facilitate the description of factor intensity of the traded sectors. These values remained constant throughout the estimation procedure to maintain factor intensities as suggested by the data. Following this, the model is estimated via indirect inference by searching for the set of parameters that brings the moments of the model closest to that of the data. The process is described as a simulated annealing search.

The results of the estimation are a set of parameters out of 1000 simulations whose VAR distribution is closest to that of the one generated from the data. Therefore, an indirect test is conducted on these estimated parameters to decide if the proposed model in Chapter 3 is a true model for Kuwait. This decision is done based on a directed Wald formed from the distribution of the simulated parameters. The results showed that the test and a conclusion of non-rejection of our estimated model were reached. To further increase the robustness of the method used, a power test is conducted, and we find that at 20% falseness, 100% of models are rejected. Thus, this gives evidence as to the accuracy of the method in rejecting false models. More so, the chapter also tells the story of persistent oil productivity shock in Kuwait using impulse response functions and our interpretations note that oil productivity shock can tell the story of the lagging non-oil sector as motivated in the data.

6 Tackling the Dutch Disease in Kuwait

6.1 Background on Kuwait's Economy

The figure below illustrates the presence of Dutch disease in Kuwait's economy[42]. The figure shows the resource curse and highlights the high dependence on oil revenue within the Kuwaiti economy. This has been a long-lasting problem in Kuwait. More so, their policies which have been aimed at diversification of the economy have proven inadequate where implemented. On average [43] about 50% of the gross revenue in this economy comes from the oil sector whereas, non-oil and non-traded sectors contribute about 10% and 40% respectively, which is typical of a resource (oil) endowed economy because none of these sectors can compete with hydrocarbons in the generation of revenue. However, the future of which many oil-endowed economies try to plan for is one where hydrocarbons may potentially run out. Thus the plan which answers the question, "how will the economy adapt when hydrocarbons run out?" is one that is very important. The answer to this question demands adequate planning and understanding of the economy and the influence of oil in the economy. The International Monetary Fund (IMF) reports on Kuwait in 2017, showed that when compared to the other Gulf states[44], Kuwait has one of the highest dependence on oil. Their data as expressed in the figure below showed that in periods after 2014, characterised by significantly lower persistent oil prices, Kuwait's export comprised mostly of oil - up to 90% of the export, thus leaving about 10% to non-oil traded output. Even more, so is the composition of the government's revenue in this economy. Interestingly, over 70% of government revenue [45] comprised of oil revenue. The implication is that any shock to oil revenue will cause a ripple effect on major macro aggregates in this economy. Thus, this raised the question which a lot of economists try to answer, "how do we diversify the economy?". I propose that to answer this, we have to understand the problem which is what we do in this paper when we propose and estimate a DSGE model for Kuwait with a deep structural base.

[42] The data for the figures are sourced from the Central Bank of Kuwait

[43] This is also shown in the table above on the *Fixed parameters* that about 50% of the gross output comes from oil contribution

[44] members of the Gulf Cooperation Council (GCC)

[45] This value should not be confused with the value above(50%), as this value expresses reliance and dependence of government expenditure on oil income sources, shown from its expenditure funded mostly by oil revenue relative to other income sources. This only described government's means of funding their expenditure and not the aggregate revenue generated from different sectors. In summary, the government's expenditure income sources are different from the aggregate income sources of Kuwait and these proportions expresses that.

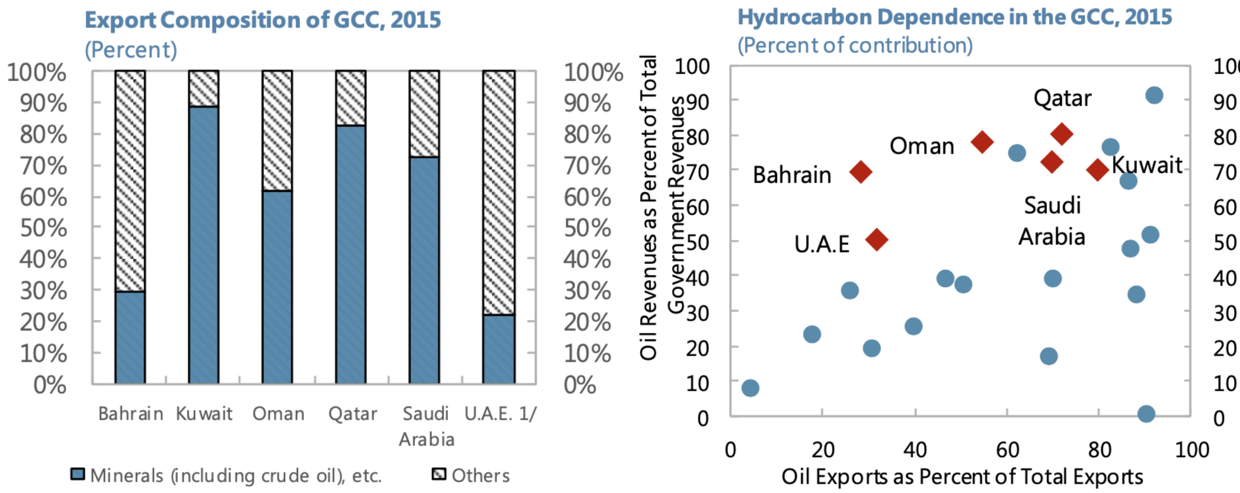

Figure 10: Export and Government Revenue Hydrocarbon Dependence of Kuwait relative to GCC countries extracted from IMF 2017 Kuwait Report

Despite all the data suggestions, we recognise that the challenge for policymakers in Kuwait is increasingly difficult. Whilst the question as to how Kuwait might adapt in the face of hydrocarbons drying out may persist, another lingering issue is that many diversification policies to the non-oil sector in the past decade are still lagging in its efficacy. This ineffectiveness might persist longer as the efforts in these policies direction might even be tougher in recent years because of the prolonged periods of relatively lower oil prices. Then the new question becomes, what will be the fate of the diversification policies if these lower prices persist?

In the next sections, we review the problems and diversification strategies suggested in the literature before concluding with our description of problems and suggestions of how to tackle the problem in Kuwait.

6.2 Kuwait's Diversification Policy

Oil wealth has played a key role in the development of Kuwait's post-war era. The importance of oil is a common feature in most oil endowed economies, especially within the Gulf region, as no other sector can generate revenue as quickly as this sector. Though Kuwait's oil production operates in an oligopolistic system under OPEC, with well-defined levels of quantity produced, it is still substantially influenced, in terms of wealth generated, by oil price volatility. Thus, it is key to be able to manage the way these funds from oil are being used to progress the economy of Kuwait. That is the reason the General Reserve Fund (GRF) and the Future Generations Fund (FGF) were created. The GRF is the main repository of Kuwait's oil revenue as well as income earned from GRF investments, whereas the FGF established in 1976 is the flagship investment fund for investment in both domestic and foreign ventures. One might say this is their major diversification strategy though most of this income generated from the fund is reinvested as required by Kuwait law and a bulk of these investments are held in foreign assets. Thus, for domestic diversification income sources, the GRF provides these funds, and they act as the state's treasury account for all income that is made available to use by Kuwait's government. Therefore, we recognise that one of the vital policy instruments in Kuwait used to propel diversification from the oil sector is the fiscal policy[46], described primarily by the way the government spends its revenue. Government expenditure varies from direct expenditure on public consumption to expenditure on subsidies, land acquisition, subsidized loans and other transfer payments to Kuwaiti citizens among others. As we have already described in the subsection above, over 70% of government revenue is generated from oil sectors[47]. Thus oil volatility affects the revenue available for investment in diversification policies, which can be measured by government investment or expenditure in non-oil sectors. Similarly, as described in Shehabi (2020), the efficacy of such diversification can be measured by the contribution of the non-oil sector to exports (proportion in terms of export composition) and the fiscal diversification, that is the proportion of government's revenue sourced from non-oil sources. In an attempt to address the diversification problem in Kuwait, Shehabi (2020) gave some reasons why the investments by the government have been ineffective in stimulating non-oil[48] sector growth. Firstly, he discusses the problem caused by investments targeting non-tradeables. This is recognised when we divide the non-energy sectors into the non-oil traded sector and the nontraded sector. As our data shows, oil contributes over 50% to value-added in this economy, whereas the non-traded and non-oil sector contributes about 40% and 10% respectively. The data for Kuwait shows that the investments from the Kuwait government have mostly been in non-traded sectors which contributions are minimal in export composition. In addition, Shehabi (2020) points out that the fiscal structure of government revenue, public sector dominance, fiscal rigidities and labour sector fragmentation among others as part of the problem of diversification inefficacy in Kuwait. Other views of the problem of diversification effectiveness can be seen in papers by Nosova (2018) which suggests that behaviour of the elitist-owned private sector discourages the policies aimed at diversifying the private sectors.

There are a lot of diversification policies suggested in a variety of papers based on their understanding of the dutch disease within the framework of their study. In light of this, having described the dutch disease, some of these papers also suggest some diversification plans for the respective economies under the microscope. From the framework of Neary and Corden (1982) and Corden (1982), many suggestions on how

[46]This is because economic policy options are generally limited in Kuwait. The monetary policy options are limited as the Central Bank of Kuwait has limited independence. On the one hand, the government is committed to maintaining a nominal exchange-rate peg against the US dollar, thus maintaining the inflation rate too. On the other hand, fiscal policy options are also limited as the government has little control over revenues, which are dominated by oil and aided by substantial foreign asset accumulation in its SWFs - Eltony (2007) and Shehabi (2020)

[47]This is because the largest source of income to the GRF is from oil revenue

[48]It is necessary to note that non-oil here refers to non-oil in this paper which has been differentiated from the nontraded sector. We note this because a lot of the literature discusses non-oil more broadly which includes effects from non-traded sectors which do not contribute to exports and may thus increase the inefficacy of diversification in the sector.

to protect the lagging sector were discussed and we summarise these in the following discussions. Firstly, one of the arguments stemmed from the conservative social welfare function with suggestions to tax the booming sector and use the revenue generated to subsidize losing factors of production thus reversing the effect on the lagging sector. This can be likened to the diversification policies in Kuwait that motivated the creation of the FGF and GRF, except that questions still lie on how the expenditures have been used to subsidize labour and other factors to boost the non-oil sector. Next, Corden suggests a direct subsidy to labour or employment to induce resource reallocation. Lastly, in a case where the boom may be thought to be temporary, they suggest an infant industry argument within features of imperfect competition.

More so, some other literature on Kuwait, such as Shah (1986) and Aljarallah and Angus (2020) suggest government's development of the quality of the human capital and institutional reforms to reverse the resource curse effects, this is because this traded sector's labour is occupied by foreign expatriates thus constraining citizens to less skilled non-traded sector jobs. In addition, other diversification policies come from Shehabi (2019) suggestion for increased control of oligopolistic rents to reverse the curse.

These papers do well in their suggestions for diversification in Kuwait and similar light, the following subsections use our DSGE model for Kuwait to describe the resource curse problem and suggest some solutions to tackle them.

6.3 Understanding Kuwait's Dutch Disease

Before we move to the policy options for Kuwait, it is necessary to understand the problem of Kuwait within the framework of our model. We proceed by using a similar mechanism to the one explained in Chapter 3.

6.3.1 Transmission Mechanism of Kuwait's Dutch Disease

Just as discussed in Chapter 3, we use a modified Johnson (1958) diagram to explain the transmission mechanism of the Dutch disease in the non-oil sector. As earlier discussed, the Dutch disease transmits via a positive shock to oil productivity which translates to a rise in the relative price of oil[49]. I explain this transmission mechanism by reviewing the intuition of a rise in the relative price of oil, of which I start by discussing the corner solutions in the figure below. Just as in our explanation in Chapter 3, we maintain the same assumptions as previous chapters and model formulation. Therefore, in addition to assumptions of perfect competition, we maintain the factor intensities in the traded sector, thus the oil sector is land-intensive, and the non-oil sector is labour-intensive. This information is important in determining the technical possibilities and factor reallocation in this model. More so, in line with other models of international

[49]We had already discussed how a positive oil technology shock has the same effect as a rise in the relative price of oil. We showed this via the equations in our model formulation in chapter 3 and we refer to Chapter 3 for this explanation

trade, we also assume that the taste and the distribution of the means of satisfying wants which make up the consumption side are given. Furthermore, on the production side, we assume that the technology and the supply of land and labour are given. Hence, land and labour are immobile, meaning that they cannot flow from domestic economy to foreign country in this model, whereas capital is the only mobile factor in this model. Lastly, we assume that both the domestic economy and foreign economy have identical factors of production and output after production, hence factors and products are homogeneous.

I start by setting out that the factor endowment of the traded sector sets an overall land-labour ratio, to which the land-labour ratios in the oil and non-oil sector weighted by the proportions of the total labour force employed must average out. The overall land-labour ratio in the figure below is set by the long-run supply curve and the ratio is given by $\frac{\bar{L}}{\bar{N}}_T$, as shown in the second quadrant. Recall that within the traded sector, the oil sector is land-intensive, whereas the non-oil sector is labour intensive. In other words, the supply of land, that is market-clearing for land, and its sectoral intensity determines the supply of oil output; also, the market-clearing for labour and sector intensity determines the supply of non-oil output. More so, there are fixed proportions of these immobile factors. Therefore, as factors are fixed in supply, this also sets the technical restrictions of the traded sector and the feasible factor prices are set at the points of intersection with the demand curve as shown in the second quadrant. We note that these points of intersection show the corner solution or extremes of the factor-price determination intuition in this model. This is shown in the figure below from the movement on the curve from relative price of land from a_{no}, where the productive resources are used up in the production of non-oil products, to a_o where these resources are focused on oil production. By implication of these extremes, the traded sector is completely specialized in non-oil production as in the first case or oil as in the latter of the extremes. Therefore, there would be no exchange ratio between commodities, though the non-produced commodity might have a virtual price equal to the exogenous world price of the traded output which is equal to marginal cost in this model, thereby setting the price of either labour or capital. Therefore, the resource restriction of the traded sector is shown below.

$$\omega_o \frac{L}{N}_o + (1-\omega_o)\frac{L}{N}_{no} = \frac{\bar{L}}{\bar{N}}_T \tag{6.3.1}$$

Thus, the fixed factor ratios which set the sectoral technical possibility as described by factor intensity is represented by the ratio $\omega_{o,no}$ in the above equation. Thus these remain fixed as we assume that sectors do not change their factor intensities[50]. At the extremes, $\omega_o = 0$ or $\omega_o = 1$, indicating all resources used up in the non-oil and oil sector respectively, where $\frac{L}{N}_o$ and $\frac{L}{N}_{no}$ in the equation above represents the optimum

[50]We assume these to maintain our suggested factor intensities, thus the oil sector remains land-intensive and the non-oil sector remains labour intensive. If these ratio changes, then it brings some flexibility in factor intensity and it means that a sector that was once land-intensive, may become labour intensive and this has some implications in interpretations. For more on that, you can check Johnson (1958)

land-labour ratio in the oil and non-oil sector respectively.

I use the intuition of the corner solution to show the implication of oil productivity shock via price movements[51], causes a Dutch disease in the non-oil sector. Hence price movements between a_{no} and a_o cause factor reallocation at the detriment of the non-oil sector. This is because as factor price increases from a_{no} and a_o it implies that labour is freed up to increase the utility on the fixed factor of land as it increases the optimum land-labour ratio supplied to the oil sector while decreasing that of the non-oil sector.

The figure below illustrates the above-described relationship.

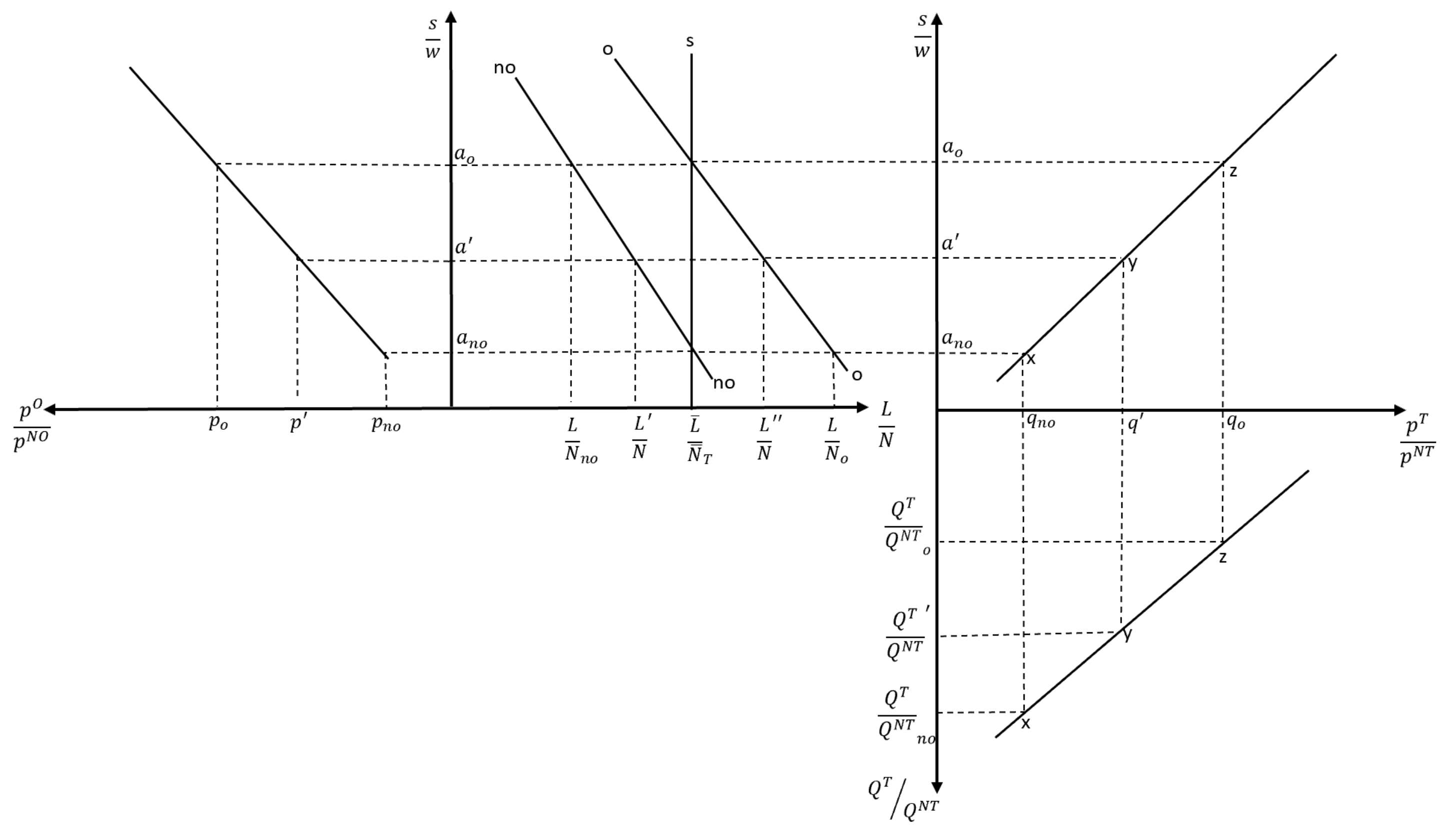

Figure 11: Factor-price interaction in traded sector

[51]Recall from the representative firm's section, just as assumed in these adapted Johnson (1958) figures, the firm operates under perfect condition, thus price is set equals to marginal cost in each of the sectors. Hence, we modelled our Cobb-Douglas style price in each sector as shown below:

$$P_t^O = w_t^{\alpha_o} \, r_t^{k\,\beta_o} \, s_t^{1-\alpha_o-\beta_o} \, \epsilon_t^{o-1} \tag{6.3.2}$$

$$P_t^{NO} = w_t^{\alpha_{no}} \, r_t^{k\,\beta_{no}} \, s_t^{1-\alpha_{no}-\beta_{no}} \, \epsilon_t^{no-1} \tag{6.3.3}$$

Where ϵ_t^o and ϵ_t^{no} are productivity shocks (technology shocks) to output in the oil, non-oil, and non-traded sectors respectively.

We note that the movement of labour between sectors is triggered by the movement of the relative price of land between extremes. Also, the factor price, which is the relative price of land, is set by exogenous output price, the relative price of oil. Hence, a positive oil productivity shock which is the same as the effect of a rise in the relative price of oil, and through factor-price determination would raise the relative price of land, factor price, thereby causing factors to reallocate in the traded sector to boost production in the oil sector at the detriment of the non-oil sector. In other words, to clear the factor markets and respond adequately to shocks and policies, the optimum land-labour ratio $(\frac{L}{N})_{o,no}$ utilized by each sector, oil and non-oil fluctuate up and down as determined by shocks (positive or negative) to the relative price of land and changes in the demand for factors. This captures the movements of labour across traded sectors to utilize the fixed factor of land.

To further elaborate on the effect of an oil technology shock, I adapt the figure shown above to bring in a shift in the factor-price curve in the first quadrant caused by an exogenous oil technology shock. Thereby, highlighting the rise in factor price resulting from the shock. I also go further and discuss the resultant effect on the real exchange rate and the demand in this economy.

Thus, as the economy is hit by an exogenous oil technology shock, which is the same as the effect of an increase in the price of oil, shown in the figure below as a shift in the output-factor price curve upwards in the first quadrant. We observe that because of the shock, the initial relative price of oil causes a higher factor price, that is a higher relative price of land. Therefore, these higher factor prices cause the optimum land-labour ratio demanded by the oil and non-oil sector to decrease. This is shown by the contraction from $\frac{L}{N}_{no}$ to $\frac{L}{N}_{no}^{'}$ in the non-oil sector and the contraction from $\frac{L}{N}_{o}$ to $\frac{L}{N}_{o}^{'}$ in the oil sector. As we had emphasized in the paragraphs above, we reiterate that changes in the optimum proportions of land-labour ratios in both the oil and non-oil sector are consistent and reconciled with the constancy of the overall land-labour ratio which is fixed in supply. However, we discuss a potential traded input supply variability as is the case here in the paragraphs below which discusses how the nontraded sector activities create a balance and clear the input market in this economy. More so, from the impact of the higher relative price of land, labour flows from the non-oil sector into the oil sector to utilize the land, this boosts output in the oil sector and decreases output in the non-oil sector. Thus, resulting in the problem of Dutch disease in the non-oil sector which may be as prolonged as the oil productivity shocks persist. We can see this effect in the figure shown below.

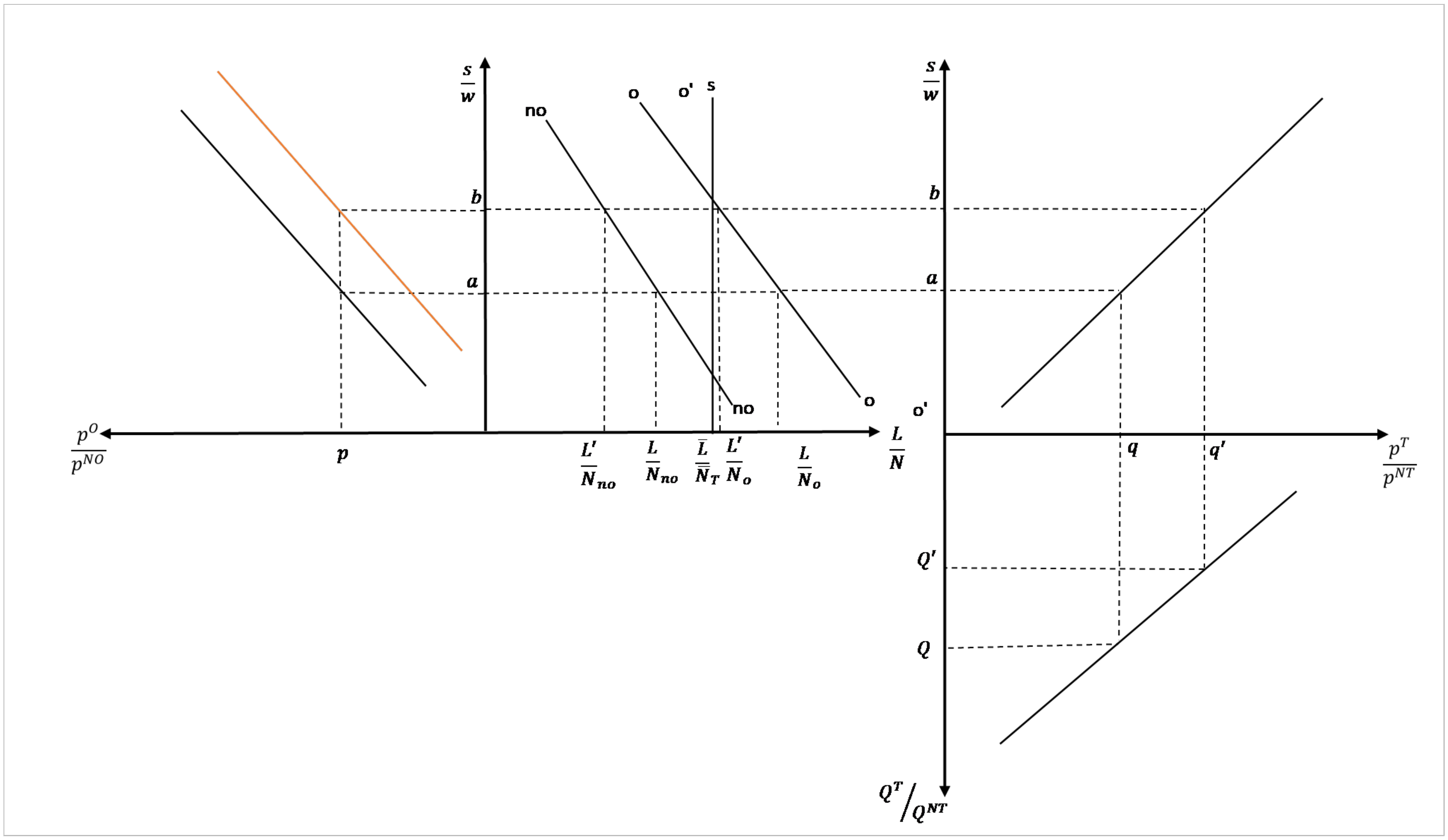

Figure 12: Kuwait's Dutch Disease Explained from Oil Productivity Shock

For the rest of the economy discussed in this figure, the resultant effect on domestic demand and the real exchange rate is described in the third and fourth quadrants. They show that at the new relative price of land b, the real exchange rate will depreciate. This is because the traded sector is more land-intensive when compared to the non-traded sector. Thus there is a real depreciation of the real exchange rate caused by rising traded prices[52] in the economy. We reiterate that the use of oil price rise as above is because it has a similar effect to a positive oil productivity shock as shown from our model formulation and equations above, thus we use that for simplicity in understanding. In continuation, this depreciation is shown in the movement from q to q' in the figure above. The impact of the real exchange rate depreciation on domestic demand as shown in the figure above is a fall in the relative demand of tradeable goods in the economy because more non-traded goods are demanded relative to traded goods. Therefore, to meet the rising demand needs in the non-traded sector, factor supply to the sector expands to meet the demand needs. This shifts the fixed factor endowment in the traded sector to the left because increased demand for non-tradeable shrinks the fixed factor resources available for production in the traded sector. This effect on the domestic demand is

[52]Recall as in earlier subsections that the traded goods price is a weighted average of oil and non-oil price. Therefore, if oil price rises, the resultant effect is a rise in traded price and real depreciation of the real exchange rate.

captured in the fourth quadrant as a movement from Q to Q' in the figure above.

Hence in sum, a rise in oil prices or in oil productivity raises land prices, reduces the non-oil sector to free up labour for expanding oil, and because the traded sector uses more land than the non-traded, lowers the relative price of nontradeables, that is the ratio of non-traded to traded price price, causing the expansion of the non-traded sector.

6.3.2 Summary of the Problem in Kuwait

In summary, from our model which has been calibrated and tested in prior chapters, we understand the description of the Dutch disease from the context of positive productivity shocks in the oil sector which is similar to the effect of an exogenous rise in oil price explained above. Within our framework, we have explained Kuwait's Dutch disease, which is described as a decline in the non-oil traded sector as a result of expansion in the oil sector. This problem arises as labour inputs are reallocated from non-oil to oil sectors because more labour is demanded in the oil sector relative to the non-oil sector because of the oil productivity shock. More so, since oil shock raises the relative price of land, the traded price rises relative to the non-traded, because the traded sector is more land-intensive than the non-traded sector. The result is a real exchange rate depreciation. Perhaps, it might be necessary to note one of the unique assumptions of our real business cycle model which is key and principal to this argument is that land and labour are both fixed in supply. Thus, these shocks that hit the various sectors come in the form of optimum factor reallocations from one sector to the other since there are fixed factors of land and labour in the model.

6.4 Kuwait's Policy Options

At this point, having understood the Dutch disease and how it transmits to Kuwait, it becomes paramount for us the answer the question of what can be done to reduce the negative effects of the oil shocks to the non-oil sector. In other words, proffering potential policy options to reverse the adverse effects on the non-oil sector in the Kuwaiti economy. As we have been able to understand the problem from the viewpoint of factor allocations, can we then suggest policies that reallocate these resources to the non-oil sector? We examine and discuss a few policy options below.

6.4.1 Labour Market Regulations

- Supply Driven Policy

  Firstly, we explore policy options geared towards increasing factor supply, particularly labour supply. The implication of an increase in factor supply expands the technical possibility of the traded sector as we know that demand determines supply in the non-traded sector. Therefore, this option will cause an increase in the optimum land-labour supplied to the non-oil sector and a reallocation of resources from the oil sector to the non-oil sector. This is because the non-oil is labour intensive and will hence utilise more labour to reverse the effects of the oil productivity shock. As a result of factor supply increases in the traded sector, factor demand also rises to clear the factor market. This is illustrated in the figure below:

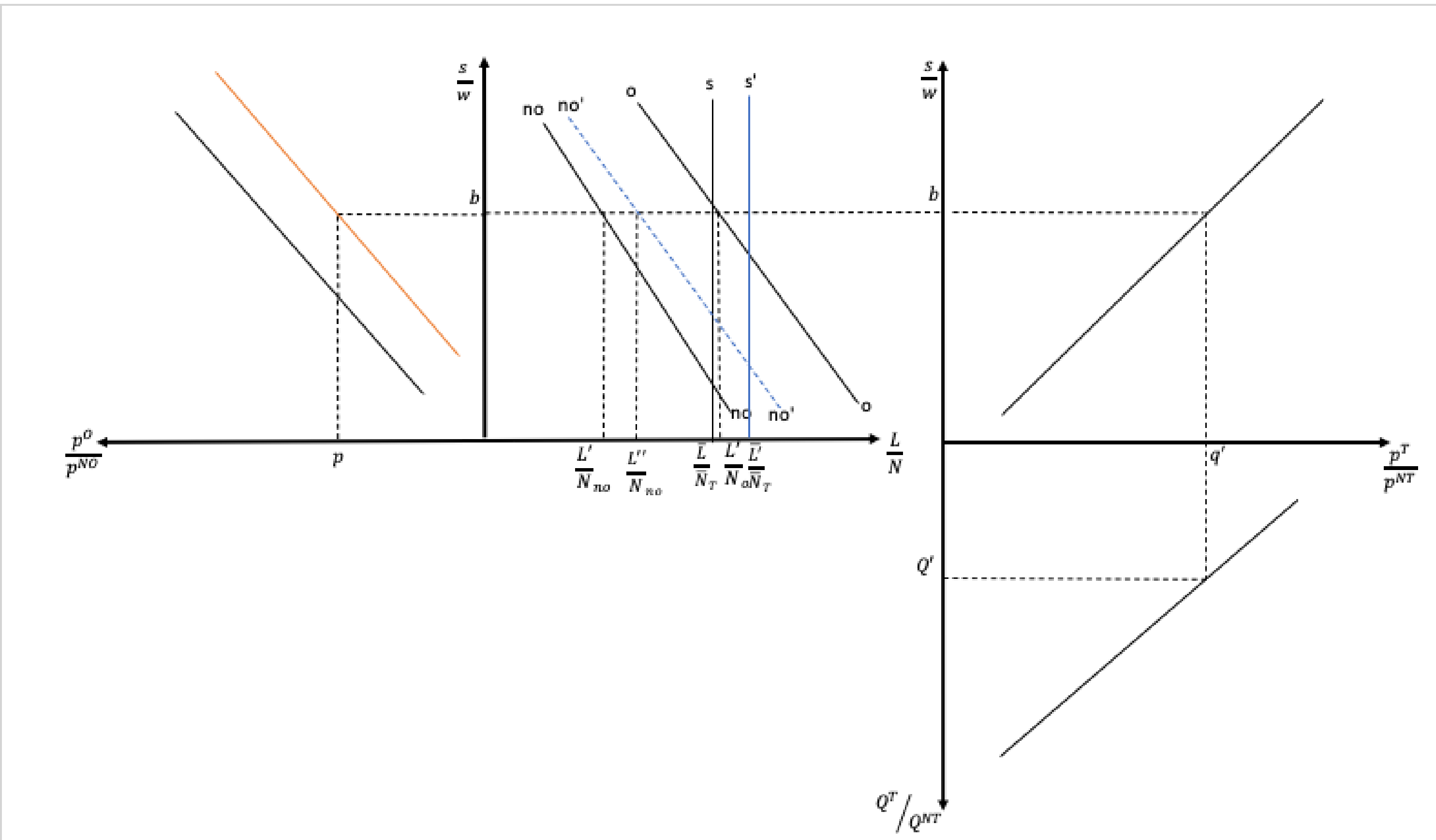

Figure 13: Supply Driven Policy in Response to Oil Productivity Shock

The expansion in the technical possibility, especially the non-oil sector can be captured in the resource constraint equation below.

$$\omega_o \frac{L''}{N_o} + (1-\omega_o)\frac{L''}{N_{no}} = \frac{\bar{L}'}{\bar{N}_T} \qquad (6.4.1)$$

Hence as labour supply shifts from $\frac{\bar{L}}{\bar{N}_T}$ to $\frac{\bar{L}'}{\bar{N}_T}$ this forces an expansion in the non-traded sector and labour can then flow from the oil sector to the non-oil sector which is labour intensive. In summary, factor demand expands in the traded sector to clear the supply and the increase in the optimum land-labour ratio supplied to the non-oil sector will cause output expansion in the sector, thereby reversing the negative impact of the oil productivity shock on the lagging sector. However, this might be at the expense of the oil sector output, which diminishes as the reverse reallocation happens.

In summary, when labour supply policy is applied to oil productivity shock in this model, the movement of labour causes the expansion in the non-oil and non-traded sector at a cost to production in the oil sector, as it reallocates labour resources from the oil sector into the labour-intensive sector. Hence, boosting non-oil production at a cost to oil production.

- Demand Driven Policy

Here, we investigate the impact of policies that may be aimed at controlling (restricting or expanding) the demand for factors in the traded sector. Thus, within our model framework, we examine what happens if there is legislation aimed at expanding factor demand in the non-oil sector or restricting factor demand in the oil sector to foster an expansion in non-oil output. This may come in terms of labour taxation in the oil sector or labour subsidy in the non-oil sector. These policies are aimed at promoting a reallocation of resources to the non-oil sector, especially in a situation where we can influence sectoral labour.

The figure below, we focus on the demand-driven policies aimed at increasing demand in the non-oil sector particularly labour subsidies to producers in the non-oil sector. From the figure, when labour subsidies are applied in the non-oil traded sector, it causes a simultaneous shift in the curves in the first and second quadrant. In the first quadrant, the curve shifts downward because of the positive impact of labour subsidy on wages paid to labour in our model. Whereas, in the second quadrant, it shifts the factor demand curve in the non-oil sector to the left reflecting the changes in labour demand in the sector resulting from the policy. This leftward shift of the curve reflects the increase in labour to utilize the land in the sector, thus making the non-oil sector even more labour intensive. Hence there is a reallocation of labour from the oil sector to the non-oil sector due to labour subsidy in the non-oil sector.

This in turn will cause the optimum land-labour ratio to decrease, hence boosting output expansion in the sector, this is shown in the movement to $\frac{\bar{L}}{\bar{N}}{}''_{no}$. However, recall that the factor supply to the traded sector is fixed, therefore as the optimum factor allocation increases in the non-oil sector, the resource constraint in the sector can only be balanced by a corresponding decrease in available labour for production in the oil sector, hence affecting the optimum factors demanded in the oil sector. This is shown in the technical restriction equation shown below.

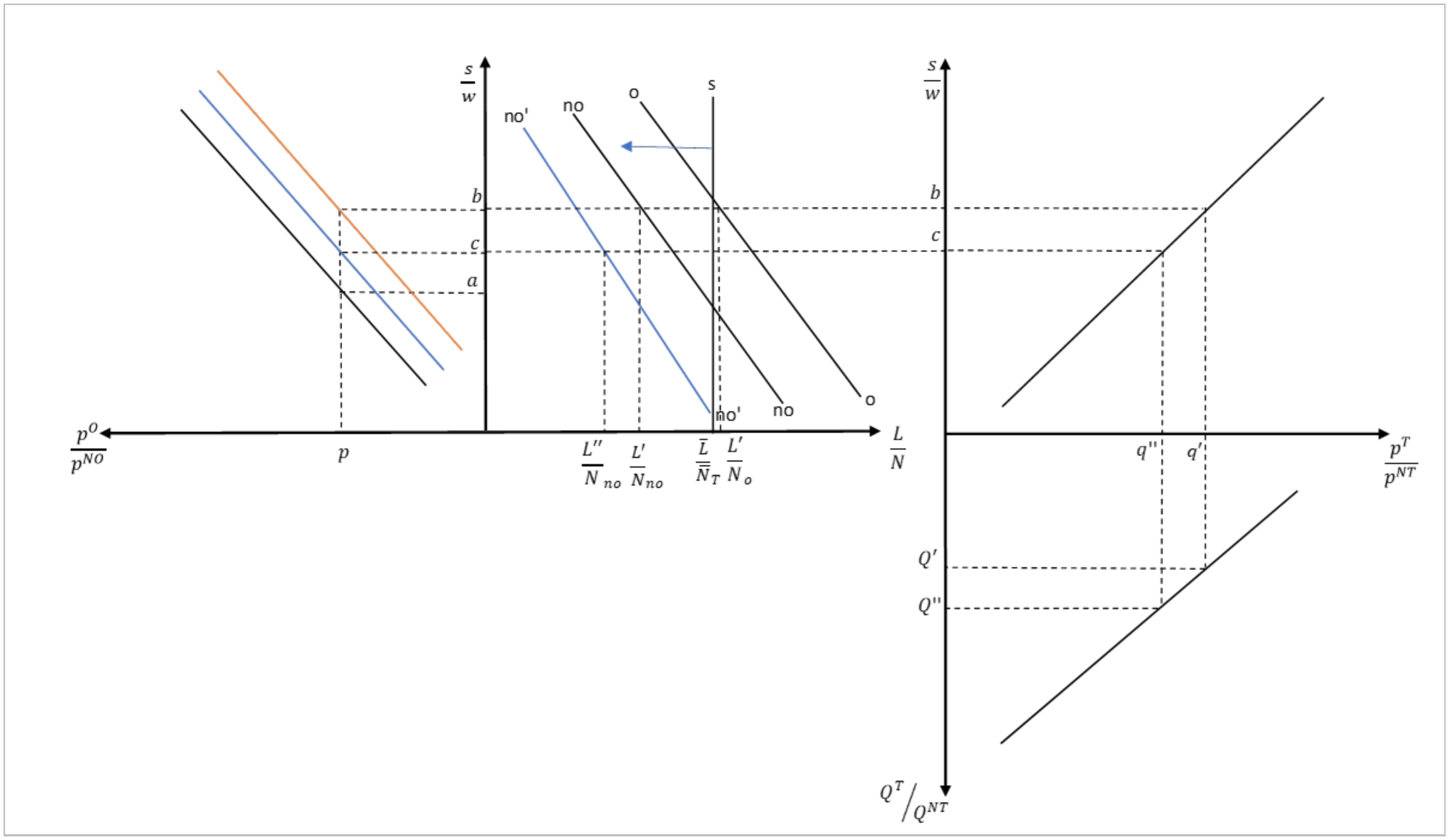

Figure 14: Demand Driven Policy (Labour Subsidy in Non-oil Sector) in Response to Oil Productivity Shock

The resulting technical possibility arising from the factor reallocations is given in the following equation:

$$\omega_o \frac{L}{N}''_{o} + (1-\omega_o)\frac{L}{N}''_{no} = \frac{\bar{L}}{\bar{\bar{N}}}_T \tag{6.4.2}$$

The figure above shows that when labour subsidies are applied to the non-oil sector, it causes a shift in the curve to *no'* to the left. This signifies an expansion in the available resources for production in the sector because labour flow out of the oil sector back into the labour-intensive non-oil sector. The resource constraint shows that in this framework with fixed factors, as the optimum resources increases in the non-oil sector, there is a corresponding decline in the oil sector. Thus, there is an offsetting effect of non-oil expansion in the oil sector caused by a decline in available resources to boost production.

For the rest of the economy discussed in this figure, the resultant effect on domestic demand and the real exchange rate is described in the third and fourth quadrants. They show that at the new wage rate c, the real exchange rate will appreciate. This is because the non-traded sector is more labour-intensive when compared to the traded sector. More so, via factor-price determination in our model, rising wages would cause the non-traded price to also rise. Thus, there is a real appreciation of the real exchange rate caused by rising non-traded prices in the economy. This appreciation is shown in the movement from q' to q'' in the figure above. The impact of the real exchange rate appreciation on domestic demand as shown in the figure above is a rise in the relative demand of tradeable goods in the economy because less non-traded goods are demanded relative to traded goods. Therefore, to balance the demand needs, factor supply to the non-traded sector declines and labour reallocates to the traded sector, hence shifting the fixed factor supply curve in the second quadrant to the left. This effect on the domestic demand is captured in the fourth quadrant as a movement from Q' to Q'' in the figure above.

In summary, when labour subsidy in the non-oil sector is applied to oil productivity shock in this model, wages rise, labour demand expands in the non-oil sector as it reallocates from the oil sector into the labour-intensive sector. Hence, boosting non-oil production at a cost to oil production.

Alternatively, one may consider policies aimed at decreasing factor demand to the oil sector which we posit will have a similar impact. This is because as optimum factor inputs decline in the oil sector, the excess inputs will have to be absorbed in the non-oil sector thus increasing labour use in the labour-intensive sector. This will cause an expansion of outputs in the non-oil sector, however, there will be an offsetting spill over effect in the oil sector.

6.5 Policy Option Evidence from Impulse Response Functions

In this subsection, we examine the influence of the suggested policies in reversing the negative impacts of oil productivity shocks on non-oil sector growth. We use the impulse response functions to show how the economy shall react to these policies.

In addition, we attempt to answer the question of which economies such as Kuwait, characterised by highly volatile boom and bust cycles, face in wake of persistent oil productivity volatility and policy influence to mitigate its negative influence on the economy. That is the question of what the optimal adjustment policy for the government may be in light of the massive output variation caused by the oil shocks and labour market regulations. Thus, within the experiment of policy effectiveness, we also suggest what the optimal government fiscal policy reaction to output variation should look like. We discuss this and the policy options IRFs in the following subsections.

6.5.1 Government's Adjustment Policy to Output Variations

The government's adjustment parameter represented by η measures how strongly government should react to changing output variances, in other words, it describes how intensely government should react to output boom-bust movements. This might not describe the fiscal policy instruments within its use as the government, but it shows the extent of these instruments contributions in terms of marginal expenditure or savings in government expenditure. Thus, it measures the intensity as given by marginal savings or expenditure on the different instruments used by the government to minimise output variations. Note that the specification of the output variance looks at the next period's output variance because the policy or shock occurs today in period t, hence the government's adjustment policy also contains some forecasting element in reaction to output variance in the next period.

Output variations are defined as the deviations of output from its initial level, thus period to period output variation, thus describing output growth or loss. Thus, as gross output moves in response to fluctuating oil productivity and suggested labour market regulations, this policy parameter measures the government's fiscal reaction to output variations. The government's adjustment parameter is shown in the updated government expenditure equation in our model below:

$$G_t = \frac{g}{y} Y_t - \eta \left(E(Y_{t+1}) - Y_t \right) + \epsilon_t^G \tag{6.5.1}$$

In the equation above, we extend the government expenditure function given in the model in Chapter 3 to include η, government output adjustment policy parameter. It might be important to note that this government policy may be expansionary or contractionary depending on the sign η takes. Note that this interpretation is under the assumption that there is a positive output deviation because if the deviation were negative, the meaning of the sign also reverses. Therefore, if η is positive, this represents government contractionary policy, this may be in terms of taxation as specified in our model. Whereas if it is negative, it represents government expansionary policies[53] which may be labour subsidy as suggested in the subsections above. In other words, government expenditure increases or decreases in this economy to minimise the output variance from the shocks to oil productivity and labour market policies aimed at reversing Dutch disease in the Kuwaiti economy.

Many papers on Kuwait have suggested the high influence of government's fiscal activity in the diversification of the economy and stabilization of key macroeconomic aggregates, thus in a similar light, the

[53] we note that the signs are opposite because of the negative(-) sign in from of eta, thus when output variance is positive, the policy tool will suggest that government takes a contractionary policy as an optimal way to minimise the variance caused to output from the oil shocks and policy options. Whereas when output variance is negative, the government takes an expansionary position in policy

government's adjustment policy described above will guide Kuwait policymakers on how to navigate the wind between boom-bust cycles caused by oil productivity shocks and policy implementation to curb its effect on the lagging sector. Therefore, the government's adjustment parameter will describe how the government uses their tools which will cause net contributions or deductions from sovereign wealth accounts (SWF) to implement their policy on taxation and subsidies within the labour market.

To obtain the best estimate of η, we run simulations of the model when it has been shocked by both the oil productivity shock and labour taxation or subsidy to reverse the effect in the non-oil sector. Then, for all the results that pass the Wald test, we choose the set of coefficients that yields the least variance to output and its corresponding adjustment parameter η.

In the next subsection, we discuss the influence labour policies may play in protecting the non-oil sector and government adjustment policy to minimise the variance to output.

6.5.2 IRFs with Labour Market Regulations and Government Adjustment Policy

Within our framework which assumes labour and land are fixed factors, an oil productivity shock would cause the non-oil sector to lag. Hence, in this section, we report the impulse response functions where policy options and regulations aimed to impact how firms use labour, influence sectoral demand and supply for labour, thereby reversing the effect in the non-oil lagging sector. In other words, we capture the influence these demand-driven policies and supply-driven policies will have on the aggregate fluctuations in Kuwait.

From our model in Chapter 3, these policies increase the cost to the firm either directly or indirectly as shown in the firm's profit equation below for the case of taxation to rewards of factor inputs.

$$\pi_t = P_t Y_t - K_t(r_t^k + \epsilon_t^k) - N_t(w_t + \epsilon_t^n) - L_t(s_t + \epsilon_t^l) \tag{6.5.2}$$

where ϵ_t^n represents the demand-driven policies, taxation or subsidies. The supply-driven policies influences the aggregate labour available from the labour supply function shown below:

$$N_t = \frac{1}{\rho_2}\frac{\theta_0}{1-\theta_0} + \frac{1}{\rho_2}\epsilon_t^C - \frac{\rho_0}{\rho_2}C_t + \frac{1}{\rho_2}w_t - \frac{1}{\rho_2}\epsilon_t^{NS} \tag{6.5.3}$$

where ϵ_t^{NS} represents the shock to labour supply caused by supply-driven policies.

More so, these labour market regulations thus affect how labour is used and in turn reverse the adverse effects on non-oil output, since labour is intensive in the non-oil sector. This is shown in the IRFs under individual policies discussed below.

- **Case 1: IRFs with Labour Demand Driven Policies**

In the case of labour demand driven policies, we particularly consider the case of labour subsidy applied to labour demand in the non-oil sector, and just as in the discussions above, we attempt to discuss the aggregate impact within Kuwait's economy using the IRFs shown below.

To show the pass-through and entrance of a non-oil labour subsidy into the model, we discuss the relevant equations which have direct impact of the policy shock. To start, the direct impact of the subsidy in the non-oil sector works entrance into the model from the non-oil price which is shown below:

$$P_t^{NO} = (w_t \, \epsilon_t^{n-1})^{\alpha_{no}} \, r_t^{k^{\beta_{no}}} \, s_t^{1-\alpha_{no}-\beta_{no}} \, \epsilon_t^{no-1} \tag{6.5.4}$$

Thus, with factor price determination within our model, this policy works itself into wage rate expressed below in logarithmic form:

$$w_t = \frac{1}{\alpha_{no}} \left[P_t^{NO} - \beta_{no} \, r_t^k - (1 - \alpha_{no} - \beta_{no}) \, s_t + \epsilon_t^{no}\right] + \epsilon_t^n \tag{6.5.5}$$

Since labour is intensive in the non-oil sector, the labour subsidy policy directly and indirectly impacts the non-oil output via the subsidy and the wage rate respectively, hence we show the impact on non-oil output through the logarithmic representation shown below:

$$Y_t^{NO} = \frac{1}{\alpha_{no}} \left[N_t + w_t - \alpha_o \, (P_t^o + Y_t^O) - \alpha_{nt} \, (P_t^{NT} + Y_t^{NT}) - \alpha_{no} \, P_t^{NO} - \epsilon_t^n\right] \tag{6.5.6}$$

Note that, ϵ_t^n represents the labour subsidy and all other terms remains as defined in the model in Chapter 3. The above equations summarize the direct entrance of this policy into our model, however in the discussions that follow, I use the impulse response functions (IRFs) to firstly describe the aggregate impact of the labour subsidy and secondly to describe what happens when labour subsidy is applied to oil productivity shocks in Kuwait's economy, and importantly how this policy impacts the Dutch disease in the non-oil sector. In other words, we use the IRFs to answer the question, "will the labour-use policies have a positive impact on this economy in the face of a positive oil productivity shock that lags the non-oil sector?"

In the first IRF below, labour subsidy is applied in the nontraded sector, and we report the impact to macroeconomic aggregates in the economy.

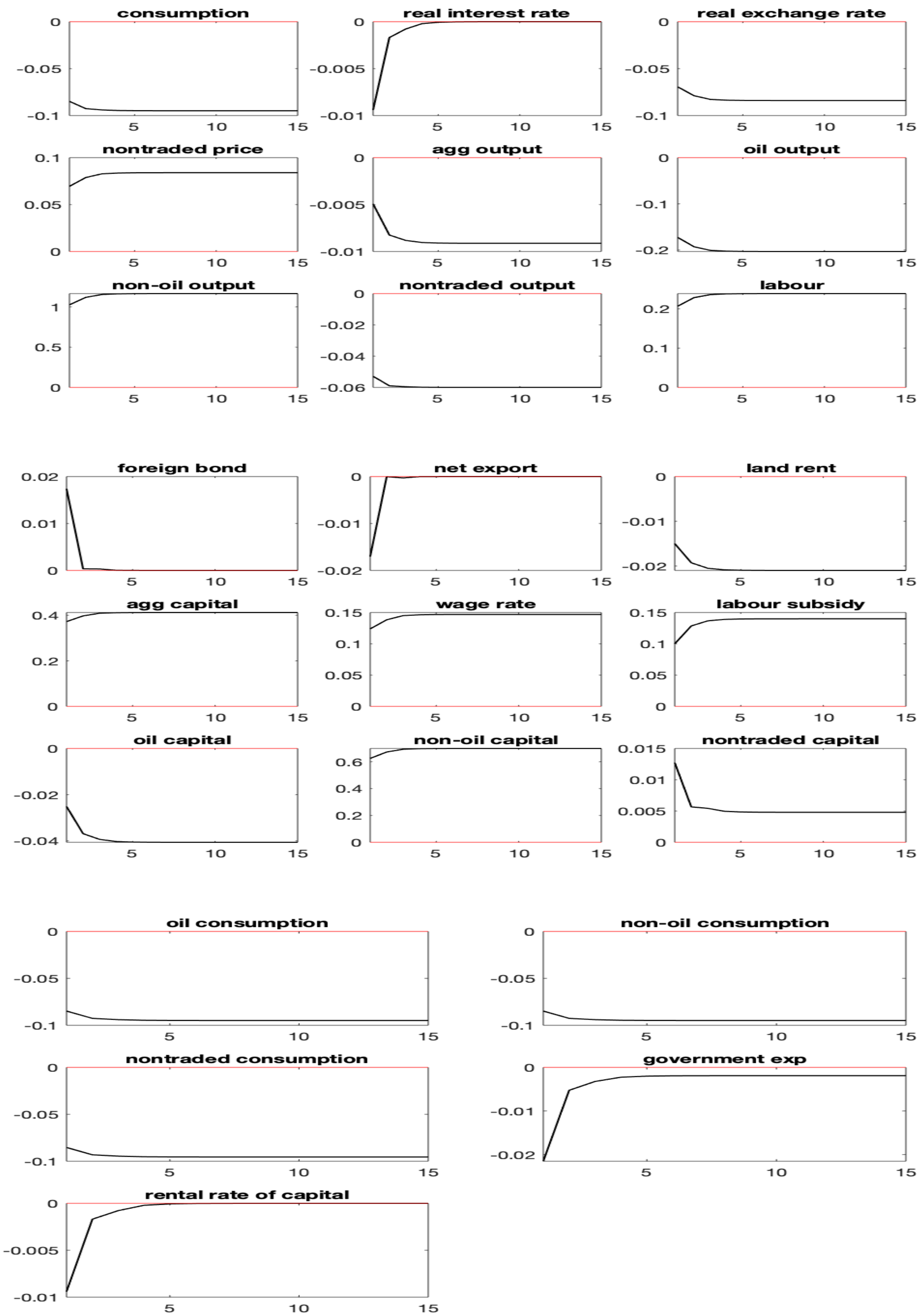

Figure 15: IRF of Estimated Labour Subsidy Shock in the Non-oil Sector

When labour subsidy policy is applied in the non-oil sector, this would have a direct impact on wage rate which increases and motivates more labour to be supplied as shown by the expansion in labour above. However, rising wages has a negative effect on land rent. Thus, with this wage rise and land rent fall, the is an expansion in the production of non-oil goods and a decline in the production of oil goods. This is because labour subsidy in the non-oil sector, stimulates the movement of labour from the oil sector to stimulate production in the non-oil sector. Whereas in the nontraded sector, as result of factor-price determination in our model, rising wages causes the non-traded price to also rise, hence causing a decline in non-traded goods demand and supply adjusts accordingly. This frees up more labour to be utilised in the labour-intensive non-oil sector. Accompanying the impact of rising non-traded price, is a real exchange rate appreciation, causing more tradeable goods to be demanded relatively to non-tradeable goods. Thus, with oil production decline and non-traded goods decline, aggregate income falls in the economy which causes a fall domestic demand given by the in consumption and her composites as well as government expenditure. Thus, with a contraction in oil and non-traded production, there would be a contraction of exports which takes the economy into a trade deficit, shown by the decline in net exports. Hence, the real interest rate falls to balance current and capital accounts as the the foreign bonds rises. This summarises the impact of a labour subsidy in Kuwait's economy.

We continue to then explore the impact of a simultaneous shock of non-oil labour subsidy and oil productivity shock in Kuwait's economy. Thus, within this model framework, to ensure that the policy is effective when the economy has been hit with an oil productive shock, we simulate the policy shock to match the duration and magnitude of the oil productivity shock and the impacts die out as soon as the perceived shocks fade. The economy-wide impact is summarized in the figure below.

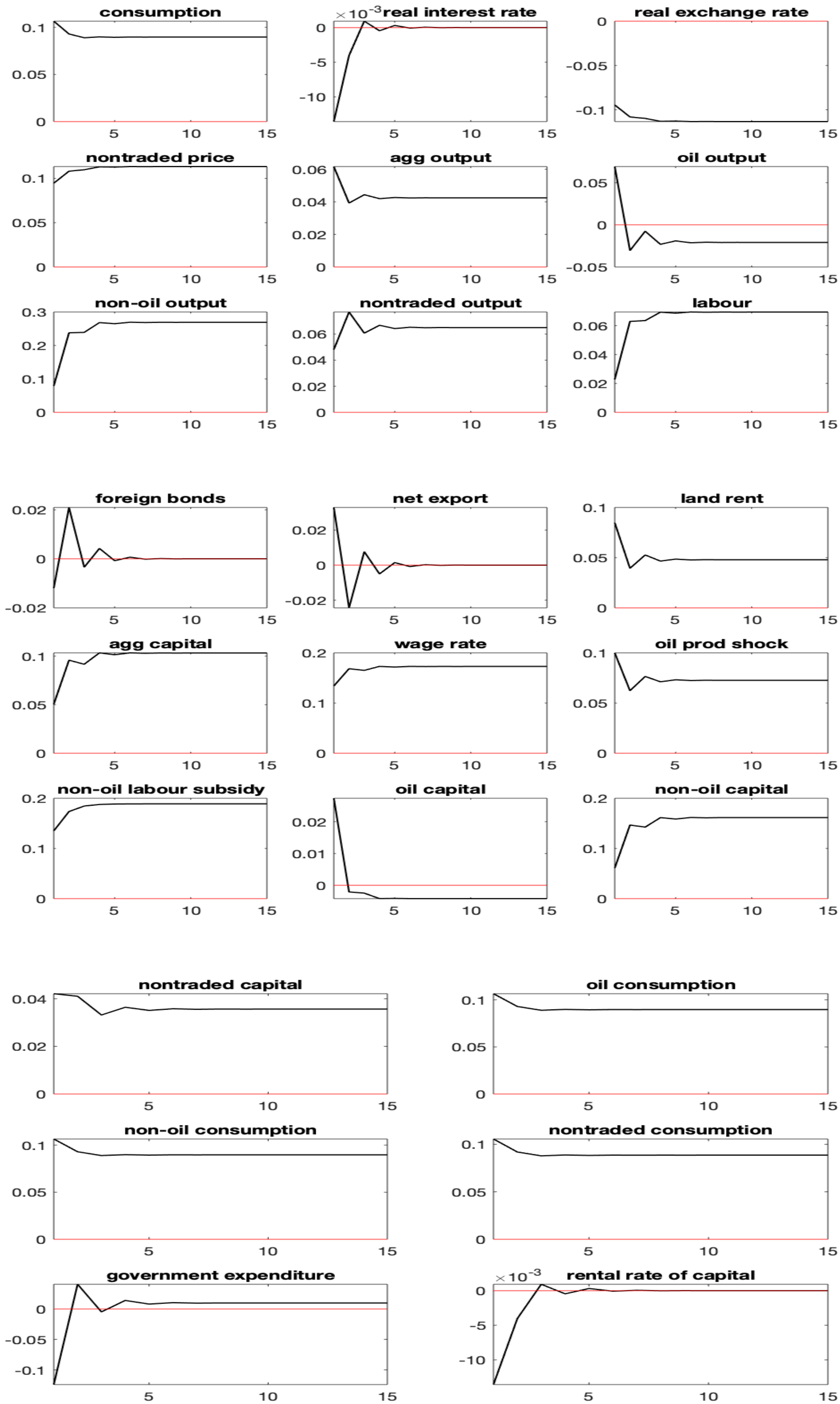

Figure 16: IRF of Labour Demand Driven Policy (labour subsidy) in the Non-oil Sector in Reaction to Oil Productivity Shock

We observe that when both shocks, oil productivity shock and labour demand policy, hit the economy simultaneously, there is an expansion in the non-oil sector, a reversal effect to the lagging non-oil sector. More so, we observe an offsetting effect in the oil sector because of resources, particularly labour, flowing out and into the non-oil sector due to the subsidy to labour in the non-oil sector. The story in this IRF is that as positive technology shock hits the oil sector, this has a direct impact on land rent which rises, generally, this will cause a movement of resources to flow from the non-oil to oil sector, causing an expansion in the oil sector and a decline in the non-oil sector. However, when subsidies are applied to labour in the economy, it causes labour to be reallocated and flow back into the non-oil sector to reverse the effect on the lagging sector. We observe that there is a rise in domestic prices caused by rising factor price, that is land rent and wage rate, while the real exchange rate is falling due to rising domestic nontraded goods price. This causes the demand for non-tradeables to fall slightly as shown by the relative decline in earlier periods, and the supply rises to clear demand in the nontraded sector. Generally, aggregate income remains positive because of output growth in the productive sectors and government's expenditure adjusting policy, increasing in initial periods to decrease variance to output caused by the simultaneous shocks from labour subsidy and oil productivity in the economy. The figure shows that consumption and domestic demand is positive due to positive income in the economy, given by consumption composites. However, with a contraction in the dominant oil sector which contributes about 50% of aggregate income, we see that its decline takes net export into a trade deficit after recording surpluses in initial periods. This causes the real interest rate to fall to balance payments in the economy as foreign debt rises in the initial periods. Lastly, capital flows freely into the most productive sectors, given by the positive flows into the non-oil and non-traded sectors relative to the oil sector.

With our core focus on the reversal in the lagging non-oil sector, we can say that the non-oil subsidies applied are very effective in reversing the declining output growth in the non-oil sector. However, it comes at a cost which is a decline in the oil output.

- **Case 2: IRFs with Labour Supply Driven Policies**

We recall the logarithmic representation of labour supply in our model as shown in the equation below:

$$N_t = \frac{1}{\rho_2}\,\frac{\theta_0}{1-\theta_0} + \frac{1}{\rho_2}\,\epsilon_t^C \; - \frac{\rho_0}{\rho_2}\,C_t + \frac{1}{\rho_2}\,w_t - \frac{1}{\rho_2}\epsilon_t^{NS} \tag{6.5.7}$$

The policy represents shocks responsible for influencing the household's preference to work or enjoy leisure. We consider a case where the policy is expansionary, such that it increases the supply of labour in this economy. This is a case of a positive preference or demand shock in this model. From our model, the impact of a positive demand shock to the economy is that it shifts the IS curve to the right. The impact being an increase in income and rise in the real interest rate, causing the economy to experience a current account surplus as the level of exports rises relative to imports, thus net foreign assets falls. For the market to clear in the economy, the real exchange rate declines until demand adjust and there is a balance of payments.

Quite similar to the case of demand-driven policies, to ensure that the policy is effective when the economy has been hit with an oil productive shock, we simulate the policy shock to match the duration and magnitude of the oil productivity shock. The IRF shown below shows the effect of a permanent supply-driven policy in reversing the effect in the lagging sector and its impact on the economy.

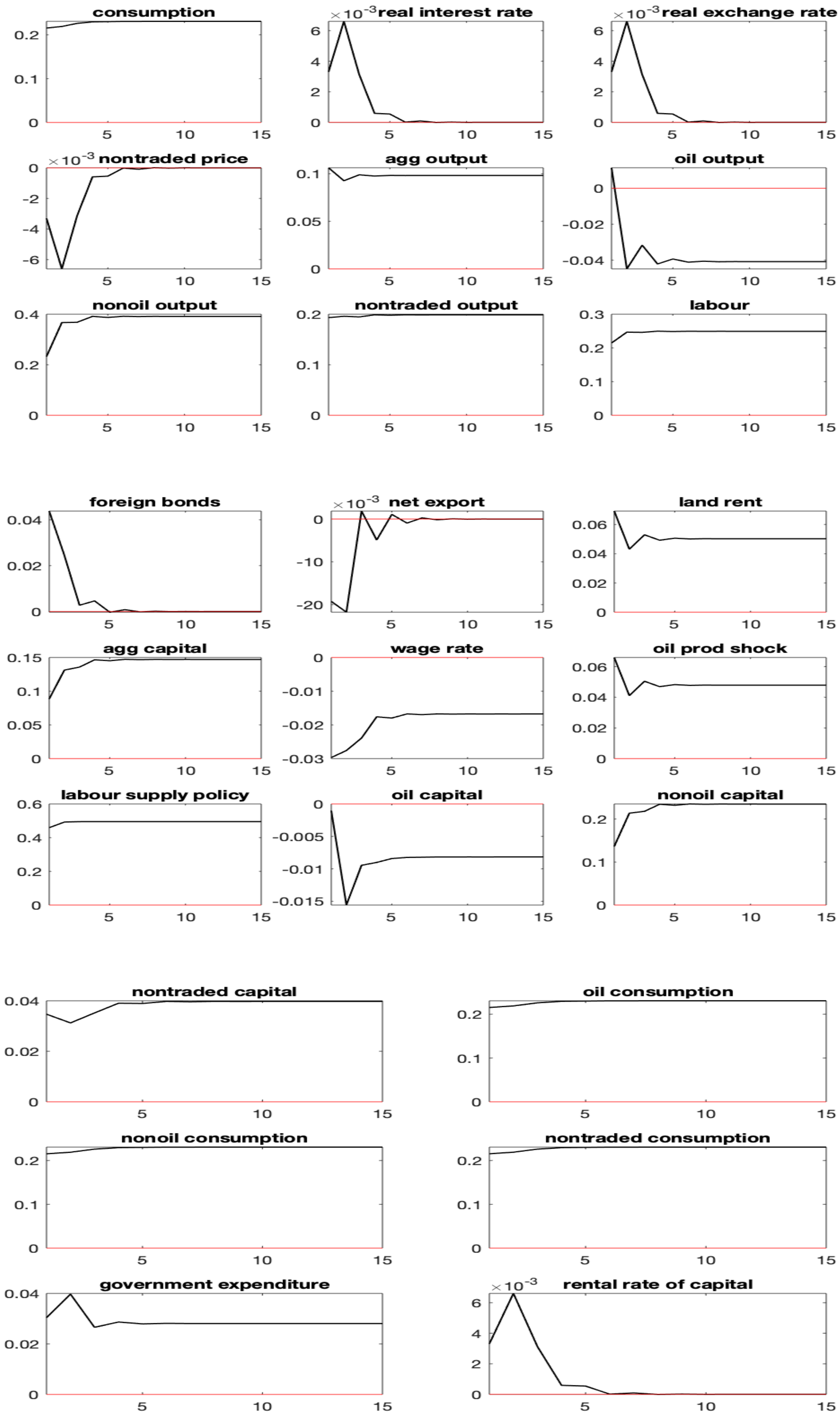

Figure 17: IRF of Labour Supply Driven Policy in Reaction to Oil Productivity Shock

In the figure above, the impact in the non-oil sector is positive and it suggests a reversal of the negative impacts of oil productivity shock. In explaining the path of policy effectiveness in the non-oil sector, the IRF shows that land rent rises as a result of an oil shock, this causes an expansion in the oil sector and a decline in the non-oil sector, however, when there is a policy to increase the supply of labour which dominates the oil shock, it quickly reverses the growth in oil and boosts growth in non-oil output which is intensive in labour. Thus, there is a fall in domestic prices as the wage rate falls, while the real exchange rate depreciates due to dominant oil productivity shocks. As a result, the demand for tradeables rises and supply rises to clear this demand. Also, aggregate income remains positive and relatively stables due to the government's expenditure expansion in initial periods to minimise any variance deviations caused by the oil shock and supply policy. More so, output remains unchanged because non-oil output rises as the oil output declines. With domestic demand being more income elastic, aggregate consumption and its composites are positive and relatively unchanged. However, just as in the case of demand-driven policies, there is a trade deficit caused by the declining oil sector which contributes about 50% to aggregate income. In response, the interest rate rises to balance payments as foreign debt rises in initial periods.

With our core focus on the reversal in the lagging sector, an increase in labour supply proves effective however it comes at a cost to the oil sector and on the demand side, fewer tradeables are demanded.

To bring more practicality to the policy recommendation, the data shows that labour in Kuwait is dominated in the non-traded sector which employs about 70% of the working population and contributes roughly between 30 - 40% of the aggregate output. The IMF report in 2018 showed that Kuwait has one of the highest wage premiums in the non-traded sector when compared to similar economies in the Gulf region. Thus, this premium encourages the movement of labour into that sector, hence the saturation. If the non-oil sector which is intensive in labour is not able to raise wages high enough to compete with the non-traded sector, labour will continue to be discouraged from entering that sector. Though our model framework does not recognise differentiated wages in the sectors, the effects of such differentiation as highlighted within relevant literature shows that they have strong factor supply and distribution effects across sectors. Hence, a wage restructuring bill may help to push the factors to the right sectors. Also, as our model is not able to investigate sectoral labour demand policies as might have been pointed out, some premium can be added to labour in the traded sector, perhaps more the non-oil sector than the oil sector to motivate the flow of labour to those areas. However, labour classification shows that the bulk of traded sector are foreign expatriates which informs that there may be a talent shortage restricting the flow of more Kuwaiti workers into the sector. Thus, a huge investment that may improve the quality of Kuwaiti labour is one suggestion to increase supply with the traded sector.

6.5.3 Welfare of the Policies

From our analysis, we look at the resultant variance to non-oil output as a measure of the welfare of the policies. More so, to increase robustness, I have also reported the quadratic sectoral variance, for a more holistic analysis. Within this analysis, I use non-oil output variance as a parameter to compare the performance of the policies. Therefore, a policy yielding lesser variance to non-oil output and the quadratic sectoral variance is inferred as the better policy because it yields comparatively lower risk. In addition, from the welfare criteria, the policies comparative benefit and reduced risk relative to the baseline model shows the effectiveness of these policies in tackling the Dutch disease in the non-oil sector. In the first part of this inference from the result in *table 11*, I compare the performance of the labour market regulations implemented to tackle the Dutch disease in the non-oil sector. Also, this table reports the government's feedback policy which communicates if the government takes on an expansionary or contractionary fiscal policy in response to both oil productivity shocks and labour market policy regulations, thus determining the government's optimal policy in the face of output volatility and policy implementation. The second inference I make from the result in *table 11*, I compare the labour market policy models with the baseline model to see if it yields any welfare benefits measured by the variance caused to non-oil output and the quadratic sectoral output variance. For this analysis, we note that the baseline model describes the model with only oil productivity shock and does not include any labour market regulations and/or government adjustment policy, hence the reason for a zero-adjustment parameter in the table below. Whereas just as described in subsections above, Case 1 describes the policy model with labour demand-driven policies, labour subsidy, in response to oil productivity shock and government reactionary policy to this effect, and Case 2 describes the policy model with labour supply policy in response to oil productivity shock and government's reactionary policy to this effect.

The variance of non-oil output computed is the mean-variance of simulated non-oil output. To obtain the variance, we run 1000 bootstrapped simulations of the economy with simultaneous shocks to oil productivity and labour market policy regulations which tackle the Dutch disease, that is either labour subsidies in Case 1 or labour supply policy in Case 2. Similarly, for the baseline model, we run 1000 bootstrapped simulations of the economy with only oil productivity shock, no policy shocks or government policy response. For each simulation, we obtain the distribution of output and take the variance for each bootstrap after which we take the mean of the estimated variance. It is necessary to note that to obtain the adjustment parameter that yields the minimum variance, we keep our estimated model parameters constant while varying the adjustment parameter in our estimation search routine. In other words, we choose the government adjustment parameter which maintains the sectoral features of Kuwait and gives the parameters that best fit the model of the economy and yields the least variance to output. We repeat this process under each policy and obtain the corresponding adjustment parameter η that yields the least variance to output. Like the computation of output variance above, individual sectoral variances are also calculated, hence we obtain the variance of non-oil output.

More so, we increase the robustness of the analysis by computing the quadratic joint sectoral variance. This measure is the square of the weighted sum of the logs of sectoral output. Recall that output is given as:

$$Y_t = 0.5\, Y_t^{NT} + 0.4\, Y_t^{o} + 0.1\, Y_t^{NO} \tag{6.5.8}$$

Hence, the quadratic sectoral variance is given as:

$$\begin{aligned} Var(Y_t) \quad = \quad & 0.5^2\, Var(Y_t^{NT}) + 0.4^2\, Var(Y_t^{o}) + 0.1^2\, Var(Y_t^{NO}) + 2(0.5)(0.1)\, Cov(Y_t^{o}, Y_t^{NO}) \\ & +2(0.5)(0.4)\, Cov(Y_t^{o}, Y_t^{NT}) + 2(0.4)(0.1)\, Cov(Y_t^{NT}, Y_t^{NO}) \end{aligned} \tag{6.5.9}$$

We obtain this from a similar simulation computation to the one described above. Hence, the value reported is the average of the sectoral variance values obtained from 1000 bootstrapped simulations of the baseline and policy models. Please note that all variables maintain their usual meaning, and Var means the variance whereas Cov means the covariance.

I begin the first part of the analysis where I compare the performance of both policies with the baseline model using the table reported below:

Policy	Adjustment parameter η	Non-Oil Output Variance	Sectoral Quadratic Varianc
Baseline	0	9961.31	194.16
Labour Demand Policy	-6.87	7306.62	129.88
Labour Supply Policy	-8.84	8550.84	159.72

Table 11: Comparative Welfare Effect of the Policy Options

Note: Model with demand policy is the policy described in Case 1, that is labour subsidy in the non-oil sector, whereas the model with supply policy is the policy described in Case 2.

The table above shows that the risk to non-oil output measured by the variance of non-oil output is higher in the baseline model when compared with the policy models in Case 1 and Case 2. More so, the table shows that when we analyse the performance of the policy models, there is a relatively higher variance to non-oil output when the supply-driven policy is implemented relative to demand-driven labour market regulations. Hence, if policymakers are risk-averse and focused on tackling the Dutch disease in the non-oil sector, maintaining output, or minimising the risk associated with volatile sectoral output, the better policy would be the demand-driven labour market policies. In support of this, to shed light on the effect on all productive sectors, given the fixed productive features of Kuwait's economy, the sectoral quadratic variance welfare measure supports this inference as the policy model with labour subsidies yields lower variance at 129.88 relative to the labour supply policy at 159.72 and the baseline model at 194.16. Furthermore, the table shows that in situations where the risk and associated variance measures of output caused by the implemented labour market regulation is high, the government's fiscal response measured by η is higher. Recall government's response is relevant in the policy models; thus, this parameter suggests that the higher the deviation to output given by the variance measures, the higher the reaction in terms of government fiscal response. To interpret this simply, η suggests that the government's adjustment policy in the face of the policies is expansionary and the extent of her fiscal expansion depends on the extent of variation in output. In summary, from the table above, risk-averse policymakers in Kuwait would prefer to implement labour demand-driven policies relative to labour supply-driven policies to tackle the Dutch disease in the non-oil sector. However, we note that in comparison of the policy models with the baseline model, the sectoral output variance is lower in the policy models which suggests that the policies are effective in tackling Dutch disease in the non-oil productive sector, and when we consider the overall risk and benefit to the productive sectors in Kuwait, both policies are effective and yields relative lower risk to variance in the overall sectoral output.

In summary, there is a reduced risk to non-oil output and the effect on all productive sectors when implementing any of the labour market policy regulations considered in Case 1 and Case 2 above and these policies are effective in tackling Dutch disease in the non-oil sector. More so, for risk-averse policymakers, the least costly policy to tackle the Dutch disease in Kuwait is the labour demand-driven policies.

6.6 Summary

In summary, policies by the government that affects labour use and labour sectoral demand positively will cause growth in the non-oil sector. These policies may be suggestive to come in terms of regulations that cause an increase in the wage rate or legislation on sectoral allocation of labour. Nonetheless, the important question of whether these policies are potent in the face of oil productivity shock has been summarised to come down to certain characteristics of the policies. The characteristics include how the policy is perceived in the economy, whether transitory or permanent and whether the policy is strong enough to dominate the shocks from the oil sector technology shocks. For a permanent role reversal in the lagging oil sector, we suggest that these government policies should be perceived as permanent and should be dominant when compared to the shocks caused by oil productivity fluctuations. We emphasize this dominance because in the case of Kuwait which may be like many resource-endowed states, the lagging sector (non-oil in Kuwait) is very small relative to the oil sector, and in this case, the oil sector is 5 times larger than the non-oil sector, thus policies to protect this sector needs to be very intense. Therefore, a dominant labour market policy would tackle the Dutch disease in Kuwait and yield greater welfare in Kuwait's productive sectors.

7 Summary and Conclusion

In the remarks that follow, I give my concluding thoughts of my thesis and some possible extensions to my work for further research.

Firstly, in modelling the economy, the choice of features to include in our model which extends the models of Kydland and Prescott (1982) was very deliberate for the understanding of business cycle movements of the Kuwaiti economy. Such consciousness in the choice of features to include and which to exclude highlights what some economists may see as the artistic feature in the construction of such DSGE models. These chosen features are an attempt to get a firm grip on the workings of the Kuwaiti economy, hence these features must be a good balance between simplicity, to be able to track the understanding of certain key shock processes on key macroeconomic aggregates, and complications to be able to push our understanding forward, towards a wider range of issues that may help resolve certain macro-objectives and give policy recommendations. As many modellers may want to criticise the workings of this model based on certain misspecifications coming from simplicity, I look at this model for Kuwait and say that for the purpose, it captures the objectives of which I set out searching. Nonetheless, I recognise that certain excluded features may also form the basis for extension to my model and thesis, and further explain certain features and problems which this model may be lacking in explanation. I recognise that one model cannot explain every problem.

In understanding Kuwait's economy, I chose to extend the models of Kydland and Prescott (1982), King, Plosser and Rebelo (1988), amongst others to include capital adjustment cost as in Hayashi (1982) and openness to trade where the goods traded are broadly divided into oil and non-oil goods. More so, the model incorporates a non-traded sector that is produced and consumed domestically. We have assumed that the rest of the world which trades with Kuwait is very large, making Kuwait such a small player to influence internationally set prices of her traded output. More so, the model features three-factor inputs, land, labour, and capital, of which land and labour are assumed to be fixed factors. The oil sector is determined to be intensive in land whereas the non-oil is labour-intensive. Thus, with features of factor-price determination, oil price changes have a resultant effect on land rewards and non-oil price changes has a resultant effect on labour rewards whereas capital is flexible and allowed to flow freely.

The results of my analysis showed that a permanent positive oil productivity shock can explain features of Kuwait's business cycle like those found in the data. I found that when a positive oil technology shock hits the economy, there is an expansion to aggregate income coming from the growth in oil and non-traded output, whereas production in the non-oil sector diminishes. This is because a positive oil technology shock raises land rent, which then triggers the reallocation of labour from the non-oil to oil sector to utilise the fixed factor of land in the oil sector (land-intensive sector). Thus, this causes the production boom in the oil sector and Dutch disease in the non-oil sector. In this economy, demand for goods in this economy is very income-driven hence when income is positive from the expansions of oil and non-traded output which make up about 90 percent of Kuwait's output capacity, the domestic demand levels thrive as income remains positive. However, the recognition of this raises questions on the sustainability of this economy in the face of diminishing oil prices and the exhaustion of the limited resource of oil in the future.

This question makes it necessary to diversify the economy's activities into the other traded sector - the non-oil sector. This has been the issue of Kuwait for several decades as the Dutch disease persists for as long as positive oil price shocks thrive. This model has done well in explaining what happens in the production sector when the economy thrives in periods of a positive oil shock. Hence, to tackle the problem of Dutch disease, in Chapter 6 of this thesis, we have recommended some policy options. In solution, I suggest a joint response of government fiscal action and some labour market regulations. This government's fiscal action is applied to reverse the Dutch disease effect and it is captured by the government's adjustment parameter in the model in Chapter 6. This action suggests the government's reaction in terms of marginal savings or expenditure in reaction to output variance caused by labour market regulations being implemented during periods of persistent positive oil technology shocks. The aim of the joint policy attempts to reverse the Dutch disease in the non-oil sector, as well as to minimise output variance and maintain domestic demand. I believe that government fiscal policy is a key tool for macroeconomic stability in Kuwait.

In the first labour market regulation, we suggest subsidies to labour wages to influence the flow of labour in the traded sector. We recognise within our model, the importance of this policy influencing the traded sector's labour demand, more so because the non-traded output supply is determined by demand factors and the real exchange rate and demand is sustained generally by aggregate income level. In my analysis, I increase the robustness of this policy experiment by evaluating the welfare of these policies in terms of the resultant effect on output variance. From the first policy experiment, we suggest that these policies dominate the positive oil productivity shock to cause a reversal of labour flow from the oil to the non-oil traded sector. This is true for all the labour market regulations suggested. In the second labour market regulation, I suggest policies that influence the supply of labour and preference to work relative to consumption or leisure. We find that this policy is also effective in reviving the lagging non-oil sector if it dominates the shocks caused by oil productivity.

Generally, when I evaluate the welfare outcomes given by the variance to non-oil output and sectoral quadratic variance, I recognise that these policies caused decreased volatility to sectoral output and non-oil output when compared to the baseline model, hence increasing welfare in this policy experiment. This shows some benefits gained from the policies suggested, hence communicating that in addition to reversing the Dutch disease and maintaining demand levels in the non-oil sector, the policies may be the best in terms of the welfare of the economy as they cause a significant benefit to productive sectors in the policy experiment. Nonetheless, I do recognise that within the welfare analysis, there is room for suggestions of more efficient policies which simultaneously reverses the Dutch disease, maintains demand levels, and maintain welfare in terms of output variance in this economy. More so, in future studies, I may also look at other welfare outcomes for the same policy experiment which may look at the household welfare in terms of the impact on domestic consumption.

Another limitation to this thesis stemmed from data availability issues. Firstly, for most of the series used, the frequency available was annual. More so, some of the series had the data missing for the year 1990 when Kuwait had the Gulf war. In solution to this, I have used some statistical interpolation techniques via Eviews statistical package to solve the problem of the missing data, since I had data before 1990 available. Also, I have implemented a combination of interpolation techniques to increase the frequency of the data, by converting the annual series to quarterly series. Furthermore, the data for some series were unavailable for Kuwait, hence I have used close proxies or instruments to replace them. I recognise that some inaccuracies and measurement errors may stem from these data inefficiencies and may stand as a strong limitation to the analysis and thesis thereof. However, I believe that for the aims of the model which are to understand the problem of the Dutch disease in Kuwait and suggest policies to tackle it, I believe that our methods of tackling these problems are sufficient for the objectives set out. Nonetheless, if better data becomes publicly available for Kuwait, I believe that a re-examination of the analysis and a tightening of the indirect inference estimation would make a good target for future analysis.

Moreover, having a closer look at the data for Kuwait, I recognise that the bulk of the labour is employed in the non-traded sector, about 70 percent of aggregate labour. Furthermore, the data suggest that the bulk of the labour in the traded sector is comprised of migrant workers and expatriates. Also, there is wide wage differentiation between the foreign labour and domestic labour as well as suggestions of a higher wage premium paid to Kuwaiti workers employed in the non-traded sector when compared to other economies in the Gulf region. These scopes are beyond the workings of this model because we do not model the effect of migrant workers and wage differentiation across the sectors. Hence, extensions that recognise these labour market complexities form significant room for future investigation. More so, since this model works for Kuwait, future research can expand the geographical region and investigate if this works for similar states such as the Gulf states with significant attention paid to the Gulf Cooperation Council (GCC) because of the influence of cross border policies as well as collective goals between the associated states. Also, our model does not include a monetary policy which is also a key policy tool for the Kuwaiti government thus extensions to include money into the model may fill this gap and address this policy.

In conclusion, this model for the economy of Kuwait is a big step for the literature because, within my comprehensive yet inexhaustible review of models and literature for Kuwait, I have not seen any proposed DSGE model to describe the workings of the economy. More so, there has been robustness and econometric tests conducted by indirect inference on the model to increase its validity and usefulness. In addition, the thesis also evaluated the power of the indirect inference method of which the literature by Le et al (2015, 2016), had suggested the power of the indirect inference when compared with other methodological approaches and varying levels of restrictions. More so, this thesis is a contribution to the growing literature on this approach as it supplies more evidence on the power of the method when using non-stationary data. My thesis steers the compass on Kuwait and potentially other oil-endowed economies in the right direction and only better research can be built from this work. However, for future research, I believe that extending the analysis to see the impact of migrant labour or foreign expatriates in Kuwait's labour market dynamics, and how much this labour dynamics tells the story for the Dutch disease in Kuwait or proffers solution to tackle the problem would be a good place to start. Moreover, with Kuwait registering one of the highest wage premiums in the non-traded sector within the Gulf region, investigating and applying this model to other Gulf states through a panel analysis would paint a bigger picture of the character of the Dutch disease within this region and I would love to investigate that. I do believe that the data issues that exist within this study would be reduced as time passes, and other sources of energy become more popular and investigating these effects on the productivity of the oil sector would be a good area to potentially investigate. I believe that there are many ways to improve on this current model and the usefulness of a DSGE model for Kuwait and other resource-endowed states is seemingly limitless.

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A Appendix - Data Details

A.1 Fixed Parameters

Here, we summarise the data that highlights the features of Kuwait which remains constant throughout the experiment. These parameters represent very strong features of Kuwait's economy and on average does not change through time. The reason they remain fixed is that they define the sectoral intensities which is a key factor in understanding the model and for all the implications explained in oil shock transmission subsections and impulse response functions analysis. When we consider the sectoral factor shares of fixed factors in this economy, we observe that within the traded sector, the oil sector is land-intensive while the non-oil sector is labour intensive which fits the facts of the model which we sort to explain. Whereas the nontraded sector's production function depends on all three factors, however, its intensity does not matter too much since its output is not traded internationally. Still, we recognise that its high labour intensity is a representation of Kuwait's high employment of its citizens in its governmental and service industries which matches the data strongly. These fixed factor shares are derived from the data for Kuwait as obtained in the National Accounts Statistics Input Output Tables 2010 reported by the Central Statistical Bureau of Kuwait. These fixed parameters are summarized in the table below.

Note that in the composition of the data, we maintain the same classification of sectors as we have done for output and other sectoral features. Thus, the oil sector comprises the Oil and Gas (Refined oil, Crude Oil) industry, the non-oil sector is composed of mining, agriculture, manufacturing (Manufacturing, Agriculture, and fishing) industries, whereas all other sectors were classified as the non-traded sector. The proportion of labour was taken as compensation of employees from this table; the capital proportion was taken as consumption of fixed capital; whereas land contribution was taken as the Gross Value Added less labour and capital contributions. The table for factor shares is summarised below.

Parameter	Role	Value
α_o	labour share in oil sector	0.1
α_{no}	labour share in non-oil sector	0.3
α_{nt}	labour share in non-traded sector	0.6
β_o	capital share in oil sector	0.2
β_{no}	capital share in non-oil sector	0.6
β_{nt}	capital share in non-traded sector	0.2
$1 - \alpha_o - \beta_o$	land share in oil sector	0.7
$1 - \alpha_{no} - \beta_{no}$	land share in non-oil sector	0.1
$1 - \alpha_{nt} - \beta_{nt}$	land share in non-traded sector	0.2
$\frac{y^o}{y}$	size of oil sector in aggregate	0.5
$\frac{y^{no}}{y}$	size of non-oil sector	0.1
$\frac{y^{NT}}{y}$	size of non-traded sector	0.4

Table 12: Fixed Parameters

A.2 Data Summary

Symbol	Variables	Data Definition
Y	Output	Gross Domestic Product (GDP) at current prices
Y^o	Oil Output	Gross Domestic Product (GDP) by industry (oil and gas), Current prices
Y^{no}	Non-oil Output	Gross Domestic Product (GDP) by industry (non-oil classification), Current prices
Y^{nt}	Non-traded Output	Gross Domestic Product (GDP) by industry (nontraded classification), Current prices
C	Consumption	Final Consumption in GDP by Expenditure, Private, Current prices
C^o	Oil Consumption	weighted portion of Final consumption, Private, Current prices
C^{no}	Non-oil Consumption	weighted portion of Final consumption, Private, Current prices
C^{nt}	Nontraded Consumption	weighted portion of Final consumption, Private, Current prices
I	Investment	Gross Fixed Capital Formation (GFCF) plus changes in stock in GDP by Expenditure, Current prices
K	Capital	calculated from perpetual inventory equation, Current prices
r	Interest rate	three-month treasury bill rate, nominal
s	Land Rent	Calculated from zero profit equation, current prices
w	Wage Rate	expenditure on wages and salaries divided by working population
G	Government Expenditure	Government expenditure in GDP by expenditure, Current prices
P^o	Oil Price	Brent Spot Price, Nominal
P^{NO}	Non-oil Price	World Commodity Price Index, Nominal
P^{nt}	Nontraded Price	weighted average of the chain-type price indexes for value-added from all industries classed as nontraded
r^f	Foreign Interest Rate	weighted average of three-month treasury bill rate from EU, Japan and US, Nominal
B^f	Foreign Bond	Ratio of Net Foreign Assets to GDP, Current Prices
Q	Real exchange rate	ratio of traded to nontraded price
N	Labour supply	persons aged between 18 and 54 in the population
NX	Net Export	Net Export from GDP by expenditure, Current prices

Table 13: Summary of Data Description

Data note:

1. All prices are expressed in Kuwaiti dinar

2. In the classification, the industry that makes up the oil sector is the Oil and Gas industry; whereas

the non-oil sector comprises mining, agriculture, manufacturing and refined products industries; then all other industries were classified as the non-traded sector. More details on the data can be found in the Data Appendix.

3. After obtaining the quarterly series from interpolation, I scale them properly and I adjust them for seasonal effects. Next, I express the nominal variables in real terms by dividing them by the price index, taking 2000 as the base year. After which, I have converted the data where appropriate into logarithmic form.

4. In scenarios where I had some missing data especially in 1990 where there was a Gulf war, I make up the incomplete series by applying some interpolation techniques as I had data before 1990. Also, I applied some techniques available on Eviews statistical package to convert frequency from annual to quarterly. More details on the methods employed can be seen in the Data Appendix.

5. Due to the lack of data, I have constructed some data for consumption by different products to obtain the weights assigned to oil consumption C^o, non-oil consumption C^{no}, and non-traded consumption C^{nt}. There is a detailed explanation of the extraction of these weights in the Data appendix section.

6. The capital is created following Caselli (2005) using the capital accumulation equation stated below.

$$K_t = I_t + (1 - \delta) K_{t-1} \tag{A.2.1}$$

More so, the initial level of capital is calculated from the equation below

$$K_0 = \frac{I_0}{(g + \delta)} \tag{A.2.2}$$

where g is the growth rate of output and δ is the depreciation rate

For the composition of capital that is allocated to oil K^o, non-oil K^{no} and non-traded K^{nt} sectors, I made a few manipulations of the data to get these proportions. Since there is no data for these proportions, I have obtained them from the data reported on public investment expenditure of ministries and departments as reported in the quarterly special edition of Central Bank of Kuwait (CBK) Statistics and Publications. The proportions are defined by the proportion of current public investment expenditure of ministries and departments, which I then grouped into sectors like the classification of industries in the output described above.

7. Land rent is defined as the reward paid for using land in the productive process. This dataset is derived from our zero-profit equation which follows from our model assumptions. Hence, land rent covers all the rental rates of land, application and other charges associated with renting land as well as profits accumulated.

   From our model, we extract land rent from the equation shown below:

$$\pi_t = P_t\, Y_t - K_t(r_t^k + \epsilon_t^k) - N_t(w_t + \epsilon_t^n) - L_t(s_t + \epsilon_t^l) \tag{A.2.3}$$

   All variables and parameters maintain their initial definitions.

8. Foreign interest rate is calculated as the weighted average of three-month treasury bill rate of the following countries and in the given proportions - EU(19%), US(60%), Japan (21%).

9. The wage rate is the reward per unit labour used up in production processes. As is the case with a few data in the series, getting the wage rate paid to domestic workers was unavailable. Thus, I was forced to extract this data from a close proxy sourced from the quarterly special edition of Central Bank of Kuwait (CBK) Statistics and Publication. The series used was the government's expenditure on wages and salaries reported in the economic classification of current expenditure. This quarterly series obtained was then divided by working population to obtain the wage rate in Kuwaiti dinar.

10. From the ILO series, we take labour supplied to the oil sector N^o as labour distributed to industry sector; for the non-oil sector N^{no}, we use labour distribution to the agriculture sector and lastly the non-traded labour N^{nt} as labour distributed to the services sector.

11. Traded price P^T is defined as a weighted sum of oil and non-oil price to make the price of traded goods in the economy. This ratio is fixed in the proportion shown in the equation below.

$$P_t^T = 0.9\, P_t^O + 0.1\, P_t^{NO} \tag{A.2.4}$$

   All terms remain as initially defined.

A.3 Data Description and Source

Output

Model variables: $Y\,, Y^o\,, Y^{no}\,, Y^{nt}$

Description and source: Aggregate output Y in this model is defined as the aggregate of output produced from the three sectors considered, that is oil Y^o, non-oil Y^{no} and non-traded Y^{nt} sectors. The data is obtained from the Gross Domestic Product by industry obtained from the quarterly special edition of Central Bank of Kuwait (CBK) Statistics and Publications. From the series, we defined the productive sectors by classifying the sectors and industries into these three major sectors. We defined the oil output as GDP generated from Oil and Gas industry, the non-oil output as GDP from mining, agriculture, manufacturing, and refined products industries, whereas all other sectors were classified as the non-traded sector. Thus, the non-traded sector includes GDP from the following industries: wholesale and retail trade, restaurants and hotels, transport, storage and communication, financial institutions (insurance, real estate, business services, community, social and personal services) and others.

Consumption

Model variable: C, C^o, C^{no}, C^{nt}

Description and source: Data on private consumption is obtained from GDP by Expenditure sourced from the quarterly special edition of Central Bank of Kuwait (CBK) Statistics and Publications. From the above publication, consumption variable C is described as a constituent of final consumption noted as private. I was then able to source data for the other classifications of expenditure consumption, oil consumption C^o, non-oil consumption C^{no}, and non-traded consumption C^{nt} from some manipulations. The described classification groups consumption in terms of products consumed in the domestic economy within the model. In our manipulation, we first sourced the data for oil consumption C^o from the BP Statistics review data on oil consumption by barrels reported by country. Hence, oil consumption calculated in Kuwaiti Dinar was obtained by multiplying the oil consumption-by-barrel with Brent crude oil prices (which defines the oil price P^o) reported in US dollars (converted to Kuwaiti dinar by multiplying by the exchange rate obtained from the International Monetary Fund (IMF) database). More so, I divide the oil consumption by the gross private consumption and find the proportion of household's consumption which goes to oil goods. The weight of non-traded consumption C_{nt} was obtained from the average proportion of non-traded output relative to gross private consumption. However, as the government is modelled to also be a user of non-traded output, thus in calculating the approximate portion of private consumption, I exclude government spending from the non-traded output, hence calculating the estimated private consumption expenditure on non-traded goods. Thus, the weight of private consumption that goes to consumption of non-oil goods is unity (1) less the sum of weights of oil and non-traded consumption. The respective proportions of oil, non-traded and non-oil consumption as a proportion of final consumption are 0.00049, 0.91997 and 0.07954.

Investment

Model variable: I

Description and source: Investment data is sourced from GDP by Expenditure reported in the quarterly special edition of Central Bank of Kuwait (CBK) Statistics and Publications. The series is the sum of gross fixed capital formation (GFCF) and the changes in stocks in that expenditure series. The data obtained was annual and current.

Capital

Model variable: K, K^o, K^{no}, K^{nt}

Description and source: Capital is calculated from the perpetual inventory equation. The capital is created following Caselli (2005) using the capital accumulation equation stated below.

$$K_t = I_t + (1 - \delta) K_{t-1} \tag{A.3.1}$$

More so, the initial level of capital is calculated from the equation below

$$K_0 = \frac{I_0}{(g + \delta)} \tag{A.3.2}$$

For the composition of capital that is allocated to oil K^o, non-oil K^{no} and non-traded K^{nt} sectors, I made a few manipulations of the data to get these proportions. Since there is no data for these proportions, I have obtained them from the data reported on public investment expenditure of ministries and departments as reported in the quarterly special edition of Central Bank of Kuwait (CBK) Statistics and Publications. The proportions are defined by the proportion of current public investment expenditure of ministries and departments, which I then grouped into sectors like the classification of industries in the output described above. The proportions of capital allocated for investment in the oil, non-oil and non-traded sectors respectively are 0.05, 0.1 and 0.85.

Oil price

Model variable: P^o

Description and source: The price of oil is taken as Brent spot price of oil as reported in BP Statistics Review of 2018[54] which is valued in the US dollars. This is converted to Kuwaiti dinar by multiplying by the exchange rate obtained from the International Monetary Fund (IMF) database. Also, the series reported by BP statistical review is compared with the figures of oil price as obtained from the IMF's database.

Non-Oil price

Model variable: P^{NO}

Description and source: The price of non-oil is taken as the World commodity price index - non-fuel

[54] this was obtained from the BP Statistical Review of World Energy June 2018 and this can be found http://www.bp.com/statisticalreview

as reported in the International Monetary Fund (IMF) database. This is converted to Kuwaiti dinar by multiplying by the exchange rate obtained from the International Monetary Fund (IMF) database.

Non-traded price

Model variable: P^{nt}

Description and source: The price of non-traded goods is calculated as the weighted average of the chain-type price indexes for value-added from all industries excluding oil and gas, mining, agriculture, manufacturing, and refined products which is consistent with our sectoral classification of output as described above.

Foreign interest rate

Model variable: r^f

Description and source: Foreign interest rate is calculated as the weighted average of three-month treasury bill rate of the following countries and in the given proportions - EU(19%), US(60%), Japan (21%).

Domestic interest rate

Model variable: r

Description and source: Domestic interest rate is calculated as a three-month treasury bill rate

Foreign bonds

Model variable: B^f

Description and source: Foreign bonds are taken as the net foreign assets as reported in the IMF and International Financial Statistics (IFS) data files. They define net foreign assets are the sum of foreign assets held by monetary authorities and deposit money banks, less their foreign liabilities. In the model, we express this as a ratio of aggregate output sourced as the GDP.

Wage rate

Model variable: w

Description and Source: The wage rate is the reward per unit labour used up in production processes. As is the case with a few data in the series, getting the wage rate paid to domestic workers was unavailable. Thus, I was forced to extract this data from a close proxy sourced from the quarterly special edition of Central Bank of Kuwait (CBK) Statistics and Publication. The series used was the government's expenditure on wages and salaries reported in the economic classification of current expenditure. This quarterly series obtained was then divided by working population to obtain the wage rate in Kuwaiti dinar.

Government Expenditure

Model variable: G

Description and Source: This describes all expenditure carried out by the government in the model. The data for government expenditure G is obtained from GDP by Expenditure sourced from the quarterly special edition of Central Bank of Kuwait (CBK) Statistics and Publications. In the bank's publication, government expenditure is classified as a constituent of final consumption.

Land

Model variable: L

Description and Source: Land describes the physical land and its resources. The data for land is described as the geographical area of Kuwait, this is defined as the land area of Kuwait as sourced from the World Bank Database. Here, land area is described as a country's total area, excluding area under inland water bodies, national claims to continental shelf, and exclusive economic zones. The data for land is fixed and does not change in line with theory as this is a fixed factor of production. However, it may be subject to diminishing returns as the population or labour increases to stretch resources.

Land Rent

Model variable: s

Description and Source: Land rent is defined as the reward paid for using land in the productive process. This dataset is derived from our zero-profit equation which follows from our model assumptions. Hence, land rent covers all the rental rates of land, application and other charges associated with renting land as well as profits accumulated.

From our model, we extract land rent from the equation shown below:

$$\pi_t = P_t Y_t - K_t(r_t^k + \epsilon_t^k) - N_t(w_t + \epsilon_t^n) - L_t(s_t + \epsilon_t^l) \tag{A.3.3}$$

Real Exchange rate

Model variable: Q

Description and source: the real exchange rate is the ratio of traded to non-traded price. The non-traded price is defined above whereas the traded price is defined as a weighted sum of oil and non-oil price to make the price of traded goods in the economy. This ratio is fixed in the proportion shown in the equation below.

$$P_t^T = 0.9\, P_t^O + 0.1\, P_t^{NO} \tag{A.3.4}$$

Labour Supply

Model variable: N, N^o, N^{no}, N^{nt}

Description and source: Labour supply N is defined as the persons aged between 18 and 54 in the population. The data is gotten from the International Labour Organisation (ILO) statistics for Kuwait distributed by sector. From this classification, I can obtain labour supplied to the oil sector N^o, non-oil N^{no} and non-traded N^{nt} sectors. One thing to note in the distribution from the ILO statistics is that it may not be as broad as classifications reported in the GDP by industry from the CBK. Hence, there might be some overlap of labour between industries. To reduce some of this measurement error, we use average values of labour in these different sectors. More so, it makes sense to do this as some of the data reported are estimates of the sectoral distribution of labour in Kuwait. From the ILO series, we take labour supplied to the oil sector N^o as labour distributed to the industry sector; for the non-oil sector N^{no}, we use labour distribution to the agriculture sector and lastly the non-traded labour N^{nt} as labour distributed to the services sector. The average weights of the oil, non-oil and non-traded sector reported in percentages are 20.2 oil, 2.4 non-oil and 77.4 non-traded.

Net Export

Model variable: NX

Description and source: Net export defines the net trade between Kuwait and the rest of the world. This is described as exports less imports. This data is extracted from the GDP by expenditure sourced from the quarterly special edition of the Central Bank of Kuwait (CBK) statistics and publication.

A.4 Data Transformation and Filtering

One of the limitations of this study may stem from measurement errors resulting from data availability. This is because of the different frequencies available for the data collected, and in some cases, the series may have some missing data especially in 1990 when Kuwait experienced the Gulf war. Thus, to make up the incomplete series, I applied some interpolation techniques as I had data before 1990, to complete missing data and, extend and convert frequency from annual to quarterly. It may be necessary to note that the interpolation technique employed depended on the nature of the series and how it trended. All the interpolation was carried out on the Eviews statistical package which has a range of techniques that can be applied. The series which were quarterly when obtained includes the consumer price index and all goods prices, nominal exchange rate, the interest rate (3-month treasury bill rate), whereas the annual series converted to quarterly includes GDP and all the component expenditures, land area, net foreign assets, and labour supply.

The Eviews package provides a range of techniques for frequency conversion and they include, the constant method which assigns the same value to all observations in the high-frequency series, the quadratic method which fits a local quadratic polynomial for each observation of the low-frequency series, then uses this polynomial to fill in all observations of the high-frequency series associated with each period, the linear method which assigns each value in the low-frequency series to the first or last high-frequency observation associated with the low-frequency period, then places all intermediate points on straight lines connecting these points, the cubic spline method which assigns each value in the low-frequency series to the first or last high-frequency observation associated with the low-frequency period, then places all intermediate points on a natural[55] cubic spline connecting all the points, the point method which copies the low-frequency data into the first or last observation for the corresponding high-frequency range, the Denton method which is a statistical interpolation that minimizes the proportional first difference between the interpolated and high-frequency target series, Chow-Lin method which is a regression-based interpolation relating one or more high-frequency target series to the low-frequency series and lastly the Litterman method which is a random walk variant of Chow-Lin method.

After obtaining the quarterly series from interpolation, I scale them properly and adjust them for seasonal effects. Next, I express the nominal variables in real terms by dividing them by the price index, taking 2000 as the base year. After which, I have converted the data where appropriate into logarithmic form.

A.5 Charts of Data, Residual and Innovations

A.5.1 Unfiltered Data of Kuwait

[55] The Eviews online platform defines the natural cubic spline to have the following properties:

- Each segment of the curve is represented by a cubic polynomial.
- Adjacent segments of the curve have the same level, first derivative and second derivative at the point where they meet.
- the second derivative of the curve at the two global endpoints is equal to zero (this is the "natural" spline condition).

I choose the cubic spline method of conversion because it is commonly used in economic series and it is a global interpolation method, meaning that changing any one point (or adding point) to the source series will affect all points in the interpolated series. More so, there are limitations to finding other high-frequency target series to apply other techniques. In addition, the cubic spline combines the quadratic, linear and polynomial techniques.

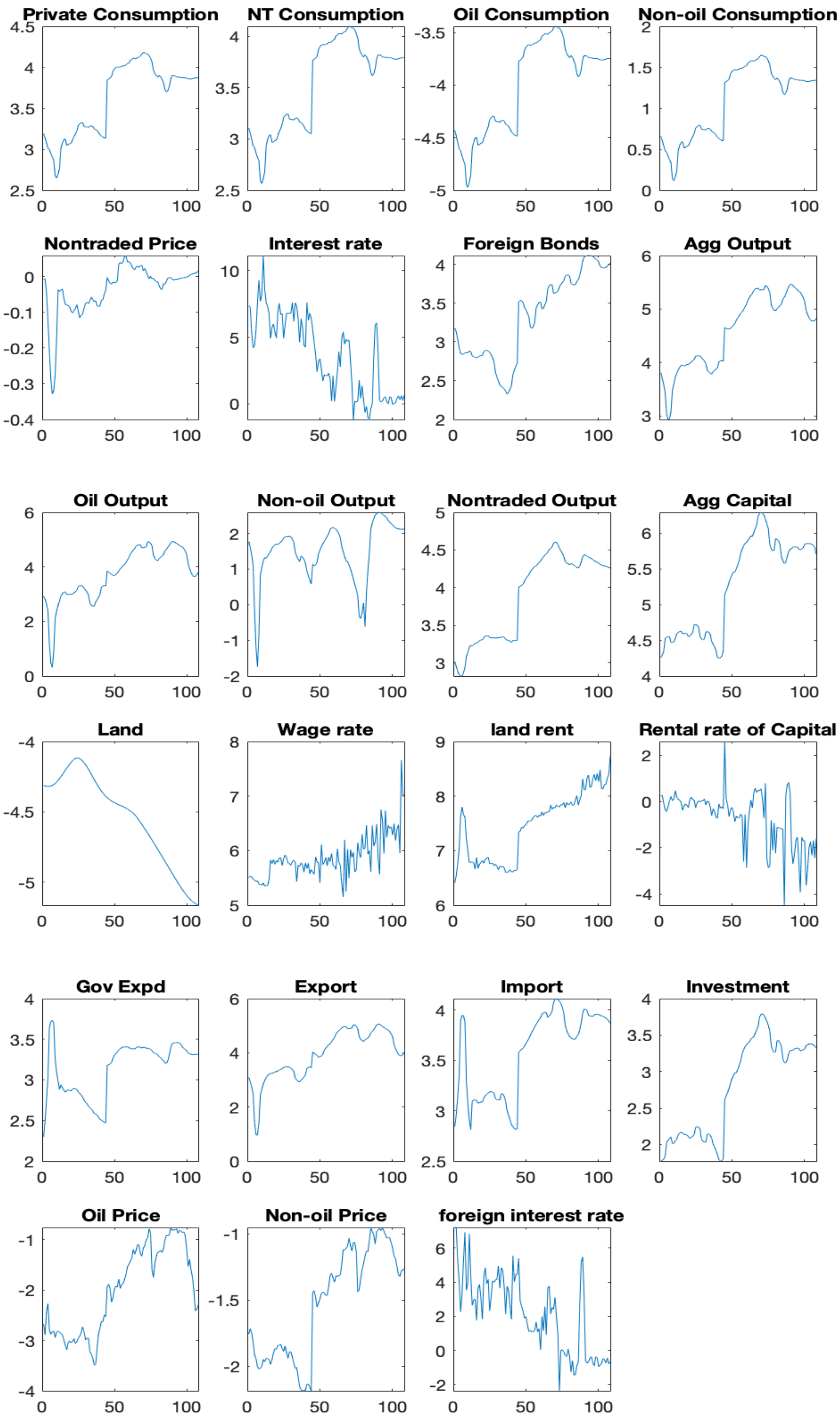

Figure 18: Unfiltered data for Kuwait Expressed in Logarithmic Form

A.5.2 Residuals

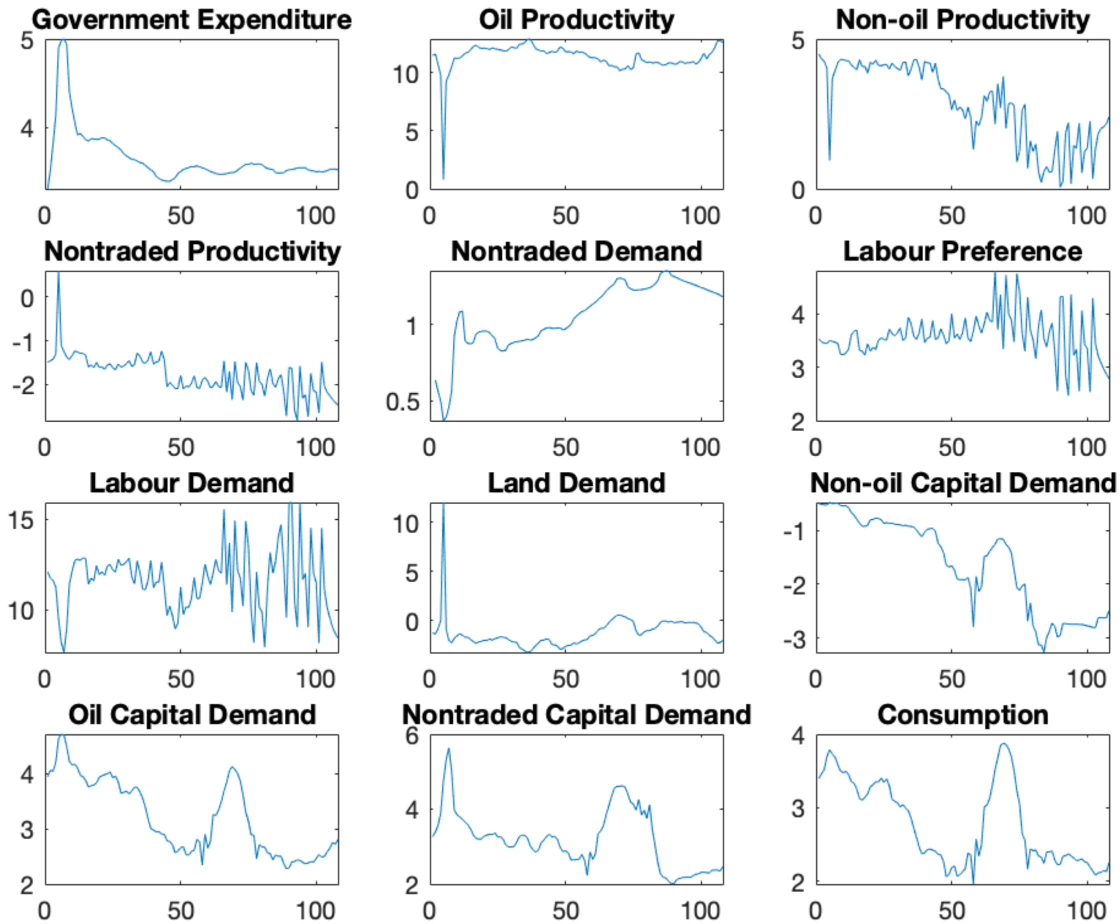

Figure 19: Residuals

A.5.3 Innovations

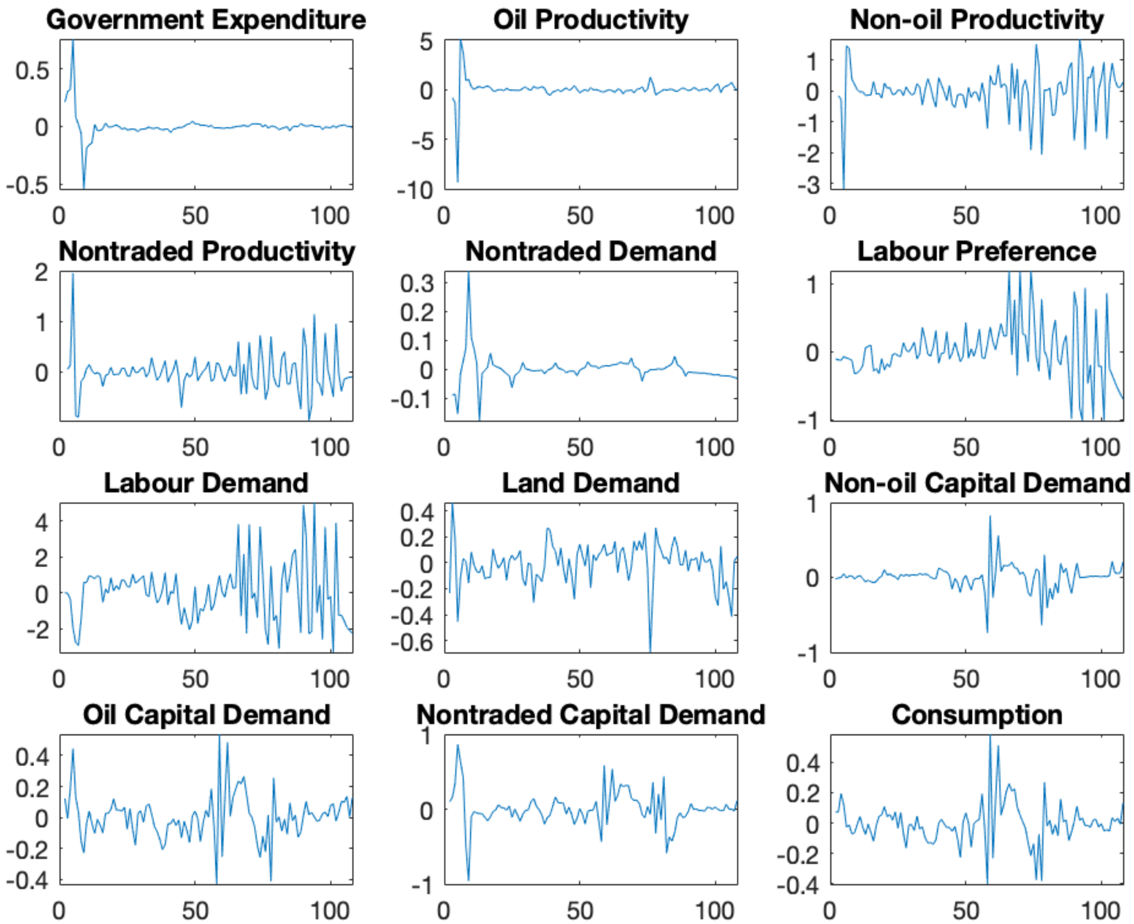

Figure 20: Innovations

A.6 Shock Processes

The parameters reported above are estimated by Indirect Inference estimation. These estimated parameters are significantly different from the calibrated parameters, and this difference affects the estimated error processes, innovations, and persistence. The estimated model contains 12 shock processes and 3 of these shocks are treated as non-stationary data based on the theory. These non-stationary shocks are the productivity shocks, and they are modelled as ARIMA (1,1,0) processes. These shocks are tested by a variety of methods which includes the Augmented Dickey-Fuller (ADF) test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, and the result of the latter is summarised in the table below. From the table, only the productivity shocks are non-stationary, or first-difference stationary, hence the ARIMA (1,1,0) specification. Whereas all other shocks are either level or trend stationary, which we summarise as stationary. These stationary shocks are modelled as AR (1) processes.

Within the ADF test, the appropriate test depends on the nature of non-stationarity characterised by the shock process. The ADF tests are done in sequential order and the steps are shown below. In this explanation, I use ϵ_t to define the shock residual, T denotes the linear time trend,β_2 to denote the parameter estimates describing the AR coefficient, and ξ_t for the shock innovations. I proceed to describe the sequential order for the ADF test below:

- Stationarity with Trend

  This test is described by the following equation

$$\epsilon_t = \beta_1 T + \beta_2 \epsilon_{t-1} + \xi_t \tag{A.6.1}$$

  The corresponding hypothesis test described above is:

  H_0:$\beta_2 = 0$: y_t is a unit root process

  H_1:$\beta_2 < 0$: y_t is a trend stationary process

- Stationarity at Level

  This test is described by the following equation

$$\epsilon_t = \beta_2 \epsilon_{t-1} + \xi_t \tag{A.6.2}$$

  The corresponding hypothesis test described above is:

  H_0:$\beta_2 = 0$: y_t is a unit root process

H_1:$\beta_2 < 0$: y_t is a level stationary process

- Stationarity at First Difference

  This test is described by the following equation

$$\epsilon_t = \epsilon_{t-1} + \beta_2(\epsilon_{t-1} - \epsilon_{t-2}) + \xi_t \tag{A.6.3}$$

  The corresponding hypothesis test described above is:

  H_0:$\beta_2 = 0$: y_t is a unit root process

  H_1:$\beta_2 < 0$: y_t is stationary first difference

In the sequence, we start by testing if the shock process is trend stationary, then we proceed to test its stationarity in level form if we conclude that it is non-stationary in the trend test and lastly if it shows that it is a unit root in both tests, we then proceed to test the shock process in first difference as shown above.

The decision rule for the hypothesis test can be made using either the t-statistic or the p-value. If the *t-statistic* is greater than the *Critical Value*, then we reject the null hypothesis and conclude that the shock being tested is trend stationary, level stationary or first-difference stationary as the case may be. Alternatively, we may also make our decision based on the p-value. If the *p-value* is less than *0.5 (the significance level)*, we reject the null hypothesis and conclude that the shock is trend stationary, level stationary or first-difference stationary.

On the other hand, the specification of the KPSS is summarised in the equations summarized below. Within the KPSS test, the appropriate test depends on the nature of non-stationarity characterised by the shock process and this test is done in sequential order. In the sequence, we start by testing if the shock process is trend or level stationary, if we conclude that it is non-stationary in this test, then we proceed to test the shock process in first difference.

The decision rule for the hypothesis test can be made using either the KPSS test statistic, also LM statistic. If the *test statistic* is greater than the asymptotic *Critical Value* reported at 1% significance level, then we reject the null hypothesis and conclude that the shock being tested is a unit root. More details of the test process are contained in the Data Appendix. In this explanation, I use ϵ_t to define the shock residual, T denotes the linear time trend,β_2 to denote the parameter estimates describing the AR coefficient, and ξ_t for the shock innovations. In the part that follows, I summarise the test procedure:

The corresponding hypothesis test described above is:

H_0:$\beta_2 < 0$: ϵ_t is a level/trend/first-difference stationary process

H_1:$\beta_2 = 0$: ϵ_t is a unit root process

- Stationarity Test Specifications

  For trend stationary test;

$$\epsilon_t = \beta_1 T + \beta_2 \epsilon_{t-1} + \xi_t \tag{A.6.4}$$

  For level stationary test;

$$\epsilon_t = \beta_2 \epsilon_{t-1} + \xi_t \tag{A.6.5}$$

  For first-difference test;

$$\epsilon_t = \epsilon_{t-1} + \beta_2(\epsilon_{t-1} - \epsilon_{t-2}) + \xi_t \tag{A.6.6}$$

The table below summarises the result from the KPSS stationarity test and the estimated shock process below. The properties of the shocks and its innovations are reported, that is the mean μ and standard deviation σ of the I(0) shock innovation $\xi_t \sim (\mu, \sigma)$. More details of other properties of the shocks are reported in the appendix.

Shocks	Description	Decision Rule	Stationarity	AR Coef
ϵ_t^o	oil productivity shock	0.194<0.739	non-stationary	-0.38
ϵ_t^{NO}	non-oil prod. shock	0.0908<0.739	non-stationary	-0.41
ϵ_t^{NT}	non-traded prod. shock	0.0435<0.216	non-stationary	-0.44
ϵ_t^{YNT}	non-traded demand shock	0.1203<0.739	trend stationary	0.92
ϵ_t^{NS}	labour supply shock	0.2253<0.739	level stationary	0.14
ϵ_t^{n}	labour demand shock	0.059<0.739	level stationary	0.29
ϵ_t^{l}	land demand shock	0.303<0.739	level stationary	0.97
ϵ_t^{KNO}	capital demand shock	0.365<0.739	level stationary	0.95
ϵ_t^{KO}	capital demand shock	0.0939<0.216	trend stationary	0.87
ϵ_t^{KNT}	capital demand shock	0.561<0.739	level stationary	0.94
ϵ_t^{C}	consumption shock	0.058 <0.216	trend stationary	0.95
ϵ_t^{G}	government shock	0.673<0.739	level stationary	0.99

Table 14: KPSS Stationarity Test Result with AR coefficient Reported at 1% Significance Level

The conclusion of the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test on the stationarity of the shock processes which is analysed at 1%[56] significance level, showed that most of the shocks considered in this test were stationary except for productivity shocks which were non-stationary. We also note that the key shock in my analysis which is the oil productivity shock is a non-stationary shock.

[56]However, all conclusions made as to the stationarity of the residuals were also valid at 5% level of significance.

	ξ_t^o	ξ_t^{NT}	ξ_t^{NO}	ξ_t^{YNT}	ξ_t^{NS}	ξ_t^{N}	ξ_t^{l}	ξ_t^{KO}	ξ_t^{KNO}	ξ_t^{KNT}	ξ_t^{C}	ξ_t^{G}
Mean	0.054823	-0.0288	0.04049	0.001986	0.0409	0.180193	-0.45182	0.003272	0.00704	0.003037	-0.01295	0.001705
Median	0.123475	-0.05846	0.024809	0.000466	0.02419	0.086551	-0.57168	0.004895	0.015184	-0.00311	-0.0013	-0.00332
Maximum	1.691921	1.940802	5.10246	0.361256	1.927649	6.996825	11.99723	0.574994	0.86495	0.621395	0.94394	0.757741
Minimum	-3.05287	-0.9749	-9.32297	-0.19874	-1.40794	-5.10321	-8.80195	-0.4193	-1.02718	-0.39487	-0.71223	-0.54022
Std. Dev.	0.720234	0.398208	1.146172	0.048784	0.550711	2.084884	1.512108	0.147458	0.236797	0.138992	0.179734	0.107618
Skewness	-1.22914	1.336453	-4.06432	3.082958	1.005925	0.851217	3.690216	0.551006	-0.34596	0.786411	0.594427	2.492285
Kurtosis	6.62858	8.564595	47.57161	32.08873	5.898379	5.125932	52.61917	6.260371	7.847816	8.163494	13.56004	30.95526
Jarque-Bera	84.84289	168.3154	9066.105	3905.097	55.49796	33.07134	11219.54	52.80652	106.9112	129.8955	503.4696	3594.944
Probability	0	0	0	0	0	0	0	0	0	0	0	0
Sum	5.811255	-3.0531	4.2919	0.210476	4.376329	19.28069	-48.3451	0.3501	0.753331	0.324988	-1.38571	0.182482
Sum Sq. Dev.	54.46739	16.64979	137.9396	0.249887	32.14793	460.7544	242.3659	2.30485	5.943733	2.047784	3.424268	1.227657
Observations	106	106	106	106	107	107	107	107	107	107	107	107

Figure 21: Innovation Properties

B Appendix - IRFs of Calibrated Model

B.1 Calibrated Parameters of the Model

Parameter	Role	Value
ρ_0	CRRA coefficient for c_t	1.0
ρ_2	CRRA coefficient for N_t	1.2
θ_0	home bias in consumption	0.5
ϕ	risk premium on foreign bond	0.2
$\frac{g}{y}$	government expenditure share in output	0.23
$\frac{C}{y}$	mean consumption to output ratio	0.36
$\frac{k}{y}$	mean capital to output ratio	1.5
σ	partial adjustment parameter	0.25
δ	depreciation rate	0.051
σ^{no}	marginal effect of nonoil price on nonoil consumption	0.01
σ^{o}	marginal effect of oil price on oil consumption	0.01
σ^{nt}	marginal effect of non-traded price on non-traded consumption	0.01
$\frac{cnt}{ynt}$	nontraded consumption share in nontraded output	0.69

Table 15: Calibrated parameters from Literature

Shocks	Description	Stationarity	AR coef
ϵ_t^o	oil productivity shock	non-stationary	0.9
ϵ_t^{NO}	non-oil productivity shock	non-stationary	0.33
ϵ_t^{NT}	non-traded productivity shock	non-stationary	0.9
ϵ_t^{YNT}	non-traded demand shock	stationary	0.92
ϵ_t^{NS}	labour supply shock	stationary	0.14
ϵ_t^{n}	labour demand shock	stationary	0.29
ϵ_t^{l}	land demand shock	stationary	0.97
ϵ_t^{KNO}	capital demand shock	stationary	0.95
ϵ_t^{KO}	capital demand shock	stationary	0.87
ϵ_t^{KNT}	capital demand shock	stationary	0.94
ϵ_t^{C}	consumption shock	stationary	0.95

Table 16: Calibrated AR coefficient of the Shock Processes

B.2 Calibrated Oil Productivity Shock

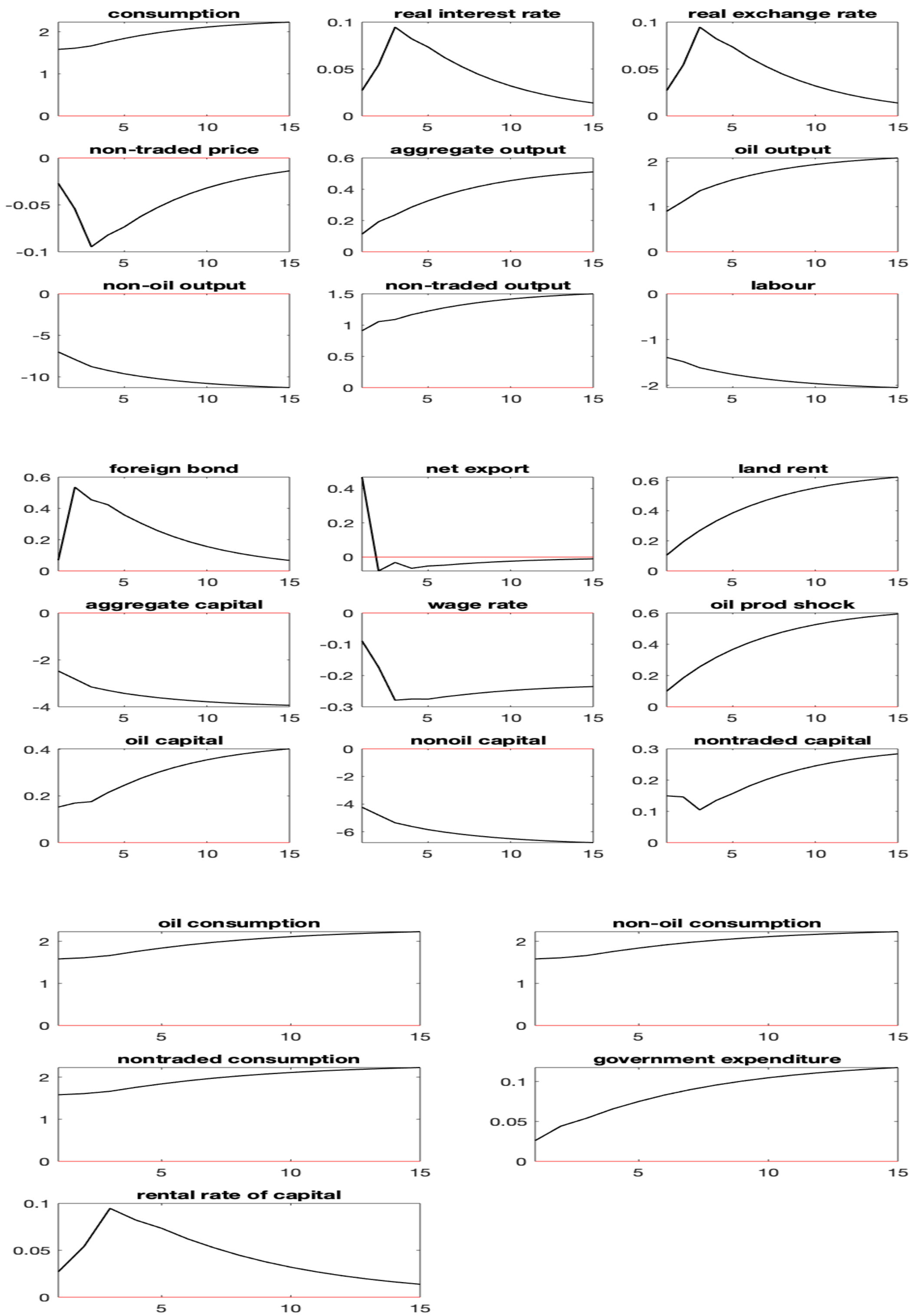

Figure 22: IRF of Calibrated Oil Productivity Shock

B.3 Calibrated Non-oil Productivity Shock

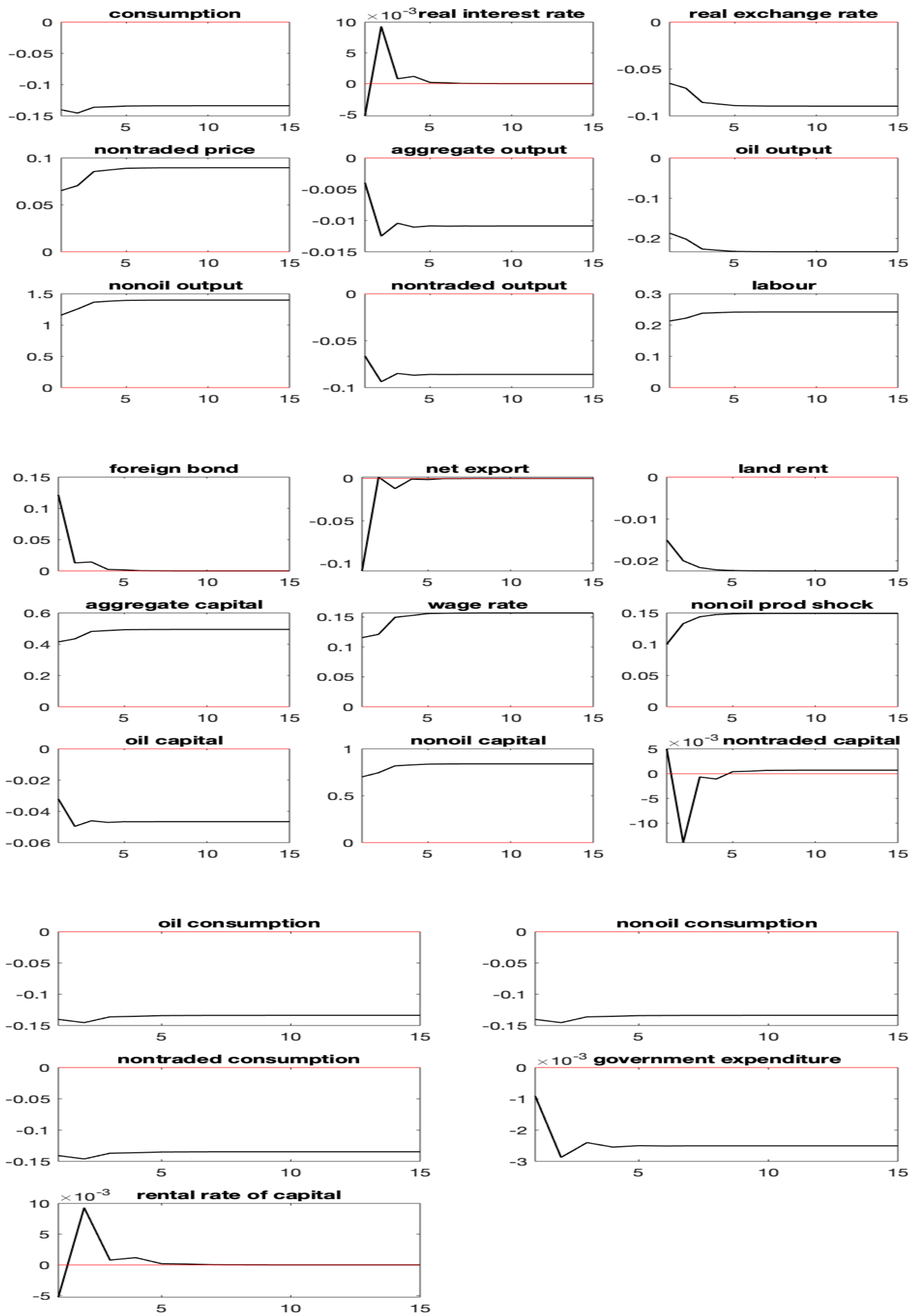

Figure 23: IRF of Calibrated Non-oil Productivity Shock

B.4 Calibrated Non-traded Productivity Shock

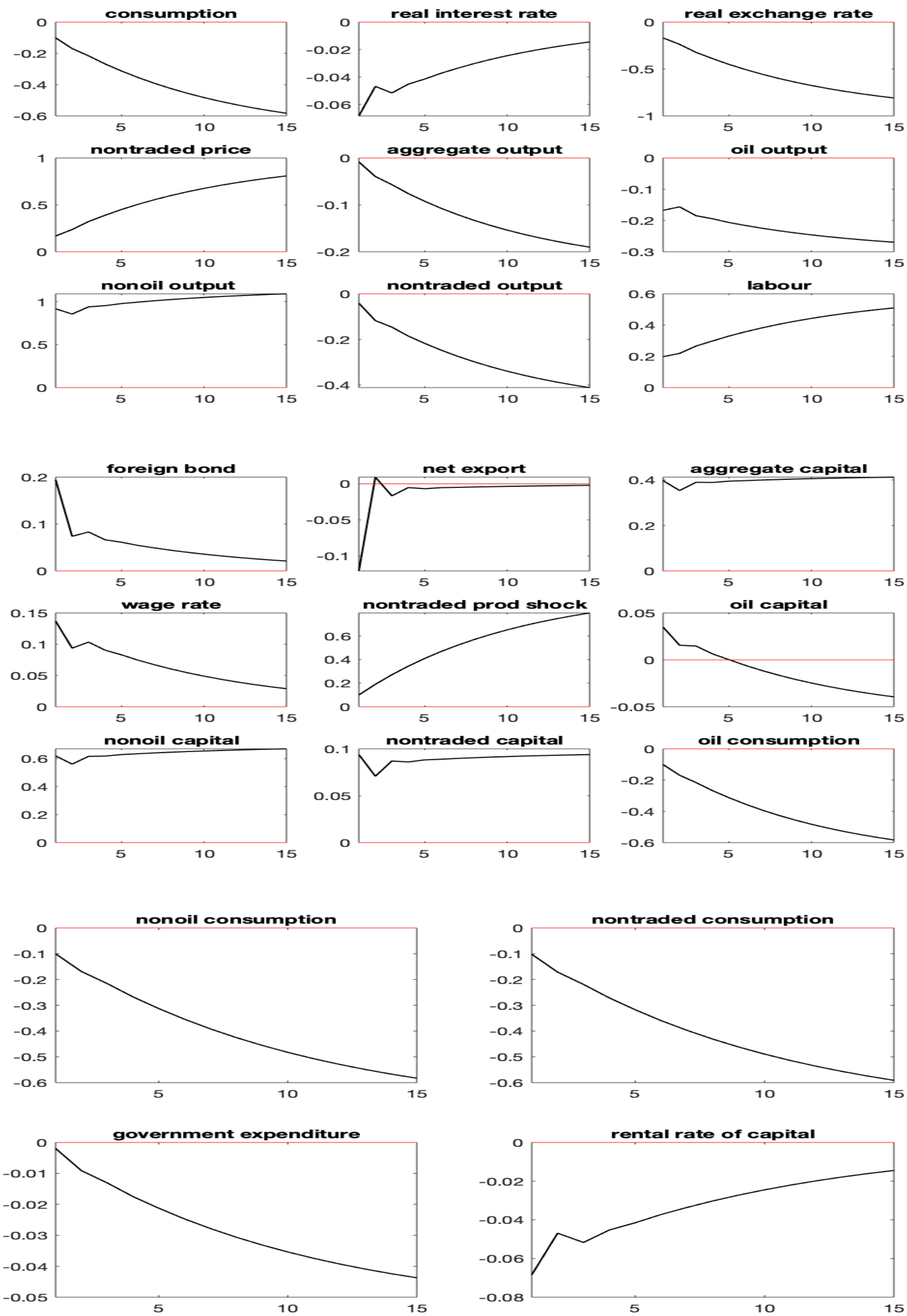

Figure 24: IRF of Calibrated Non-traded Productivity Shock

B.5 Calibrated Non-traded Demand Shock

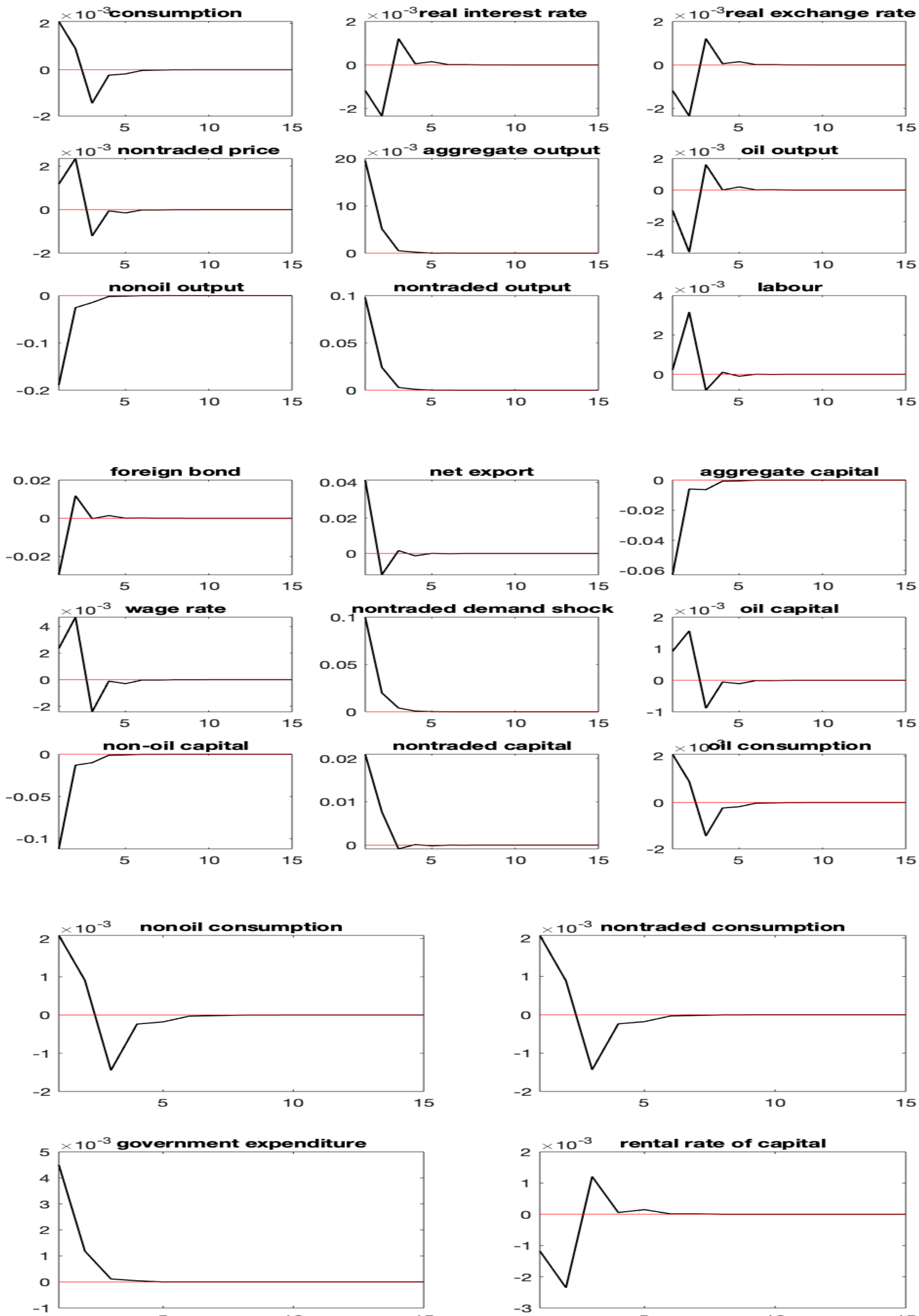

Figure 25: IRF of Calibrated Non-traded Demand Shock

B.6 Calibrated Labour Supply Shock

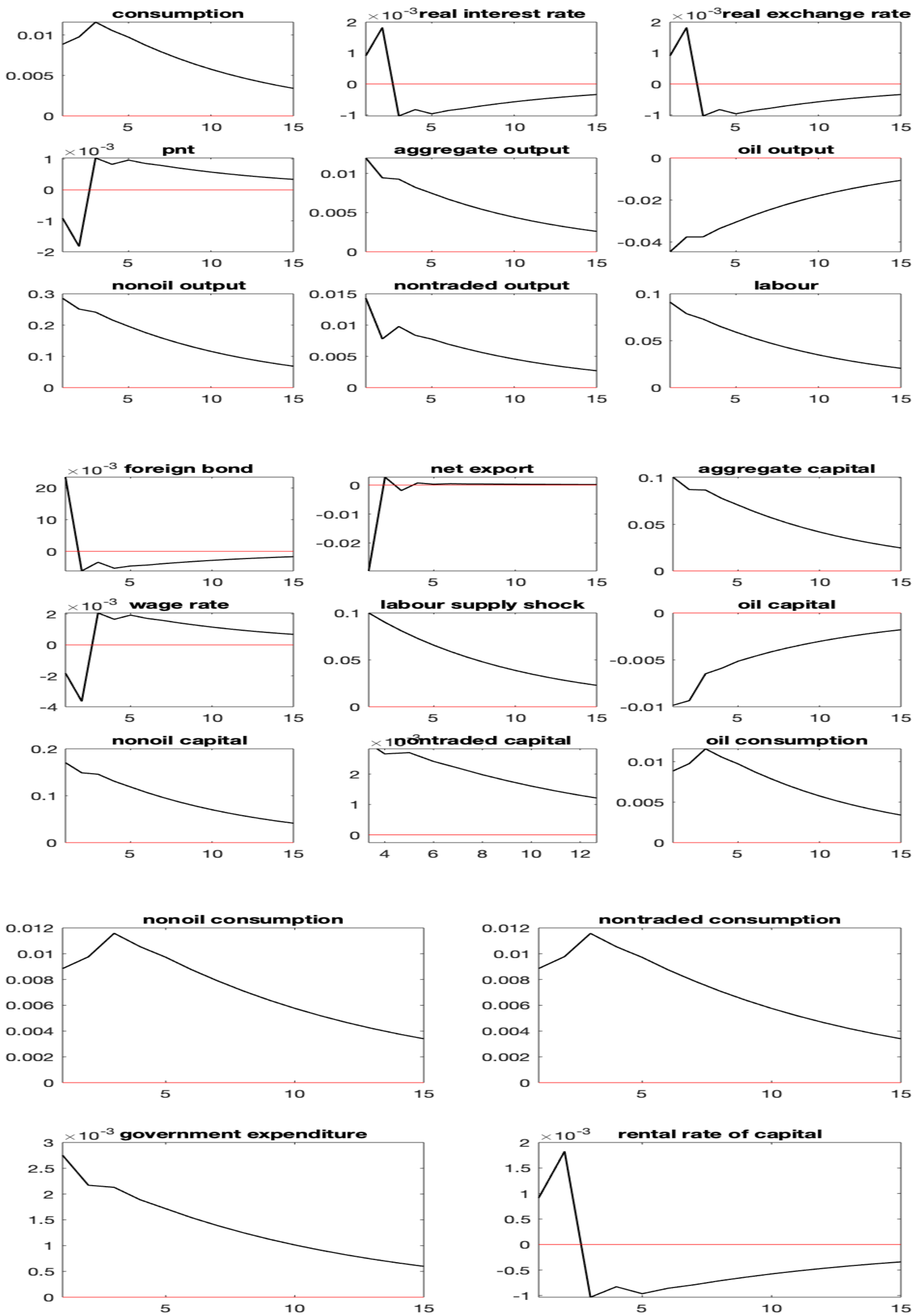

Figure 26: IRF of Calibrated Labour Supply Shock

B.7 Calibrated Labour Demand Shock

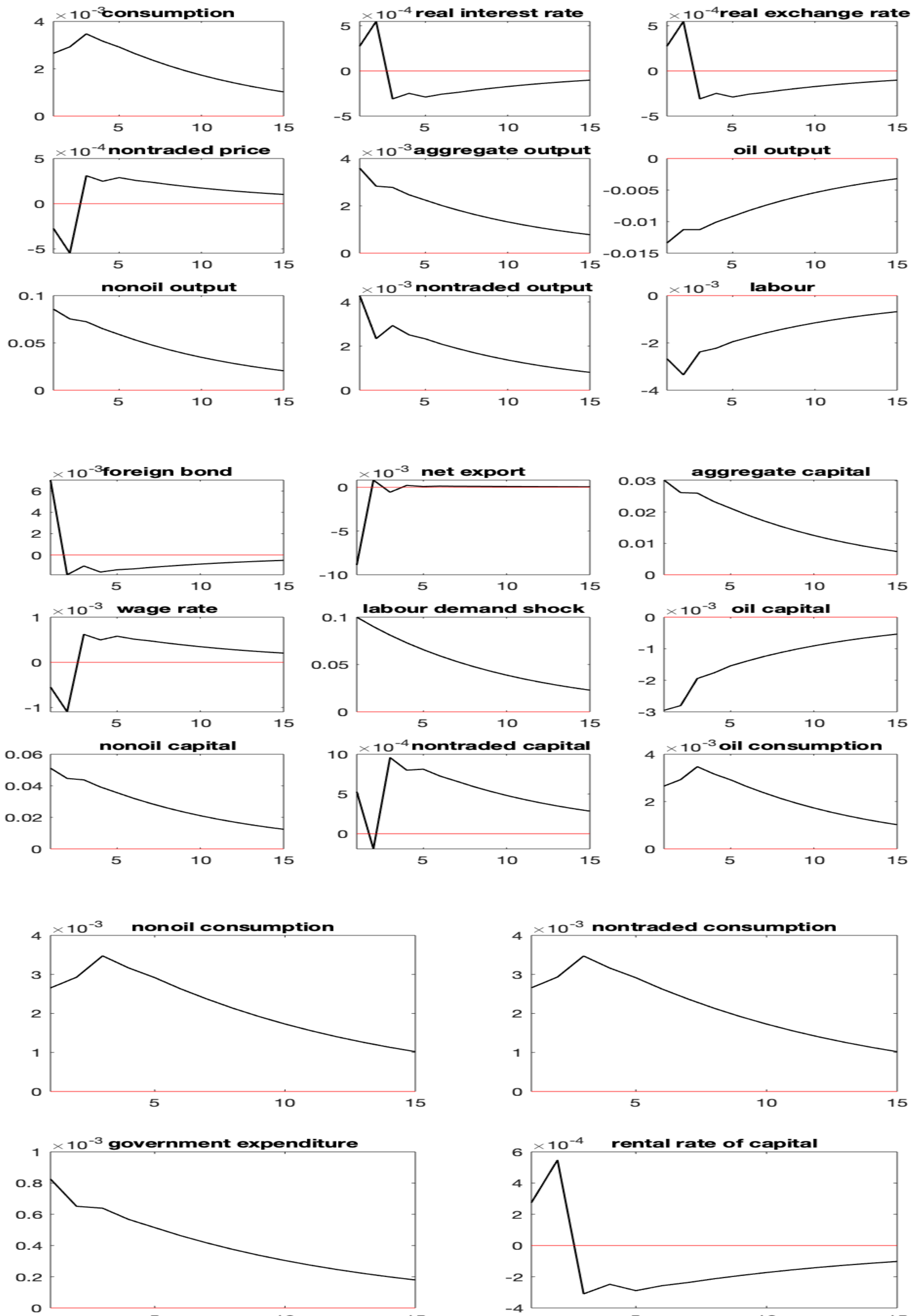

Figure 27: IRF of Calibrated Labour Demand Shock

B.8 Calibrated Land Demand Shock

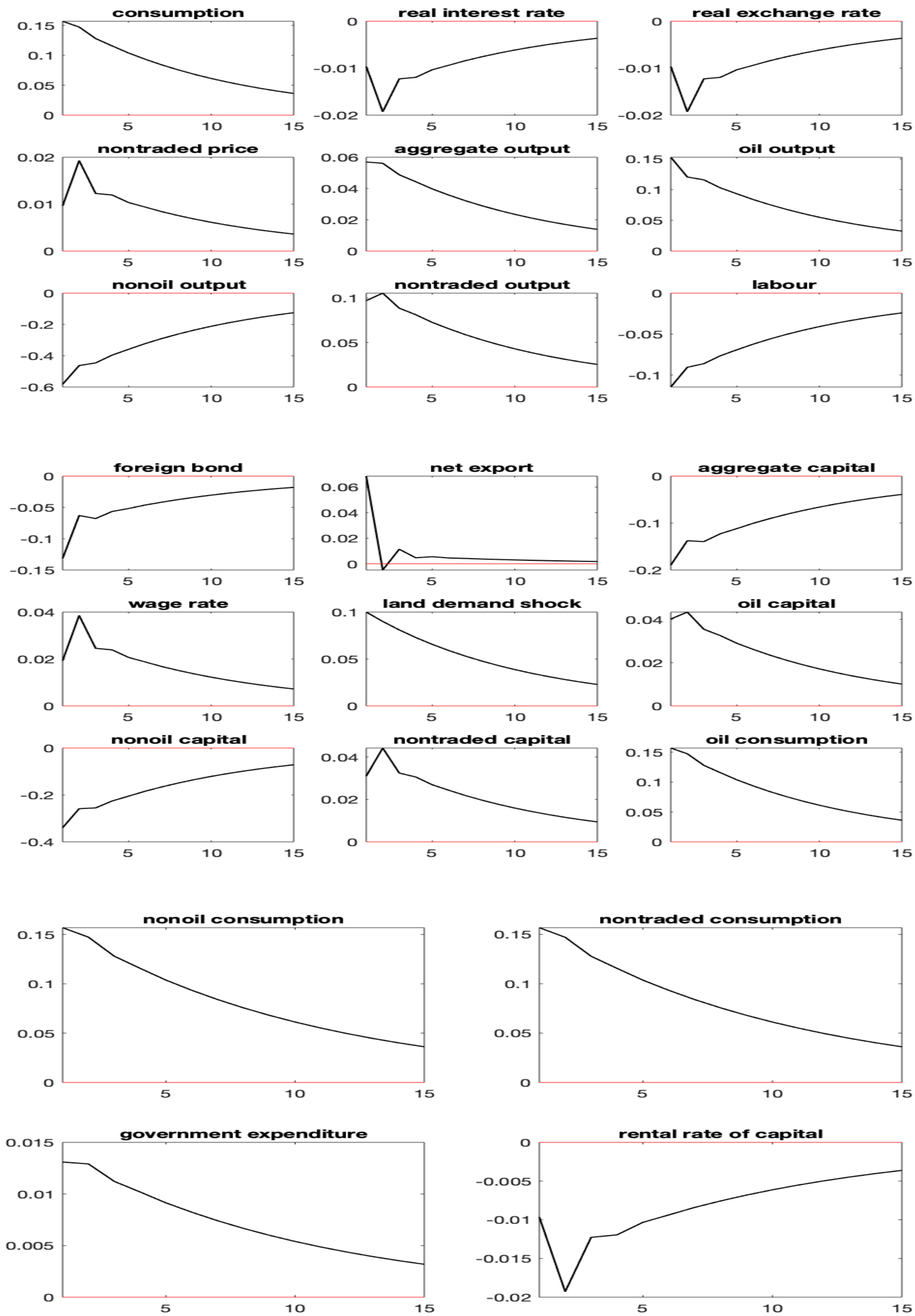

Figure 28: IRF of Calibrated Land Demand Shock

B.9 Calibrated Consumption Shock

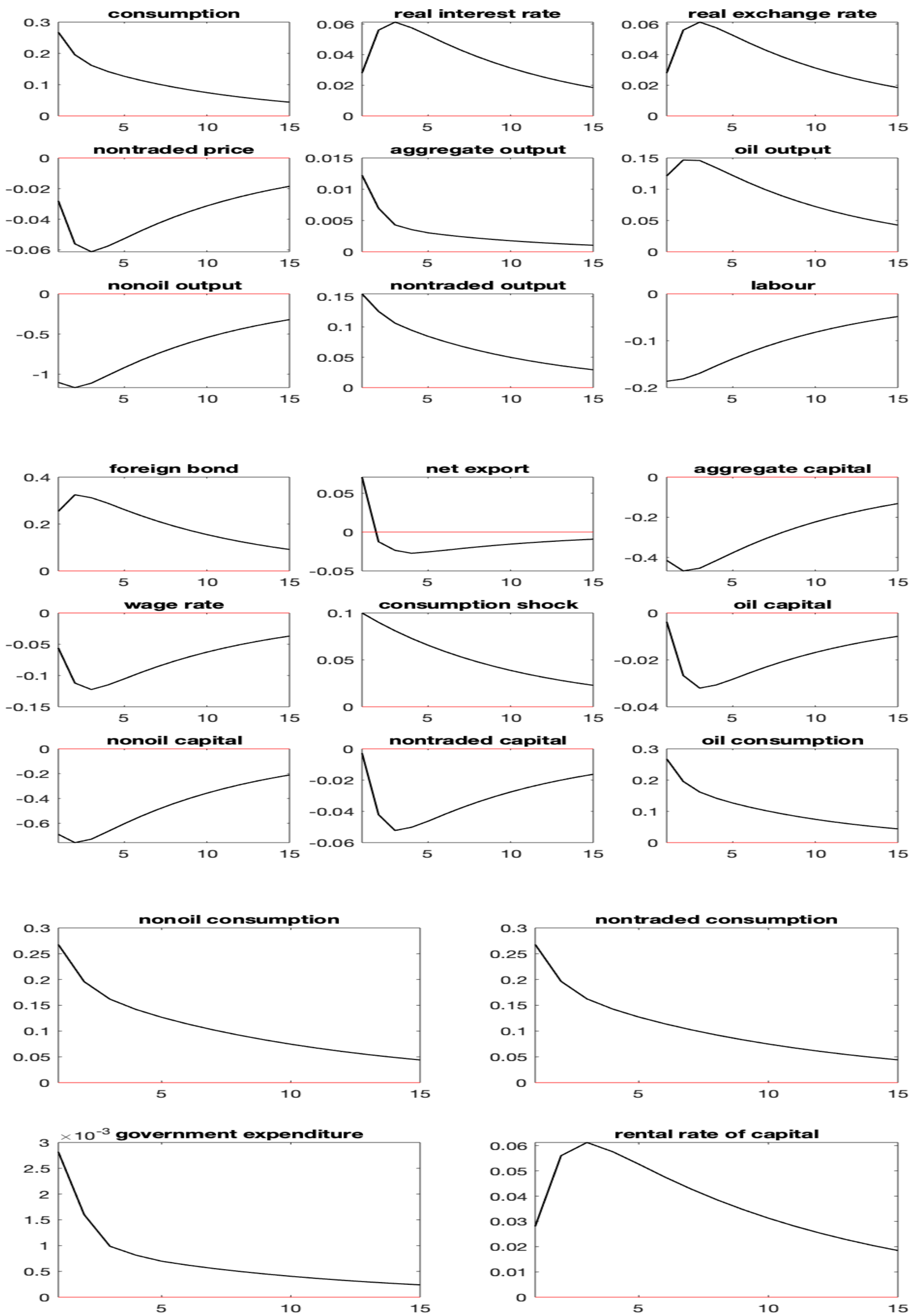

Figure 29: IRF of Calibrated Consumption Shock

C Appendix - IRFs of Estimated Model

C.1 Estimated Parameters of the Model

Parameter	Role	Value
ρ_0	CRRA coefficient for c_t	1.2
ρ_2	CRRA coefficient for N_t	1.1
θ_0	home bias in consumption	0.32
ϕ	risk premium on foreign bond	0.13
$\frac{g}{y}$	government expenditure share in output	0.21
$\frac{C}{y}$	mean consumption to output ratio	0.29
$\frac{k}{y}$	mean capital to output ratio	0.86
σ	partial adjustment parameter	0.13
δ	depreciation rate	0.053
σ^{no}	marginal effect of nonoil price on nonoil consumption	0.014
σ^{o}	marginal effect of oil price on oil consumption	0.013
σ^{nt}	marginal effect of non-traded price on non-traded consumption	0.0068
$\frac{cnt}{ynt}$	nontraded consumption share in nontraded output	0.66

Table 17: Indirect Estimated Parameters

Shocks	Description	Stationarity	AR coef
ϵ_t^o	oil productivity shock	non-stationary	-0.38
ϵ_t^{NO}	non-oil productivity shock	non-stationary	-0.41
ϵ_t^{NT}	non-traded productivity shock	non-stationary	-0.44
ϵ_t^{YNT}	non-traded demand shock	stationary	0.92
ϵ_t^{NS}	labour supply shock	stationary	0.14
ϵ_t^{n}	labour demand shock	stationary	0.29
ϵ_t^{l}	land demand shock	stationary	0.97
ϵ_t^{KNO}	capital demand shock	stationary	0.95
ϵ_t^{KO}	capital demand shock	stationary	0.87
ϵ_t^{KNT}	capital demand shock	stationary	0.94
ϵ_t^{C}	consumption shock	stationary	0.95

Table 18: Estimated AR coefficients and Stationary of the Shock Processes

C.2 Estimated Oil Productivity Shock

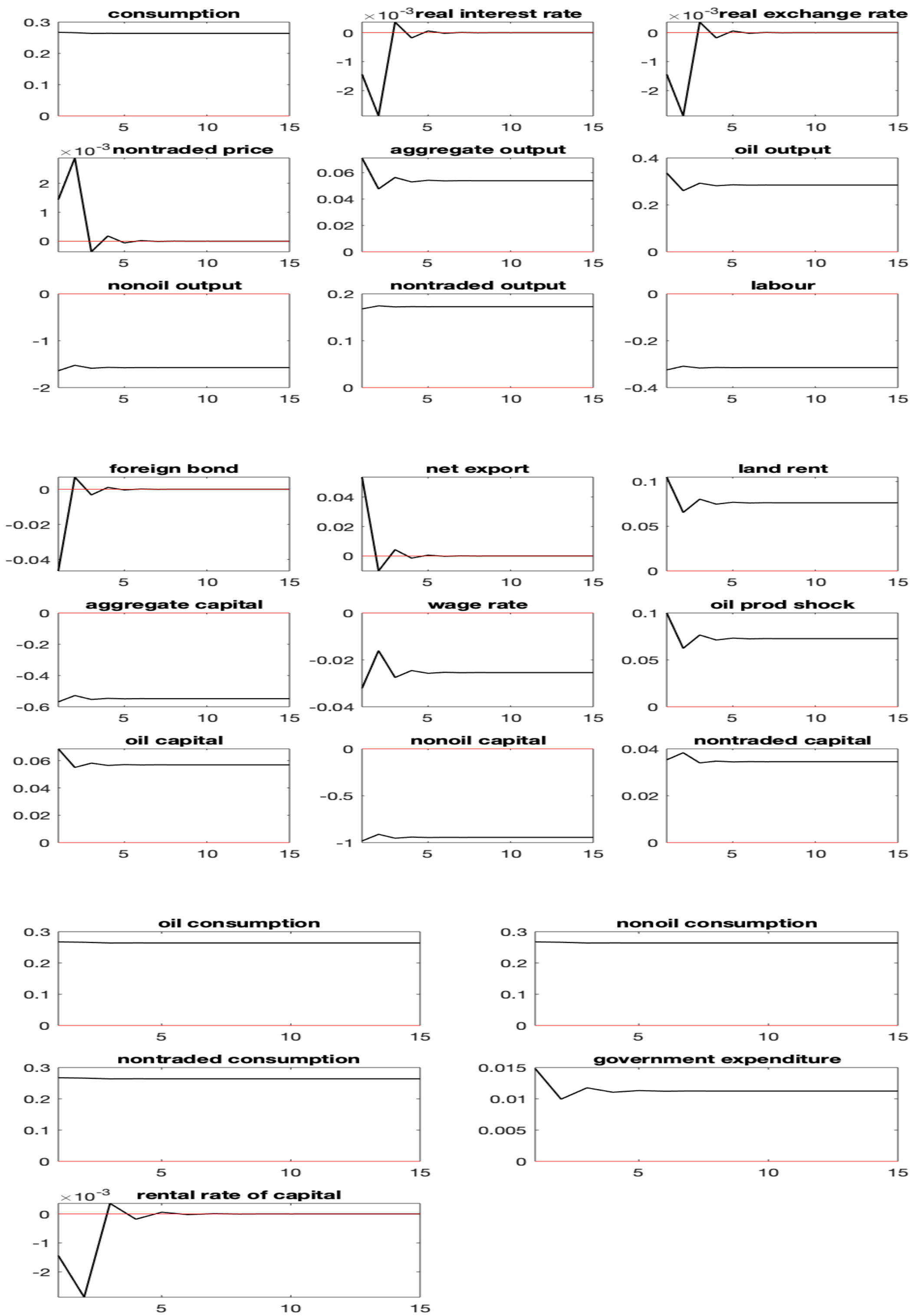

Figure 30: IRF of Estimated Oil Productivity Shock

C.3 Estimated Non-oil Productivity Shock

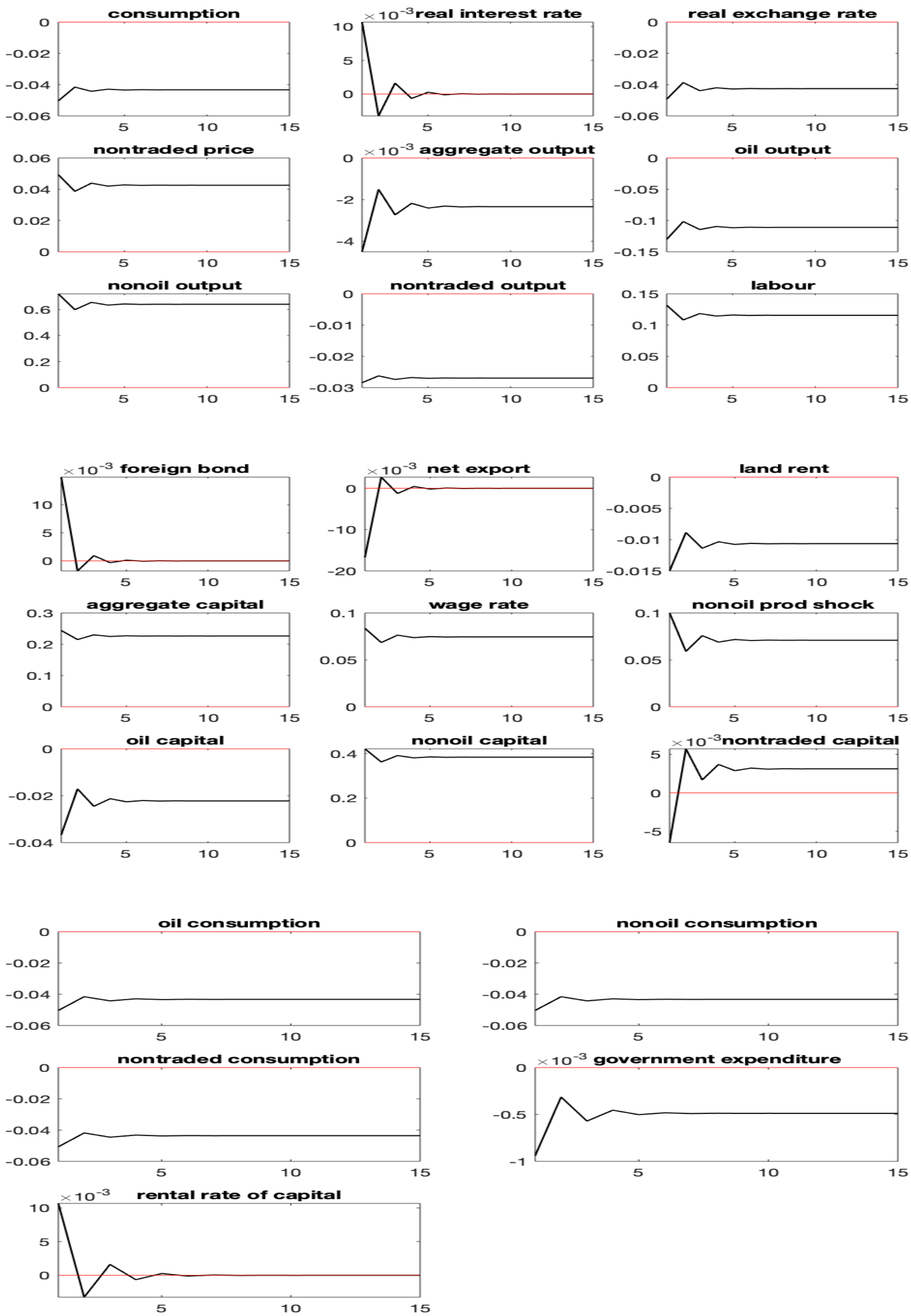

Figure 31: IRF of Estimated Non-oil Productivity Shock

C.4 Estimated Non-traded Productivity Shock

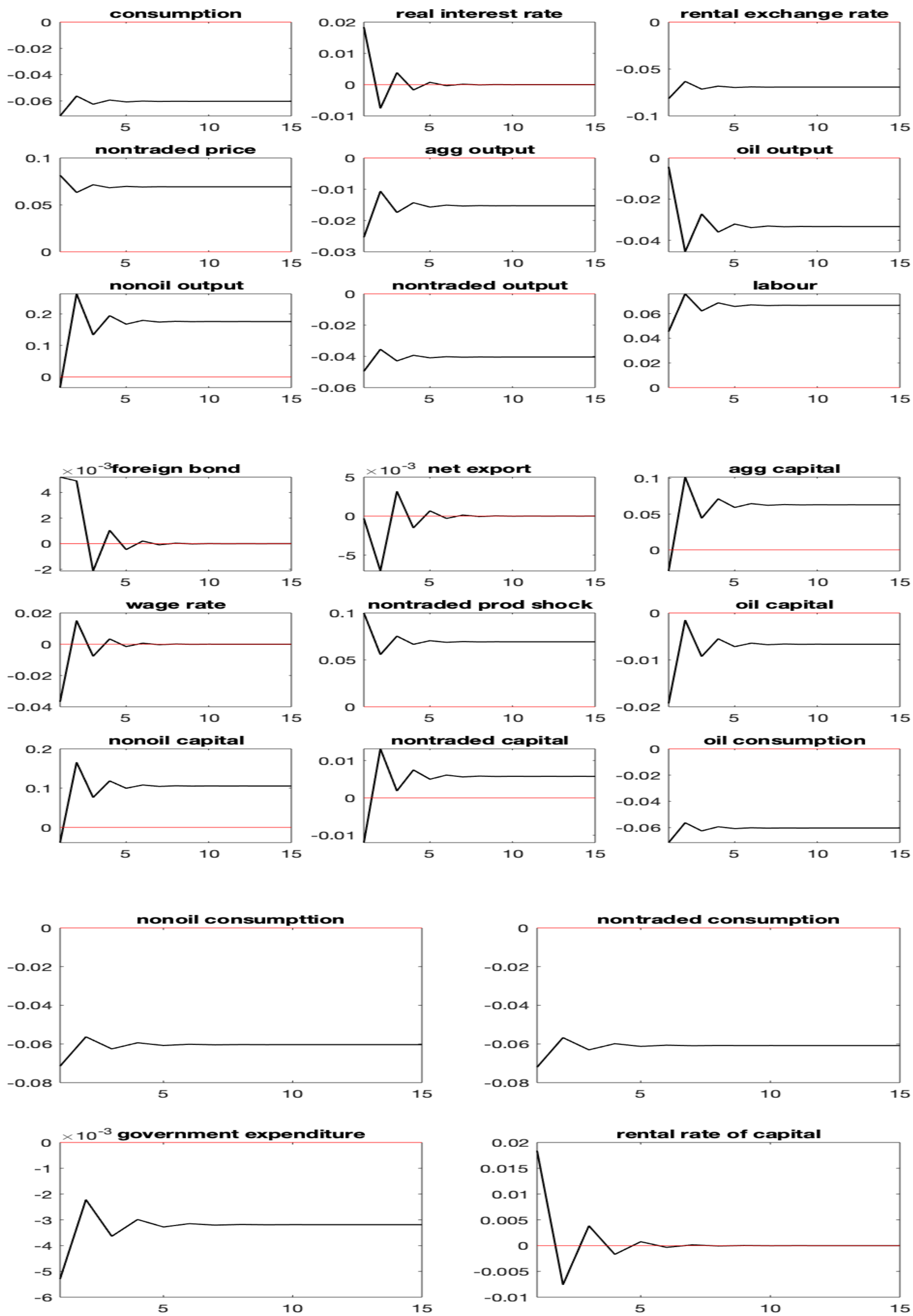

Figure 32: IRF of Estimated Non-traded Productivity Shock

C.5 Estimated Labour Supply Shock

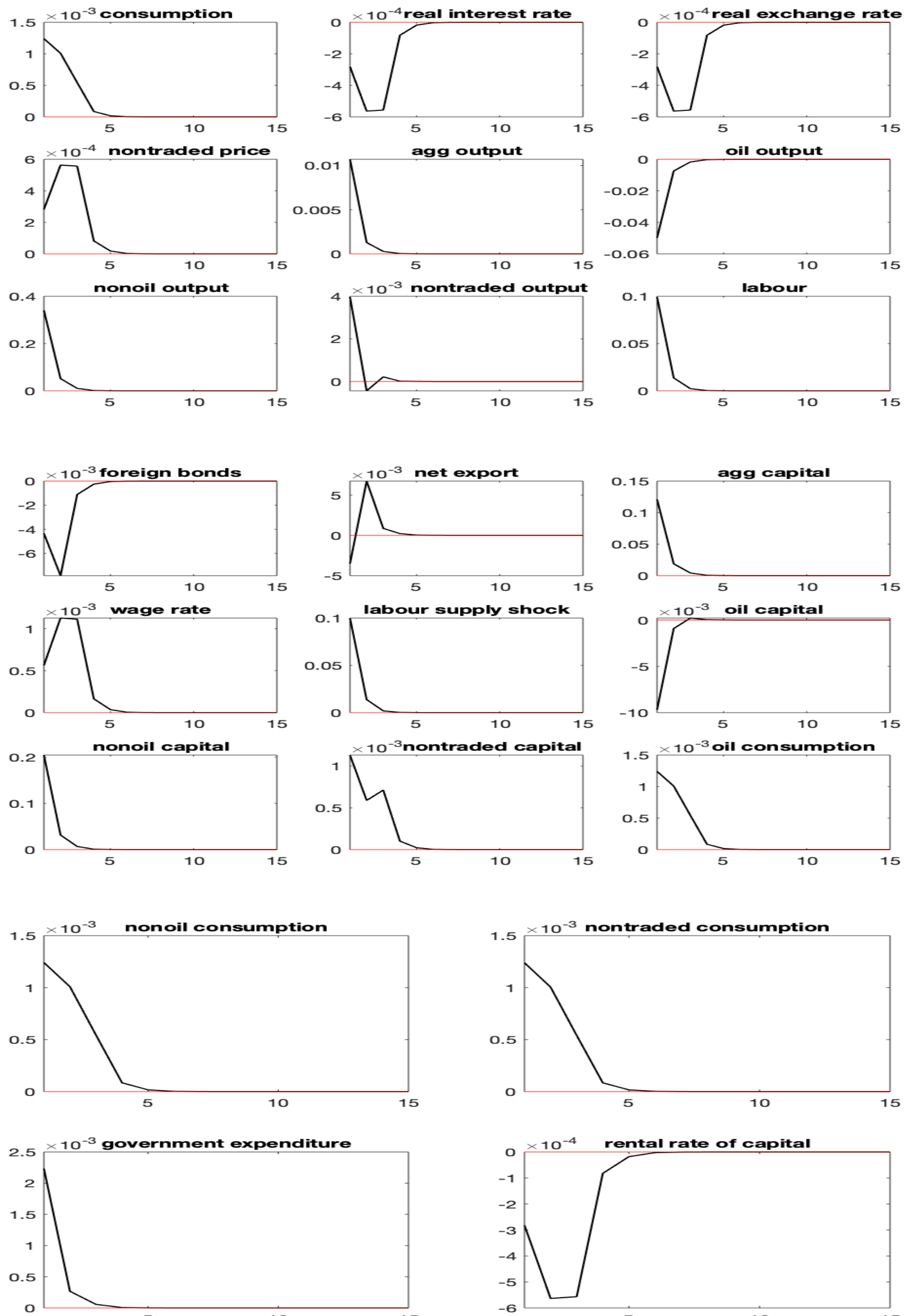

Figure 33: IRF of Estimated Labour Supply Shock

C.6 Estimated Non-traded Demand Shock

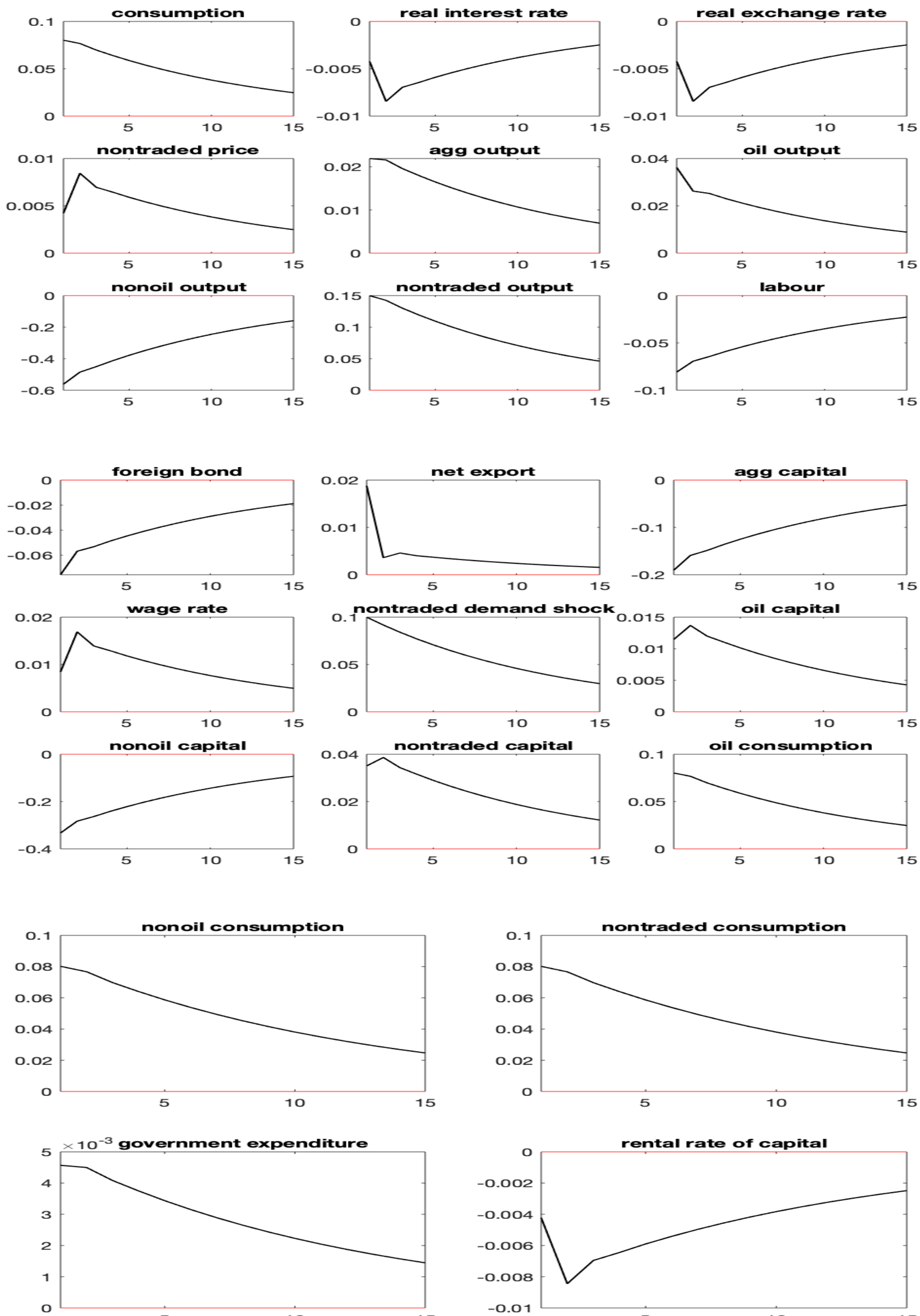

Figure 34: IRF of Estimated Non-traded Demand Shock

C.7 Estimated Land Demand Shock

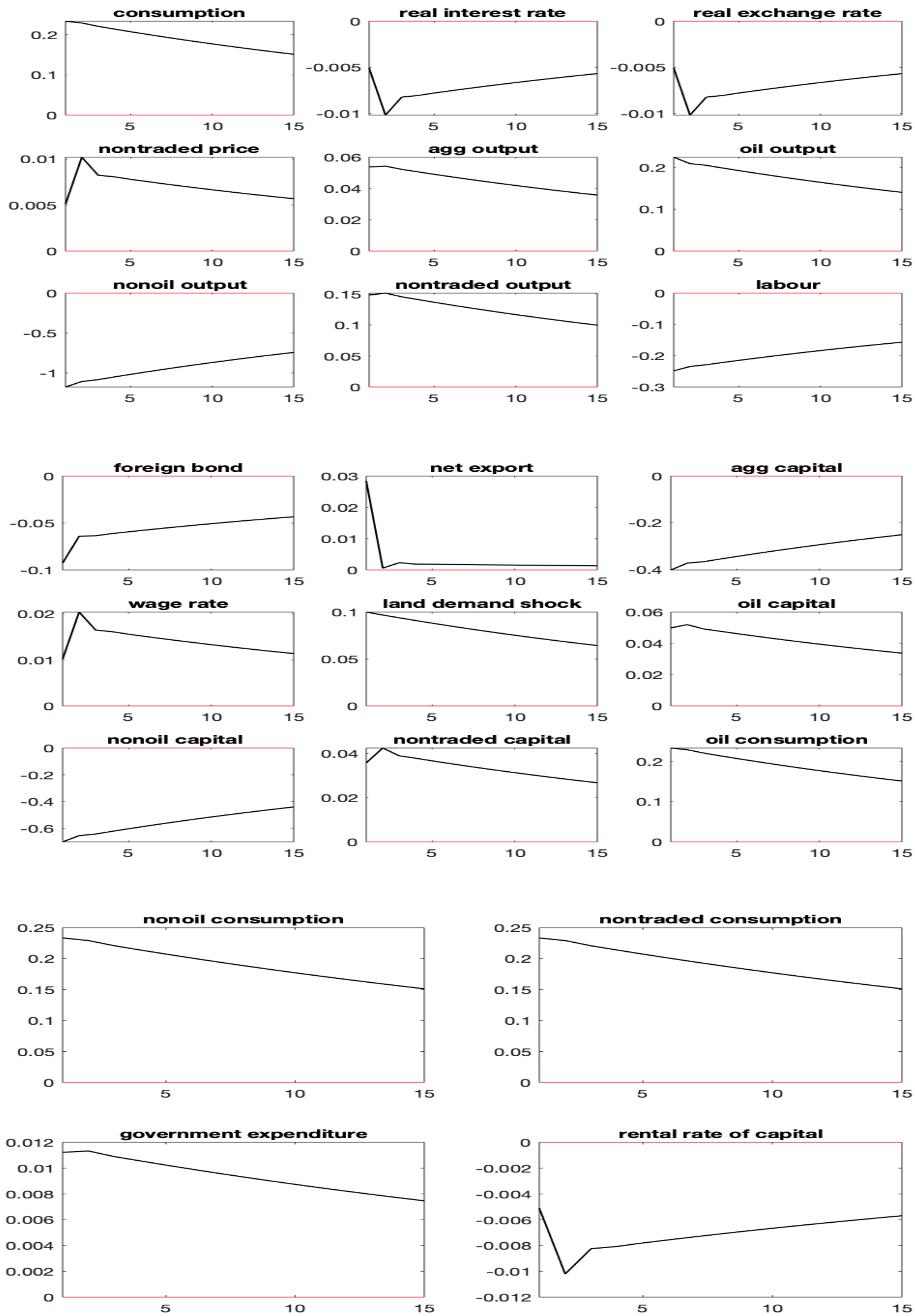

Figure 35: IRF of Estimated Land Demand Shock

C.8 Estimated Labour Demand Shock

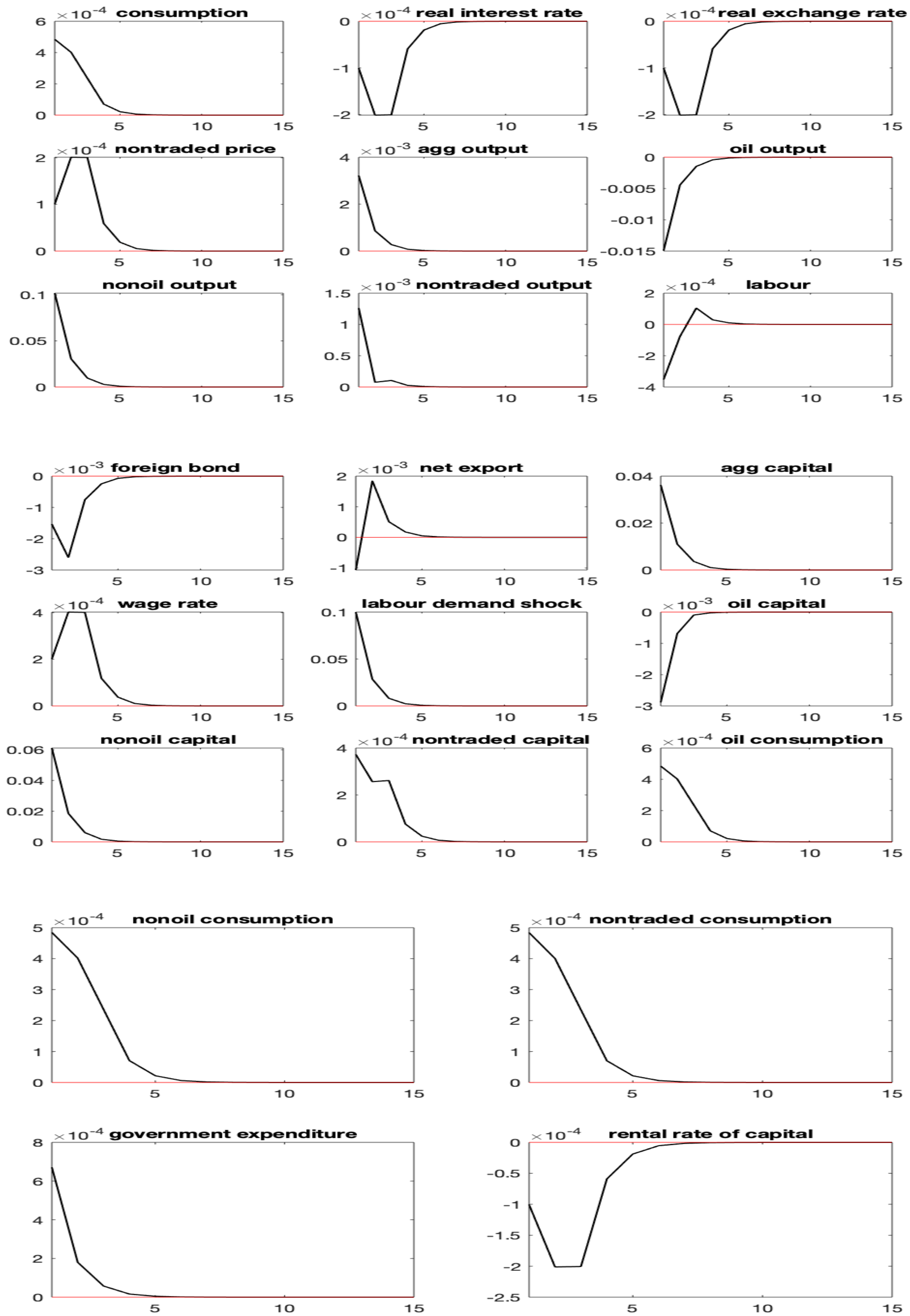

Figure 36: IRF of Estimated Labour Demand Shock

C.9 Estimated Private Consumption Shock

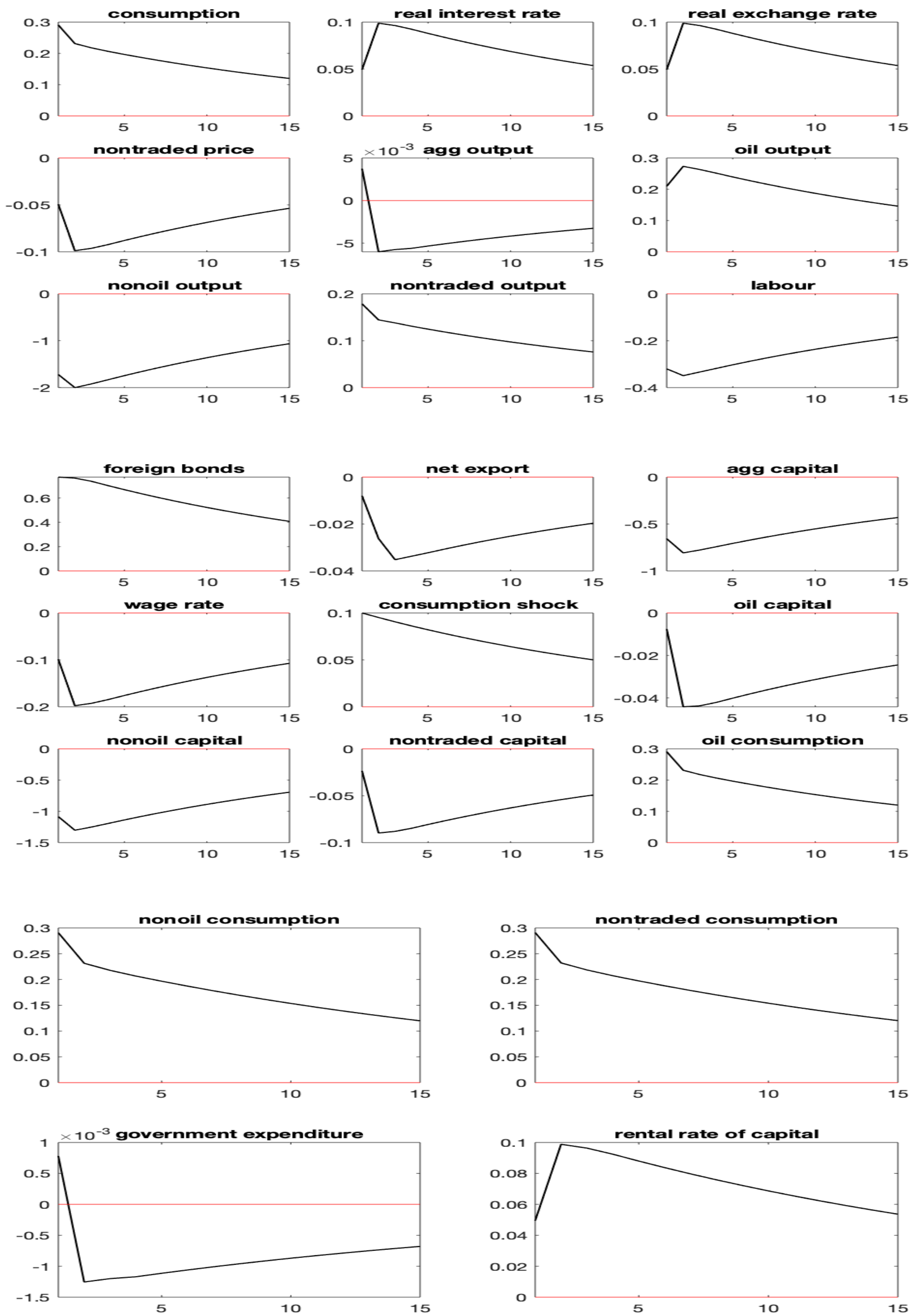

Figure 37: IRF of Estimated Private Consumption Shock

C.10 Estimated Government Expenditure Shock

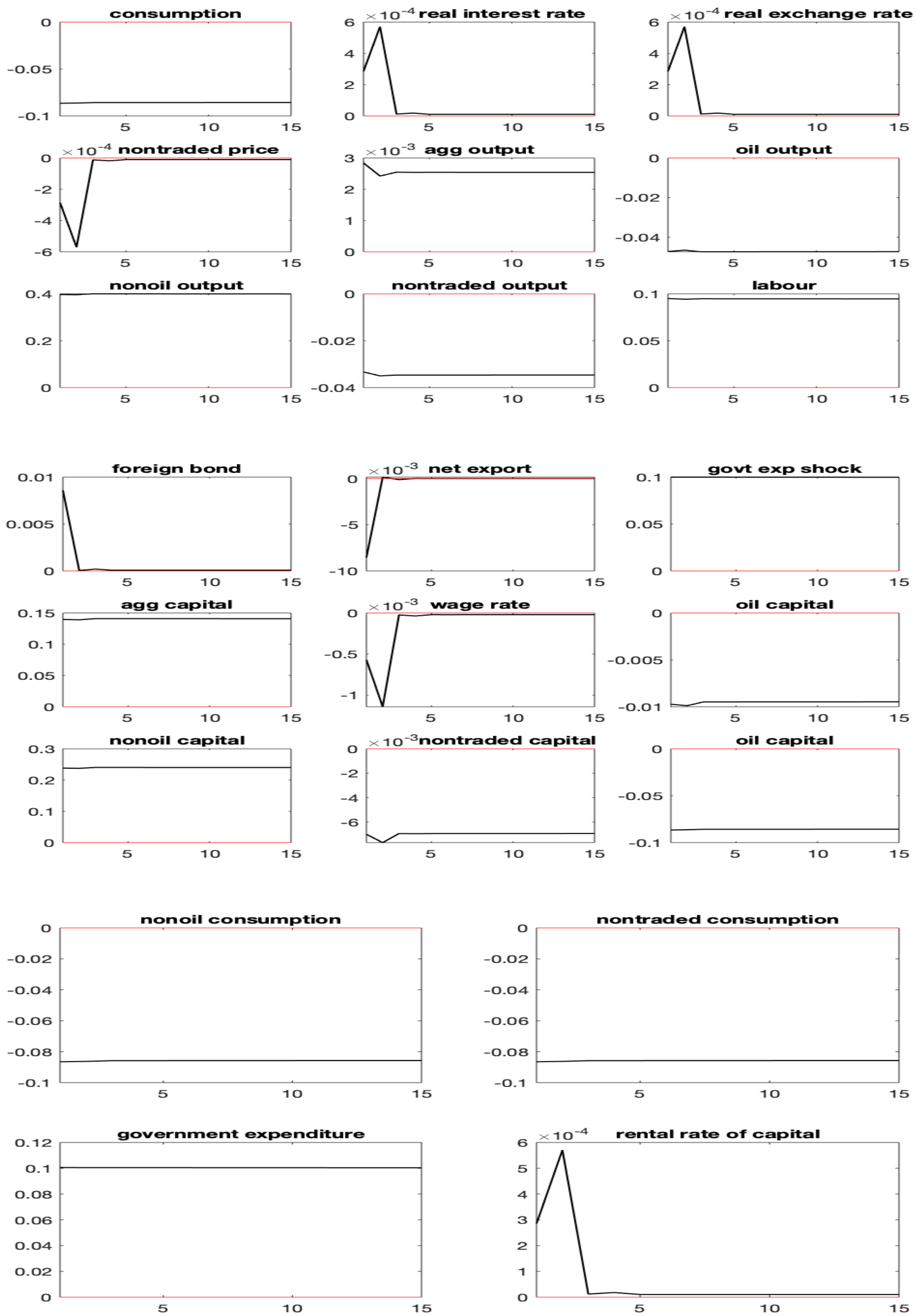

Figure 38: IRF of Estimated Government Expenditure Shock

C.11 Estimated Oil Price Shock

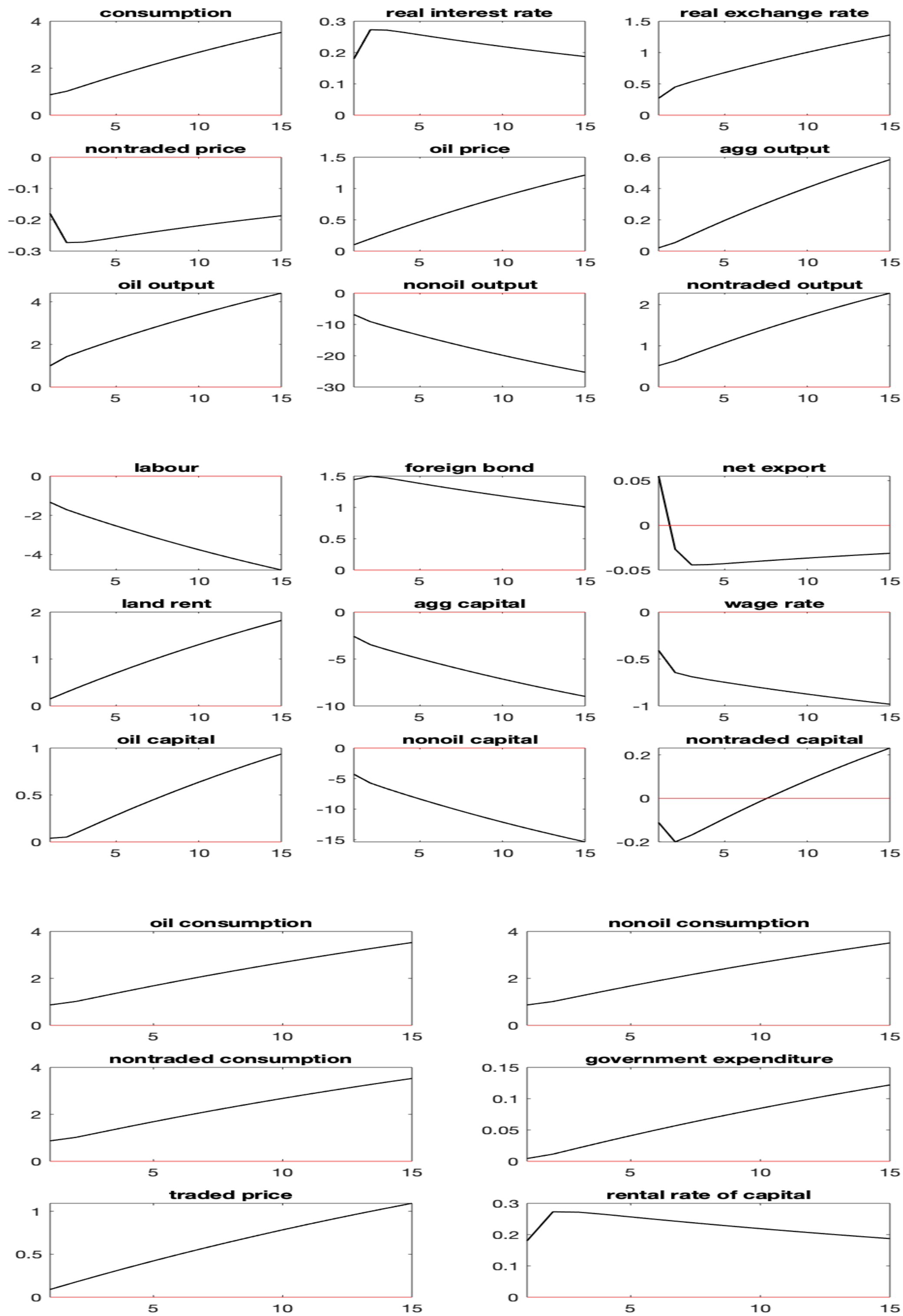

Figure 39: IRF of Estimated Oil Price Shock

C.12 Estimated Non-oil Price Shock

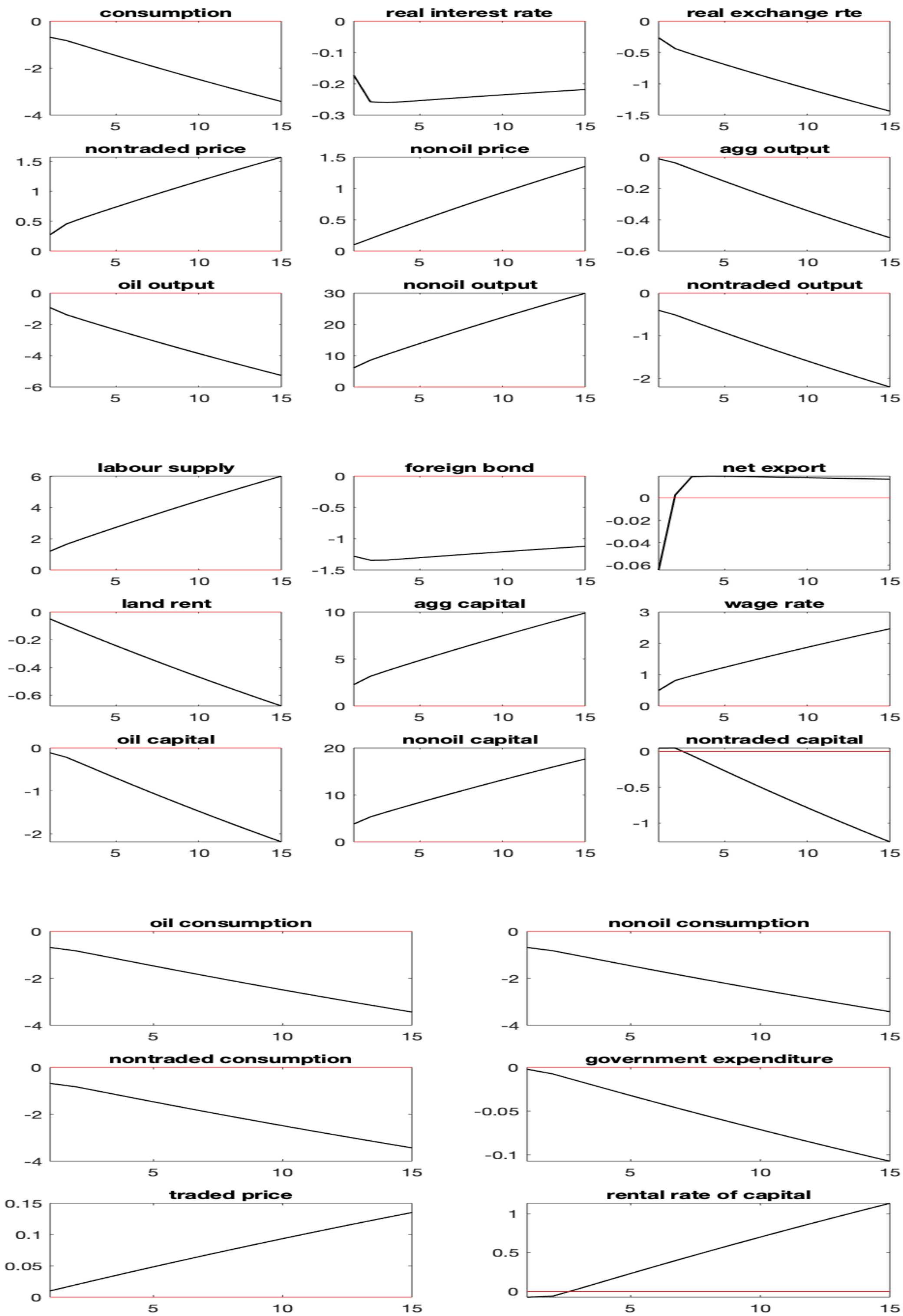

Figure 40: IRF of Estimated Non-oil Price Shock

C.13 Estimated Labour Subsidy Shock in the Non-oil Sector

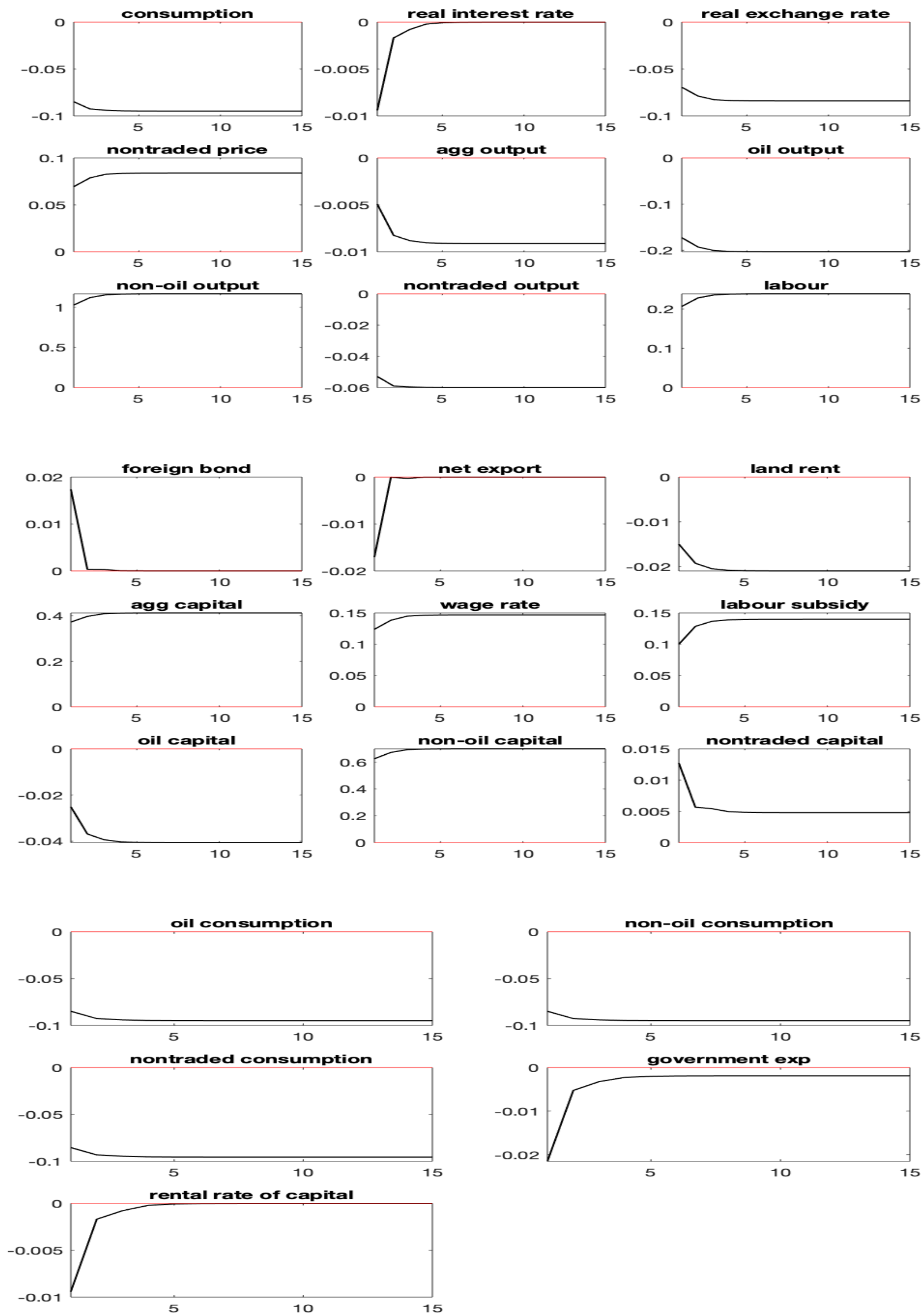

Figure 41: IRF of Estimated Labour Subsidy Shock in the Non-oil Sector