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ESSAYS ON
MACROECONOMIC FLUCTUATIONS AND EXPORT COMMODITY SECTORS OF EMERGING ECONOMIES

THESIS PRESENTED AS PARTIAL REQUIREMENT OF
DOCTOR OF PHILOSOPHY IN ECONOMICS

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Declaration

I declare that this thesis work is my original contribution and has not been presented for degrees in any other academic institution. To the best of my knowledge, no previously published and unpublished works are included without being duly acknowledged.

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Abstract

This thesis consists of a brief introductory chapter and two main chapters that identify the importance of the export commodity sector as a transmission of external shocks to emerging economies. The first chapter is an introductory chapter where a brief economic growth, macroeconomic questions, and vulnerability of emerging economies to external shocks are briefly highlighted from African economies perspective.

In the second chapter, a Bayesian Vector Autoregressive (BVAR) model was employed to investigate the relationship between export commodity prices and economic activity in selected African economies. The results reveal that emerging economies do indeed respond to external shocks, and the intensity of their response varies across different economies. Particularly noteworthy is the heightened output reaction in low-income economies with limited shock absorption capacity. These findings underscore the significant role played by export commodity prices as a transmission channel for external shocks in emerging economies, emphasizing the need to incorporate this unique sector in macroeconomic modeling.

Using the results from the second chapter as a steppingstone, the third chapter centers on Morocco, a small open emerging economy with a heavy reliance on phosphate mineral exports. A New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model was developed to assess how key macroeconomic variables in Morocco react to both domestic and external shocks. The research confirms the theoretical predictions

and empirical evidence regarding small open economies while emphasizing the role of Morocco's distinctive mineral sector, closely tied to global market pricing, as a conduit for external shocks impacting the country's economy.

These studies are not without their limitations. Although the chapter-specific limitations are specified in the respective chapters, the two main chapters share a common limitation of focusing on short-term economic fluctuations of emerging markets rather than long-term economic growth. The general introductory chapter highlighted medium and long-term growth trends. However, it is important to note that the next two main chapters of the thesis focus mainly on explaining short-term growth and business cycle fluctuations of African emerging economies. Therefore, the agenda of understanding the medium- and long-term growth drivers of emerging economies is left as a future agenda.

In conclusion, these studies shed light on the consequences of a limited reliance on commodity exports in emerging economies. They highlight the significance of external shock transmission mechanisms and the need for nuanced macroeconomic modeling to account for the unique characteristics of these economies.

Keywords: Emerging economies; BVAR; DSGE; Export commodity price.

CHAPTER I

INTRODUCTION

Emerging economies have a significant place in the global economic scene, making their economic performance a topic of keen interest for economists, policymakers, and investors alike. The African continent is home to a range of emerging economies with varied economic conditions, abundant natural resources, and, more importantly, growth potential. The investigation into the roots of economic growth, or lack thereof, in Sub-Saharan Africa garnered significant interest after the seminar paper by Barro (1991). The prominent finding from Barro (1991) later validated by Sala-i Martin et al. (2004) is that Africa's growth dynamics possess a distinctive quality, and the conventional determinants of economic growth do not fully elucidate the growth patterns within African economies. The Barro enigma, and the empirical evidence that followed it, have long been a puzzle in the field of economic growth literature. A key aspect of this riddle is the question of what truly drives growth in African economies, and the extent of external shock's influence has garnered increased attention. In line with this, the quest to understand the main drivers of short-term economic fluctuations in African economies has remained one of the main research agendas.

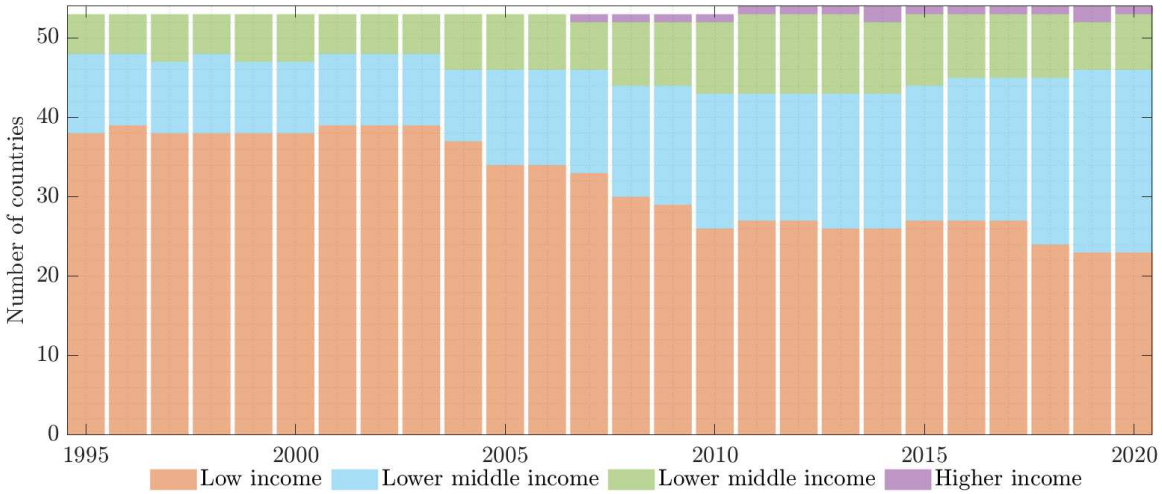
While it is undeniable that African economies are either low-income or emerging countries, they operate within their distinctive economic orbits. These orbits are influenced by their economic makeup, historical legacies, and global economic trends, resulting in significant economic diversity across the continent. Despite the challenges that African economies face, such as climate change and natural disasters, weak infrastructure, and political instability, they have made significant progress in improving their macroeconomic fundamentals since the beginning of the century (Chitonge, 2015). One example of this progress is the increasing number of African countries that were classified as low-income but have now transitioned into the middle-income

group since the turn of the century. However, exiting poverty and achieving prosperity is a lengthy process, and African economies must maintain a steady pace of sustainable growth together with stabilizing short-term business cycle fluctuations. While some experts caution against overly optimistic predictions, positive developments have given rise to hope and expectations that the goal of lifting millions out of poverty in the region by 2030 is achievable (Frankema and Van Waijenburg, 2018).

As of the 2020 classification[1] by the WB, economies are grouped into four categories depending on their Gross National Income (GNI) per capita, as determined by the World Bank Atlas methodology. Of the economies grouped by income, 23 out of 27 of the world's low-income countries are from Africa (refer to Figure 1.1). This underscores the significant challenge confronting African economies despite recent developments attributed to investments in infrastructure and industrialisation, as well as policies aimed at promoting Foreign Direct Investment (FDI), among other factors.

Despite the challenging historical circumstances, Africa has maintained an average annual growth rate of over 5% since 2000. Furthermore, several economies in Africa have been successful in creating a growth miracle, as reported by (Ncube, 2015). For example, South Africa overcame significant economic and social inequalities that were connected to its history of apartheid and has achieved significant progress towards a better economic outlook. Currently, South Africa is one of only two high-income countries on the continent. The country's success story has been built upon its abundant natural resources, developed economy, and thriving financial sector. Many other nations in Africa, such as Ethiopia, Botswana, Ghana, Egypt, Angola, and

[1]For the 2022 fiscal year, economies are classified into four groups based on their World Bank Atlas method calculated Gross National Income (GNI) per capita level. Accordingly, low-income, lower-middle-income, upper-middle-income and middle-income economies are defined as those with a respective 2020 GNI per capita of $\$1,045$ or less, between $\$1,045$ and $\$4,095$, between $\$4,096$ and $\$12,695$, and $\$12,696$ or more.



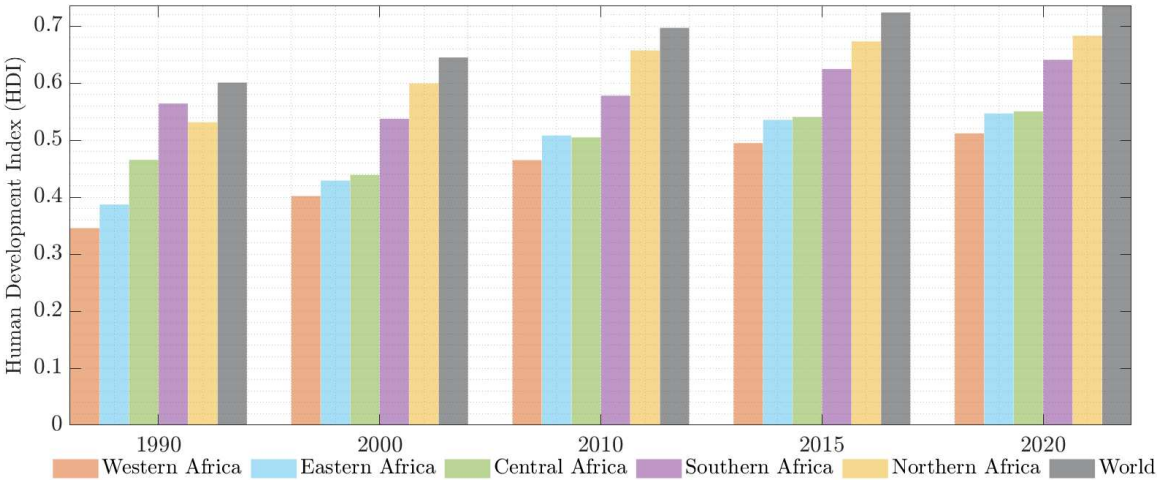
Source: Author's computation using data from the WB - World Development Indicators (WDI) (2023)

Figure 1.1: WB's Income classification of African economies over time, 1987 - 2022

Nigeria have also achieved similar success.

Addressing the complex and multifaceted macroeconomic issues confronting emerging African economies is crucial. However, the primary focus is on facilitating economic reform and diversification, promoting inclusive growth, ensuring fiscal sustainability, developing infrastructure, and attracting foreign direct investment (van Niekerk, 2020). Criticism has been raised towards the recent economic growth improvements in African economies for being inadequately inclusive in ensuring the benefits are shared across all segments of the population (Ncube, 2015). As can be observed from Figure 1.2, the African continent is still falling behind the global average in terms of human development index levels. Therefore, it remains to be determined whether African economies can convert every iota of economic growth into an inclusive growth and development process that can result in poverty reduction.

As generating sustainable and inclusive economic growth remains a pressing issue in Africa, it is imperative to identify the key factors driving this growth and its short-term fluctuations. Although factors of domestic origin are crucial, African economies



Source: Author's computation using data from the United Nations Development Programme (UNDP) (2022)

Figure 1.2: Human development levels of African economies over period, 1990 - 2020

often face external shocks, which also warrant investigation. Historically, African economies have heavily relied on few, if not a single, sectors such as oil, minerals, and agriculture. This reliance has left African economies susceptible to external shocks, commodity price fluctuations, and climate change that impact their performance in these sectors. Therefore, fiscal deficits and challenges in the diversification of the economy are among the priority issues for policymakers in Africa.

External shocks to African economies are unpredictable events that disrupt their economic performance. In Africa, these shocks are evident in recurring changes to the climate, including drought and flooding, fluctuations in commodity prices, instability in global finance, and geopolitical instability. Geopolitical conflicts in several regions across the continent greatly disrupt trade flows, damage the already inadequate infrastructure, and prohibit the countries from fully harnessing their potential (Ferreira et al., 2023). The progress of African economies has been significantly hampered by the global financial crisis and subsequent recessions, as these adverse shocks result in sudden capital outflows, currency depreciation, and increased borrowing costs (Allen

and Giovannetti, 2011; Aryeetey and Ackah, 2011). Empirical research by McGregor (2017), Hirsch and Lopes (2020) and Sanya (2020) has confirmed the negative effect of frequent fluctuations in commodity prices on the economic performance of African countries. This calls for a meticulous and thorough inquiry to comprehend the function and chart a well-defined route of transmitting external shocks to African economies. This will aid policymakers in devising alternative coping mechanisms to withstand the impact of external shocks and foster a more robust and flourishing future, impeding any risk of fiscal crises and economic volatility.

Despite extensive empirical contributions attempting to understand the impact of external shocks on emerging economies, opinions on the topic remain divided. Nevertheless, compelling evidence in favour of external shocks as the primary driving force behind macroeconomic fluctuations in emerging economies has been found in empirical works by Kose and Riezman (2001), Canova (2005), Maćkowiak (2007), Abrego and Österholm (2010), McGregor (2017) and Avom et al. (2021). However, there is strong evidence to support the narrative that economic fluctuations in Africa stem mostly from domestic shocks (see Addison et al., 2016; Hoffmaister and Roldos, 2001; Sissoko and Dibooglu, 2006, for example). This underscores the lack of consensus and inconclusive evidence on the degree and direction of external shocks that contribute to the macroeconomic conditions of African economies. Such discrepancies may arise due to the empirical approach and structural theoretical model construction techniques employed to study African economies, as these methods have limitations in terms of comprehensively incorporating the key characteristics of each economy's structural framework (Imam and Salinas, 2015).

Since the export commodity sector is at the centre of this thesis, it is important to specifically highlight the different channels by which shocks to this sector can be transmitted to emerging economies in general and African economies in particular.

A closer examination of this sector takes us to one of the oldest international finance bottlenecks of emerging economies, foreign exchange constraints. African economies heavily depend on exporting a singular sector, but they import mostly intermediate capital goods that are essential to their economy's production activities. Nevertheless, emerging economies are struggling to finance these imports due to the scarcity of foreign exchange reserves.

As a result of the significance of foreign exchange reserves for African economies to fund their import of capital and intermediate goods, export commodity price movements have widespread consequences. Foreign exchange constraints have become increasingly alarming to both the public and officials in emerging economies, and this issue has drawn the attention of scholars. As a recognition of the importance of the availability of foreign exchange as a crucial factor in determining economic activities for emerging economies, Porter and Ranney (1982) noted that

> ....in developing countries where idle capacity accompanies surplus labour, there is scope for expanding output without diminishing returns to labour, provided only that foreign exchange can be located to purchase the needed raw material imports (Porter and Ranney, 1982, p.753, emphasis added).

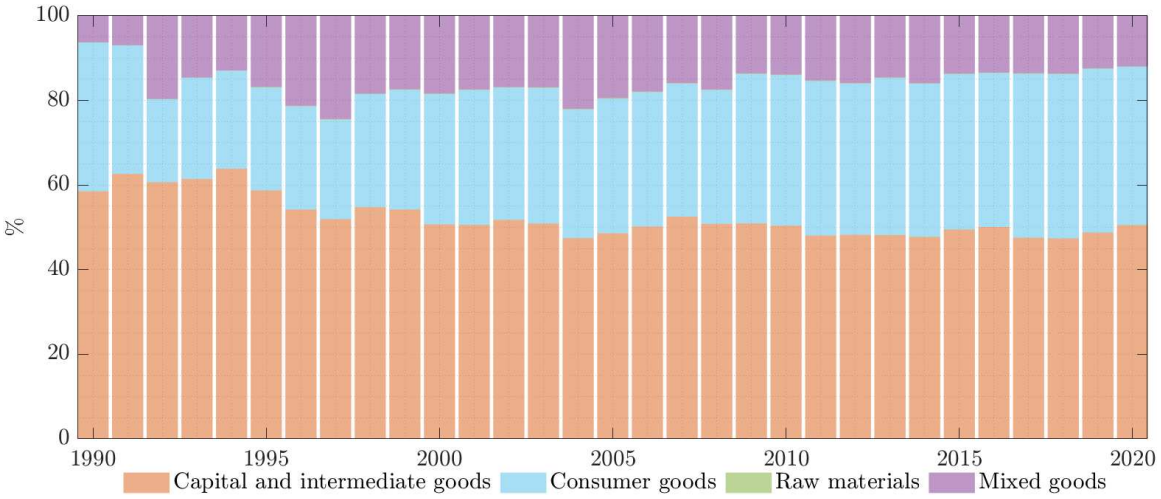
Porter and Ramsey's argument is shared by many authors as it became apparent that foreign exchange constraint is an emerging economy's concern considering their characteristic features. The crucial supply-determining role foreign exchange plays in the economic performance of emerging economies is ascertained by further empirical contributions (see Senbeta, 2011, for details).

A compelling argument by Stiglitz et al. (2006) suggests that foreign exchange reserves are crucial for emerging economies to optimize their production capacity. Stiglitz et al. (2006) presents the argument clearly and robustly, stating that:

> ....unlike advanced economies where the inadequacy of effective demand is the reason for the main short-run macroeconomic problem, the problem for many emerging countries is the deficiency of productive capacity and not the anomaly of its underutilization. And ..., the availability of foreign exchange may become, under many circumstances, the principal factor limiting economic activity. Demand constraints do exist, ..., but supply constraints generated either by the availability of capital or by the availability of foreign exchange are more important (Stiglitz et al., 2006, p.56, emphasis added).

Such arguments are supported by historical data on emerging economies' import composition of goods. For example, an analysis of Africa's largest region (SSA) shows a significant dominance of intermediate and capital goods over consumer goods in imports. Disruptions to export commodity prices in emerging economies will directly affect the availability of foreign exchange reserves, in turn influencing production capacity through the quantity of intermediate and capital goods that can be imported using those reserves. Therefore, a strong and direct link between shocks to export commodity prices and the economic performance of African economies is firmly established on both theoretical and empirical grounds.

In summary, the movements within the primary export sectors of emerging economies hold significant importance for our investigation into the macroeconomic dynamics of these economies. Cognizant of this understanding, it is imperative to consider these key export sectors in both our empirical and structural theoretical modelling of emerging economies. Therefore, this dissertation investigates the significance of fluctuations in export commodity prices by employing an empirical Vector Autoregressive with Exogenous Variables (VARX) model and a Dynamic Stochastic General Equilibrium (DSGE) model incorporating an export commodity sector.



Source: Author's computation using data from the World Integrated Trade Solutions (WITS) (2022)

Figure 1.3: SSA's import share of goods over the period, 1990 - 2020.

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CHAPTER II

THE ROLE OF EXTERNAL SHOCKS TO MACROECONOMIC FLUCTUATIONS OF EMERGING ECONOMIES: EXPLORING THE EXPORT COMMODITY PRICE CHANNEL

Abstract

External shocks are important to the macroeconomic fluctuations of emerging economies. Nevertheless, little theoretical and empirical evidence exists to authenticate the importance of external shock transmission through the single commodity export dependency of such economies. A Bayesian Vector Autoregressive (BVAR) model has been estimated for selected African economies in this study, taking into consideration the price of their main export commodities. The purpose of the study is to investigate the interaction between fluctuations in export commodity prices and economic activity over time. Most of the findings align with the theoretical framework and empirical evidence on emerging economies, which typically respond to external shocks. However, there are significant variations in the responses across economies. Notably, the results highlight a more pronounced output reaction to a shock in export commodity prices in the low-income economy, which has a lower shock absorption capacity. The results demonstrate that export commodity prices play a significant role as a transmission channel of external shocks to emerging economies. Therefore, it is crucial to consider this unique sector in emerging economies' macroeconomic modelling. The findings are robust and valid for different prior specifications and exogenous variable lag length selections.

JEL classification: C11; E32; F41; O55

Keywords: Emerging economies; Bayesian VAR; Export commodity price; External shocks.

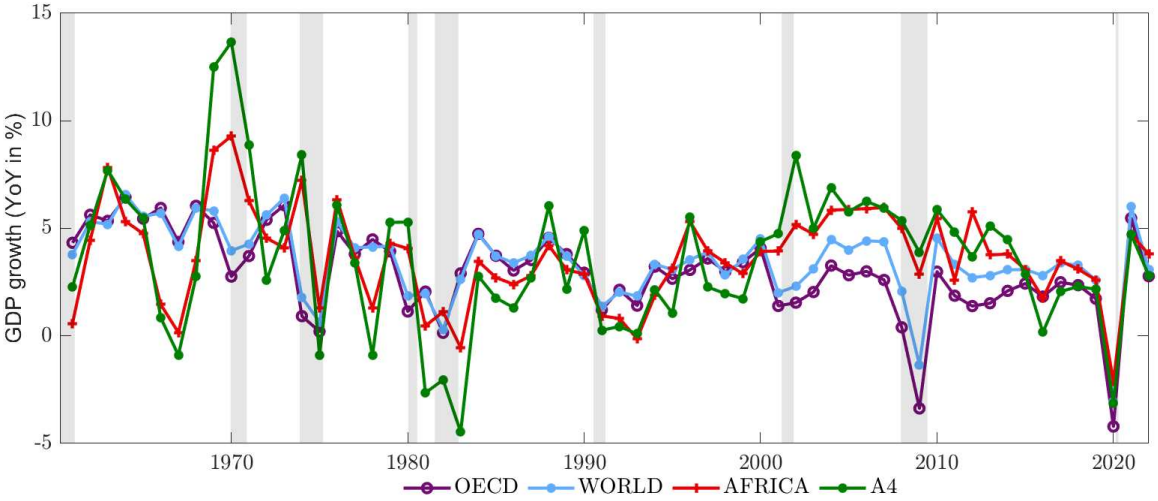
2.1 Introduction

The post-colonial period journey of African economies has been consistently inconsistent as most of them stumbled across a series of challenges and subsequent progress in search of their own economic destiny. Sylwester (2005) highlighted the massive economic growth boost following the removal of control by 'external power'. A relatively faster economic growth trajectory has been registered in the periods between the beginning of decolonization in the late 1950s and the mid-1970s (Artadi and Sala-i Martin, 2003). However, this optimism did not follow through as reflected in the Figure 2.1, nearly the last three decades of the twentieth century are not only marked by African economies' poor economic performance relative to the rest of the world economy and OECD averages but also characterized by periods of instability, conflict, and economic mismanagement. This has led to the years between 1975 and 1995 particularly to be quoted as 'Africa's lost decades'.

The task for African economies to march towards sustainable economic growth and development has been daunting due to the unfortunate legacy of exploitation that has left these countries with limited human capital and weakened institutions (Englebert, 2000). Furthermore, strong dependence on a few export commodities, lack of diversified industries, and inadequate infrastructure of these economies created an undesirable structural imbalance (Hirsch and Lopes, 2020).

Figure 2.1 shows African countries experienced a period of recovery from the mid-1990s to the 2008s global financial crisis. Some African economies such as Botswana, Egypt, Ethiopia, Ghana, Morocco, Nigeria, Rwanda, Tanzania, South Africa, and Uganda outperformed the continent with successful periods of 'growth miracles'. As indicated by the A4 growth index[2] from Figure 2.1, the four African economies con-

[2] A4 represents the GDP weighted average growth rate of Ethiopia, Morocco, Nigeria and South Africa.



Source: Author's computation using data from the WB - WDI (2022)

Figure 2.1: GDP growth rate of the World, OECD, SSA and average of 4 of the fastest growing African economies

sidered for the study are among the top achievers as their weighted average growth lies above the continent's average. Favorable domestic policy reforms, a relatively stable domestic political environment, natural resource attractiveness to China and India, an increase in the flow of foreign direct investment, and commodity price booms are considered the main factors behind the continent's 'growth miracles' (Collier and Goderis, 2008; Hirsch and Lopes, 2020; McGregor, 2017). However, maintaining the upward trajectory has not been easy for these economies with the occurrence of the global financial, the European debt, and the recent pandemic crises.

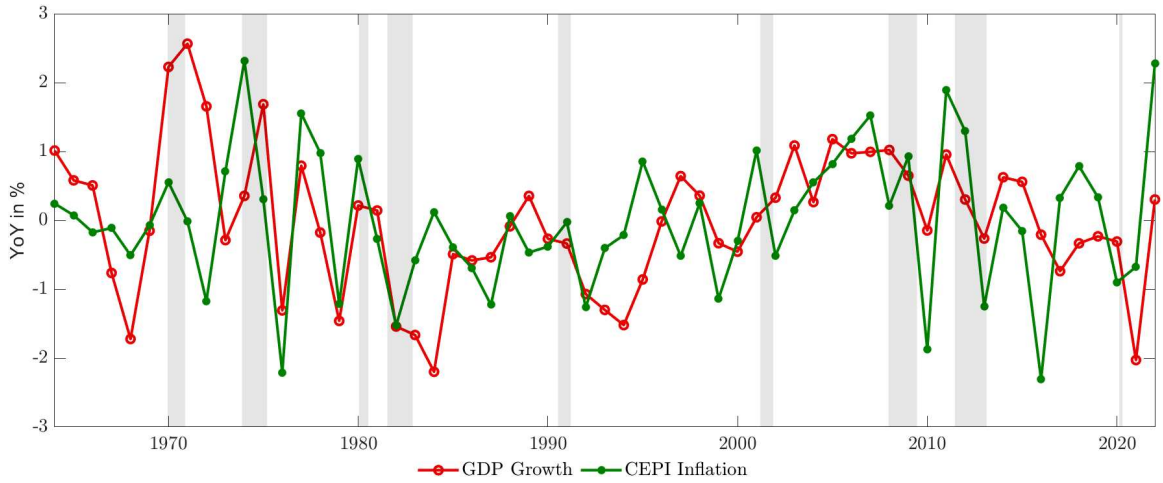
The four economies considered for this study are Ethiopia, Morocco, Nigeria, and South Africa. These economies represent a diverse composite of emerging economies in Africa and are among the economic powerhouses of the continent. For instance, the four economies produced more than 42% of Africa's GDP over the period 1998 - 2019 (WB - WDI(2023)). Furthermore, these economies reflect an interesting feature of most African economies as they rely on a single commodity for their respective export revenue. These interesting features coupled with the different exchange rate regimes employed by the four economies and availability of data are the motivating

factors to consider Ethiopia, Morocco, Nigeria, and South Africa for this study.

Since the global financial crisis, the European debt crisis, and the recent pandemic occurrence, scholars frequently raised the question of whether African economies can maintain their success stories or not, especially after witnessing the slow growth trajectories of these economies coinciding with the various global financial crises. However, the answer to this question depends on the origin of economic growth these economies experienced over time. This is because these economies could be able to maintain growth success if domestic factors are the dominant driving force behind it whereas it can be a difficult task to continue the successful trajectory if external factors are the main drivers.

Because of the various global crises, global growth has slowed down, and frequent austerity measures have been introduced by the advanced economies that led to a substantial decline in demand for African economy exports and inflow of aid and remittances to these economies. The decline in demand for African commodity exports together with the frequent fluctuation of prices to these commodities comes at the detriment of these economies' growth performance as their export revenue is heavily dependent on few, if not one, commodities. This is shown by the strong link between the growth performance and export commodity index for Africa as a continent as well as the four selected economies as can be seen from Figure 2.2 and Figure 2.3. The figures demonstrate that growth fluctuations in Africa and selected emerging economies have lagged in fluctuations to the export commodity index during various episodes over time. This corresponds with evidence indicating a delay in the transmission of shocks from the rest of the world to Africa.

In line with recent economic crises and frequent commodity price downfalls, the economic successes of African economies in the periods between the 1990s and the global financial crisis have been reversed and the trajectories have been less promising. This

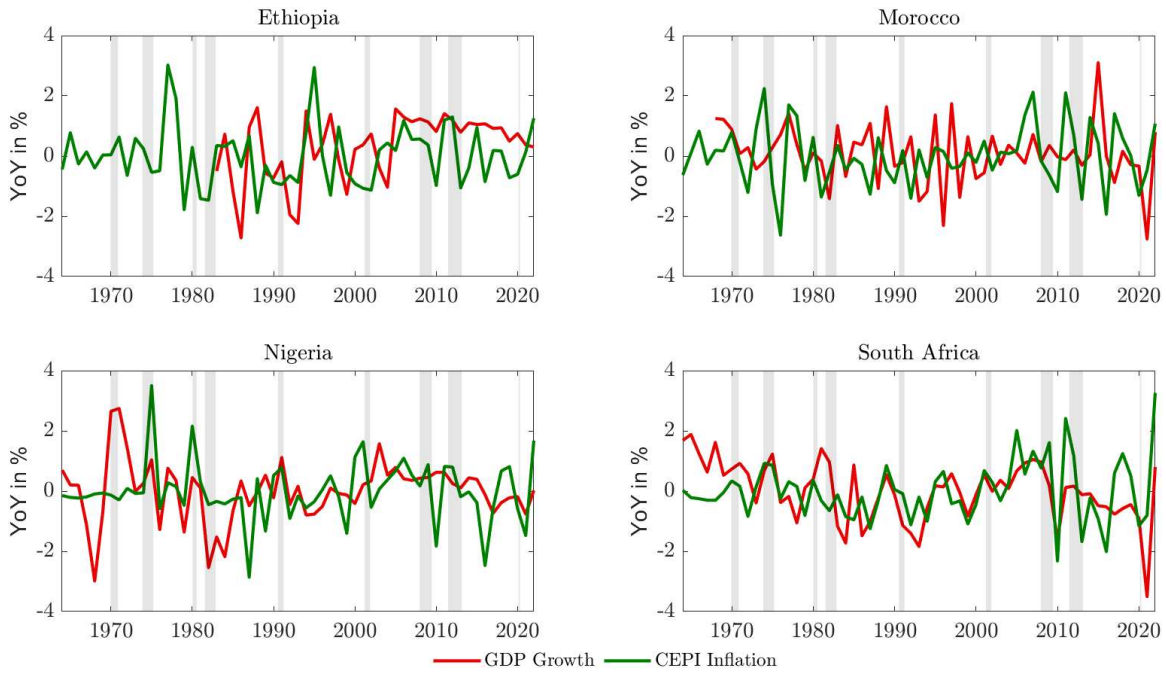


Source: Author's computation using data from the WB - WDI (2022).

Figure 2.2: GDP growth rate of Africa and commodity export price index inflation.

has created a reasonable fear by some that the previously recorded growth performances could be hard to come by (Abaidoo and Agyapong, 2021; McGregor, 2017). Hence, any task of forecasting the future trends of African economies starts from investigating how external vis-a-vis domestic factors affect the economic fluctuations of these economies.

In this study, the relative importance of domestic and external shocks to the macroeconomic fluctuations of four selected fast-growing African economies is formulated with a particular emphasis on export commodity price fluctuations. The study builds on a methodology formulated by Maćkowiak (2007) that incorporates output, consumer price, exchange rate, and nominal interest rate as domestic variables, and the external variables include foreign output, interest rate, each country's specific export commodity price, and aid. However, this study abstracts from Maćkowiak (2007) by taking the EU economy as a foreign block instead of the United States (US) economy since the selected four African economies have a much more strong trade affiliation with the EU more so than the US economy. Hence, a relatively parsimonious model is estimated for the four economies using the Bayesian Vector Autoregressive (BVAR) method. Though there are a variety of BVAR ways to assess the importance of exter-



Source: Author's computation using data from the WB - WDI and International Monetary Fund (IMF) - Commodity Terms of Trade (CTOT) (2022)

Figure 2.3: Commodity export price index inflation and economic growth of Ethiopia, Morocco, Nigeria and South Africa.

nal shocks to the selected African economies, a normal conjugate prior specification is employed due to its advantages of being less susceptible to researcher's bias and fit BVAR estimation with a relatively short span of available time series data.

This paper joins the strand of literature on emerging economy that tries to address the role of external shocks to macroeconomic fluctuations of these economies (Abrego and Österholm, 2010; Ahmed, 2003; Avom et al., 2021; Collier and Goderis, 2008; George and McCulloch, 1993; Hoffmaister and Roldos, 2001; Maćkowiak, 2007; Österholm and Zettelmeyer, 2008; Raddatz, 2008a; Senbeta, 2012; Yildirim and Arifli, 2021, to mention a few). As per the existing literature, three fundamental channels are considered to be the dominant channels of external shocks transmission to African economies. One is through fluctuations in commodity prices since African economies are exporters of shock-prone commodities. The second key channel is through a change in the global interest rate that fuels African economies' burden of foreign

currency-denominated liability. Lastly, exchange rate fluctuation is also considered as an important channel that leads to unstable prices of imported capital inputs that are integral to African economies' production process. However, exchange rate fluctuation itself can be a consequence of variations in the prices of export commodities.

In trying to address the role of 'external shocks' to African economies, most of the empirical works are grounded on changes to advanced economy's output and interest rate in addition to a sudden change in aggregate commodity prices. However, this study differs from the existing literature on various points.

First, the previous empirical works have their analysis focused on emerging economies in general instead of emphasizing on specific emerging economies. This approach is helpful to address the main drawback related to short-time data available for African economies though the homogeneity assumption throws a reasonable doubt to results (Kose and Riezman, 2001; Raddatz, 2008a). Africa is not a country and we do not need to treat Africa as a single entity as there are substantial variations in terms of economic growth and development, exposure to external shocks, and capacity to absorb the undesirable elements of external shocks. It is a common feature within the continent where some African countries enjoyed a 'growth miracle' while some languished in some unfortunate 'growth disasters'. Therefore, analyzing growth and the potential sources of economic fluctuations in Africa requires considering the specific environment and characteristics of the economies within the continent. Some DSGE models developed for emerging economies are often criticized for being too abstract in their calibration and lack proper representation of the realistic features of these economies (Rasaki and Malikane, 2015).

Setting an aggregated emerging economies in general and African economies in particular to conduct a structural panel-based or a merged regional analysis and making generalized assertions could lead to a misleading generalization due to the unrealistic

homogeneity assumptions of these economies (Avom et al., 2021; Raddatz, 2008b; Senbeta, 2012). As a result, the role of different external shocks in explaining domestic economic fluctuations of African economies could significantly vary from one economy to the other. Hence, a proper independent analysis of the specific economy of interest is a better way to gain a good reflection. This study attempts to address the role of export commodity price disturbances as a viable transmission channel of external shocks to selected African economies. Cognizant of this understanding and to observe economies with a different type of export commodity dependency, selected African economies that belong to one of the most vulnerable regions to external shocks namely Ethiopia, Morocco, Nigeria, and South Africa are considered for the study. As of 2019, these economies represent close to 60% of the continent's gross domestic product while their growth trajectories since the mid-1990s are among the African growth miracles as it can be witnessed from Figure 2.1.

Second, less emphasis is given to country-specific commodity price fluctuations in previous works. Some empirical works established commodity price shocks as an important type of external shock and cause a problem to economic fluctuation in emerging economies (Abaidoo and Agyapong, 2021; Addison et al., 2016; Blattman et al., 2007; Collier and Goderis, 2008; Drechsel and Tenreyro, 2018; Haider et al., 2023; McGregor, 2017; Medina, 2010; Nuru and Gereziher, 2022). This emanates from the well-documented fact that African economies are net exporters of either primary agricultural raw materials or metal ores or natural gas. Addison et al. (2016) emphasized on agricultural commodity export price shocks only and concluded such shocks have very little effect on the per capita income fluctuations of selected Sub-Saharan African countries. However, the study focused only on the economic growth impact of agricultural commodity price changes that are price inelastic in demand.

In response to the drawback of employing panel-based studies on African economies,

Raddatz (2007) argues that the criticism can be addressed by considering homogeneous countries. However, empirical works by Drechsel and Tenreyro (2018); Ghoshray (2011); Ghoshray et al. (2014); Kellard and Wohar (2006) and Abaidoo and Agyapong (2021) established the dynamics of individual commodity prices lead to a widely different result across economies implying for the need to model individual commodities separately.

Contrary to studies that have focused on analyzing the aggregate commodity price fluctuations, this study acknowledges the diverse nature of African economies' export commodities and attempts to capture the heterogeneity that may exist among these economies. Hence, the study estimates the role of export commodity price fluctuation on macroeconomic fluctuations of selected African economies. Since most of African economies are characterized by heavy export dependence on few, if not one, commodities, any decline in the price of these internationally traded commodities comes as a detriment to the government budget balance that further exacerbates the weak shock absorption capacity of these economies. African economies being shock-prone commodity exporters is one viable channel by which external shocks are transmitted to macroeconomic fluctuations since prices for export commodities are internationally volatile.

Studies conducted to analyze country-specific export commodities produced inconsistent results. For instance, Oyeyemi (2013) highlighted the positive significant effect of a positive oil price shock on output. On the contrary, Alenoghena et al. (2020)'s empirical contribution indicated the negative impact of an oil price shock on Nigeria's output fluctuation implying the 'Dutch Disease' theory is valid for the Nigerian economy as the oil price shock results in a shift in resources to produce more oil and other important sectors of the economy suffer significantly. On the other hand, a significant positive effect of a coffee price shock on output fluctuation is reported for

Ethiopia by Nuru and Gereziher (2022). Beyond the results being inconclusive, the literature on country-specific export commodity prices is limited and this paper adds to the literature on the macroeconomic effect of export commodity price shocks for emerging economies with a particular focus on Ethiopian, Nigerian, Moroccan, and South African economies.

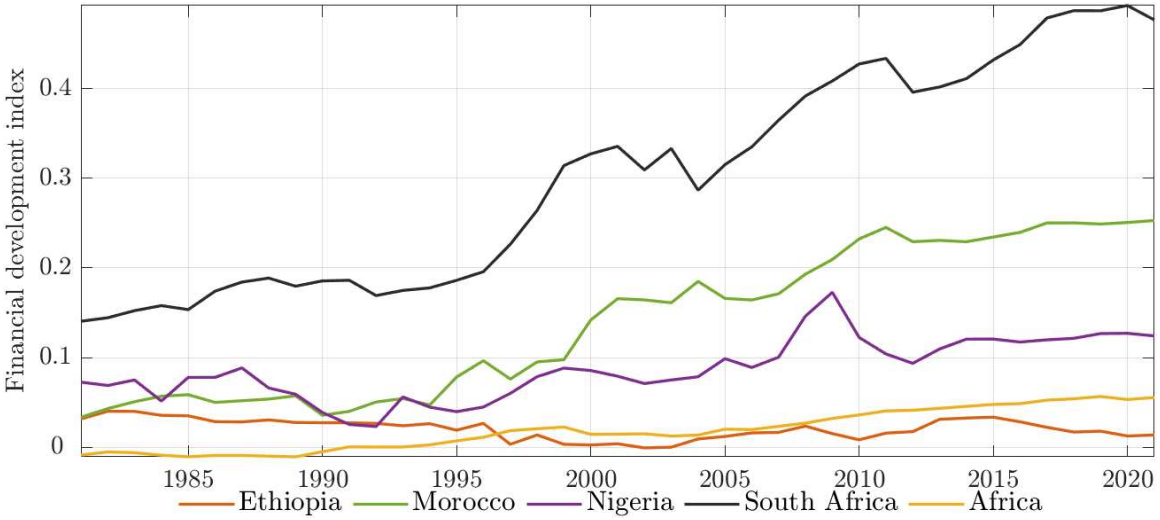
The rest of the paper is organized as follows. A brief macroeconomic overview of the four economies is discussed under Section 2.2. The related empirical literature is presented in Section 2.3. The employed empirical methodology is described under Section 2.4, while data and implementation of the model are discussed in Section 2.5. Key results and discussions are reported under Section 2.6. Section 2.7 presents robustness check and the concluding remarks are reported in Section 2.8.

2.2 Macroeconomic Overview of Economies Under Study

2.2.1 Financial Sector Development

Ethiopia, Nigeria, Morocco, and South Africa exhibit unique characteristics in their financial sector development, influenced by their historical, cultural, and economic backgrounds. Though the levels of financial sector development are substantially different across the four economies, the sectors play vital roles in their respective economies.

Considering IMF's financial sector development index that takes into account the access, depth, and efficiency of financial institutions and financial markets, the four economies exhibit a significant difference as can be seen in Figure 2.4. South Africa is by far the economy with the highly ranked one in its financial sector development followed by Morocco. However, the financial sector development in Ethiopia is among the poor ones and with no significant progress over the last four decades that re-



Source: Author's computation using data from the IMF - FDI (2022)

Figure 2.4: Financial development index over the period, 1980 - 2020.

mains fairly below the continent's average since the mid-90s. Although the country remains behind South Africa and Morocco, Nigeria has made positive progress since the beginning of the century.

A key aspect of the four economies' financial sector is the exchange rate policy being adopted. In this regard, Ethiopia and Nigeria operate a managed exchange rate regime, where the respective central banks intervene in the foreign exchange market to maintain stability. As such, the official exchange rate in Ethiopia and Nigeria is often pegged to a basket of major currencies, allowing for a degree of flexibility. The operational exchange rate policy in Morocco and South Africa on the other hand is a floating exchange rate regime where market forces determine the respective exchange rates.

Another key financial sector feature of the four economies is the stock exchange market. In this regard, South Africa's Johannesburg Stock Exchange (JSE) is the largest and most liquid stock exchange in Africa that serves as a critical platform for capital raising and investment. The Nigerian Stock Exchange (NSE) and Casablanca Stock Exchange (CSE) are among the largest in Africa hosting numerous listed companies

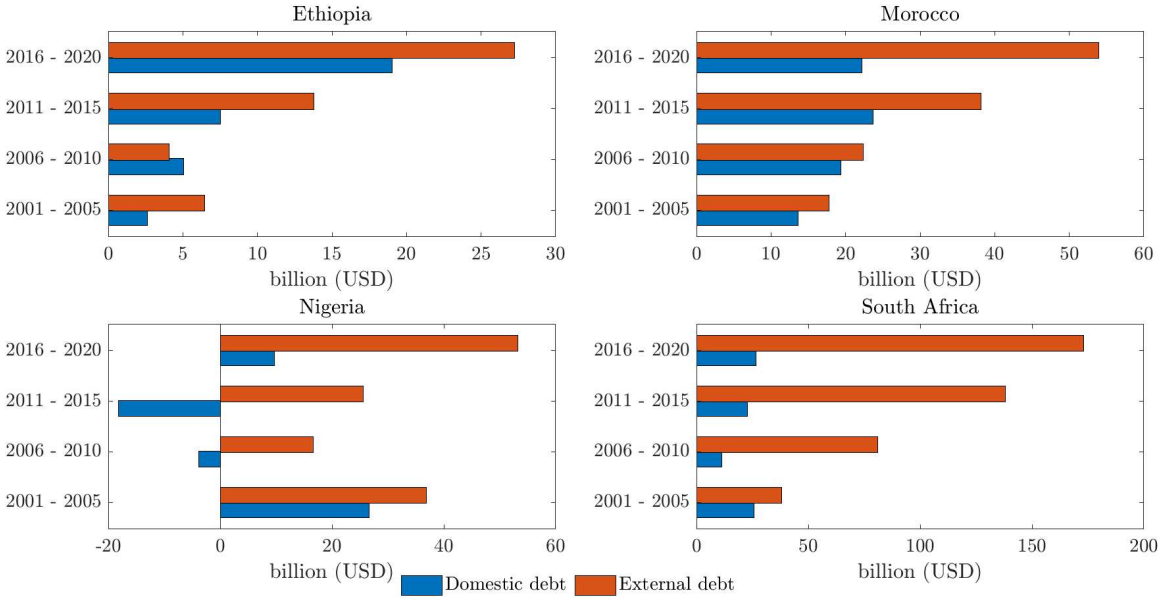
and acting as a catalyst for capital mobilization in Nigeria and Morocco respectively. However, Ethiopia's stock exchange market called the Ethiopian Commodity Exchange (ECX) is barely at its infant stage and operates only for a few agricultural products.

The banking sector operations in the four economies exhibit significant variations where Nigeria, Morocco, and South Africa have relatively large banking sectors comprising both domestic and foreign commercial banks operating with microfinance institutions and credit cooperatives. Despite the recent push for liberalization, resulting in the licensing of private banks and microfinance institutions, the banking sector in Ethiopia is dominated by state-owned financial enterprises and is characterized by a limited number of banks and microfinance institutions. Central banks of the four respective economies utilize various tools including reserve requirements and open market operations to maintain price and economic stability. However, the degree of independence of central banks in the four economies is quite different. More importantly, while central bank operations in South Africa and Morocco enjoy respective strong and moderate independence, central banks in Ethiopia and Nigeria continuously face significant pressure from the government, resulting in a relatively low degree of independence.

In conclusion, it is undeniable that each country's financial sector plays a crucial role in supporting economic growth, stability, and development. Hence, Ethiopia is in the process of opening and expanding its financial sectors while Morocco, Nigeria, and South Africa have relatively well-established and sophisticated financial markets, contributing significantly to their respective economies.

2.2.2 External Debt Burden and Sustainability

In emerging economies like Ethiopia, Morocco, Nigeria, and South Africa, financial resources through external debt play an important role as domestic saving is insufficient to finance all development projects. Except for Nigeria, the overall public debt for these economies is by in large from external sources that come with its own risk (see Figure 2.5). The exception (since 2005) to Nigeria is due to the debt relief support provided to the country through the Heavily Indebted Poor Countries (HIPC) initiative that led to a significant reduction of the country's external debt obligations.



Source: Author's computation using data from the WB - WDI (2022)

Figure 2.5: Composition of debt from domestic and external sources.

Despite the support provided to the country under the HIPC initiative, Ethiopia's external debt substantially dwarfs the size of debt from domestic sources. As Ethiopia, Morocco, Nigeria, and South Africa are indebted to external lenders, one obvious risk that comes with external debt is the subsequent obligation of debt repayment in the form of principal and interest payments. Such external debt servicing creates a crowding-out effect because of the high real interest rates, higher domestic tax rates, and decline in investment returns. The problem of external debt servicing

constraint is also further exacerbated by the 'original sin' constraint where these countries are unable to borrow and make payments in terms of their own domestic currency (Eichengreen et al., 2005).

	USD	Euro	Yen	Multiple currency	Pound	SDR	Others
Ethiopia	54.05	13.06	0.53	8.33	0.79	2.02	21.23
Morocco	35.40	44.31	2.95	8.68	0.17	0.40	8.08
Nigeria	49.90	7.36	4.70	13.76	7.48	2.63	14.17
South Africa	84.54	6.75	2.63	0.00	0.01	0.00	6.07

Source: Author's computation using data from the WB - WITS(2022).

Table 2.1: External debt currency compositions over the period, 1998 - 2019.

The vast majority of external debt for Ethiopia, Nigeria, Morocco, and South Africa is denominated in foreign currencies (see Table 2.1) and hence they are not insulated from the 'original sin' international finance problem. As the size of external debt has been overwhelming to Ethiopia and Nigeria, the two countries benefited from the 1996 debt relief under the HIPC initiative that was completed in 2005 for both countries. Although South Africa and Morocco did not receive traditional debt relief programs like the HIPC initiative as they were considered middle-income countries with a relatively lower debt burden compared to many low-income countries in Africa, the two countries mainly relied on various economic policies, bilateral agreements, and access to international financial markets to manage their respective debt and financial stability.

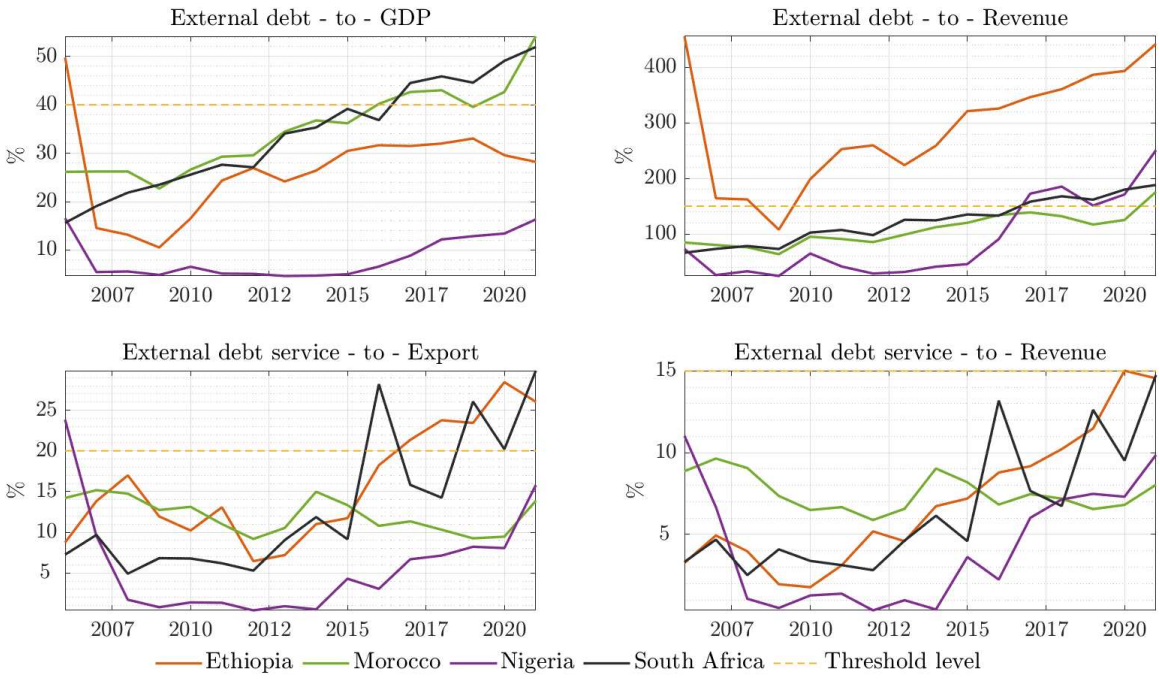
Ensuring debt sustainability is prioritized for African economies to achieve policy objectives without compromising their capacity to finance further developmental projects. In this regard, Ethiopia and Nigeria are part of the WB and IMF's Debt Sustainability Assessment (DSA) framework developed for low-income countries. As a substantial part of their public debt is registered as external debt, debt burden, and sustainability indicators are important indicators for the two countries' financial

sector stability. Although all countries are expected to maintain a sustainable debt, the DSA framework that applies to Ethiopia and Nigeria requires the two countries to meet their current and future external debt services in full, without recourse to debt relief, accumulation of arrears, rescheduling of debts and without unduly compromising growth. Accordingly, stock and flow-based debt sustainability indicators are projected and compared against the country's specific thresholds[3]. For instance, since the 2005 debt relief, Ethiopia and Nigeria's flow-based debt sustainability indicators have been fairly below the required threshold levels although recent trajectories are not in their favor (see Figure 2.6). Regarding stock debt sustainability indicators, Nigeria's economy seems to have a lower level of financial distress while Ethiopia's percentage of external debt to fiscal revenue warrants a concern for the country's future debt repayment capacity.

Though the DSF is not directly applicable to the economies of Morocco and South Africa, the respective percentage of external debt stock and its servicing to GDP, export, and fiscal revenues indicates relatively stable trajectories in the past 20 years. One can see from Figure 2.6, that percentages of external debt to GDP and fiscal revenue for the two economies are on an upward trajectory but they remain fairly within the manageable size relative to most middle-income countries.

All in all, the latest IMF's debt assessment reports labeled Morocco, Nigeria, and South Africa as among the moderate-risk borrowers while Ethiopia is labeled as a high-risk borrower (IMF, 2020). Relevant reforms and continuous efforts to employ fiscal rules anchored on the respective countries' public debt are recommended to facilitate the four economies' access to the international financial market.

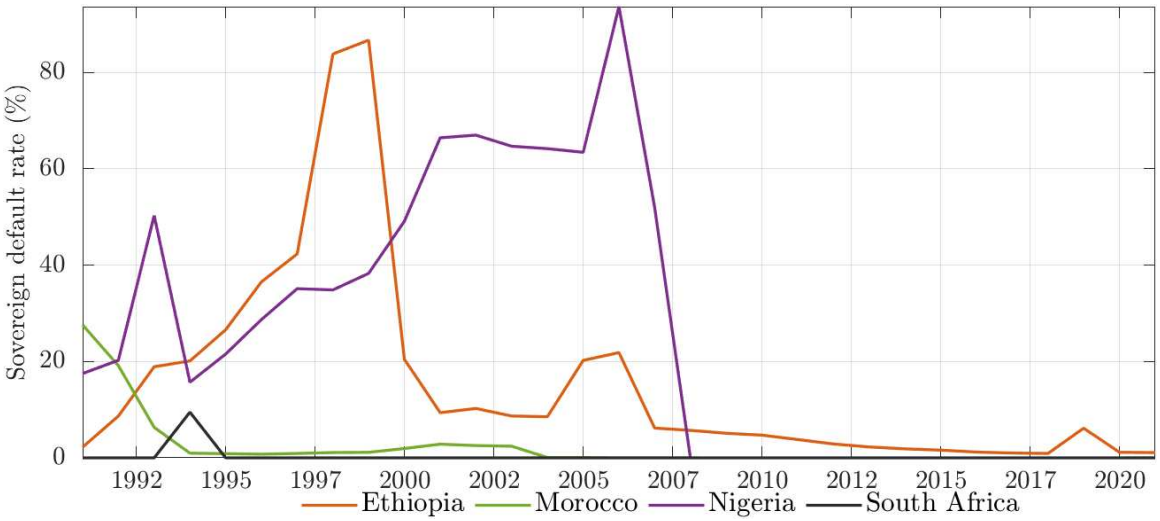
[3]According to the 2018's Debt Sustainability Framework (DSF), the basic equation to calculate debt sustainability indicator takes the form: $Indicator = \frac{Indeptedness}{Repayment\ capacity}$. External debt as a percentage of GDP, export and fiscal revenue are considered as stock-based indicators while the percentage of external debt service to export and fiscal revenue are used as flow-based measures (IMF, 2020).



Source: Author's computation using data from the WB - WDI (2022).
NB: The threshold levels are applicable to Ethiopia and Nigeria only since Morocco and South Africa are not subject to the DSF.

Figure 2.6: External debt burden indicators over the period, 2005 - 2020.

Another aspect of the economy's debt exposure is related to their historical sovereign debt default episodes. As debt pressure continues to grow, many emerging economies experience the unfortunate dilemma of either stretching finances and servicing their debt or defaulting and suffering from the subsequent consequences. The practice from Ethiopia, Morocco, Nigeria, and South Africa is not different although there are significant differences between the four economies as can be seen from Figure 2.7. More importantly, Ethiopia and Nigeria defaulted quite a significant amount of their outstanding debt during the pre-financial crisis periods while the frequency as well as the percentage default rates have been at their minimum during the post-financial crisis periods. However, the default rate practices of Morocco and South Africa have been consistently close to zero over the years reflecting the strength of the country's public debt stability.



Source: Author's computation using data from the WB - WDI (2022).

Figure 2.7: Sovereign debt default rate over the period, 1990 - 2020.

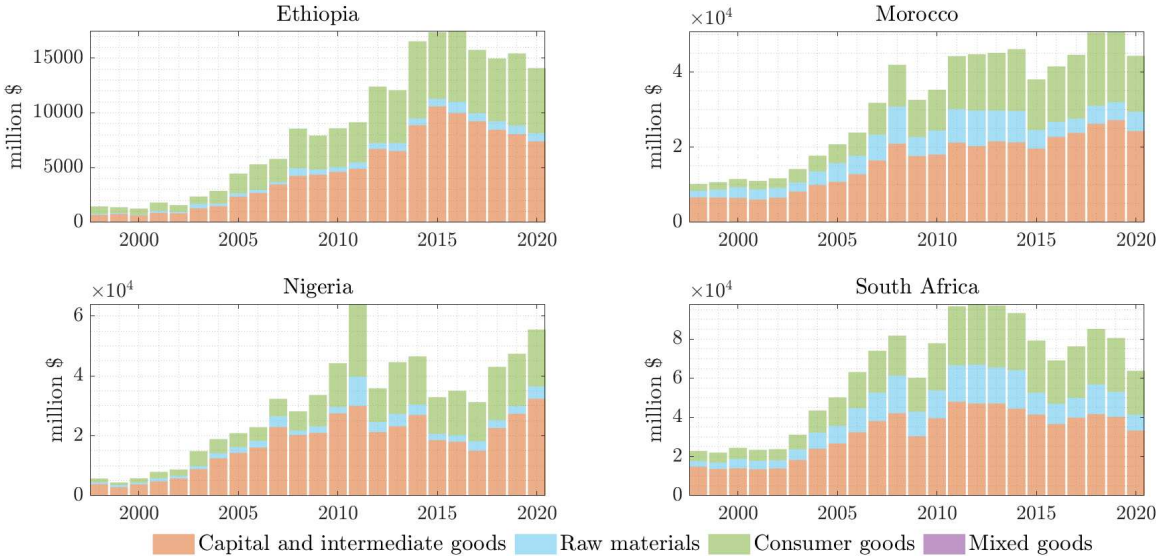
2.2.3 Trade Dynamics and Economic Development

International trade plays a pivotal role in the economic development of countries across the world and Ethiopia, Nigeria, Morocco, and South Africa are no different as they are nations with distinct trade profiles and development trajectories. For one, these economies are characterized by limited export diversification, and a substantial amount of their export revenue is generated from few or single export items (see Table A.1). Despite the efforts to diversify exports, Ethiopia's economy relies heavily on primary exports such as coffee, textiles, and leather products. Similarly, the respective export revenues for Morocco, Nigeria, and South Africa are dominantly from phosphate, oil, and precious metals.

Though their strong trade affiliations are with European nations, trade partners for Ethiopia, Morocco, Nigeria, and South Africa are relatively diverse, including Europe, China, the United States, and neighboring African countries. However, it is worth noting that each of these countries has its unique trade policies, export sectors, trade partners, and challenges, which contribute to their economic trajectories. As they continue to leverage trade as a catalyst for sustained economic growth and devel-

opment, further diversification of exports and their destinations is a common theme across these nations in line with other necessary economic reforms.

Consistent with the key features of emerging economies, the import of intermediate and capital goods is by far the most imported goods in Ethiopia, Morocco, Nigeria, and South Africa. As we can observe from Figure 2.8, the value of imported intermediate and capital goods for these economies has increased over time. Intermediate



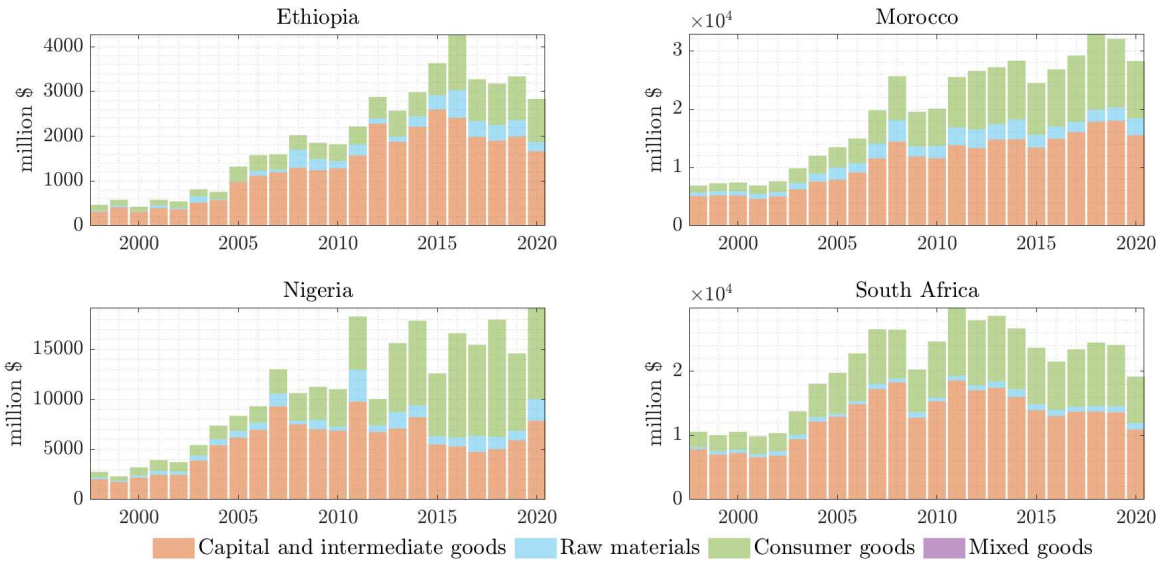
Source: Author's computation using data from the WB - WITS (2022)

Figure 2.8: Import composition of goods over the period, 1998 - 2020.

and capital goods imports taking the lion's share of Ethiopian, Nigerian, Moroccan, and South African economies is an indication of the crucial supply-determining role of these goods in emerging economies.

In terms of trade composition with the EU (see Figure 2.9), the trend follows a similar trajectory as the overall trade composition where the four countries mainly import capital and intermediate goods followed by consumer goods while their export composition is aligned with the features in Table A.1.

In addition to trade flows, remittances received from abroad play their role for Ethiopia, Morocco, Nigeria, and South Africa. As we can witness from Table A.1, the



Source: Author's computation using data from the WB - WITS (2022)

Figure 2.9: Import composition of goods imported from the EU over the period, 1998 - 2020.

share of remittances to GDP is significantly greater for Morocco and Nigeria while it is among the lowest for Ethiopia and South Africa. More importantly, a testament to the strong tie between the EU and the four economies, the WB's bilateral remittance matrix between 2011 - 2019 indicates that a respective $15.91, 88.43, 32.27$ and 36.86 percent incoming remittances to Ethiopia, Morocco, Nigeria and South Africa originates from the EU. Except for Ethiopia where most of the remittances received are from North America and the Middle East, EU is the leading origin of remittances for Nigeria, Morocco, and South Africa.

2.3 Review of Literature

As clearly stated in the introductory section, African economies have been far from a stable economic trajectory and faced persistent economic fluctuations over time. However, the critical question remains what are the dominant sources of such economic fluctuations? Particularly, what role do external shocks have in provoking economic fluctuations in emerging economies? is among the hot economic questions in

these economies. Addressing these questions has a paramount significance to African economies as the answers are crucial to formulating sound macroeconomic policies to deal with macroeconomic fluctuations and mitigate the potential adverse effects of shocks. In this regard, particularly on the matter of the distinct role of external shocks to emerging economies, the empirical works have produced inconclusive evidence (Abrego and Österholm, 2010; Addison et al., 2016; Athukorala and Rajapatirana, 2003; Avom et al., 2021; Canova, 2005; Kose and Riezman, 2001; Mendoza, 1991; Raddatz, 2007, 2008a; Schmitt-Grohé and Uribe, 2003; Senbeta, 2012; Soludo, 1993; Yildirim and Arifli, 2021).

One strand of the empirical literature stresses the dominant influence external shocks have on fluctuation in emerging economies (Abrego and Österholm, 2010; Canova, 2005; Kose and Riezman, 2001; Maćkowiak, 2007). Recent works by McGregor (2017), Avom et al. (2021), and Rodríguez et al. (2023) also found strong evidence in favour of external shocks originating from the global economy as the main driving forces behind macroeconomic fluctuations of emerging economies. This strand attributes the argument and evidence to the conventional perception that 'when the US/EU sneezes, emerging economies catch a cold'. Higher trade openness and the higher foreign currency-denominated liability (external debt) to African economies are used as a supportive argument to substantiate that African economies are vulnerable to external shocks.

On the other hand, there is a wide range of empirical evidence to support domestic shocks as largely the main drivers of economic fluctuations in emerging economies (Addison et al., 2016; Hoffmaister and Roldos, 2001; Sissoko and Dibooglu, 2006). As strong as it sounds, proponents of this argument stress that although it is undeniable that emerging economies are not immune from external shocks, the role of these shocks is overstated which has allowed policymakers in these economies to do little

to insulate their economies from external shocks. This argument opens a window of criticism to policymakers in emerging economies for folding their arms on their chest and externalizing their policy conduct issues into sources associated with the external world while they have an immense amount of natural and human resources.

In contrast to the two extreme strands of empirical studies by Rasaki and Malikane (2015) and Abere and Akinbobola (2020) indicated that both domestic and foreign shocks are equally important in explaining the macroeconomic fluctuations of African economies. These findings highlighted that African economies' vulnerability to external shocks is contingent on the economy's global financial integration, the nature of export commodities, and domestic institutional environments to absorb external shocks.

Notwithstanding the empirical works grounded to establish the role of external shocks in African economies' macroeconomic fluctuations, this study makes three contributions to the literature. First, as far as the responsiveness of the economies to foreign shocks is concerned, it is established that all the economies do react to changes in foreign variables. However, the responsiveness is quite different across the economies considered in this study. More specifically, the relatively more advanced African economies that are enjoying a higher and lower-middle income status, South Africa, and Morocco respectively, tend to have a higher absorption capacity of foreign shocks compared to the low-income economies, Ethiopia, and Nigeria. Second, looking at the historical contribution of domestic and external shocks in explaining the dynamics of output, all four economies are found to be more vulnerable to export commodity price fluctuations. Lastly, we have established that the importance of external shocks to African economies' forecast error variance is contingent on the level of financial sector development of the economies in question.

2.4 Empirical Methodology

To understand the importance of external shocks in general and commodity export price fluctuations in particular on the main macroeconomic aggregates of selected African economies, a BVAR models are estimated for each economy. Contrary to calibrated theoretical and structural panel-based models, BVAR are found to be useful as there is no need to make a country symmetric assumption and a separate model can be estimated for each economy. As such, BVAR models have the beautiful feature of allowing the researcher not to make any assumption regarding the set of dependent or independent variables as these models entertain the possible interdependence between variables included in the model. Hence, these models are a good fit to address the four main tasks of a macro-econometrician, data description, forecasting, structural inference, and policy analysis, as noted by Stock and Watson (2001).

In general, unrestricted traditional Vector Autoregressive (VAR) models are not free from some drawbacks where the issue of 'curse of dimensionality' is the main one. This is because the possibility of one variable and its lags can influence another variable without restriction leads to an overparameterization which is worse when dealing with short time series data as is the case for most African economies. As a response to resolve this drawback, BVAR models are the most popular and address the overparameterization problem with the help of different prior specifications about parameters of interest to be estimated. In this regard, the continuous development of computationally powerful machines and Markov Chain Monte Carlo (MCMC) methods have offered a massive help and improved the performance of BVAR models (Koop et al., 2010).

Prior specifications under BVAR model take away researchers' outright judgment to automatically exclude a variable from the estimation of the model. More importantly, the available data and posterior distributions of explanatory variables are used to log-

ically introduce shrinkage and determine the inclusion and exclusion of regressions into the model. The literature has used a variety of prior specifications and according to Koop et al. (2010) the prior specifications are different on three counts: (i) model parsimony related to the ability to shrink the model parameters, (ii) the ability to lead to analytical posterior results and predictive densities or Bayesian inference can be carried out with the help of MCMC computations, and (iii) flexibility they offer to deal with BVAR models compared to the traditional unrestricted VAR models. Accordingly, to utilize a more objective approach and allow the data to have a greater influence on the posterior distributions, Normal- Wishart conjugate prior specifications are used in this study[4](see Ferroni and Canova, 2021; Koop et al., 2010, for details). Such prior specifications are quite useful as they allow us to derive a closed-form expression for the posterior distribution and simplify our interpretations. Hence, using conjugate priors is justified with the intent to ensure the estimated parameters are as data-driven as possible and easily interpretable.

To achieve the main objective of assessing the relative importance of external shocks to the selected economies, the starting point is the standard form of a restricted VAR model:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + ... + \beta_p Y_{t-p} + \beta_0^* X_t + \beta_1^* X_{t-1} + \beta_2^* X_{t-2} + ... + \beta_q^* X_{t-q} + \varepsilon_t \tag{2.4.1}$$

where $Y_t = (Y_{1t}, Y_{2t}, ..., Y_{nt})$ denotes an $(n \times 1)$ vector of domestic variables to each of the selected African economies, $X_{t-i}(i = 0, ..., q)$ is an $(m \times 1)$ vector of exogenous variables of the model represented by the EU economy. p and q are the respective

[4]Using a modified version of the MATLAB code written by Gary Koop (2010) to replicate results in Koop et al. (2010) and the empirical macro toolbox by Ferroni and Canova (2021), results are triangulated across alternative prior specifications such as Independent Normal-Wishart and Stochastic Search Variance Selection (SSVS) prior specifications are used and have been found consistent and no significant differences are observed worthy of reporting except the Jeffrey priors provide narrower confidence intervals of impulse response results.

optimal lag lengths for domestic and exogenous variables. $\beta_i^*(i = 1, ..., q)$ are $(m \times m)$ matrix of the coefficients of the exogenous variables, β_0 is $(n \times 1)$ coefficient for the constant/deterministic term, and $\beta_i(i = 1, ..., p)$ are $(n \times n)$ matrices of the coefficients of the domestic variables, while ε_t is an $(n \times 1)$ vector of independently and identically distributed error terms reflecting structural shocks of domestic origin that satisfy the condition $E(\varepsilon_t) = 0$ and $E(\varepsilon_t \varepsilon_t') = \Sigma$. With the understanding that the selected African economies are small open economies compared to the EU economy, the estimation process utilizes the widely used exogeneity block restriction assumption so that the domestic shocks have negligible or no impact on the external variables but not vice versa.

Bayesian implementation of 2.4.1 requires prior specifications for $\beta_i s, \beta_i^* s$ and Σ. Hence, the conjugate prior for $\beta_i s, \beta_i^* s$ and Σ takes the form[5]:

$$\alpha|\Sigma \sim N(\underline{\alpha}, \Sigma \otimes \underline{V}) \tag{2.4.2}$$

$$\Sigma^{-1} \sim W(\underline{S}^{-1}, \underline{v}) \tag{2.4.3}$$

where α is vector of all the coefficients of the model, $\alpha = vec(\beta_i s, \beta_i^* s)$ and Σ represents the covariance matrix. The researcher can set the hyperparameter values, $\underline{\alpha}, \underline{\alpha}, \underline{S}^{-1}$ and $\underline{v}$. $\underline{\alpha}$ and $\underline{V}$ are the prior mean and variance of the coefficients, respectively. Similarly, $\underline{S}^{-1}$ and $\underline{v}$ are the respective prior of the matrix of the standard errors of the model and the degrees of freedom. Accordingly, the conditional posteriors are analytically derived and results in the form:

[5]The detailed analytical derivations can be found in Koop et al. (2010)

$$\alpha|\Sigma, y \sim N(\hat{\alpha}, \Sigma \otimes \hat{V}) \tag{2.4.4}$$

$$\Sigma^{-1}|y \sim W(\hat{S}^{-1}, \hat{v}) \tag{2.4.5}$$

where y is our data, $\hat{v} = T + \underline{v}$ and T is the total number of observations. $\hat{\alpha}$ and $\hat{S}$ are the respective estimates for α and Σ. $\hat{V} = (\underline{V}^{-1} + X'X)^{-1}$ with X as the regressor on right hand side of our VAR.

The conjugate priors used in this study have the advantage that analytical results exist for posterior inference and prediction without the need of an MCMC simulation(Koop et al., 2010). However, the impulse response, historical decomposition, and forecast error variance results require a MCMC simulation since they are a non-linear function of the estimated $\beta_i's$ and Σ. Accordingly, the results reported in this study are based on 100,000 MCMC draws.

2.5 Data and Measurement of Variables

The estimation of a BVAR model in this study makes use of quarterly data from four selected African economies as domestic economies and the EU as an external block. The four selected economies are Ethiopia, Morocco, Nigeria, and South Africa and the sample period considered covers the periods from 1998Q1 to 2019Q4. Though it is reasonable to think that these economies do not fully represent the diverse continent, of Africa, they are among the powerhouses of the continent, and the availability of quarterly time series data is considered for each economy. These economies reflect an interesting feature of most African economies as they rely on a single commodity for their respective export revenue. For instance, over the period between 1998 - 2019, Ethiopia (coffee exporting country), Morocco (phosphate exporting country),

Nigeria (oil exporting country), and South Africa (precious metal exporting country) respectively generated 37.37%, 23.55%, 92.78% and 32.51% of their external revenues from coffee, phosphate, oil and precious metal (Table A.1 for details). The selected economies also provide an interesting mix in such a way that the results regarding the contribution of export commodity price shock will not be one-dimensional since the export commodities considered are from diversified sectors.

Unlike Hoffmaister and Roldos (2001), Maćkowiak (2007), Barrot et al. (2018) and Zgambo and Funyina (2022) who have considered either the US economy or the whole Rest of the World as a foreign block in their modeling of emerging economies, this study uses the European Union as a foreign block since the four selected African economies have strong trade and overall economic affiliations with the European Union more than any other economic regions[6]. This consideration is useful to narrow down the origins of external shocks for the selected economies.

The set of variables considered for the study follows Maćkowiak (2007) as they provide simple, tractable, and interpretable results without loss of model parsimony and allow result comparability with previous studies. Accordingly, real gross domestic product (Y), consumer price index (CPI), real exchange rate[7] (E) and nominal interest rate (R) variables are considered as domestic variables for each economy. On the other hand, the European Union representative variables used in the list of external variables are EU real gross domestic product (Y^*) and EU nominal interest rate (R^*). The real value aid and official assistance received by the respective economies as a percentage of their GDP (A^*) is also considered as an exogenous variable. As the focus of this study, the other key external variables used are the price of each econ-

[6]For instance, over the period 1998 - 2019, a respective average of 37%, 75%, 34% and 38% Ethiopia's, Morocco's, Nigeria's and South Africa's exports are directed to Europe more than any other export destinations(WB - WITS, 2023).

[7]Exchange rate is defined as the value of a unit of foreign currency (euro) in terms of each economy domestic currency and hence a rise in exchange rate implies depreciation of domestic currencies and vice-versa for appreciation.

omy's key export items namely, the price of coffee for Ethiopia, phosphate price for Morocco, price of oil for Nigeria, and precious metal price for South Africa. Data for the domestic variables are obtained from the respective economy's central statistical agencies and central banks whereas Eurostat is used as the main source of data for the EU-based variables. Data for price indexes of coffee, phosphate, oil, and precious metals are taken from Federal Reserve Economic Data (FRED). Hence, the vector of variables (their measurements described in Table A.2) used for the BVAR estimation of each selected economy is given as:

$$Y_t = \{PI^c, GDP^*, R^*, A^*, GDP, CPI, E, R\} \tag{2.5.1}$$

where PI^c represents the price index of each economy's main export commodity item.

2.6 Results

Using the aforementioned model specification and empirical approach, I estimated the BVAR model with four lags of the quarterly data for each economy. It is worth mentioning that the VARX literature treats the optimal lag length for the exogenous variables differently from the endogenous variables where in some cases, the same lag lengths are employed while there are also empirical contributions that take into account zero lags for the exogenous variables. In the Section 2.7, I also analyze the robustness for different prior specifications and lag order for the exogenous variables. For the different choices, the responses are found to be robust.

2.6.1 Impulse Responses

To understand how responsive the selected African economies are to the respective export commodity price shocks, an impulse response analysis is considered. For the impulse response analysis, the standard assumption states that a shock to the rest

of the variables is set to zero when we are studying the shock to one variable. This requires an identification strategy whereby the Cholesky decomposition is applied in this study to identify the independent shocks. Under this identification, the independent standard normal shocks, ε_t using the estimated variance-covariance matrix of the reduced form shocks. Accordingly, the ordering of variables in Equation (2.5.1) are used to ascertain the relevant relationships, $\Sigma = PP'$ and $\varepsilon = P^{-1}\mu_t$ where μ_t is the error term and P^{-1} is a lower triangular matrix. This identification strategy implies some of the variables included in our model have a contemporaneous impact on the rest of the variables while they have not been affected by the other variables. Cholesky identification has an advantage since it generates a unique identification with fewer complications than other identification structures (Lucchetti, 2006). Computing impulse responses requires a key identification assumption such that the dynamics of variables in the system are adequately represented by the specified model. As a result, the ordering of variables is key in our impulse response results and hence the model specification and variable ordering builds on the contribution by Maćkowiak (2007).

Since all the variables included in the model are transformed into logs, the results can be interpreted as elasticities where a one-unit shock in one of the variables can be interpreted as a change to the shock and the corresponding impulse variables in percentage points. Furthermore, the respective export commodity price shock is normalized to increase the real prices by 10 percentage points on impact. In the impulse response figures reported below (Figure 2.10), the solid blue line is the posterior median whereas the shaded darker blue and lighter blue areas represent 68 % and 90 % confidence intervals respectively.

2.6.1.1 Export Commodity Price Shock

To highlight the importance of export commodity price shocks, an impulse response to the respective commodity prices is considered and the results are reported below.

Generally speaking, a rise in export commodity price, presented in Figure 2.10, tends to lead to a positive response to real GDP and appreciation of domestic currencies for Ethiopia, Nigeria, Morocco, and South Africa. The positive response of output can be explained in two ways. On the one hand, a higher export commodity price induces an added incentive to production and hence an expansion in output. On the other hand, a higher export commodity price implies improved terms of trade and higher domestic purchasing powers that in turn result in a higher domestic aggregate demand.

The results on consumer prices are mixed such that a rise in the respective export commodity price induces a temporary inflationary pressure in Morocco but theoretically valid negative responses to consumer prices are reflected in South African, Ethiopian, and Nigerian economies. However, it is important to note that consumer price responses in Nigeria and Ethiopia are relatively weak. Furthermore, the response of the nominal interest rate is also inconsistent for the economies considered as the response is inconclusive.

The main result that is consistent across all the economies is the expansionary output response to the export commodity price shock and it has a theoretical and empirical foundation for emerging economies. This is because a rise in export commodity price induces an additional foreign exchange revenue to these economies that is key to importing intermediate and capital goods that are integral supply determining factors to them. A rise in foreign exchange revenue and the subsequent boost in production of emerging economies coupled with the relatively cheaper import of consumer goods is expected to induce a decline in consumer price. The inflationary response of consumer prices in Morocco may be explained by the positive income effect. A higher purchasing power may increase domestic demand, which in turn can induce higher inflation.

As a higher commodity price is associated with a rise in the inflow of foreign cur-

rency to the respective economies and an appreciation of the respective economies domestic currency is expected both theoretically and empirically. Accordingly, the negative impact responses of real exchange rates for Ethiopia, Morocco, Nigeria, and South Africa confirm this prediction. Thus, export commodity price shocks have economically significant effects on each of the economies under consideration.

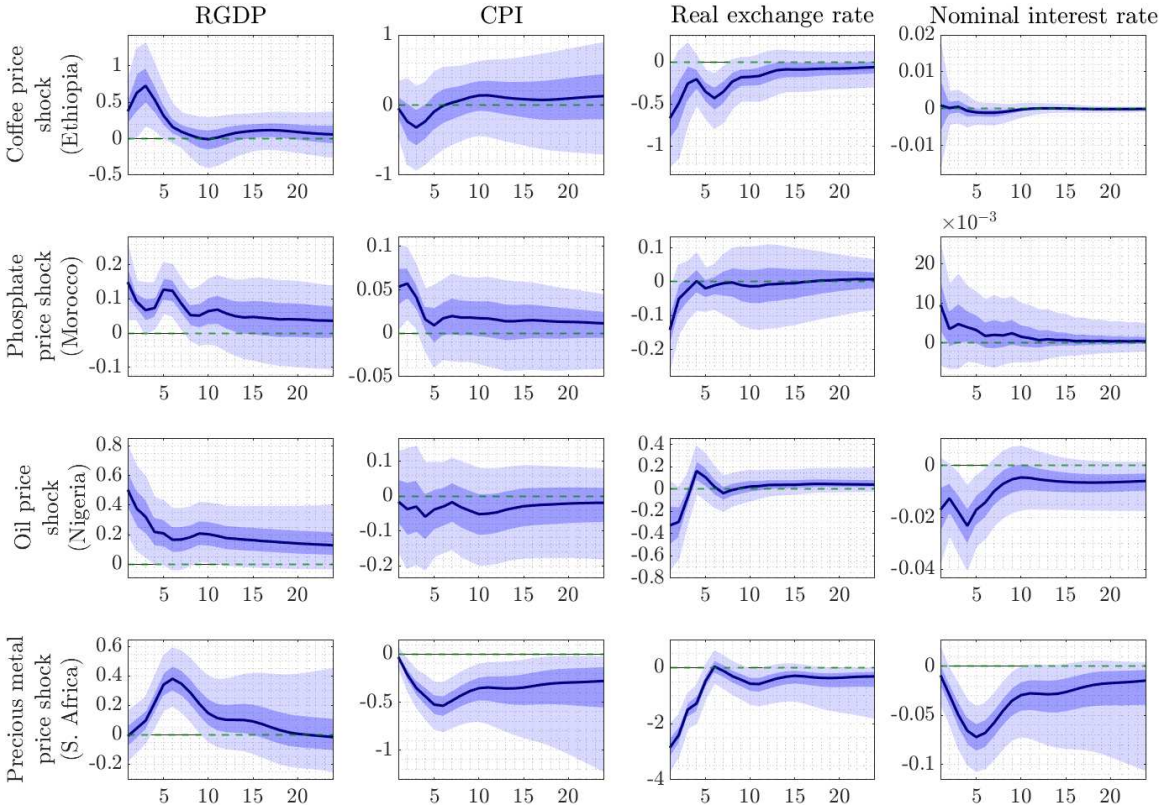


Figure 2.10: Responses to a 10 percent positive export commodity price shock

Close examination of the impulse responses of the Ethiopian economy, the results are of the expected signs. For instance, at its peak (after 3 quarters), a 10 percentage point positive coffee price shock results in a 0.7 percentage point increase in real GDP and a 0.6 percentage point decline in the exchange rate of the Ethiopian currency (birr) against euro. Though weak, the response of consumer price has its sign in line with theoretical prediction.

These results for Ethiopia are consistent with the findings by Nuru and Gereziher

(2022). The response of output is stronger for Ethiopia implying the low shock absorption capacity of the economy relative to the other economies under this study. Finally, the response of Ethiopia's nominal interest rate response is found to be weak and insignificant.

Though there is a lack of empirical evidence for a direct comparison, the response of Morocco's economy to a phosphate price shock is compatible with theory, with one exception. The exception is the positive consumer price response that can be argued as being counterintuitive. More importantly, on impact, output and consumer price respectively increase by 0.15 and 0.05 percentage points while the exchange rate of Moroccan Dirham declines by 0.15 percentage points following a 10-percentage point positive phosphate price shock. However, the response of the nominal interest rate is found to be weak.

The responses of Nigeria's economy to an oil price shock as well show significant responsiveness of macroeconomic fundamentals to an oil price shock. On impact, a 10-percentage point increase in the price of oil leads the real output to increase by 0.35 percentage points. Furthermore, the result shows a 0.38 percentage point appreciation of the Nigerian Naira following a 10-percentage point increase in the price of oil and these results are consistent with previous empirical contributions by Olomola (2006) and Oyeyemi (2013).

The real output of South Africa responds positively (0.32 percentage point increase in quarter 6) to a 10-percentage point increase in the price of precious metals. Like the other economies, a rise in the price of precious metals leads to an appreciation of the South African Rand (a 3-percentage point exchange rate decline). The response of inflation and nominal interest rate are found to be significant and consistent with theoretical predictions for the South African economy. The significant transmission of precious metal price shock to lower consumer prices and interest rates reflects a

relatively more reactive monetary policy operation of South Africa's central bank during a precious metal price fluctuation.

Overall, the impulse response analysis of the economies under study revealed results that are consistent with theoretical arguments, and the respective export commodity price shocks are found to be a viable transmission channel of external shocks to emerging economies. Notwithstanding that, though the responses of real GDP and exchange rate are consistent across each economy, the results revealed mixed consumer price and interest rate responses. Morocco and South Africa are found to have a better external shock absorption capacity than Ethiopia and Nigeria as the evidence indicates the responses of key macroeconomic variables in Morocco and South Africa are smaller compared to Ethiopia and Nigeria. More importantly, the evidence under Figure 2.4 reflects where the four economies stand in terms of their financial sector development. Such differences in financial sector development may be one of the main factors behind the shock-absorbing capacity of the four economies, as a well-developed financial sector plays a crucial role in enhancing an economy's resilience to various shocks.

2.6.2 Forecast Error Variance Decomposition

To assess the contribution of different domestic and external shocks to the variation in the domestic variables of the selected economies, a Forecast Error Variance Decomposition (FEVD) is generated for 24 ahead forecasts. Such FEVD result tells us how much of the unanticipated changes in the domestic variables are explained by the different domestic and external shocks over different time horizons. The FEVD is generated with the assumption that the domestic variables do not have a contemporaneous impact on external variables whereas the reverse is not true. Hence, following Ouliaris et al. (2016), a block exogeneity setting is established in the estimation pro-

cess to make sure that this assumption is maintained. In what follows, the FEVD for Ethiopia, Morocco, Nigeria, and South Africa is reported by Figure 2.11.

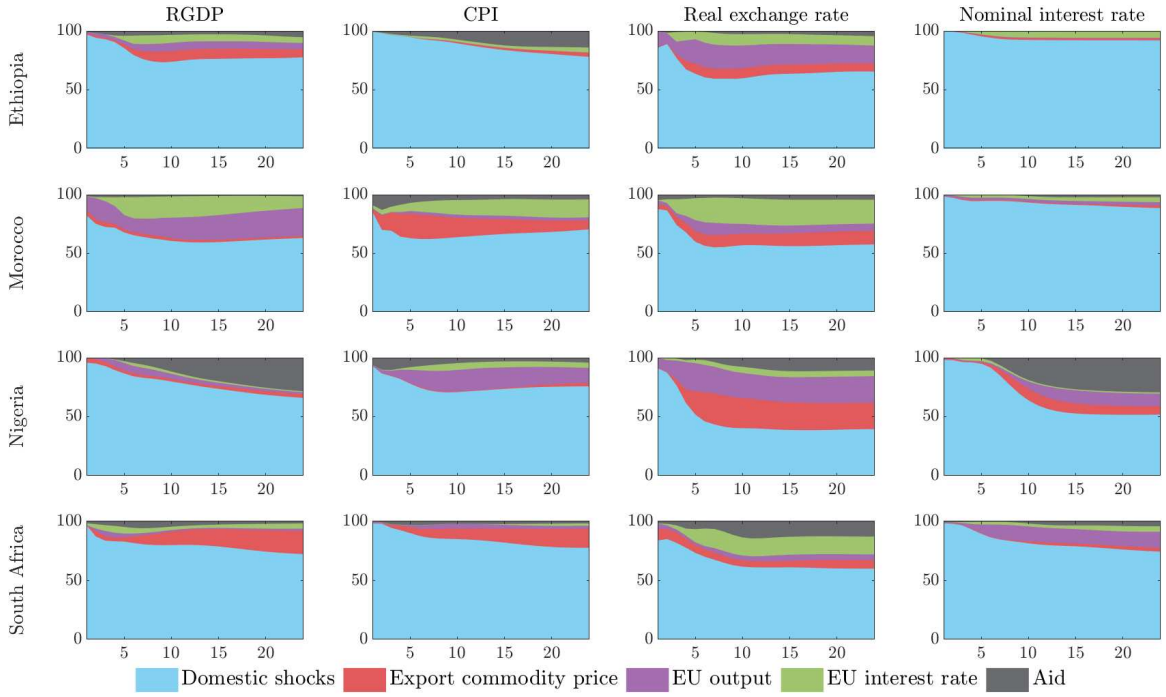


Figure 2.11: Ethiopia, Forecast error variance decomposition of domestic variables

The forecast error variance decomposition analysis revealed three main results. First, domestic shocks are mainly the main contributors in the short run (in the first 4 quarters) whereas the role of external shocks tends to be larger in the medium term and the long run. This might have to do with the less integration of African economies to the global financial markets and shocks from the external world take some time to be transmitted to African economies although the effect tends to be more persistent.

Second, the contribution of external shocks to the fluctuations of domestic variables varies significantly between the selected economies. This provides a strong foundation for the argument that generalizing about African economies and their vulnerability to external shocks is likely to be misleading. More importantly, consistent with the commonly held belief that emerging economies are less integrated into the global financial market, the relatively low-income economies (Ethiopia and Nigeria) are found

to be less sensitive to EU interest rate shocks.

Furthermore, among the external shocks, the contribution of EU output shock is found to be more relevant to Ethiopia, Morocco, and Nigeria. The higher role of EU output in these economies can be explained in two ways. On the one hand it is due to the link between EU output and migrant and institutional remittance inflows to these economies as this result is consistent with Drummond and Ramirez (2009) and Ahamada and Coulibaly (2013); Brambila-Macias and Massa (2010); Eggoh et al. (2019); Imam and Salinas (2015); Juselius et al. (2014); Olayungbo and Quadri (2019); Perez-Saiz et al. (2019); Sobiech (2019). On the other hand,

Third, the contribution of external shocks is found to be stronger for nominal variables (real exchange rate) than their contribution to real output level. More importantly, except for South Africa, the real exchange rate is found to be more sensitive than real output to export commodity price shocks.

The respective export commodity prices contribute 10, 5, 7, and 15 percent to the variation of the real GDP growth rate over the medium and long term (between 5-24 ahead forecasts) for Ethiopia, Morocco, Nigeria, and South Africa, respectively. The export commodity price shock contribution for Nigeria and Morocco appears to be lower than expected, despite oil and phosphate being among the most volatile commodities internationally and playing a significant role in the two economies. However, the respective export commodity prices for Nigeria and Morocco are key contributors to exchange rate fluctuations, which in turn are a fundamental driving force behind GDP growth.

2.6.3 Historical Variance Decomposition

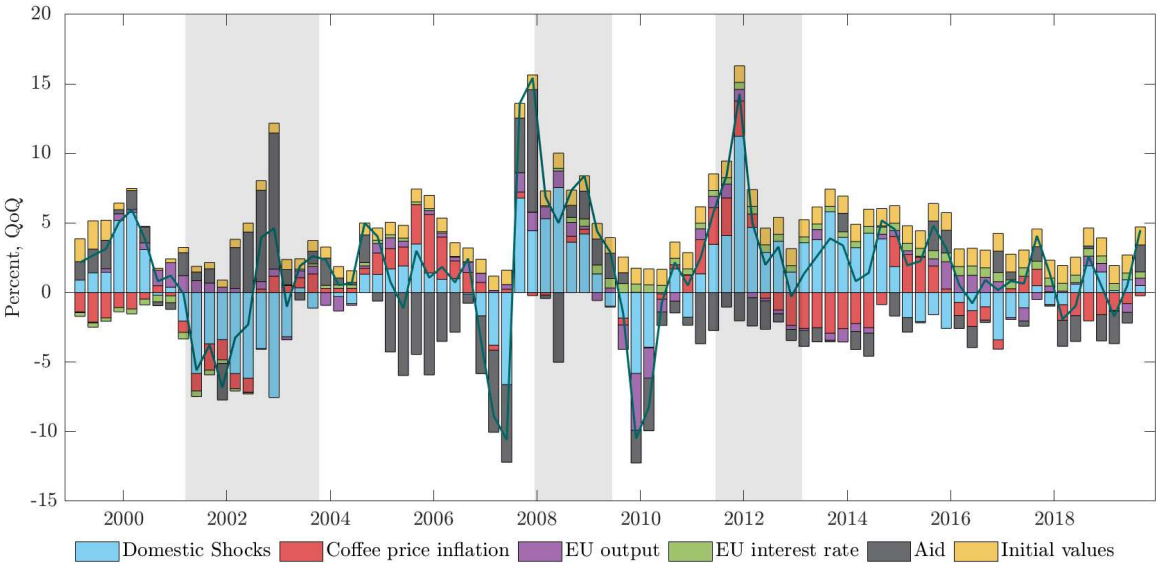
Another set of VAR model results that are quite useful to dissect the contribution of different shocks to the variables of interest in the model is historical variance de-

composition. For this purpose, I estimated the VARX model using the first difference transformed variables i.e., domestic inflation, exchange rate depreciation, the growth rates of real GDP, and nominal interest rate as domestic variables whereas export commodity price inflation, EU real GDP growth, EU interest rate and the growth rate of the percentage of aid to real GDP as external variables. Hence, to examine to what extent the external shocks in general, and the export commodity price shocks, in particular, have contributed to the fluctuations of economic growth in each economy under consideration, a historical decomposition of real GDP growth is computed for the period 1998QII - 2019QIV and the results are presented below.

2.6.3.1 Ethiopia

Since the beginning of the century, the real GDP of Ethiopia has experienced rapid growth with few notable periods of slump exceptions during the early 2000's global recessions, late 2007 and early 2010 (see Figure 2.12). The recession in the early 2000s was caused by the Ethiopian-Eritrean war, while the recession in late 2007 was due to the global food crisis, to which the country is vulnerable due to food insecurity. The recession in early 2010, on the other hand, was a delayed reaction of Ethiopia's economy to the global financial crisis. This has led to Ethiopia's economy being branded as one the top fastest-growing economies in Africa in the last 20 years. During these different episodes of economic growth performance, the economy is hit by several negative and positive shocks with domestic and external origins. Shocks of domestic origin significantly contributed to the fluctuations in Ethiopia's economic growth over the different episodes.

Among the external shocks, aid and official assistance shocks have contributed to Ethiopia's real GDP growth particularly before 2010, at which point the global financial crisis meant a decline in the flow of aid hence its contribution decayed. However, coffee price shock is visibly a key contributor to Ethiopia's economy over the years.



Note: The gray shaded area represents recession periods for EU economy and the dark cyan line plot is the data points for real GDP growth rate of Ethiopia.

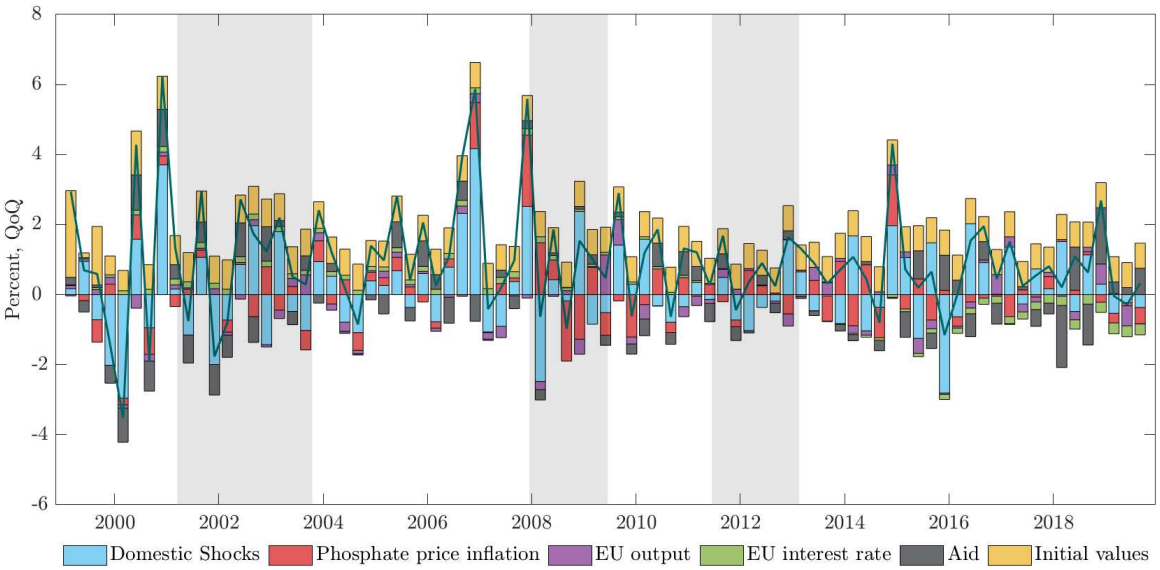
Figure 2.12: Ethiopia, Historical decomposition of real GDP growth, 1998QII - 2019QIV.

More importantly, except for the two main episodes of a significant drop in coffee prices during the early 2000s and the period between 2013 - 2014, coffee price shocks have contributed mostly towards the upward trajectories of Ethiopia's economic growth. However, it is worth noting that the contribution of EU output and interest rate shocks are found to be less important which is not a surprise as the influence of these shocks can easily be translated to aid and impact on the price and demand for Ethiopia's main export item, coffee.

Despite the recessions experienced by the EU economy during the financial and debt crisis periods, Ethiopia's economy expanded due to the country's Agricultural Development-Led Industrialization (ADLI) policy in 2008 and further infrastructural development, such as the Ethiopian Renaissance Dam (construction began in 2011). As can be seen from Figure 2.12, the domestic shocks had a significant dominant contribution to Ethiopia's GDP growth fluctuation during these periods.

2.6.3.2 Morocco

Though the rate of growth is lower than Ethiopia's, Morocco's economy is among the best-performing economies in Africa consistently delivering steady economic growth in the last two decades. A variety of domestic and external shocks have contributed to this performance where domestic shocks take the largest share. The contribution of external shocks is fairly distributed between phosphate price, aid, and EU output shocks whereas the contribution of EU interest rate shock is relatively minimal over the different episodes of Moroccan economy.



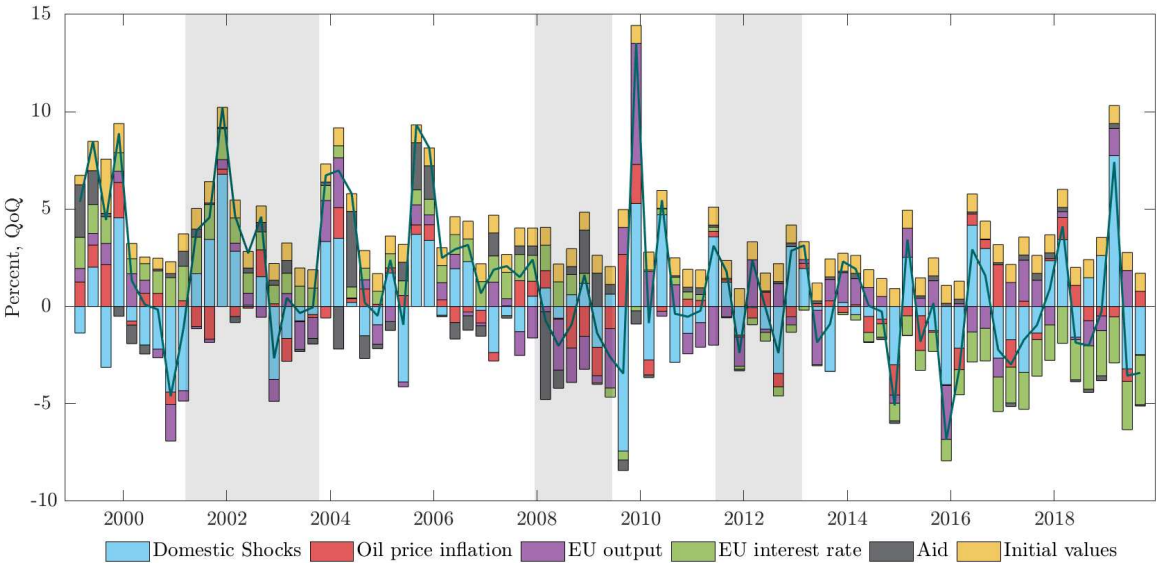
Note: The gray shaded area represents recession periods for the EU economy and the dark cyan line plot is the data points for the real GDP growth rate of Morocco.

Figure 2.13: Morocco, Historical decomposition of real GDP growth, 1998QII - 2019QIV.

Morocco has the strongest trade affiliations with the EU hence the contribution of EU output shocks being visible in explaining Morocco's real output fluctuation. Fluctuations in phosphate prices have significantly contributed in both ways of slowing down economic growth and amplifying positive performances, especially since the global financial crisis when the price of phosphate experienced significant fluctuations.

2.6.3.3 Nigeria

Nigeria's economy experienced a lot more ups and downs than the other economies under consideration since the early 2000s. More importantly, the return to civilian rule in the early 2000s led to political stability and economic expansion until the beginning of the Boko Haram Insurgency in early 2009. The overall economic growth performance of Nigeria can be considered as an economy with a lot more highs before the 2008 financial crisis and with more slumps and recoveries during the post-crisis periods. In all the periods of highs and lows, shocks to crude oil prices happened to be



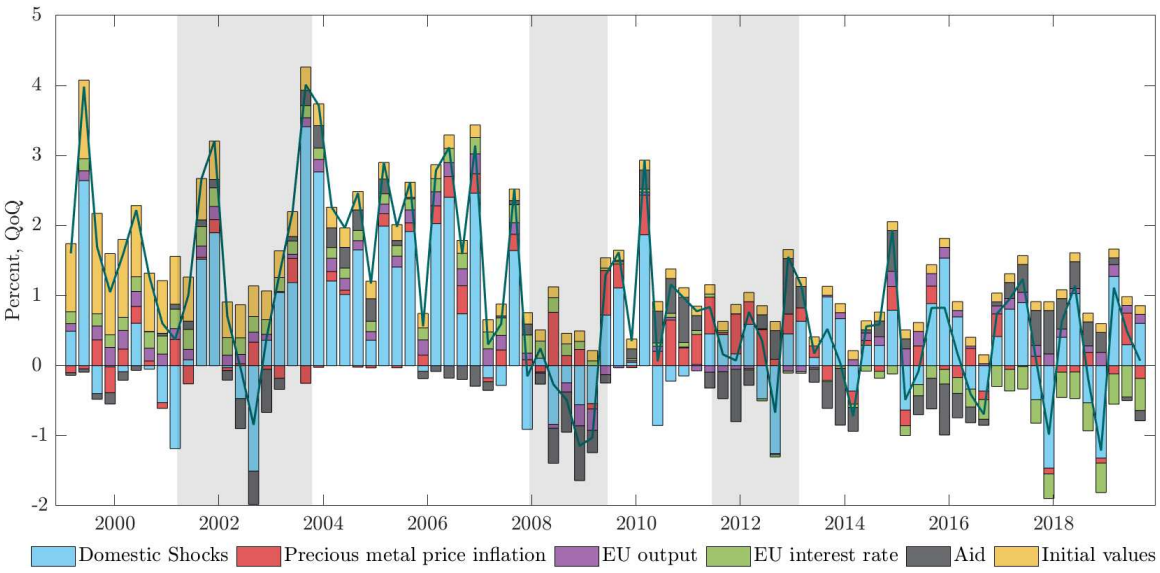
Note: The gray shaded area represents recession periods for EU economy and the dark cyan line plot is the data points for real GDP growth rate of Nigeria.

Figure 2.14: Nigeria, Historical decomposition of real GDP growth, 1998QII - 2019QIV.

among the key external shock contributors together with EU interest rate shocks. As Nigeria has one of the oldest stock exchange markets in the continent, the significant contribution of EU interest rate shocks is consistent with expectations. A notable mention is how the contribution of aid flow shocks has become less and less important since the early 2010s. The transition of Nigeria's economy to middle-income status in 2009 and the global economic slowdown have led to a decline in the flow of aid and official assistance to the country.

2.6.3.4 South Africa

The pre-2008 economic growth performance of South Africa has a lot more positive trajectories than the periods after. The end of apartheid in the mid-1990s led to international reintegration, increased investment, and economic growth in South Africa, as evidenced by the continuous expansion of the economy until the global financial crisis of 2008. Overall, South Africa's economic growth is moderate compared to the other countries in this study though it is also a reflection of the lower starting point of the other countries, particularly Ethiopia and Nigeria. As a testimony of the country's better integration into the global financial market, the contribution of EU interest rate is significant across different periods while shocks to EU output growth are relatively minimal. The key unique feature regarding the contribution of precious metal price shock is the contribution being more relevant in driving up South Africa's economy than dragging it down. This is because precious metals are highly income and price-elastic goods, and South Africa's economy benefits more than its loss because of a rise in the price of precious metals.



Note: The gray shaded area represents recession periods for the EU economy and the dark cyan line plot is the data points for real GDP growth rate of South Africa.

Figure 2.15: South Africa, Historical decomposition of real GDP growth, 1998QII - 2019QIV.

Considering South Africa is one of the wealthiest countries in Africa, the significant contribution of aid to the real output fluctuation might seem counterintuitive. However, the flow of aid and official assistance to South Africa has been one of the major sources of capital after apartheid ended in 1994. The result is consistent with previous empirical observations by Leshoro (2013).

In conclusion, external shocks are found to be important contributors to the Ethiopian, Moroccan, Nigerian, and South African economies. Furthermore, the contribution of each country's key export commodity price fluctuations is economically significant. Furthermore, the contribution of aid is found to be important to these economies regardless of their level of income and economic conditions while EU interest rate shocks are more important to economies with better financial sector development and global financial integration (South Africa and Nigeria).

2.7 Sensitivity Analysis

The prior specification and lag length selection of exogenous variables in the model specification are based on some restrictive assumptions. On the prior specification employed, results from different prior specifications are found to be not significantly different from the benchmark model. For instance, the benchmark model is compared with the hierarchical prior, SSVS, under Figure A.1, and results are found to be robust. Considering the lag length choices of exogenous variables in a VARX model is among the contested areas either to include lags or exclude lags, a different lag length choice of the exogenous variables are found to be worthy of reporting as the results are presented below. Consistent with the literature and as suggested by information criteria, the benchmark model considered a lag length equal to 4 for the exogenous variables while the modified model is based on a zero-lag length of the exogenous variables. As the results clearly show, the responses to each of the variables are

similar to the benchmark model and the main difference is the higher and much more persistent response of real exchange rate in the modified model except for South Africa (refer to Figure 2.16).

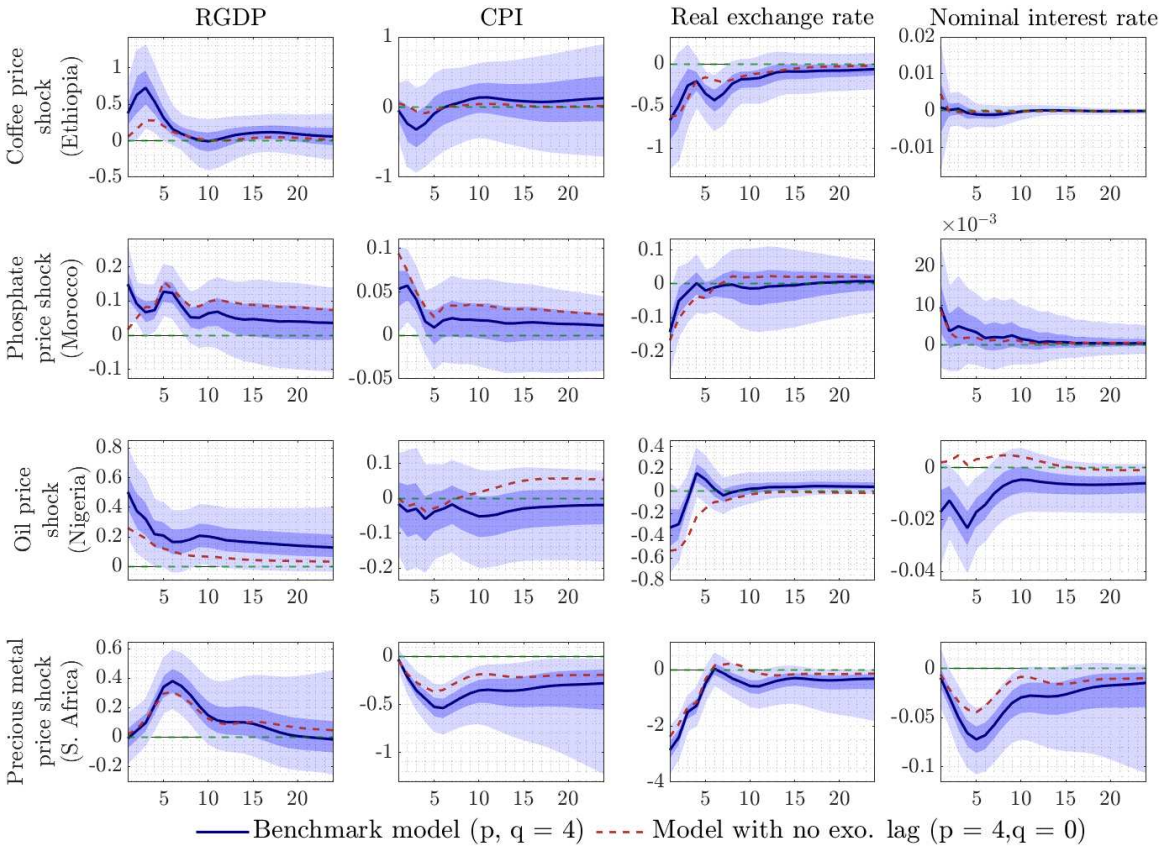


Figure 2.16: Responses to a 10 percent positive export commodity price shock

2.8 Conclusion

A Bayesian VAR model with key domestic endogenous and exogenous variables is employed with the adaptation of the foundation laid by Maćkowiak (2007). The model is estimated in the context of Ethiopian, Moroccan, Nigerian, and South African economies where these economies are among the powerhouses of Africa and have a common feature of single export commodity dependency. Based on the evidence that these economies have most of their trading (mainly export) relationship with EU economies, the EU representative variables are considered to represent the influence

of external shocks. More importantly, the model is estimated using data on real GDP, consumer price index, real exchange rate, and nominal interest rate variables as the domestic endogenous variables for the respective economy. EU output, EU interest rate, aid as a share of real GDP, and the respective country's key export commodity prices are used as exogenous variables. Accordingly, impulse response, historical decomposition, and forecast error variance decomposition results are dissected to understand the role of external shocks in general and export commodity price shocks in particular.

Results from impulse responses are found to be consistent with theoretical predictions where the respective economy's real output, inflation, and exchange rate variables are sensitive to export commodity price shocks. The results from historical variance and forecast error variance decomposition as well consistently revealed the important role of export commodity price shocks while the role of aid is more important to Ethiopia, Nigeria, Morocco, and South Africa.

The study provided an important lesson in highlighting what can be conclusively argued and the differences that exist across emerging markets. Although the results of the VARX model have provided conclusive and robust results on the role of export commodity price shocks on real output and the real exchange rate, the results are not without limitations. First, the response of consumer prices to export commodity price shocks turns out to be inconclusive and counterintuitive for the Moroccan economy. Such inconsistencies may be due to the limitations of VARX models, which are data-driven and do not incorporate a priori economic theory.

Second, the analysis of this study relied on a parsimonious VARX model to ensure comparability with previous research, such as Maćkowiak (2007). However, a larger VARX model could have been estimated to include additional characteristics such as financial sector development, external debt burden, and trade dynamics. This would

have provided further insights into the trends of the selected economies.

Third, VARX models can be sensitive to the identification strategy used and are therefore subject to problems of endogeneity and omitted variable bias problems, as they do not impose economic restrictions on the relationships. In this respect, the lack of robustness checks employing other alternative identification strategies, such as sign restriction or instrument variable-based identification strategies, is another limitation of the study. This opens a window of opportunity for further research based on a structural theoretical model for a specific emerging economy with proper consideration of the commodity export sector.

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CHAPTER III

EXTERNAL SHOCKS, MACROECONOMIC FLUCTUATIONS AND WELFARE IMPLICATIONS: A SMALL OPEN ECONOMY NEW KEYNESIAN DSGE MODEL WITH AN EXPORT COMMODITY SECTOR

Abstract

How do key macroeconomic variables of a small open economy react to domestic and external shocks? Can a small open emerging economy's dependence on a single commodity for export serve as a viable avenue for external shocks to transmit? A New Keynesian DSGE model, incorporating a distinctive structural characteristic of a commodity sector reliant on phosphate minerals, nominal price rigidity, and rule-of-thumb households, has been developed to provide insights into the questions at hand concerning the economy of Morocco. Bayesian estimation has been employed to understand the behavior of key macroeconomic variables and welfare implications in response to different domestic and external shocks. The results confirm theoretical predictions and empirical evidence on small open economies where external shocks have a significant impact on these economies. Additionally, the inclusion of Morocco's distinctive mineral sector in an otherwise conventional New Keynesian model, which is subject to heavy dependence on the global market for its pricing, is determined to constitute a viable conduit for external shocks affecting the country's economy. Overall, this paper provides valuable insight into the consequences of a constrained reliance on commodity exports in emerging economies.

JEL classification: C11; E32; F41; O55

Keywords: Small Open Economy; New Keynesian DSGE; Bayesian estimation, Export commodity sector.

3.1 Introduction

Being among the lower-middle-income countries, Morocco experienced steadily stable economic growth since the turn of the century. A combination of better agricultural productivity and a rising export commodity price, mainly mineral sector commodities, are often considered as the drivers of growth in the country. As is the case for many emerging economies, the country continues to battle with various challenges where the undesirable outcomes of external shocks are among the important hurdles.

Researchers, scholars, and policymakers have long been interested in examining the significance of external shocks on emerging small open economies. Structural VAR models are extensively employed to identify external shocks and their impact on macroeconomic fluctuations of small open emerging economies. However, empirical VAR models have limitations in identifying external shocks, such as spillover effects from external monetary policy, and fail to account for shocks to the emerging economy's main export commodity sector. Additionally, the literature on structural model development in accounting for emerging economy's main export commodity sector and investigating the main factors responsible for macroeconomic fluctuations in Morocco is limited.

Due to the existing debt burden and limited access to the international financial market, empirical and theoretical models in small open economies have focused on the spillover effect of external monetary policy shocks in emerging economies. While this channel is undoubtedly crucial for small open emerging economies, studying emerging economies is far more complex than employing models that have been proven to be feasible for advanced economies (Prasad and Zhang, 2015). To this end, this paper argues that the introduction of an export commodity sector is an important external shock transmission channel for small open emerging economies.

In the Moroccan economic context, Mossadak (2013) and Lahcen (2014) conducted research using standard New Keynesian DSGE models to investigate the impacts of fiscal and monetary policies. However, their studies solely relied on an implementation of the standard New Keynesian DSGE model neglecting the crucial macroeconomic characteristics of the country. The absence of attention paid to the export commodity sectors of small open emerging economies is a significant constraint, particularly given the evident volatility of commodity prices. The study by Konebayev et al. (2020) addresses this for the Kazakhstan economy, demonstrating the direct impact of export commodity sectors on welfare contributions via a clear transmission channel. Although the aim of the study is not to emphasize the significance of a price disruption in export commodities in a small, emerging economy, the findings by Mirfatah et al. (2021) suggest a theoretically plausible means of incorporating the export commodity sector's impact on Canadian economy.

A New Keynesian DSGE model framework with a particular emphasis on an export commodity sector is employed in this paper. Over the period between 1998 and 2019, the phosphate export commodity sector accounts for about 13 percent of Morocco's GDP and 23.55 percent of the country's total exports. The key features of the model include the introduction of Rule of Thumb (RoT) households, an export commodity sector, and an exchange rate-responsive monetary policy into an otherwise standard New Keynesian DSGE model. While the model uses Adolfson et al. (2007) and Mirfatah et al. (2021) as benchmarks, it abstracts from the two contributions on two accounts. First, fiscal policy stabilizers are introduced which is found to be useful in replicating some of the Two Agent New Keynesian (TANK) model fiscal policy results as in Galí et al. (2007). Second, considering the Moroccan economy has strong economic affiliations with the EU economy more than any other economic region, the EU economy is used as the external RoW block to construct and estimate the theoretical model for Morocco.

The main objective of this paper is to illustrate the contribution of various domestic and external structural shocks to macroeconomic fluctuations of small open emerging economies particularly the importance of phosphate price shocks. This will enable us to outline a simple but economically interpretable transmission mechanism of external shocks to emerging small open economies through their key structural feature, limited export commodity dependency. Furthermore, the paper also provides insight into monetary policy conduct in the context of the Moroccan economy as the country is continuously looking to transition into an inflation-targeting policy framework.

In this paper, it is demonstrated that incorporating a limited export commodity dependency feature into a New Keynesian DSGE model is a viable channel for the transmission of external shocks in small open emerging economies. It is of particular importance to note that a positive export commodity price acts as an external supply shock, leading to an increase in output and exports for emerging economies, while simultaneously causing a downward pressure on inflation. Historically, export commodity price shocks accounted for explaining a significant fluctuation in Morocco's real output. In contrast, other external shocks are found to have a profound contribution to the historical dynamics of nominal variables such as inflation and exchange rate, mainly driving upward movements of inflation and depreciation of exchange rate. However, their contribution to the historical real output fluctuation is found to be minimal. Moreover, it has been established that implementing a monetary policy rule that is responsive to fluctuations in exchange rates yields welfare benefits. This approach also enables small open economies to mitigate the adverse consequences of external shocks.

The rest of the paper is organized as follows. In Section 3.2, key features of the theoretical model are presented. Estimation strategy, description of data used for estimation, and results of the Bayesian estimated parameters are reported under Sec-

tion 3.3. Section 3.4 presents the main impulse response and historical decomposition results of the model while an alternative monetary policy sensitivity analysis is presented in Section 3.5. Section 3.6 concludes and closes by adding some remarks for future research works.

3.2 The Model

A SOE - RoW two-block New Keynesian DSGE model is set up in the context of the Moroccan economy. The SOE is affected by shocks from the RoW, while the latter is assumed to be big and immune from SOE shocks although there is a mineral export flow from the SOE to the RoW. The model closely follows Adolfson et al. (2007) and Mirfatah et al. (2021). Several real frictions in the form of habit persistence, investment adjustment cost, capital utilization, and RoT households are included together with a nominal price stickiness feature. The theoretical model presented in this section is designed to capture the export commodity sector dependency feature of small open emerging economies and the sector's role as a viable external shock transmission channel. The export commodity sector for Morocco refers to the phosphate sector production of the economy where 60 percent of its production is owned by the government while the remaining share is transferred to RoT households based on the assumption that the sector employs largely RoT households. For notation convenience purposes, variables with * belong to the RoW block, and variables with no * refer to the SOE. Additionally, the expressions SOE and Morocco are used interchangeably and the same is true between EU and RoW throughout the paper. Furthermore, the following general notations are used throughout the paper to distinguish between SOE and RoW variables.

	Domestic Production	Imported Good	Aggregate
Home Country Quantity	$X_{H,t}$	$X_{F,t}$	X_t
Home Country Price	$P_{H,t}$	$P_{F,t}$	P_t
Foreign Country Quantity	$X^*_{F,t}$	$X^*_{H,t}$	X^*_t
Foreign Country Price	$P^*_{F,t}$	$P^*_{H,t}$	P^*_t

3.2.1 Domestic Economy

3.2.2 Households

To illustrate the distributional effects of structural shocks and provide a feasible transmission channel to fiscal policy, a certain fraction of households are assumed to be Ricardian or savers while the other fraction is RoT households. The Ricardian household is assumed to have access to the financial market and hence use their savings to smooth consumption. On the other hand, RoT households are assumed to be constrained and they consume out of their wage income, transfer from the government, and an additional windfall income from phosphate production. For notation simplicity, variables with a superscript of 's' and 'r' refer to Ricardian and RoT households respectively with one exception where the superscript in Π^s refers to the depreciation of the domestic currency.

As is in the Smets and Wouters (2007a), the single-period utility general form suggested by King et al. (1988) is employed for both types of households with two exceptions where a preference shock to the discount factor is added and an internal habit persistence is considered unlike the original Smets and Wouters (2007a) model.

$$U_t(C_t, N_t) = E_0 \sum_{t=0}^{\infty} \beta^t b_t \left\{ \frac{\left(C_t - \chi C_{t-1}\right)^{1-\sigma}}{1-\sigma} \exp\left((\sigma - 1)\frac{N_t^{1+\varphi}}{1+\varphi}\right) \right\} \tag{3.2.1}$$

where C_t and N_t respectively represent the real consumption and hours of work for both types of households. σ and φ respectively represent the inverse of elasticity of substitution in consumption and the inverse of elasticity of labor supply (inverse

of Frisch labour supply elasticity). χ is the internal habit persistence parameter. b_t represents an exogenous $AR(1)$ process preference shock to the discount factor $\beta \in (0,1)$.

Proceeding to the optimization problem of households, $(1-\lambda)$ fraction of households are assumed to be Ricardian consumers. These households are assumed to be the only ones that can buy both domestic public bonds ($B_{GH,t}$) and foreign bonds ($B^*_{F,t}$). Assuming the rate of return on domestic private assets and public bonds are the same (R_t) and households enter period 0 with zero asset/debt the budget constraint becomes:

$$P_t C^s_t + P_{B,t} B_{GH,t} + S_t P^*_{B,t} B^*_{F,t} = W_t(1-\tau^w_t)N^s_t + B_{GH,t-1} + S_t B^*_{F,t-1} + (1-\tau^d_t)D^s_t - P_t T_t \tag{3.2.2}$$

where $B_{GH,t}$ and $B^*_{F,t}$ respectively represent the number of nominal one-period domestic and foreign bonds held at the end of period t each paying a one unit currency in the following period. $P_{B,t} = \frac{1}{R_t}$ and $P^*_{B,t} = \frac{1}{\Phi_t(.)R^*_t}$ represents the price of domestic and foreign bonds where the respective nominal gross interest rates are given by R_t and R^*_t. T_t is the lump sum transfer to/from households and W_t is the nominal hourly wage rate. D^s_t is a dividend payment to Ricardian households which is subject to a profit tax, τ^d_t. $\Phi_t(.)$ is the risk premium for the SOE's participation in the international financial market as discussed in Section 3.2.9 and S_t the nominal exchange rate. The risk premium $\Phi_t(.)$ depends on the net foreign asset position of the SOE relative to its GDP and the aggregate net asset position of the economy. Since the net asset position is aggregate and not individual, it is an exogenous factor in the households' optimization problem. Using the general price index as the aggregate price of the economy (P_t), the budget constraint for Ricardian households in real terms can be

expressed as:

$$C_t^s + B_{GH,t} + B_{F,t} = w_t(1-\tau_t^w)N_t^s + R_{t-1}\frac{1}{\Pi_t}B_{GH,t-1} + R_{t-1}^*\Phi_{t-1}(.)\frac{\Pi_t^s}{\Pi_t}B_{F,t-1} + (1-\tau_t^d)d_t^s - T_t \tag{3.2.3}$$

where $\Pi_t = \frac{P_t}{P_{t-1}}$ represents gross inflation, $\Pi_t^S = \frac{S_t}{S_{t-1}}$ is the gross depreciation, $w_t = \frac{W_t}{P_t}$ is the real wage and $d_t^s = \frac{D_t^s}{P_t}$ is dividend payment to Ricardian households in real terms.

The optimization problem for Ricardian households takes the form:

$$\max_{C_t^s, N_t^s} U_t = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ b_t \frac{\left(C_t^s - \chi C_{t-1}^s\right)^{1-\sigma_s}}{1-\sigma_s} \exp\left((\sigma_s - 1)\frac{N_t^{s(1+\varphi_s)}}{1+\varphi_s}\right) \right\} \tag{3.2.4}$$

Subject to Equation (3.2.3)

Accordingly, taking the first order conditions for $C_t^s, N_t^s, B_{GH,t}, B_{F,t}$ and rearranging the expressions provides the inter-temporal substitution between consumption and leisure as:

$$w_t(1-\tau_t^w) = \frac{(C_t^s - \chi C_{t-1}^s)(N_t^s)^{\varphi_s}}{1 - \beta\chi\frac{U_{t+1}^s}{U_t^s}\frac{C_t^s - \chi C_{t-1}^s}{C_{t+1}^s - \chi C_t^s}} \tag{3.2.5}$$

Similarly, the Euler equation expressions associated with domestic and foreign assets take the form:

$$1 = E_t\left[\frac{\Lambda_{t+1}^s}{\Pi_{t+1}}\right]R_t \tag{3.2.6}$$

$$1 = E_t\left[\Lambda_{t+1}^s \frac{\Pi_{t+1}^s}{\Pi_{t+1}}\right]\Phi_t(.)R_t^* \tag{3.2.7}$$

where $\Lambda^s_{t+1} \equiv \beta \frac{U^s_{C,t+1}}{U^s_{C,t}}$ is the stochastic discount factor and
$U^s_{C,t} = \left(C^s_t - \chi C^s_{t-1}\right)^{-\sigma_s} \exp\left((\sigma_s - 1)\frac{N_t^{s(1+\varphi_s)}}{1+\varphi_s}\right)$ is the marginal utility of consumption.

Arbitrage between nominal bonds denominated in different currencies gives rise to the Uncovered Parity Condition (UIP) condition as follows:

$$E_t\left[\frac{\Lambda_{t+1}}{\Pi_{t+1}}\right] R_t = R^*_t \Phi_t(.) E_t\left[\Lambda_{t+1}\frac{\Pi^s_{t+1}}{\Pi_{t+1}}\right] \tag{3.2.8}$$

The rest of (λ) households are RoTs and they do not have access to the asset markets but rather consume all the wage income, transfers, and a windfall income from phosphate production. Hence the budget constraint (including the exogenous phosphate production share where τ^p is the government's share of phosphate production) is given by:

$$P_t C^r_t = W_t(1-\tau^w_t)N^r_t + (1-\tau^p)S_t P^*_{p,t} Y^p_t - P_t T_t \tag{3.2.9}$$

where $P^*_{p,t}$ and Y^p_t respectively represent the nominal price of phosphate and the total phosphate production. Using the general price level, the budget constraint in real terms takes the form:

$$C^r_t = w_t(1-\tau^w_t)N^r_t + (1-\tau^p)\Omega_t \frac{P^*_{p,t}}{P^*_t} Y^p_t - T_t \tag{3.2.10}$$

where Ω_t is the real exchange rate given by $\frac{S_t P^*_t}{P_t}$ and P^*_t is the RoWs aggregate price level.

Unlike to the Ricardian households, the optimization problem for RoT involves only a choice between consumption and hours of work. Hence, after rearranging the first order conditions of RoT households, the inter-temporal substitution between con-

sumption and leisure becomes:

$$w_t(1-\tau_t^w) = \frac{(C_t^r - \chi C_{t-1}^r)(N_t^r)^{\varphi_r}}{1-\beta\chi\frac{U_{t+1}^r}{U_t^r}\frac{C_t^r-\chi C_{t-1}^r}{C_{t+1}^r-\chi C_t^r}} \tag{3.2.11}$$

The aggregate consumption and hours of work are obtained by a weighted consumption and hours of work by the two types of households as follows:

$$C_t = \lambda C_t^r + (1-\lambda)C_t^s \tag{3.2.12}$$

$$N_t = \lambda N_t^r + (1-\lambda)N_t^s \tag{3.2.13}$$

3.2.2.1 Consumption Demand

Each level of aggregate consumption by Ricardian and RoT households, $C_t = C^r, C^s$ is a composite of home produced ($C_{H,t}$) and imported goods ($C_{F,t}$). Following Adolfson et al. (2007), the elasticity of substitutions between home and imported goods in the consumption (μ_C), investment (μ_I), and government spending (μ_G) goods is assumed to be the same. At this point, the household's consumption problem is a two-stage problem. On the one hand, each type of household maximizes the composite consumption of home-produced and foreign goods subject to the total consumption spending (or minimizes the spending subject to the Dixit-Stiglitz consumption aggregator of home and foreign goods) as follows:

$$\max_{C_{H,t},C_{F,t}} C_t = \left[(w_C)^{\frac{1}{\mu_C}}(C_{H,t})^{\frac{\mu_C-1}{\mu_C}} + (1-w_C)^{\frac{1}{\mu_C}}(C_{F,t})^{\frac{\mu_C-1}{\mu_C}}\right]^{\frac{\mu_C}{\mu_C-1}} \tag{3.2.14}$$

subject to the total consumption spending Equation (3.2.15)

$$P_tC_t = P_{H,t}C_{H,t} + P_{F,t}C_{F,t} \tag{3.2.15}$$

Solving this optimization problem for the households provides us the corresponding Dixit-Stiglitz price index and the respective optimal demand functions for home-produced and imported goods as:

$$P_t = \left(w_C P_{H,t}^{1-\mu_C} + (1-w_C) P_{F,t}^{1-\mu_C}\right)^{\frac{1}{1-\mu_C}} \tag{3.2.16}$$

where P_t is the aggregate price level (CPI), $P_{H,t}$ and $P_{F,t}$ respectively refer to the price of home and imported consumption goods respectively.

$$C_{H,t} = w_C \left(\frac{P_{H,t}}{P_t}\right)^{-\mu_C} C_t \tag{3.2.17}$$

$$C_{F,t} = (1-w_C) \left(\frac{P_{F,t}}{P_t}\right)^{-\mu_C} C_t \tag{3.2.18}$$

where w_C is the home good bias in domestic consumption.

The second consumption problem for the household involves the allocation of the chosen consumption level across the different varieties of differentiated goods. This is achieved by either maximizing the consumption of a variety of goods among the differentiated consumption goods subject to the spending on differentiated consumption goods or minimising the spending subject to the consumption index of a variety of goods. The household purchases differentiated goods, $i \in [0,1]$, in a retail market and combine them into composite goods using a CES aggregator (for both home and imported goods):

$$C_{H,t} = \left[\int_0^1 \left(C_{H,t}(i)\right)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{1-\varepsilon}} \tag{3.2.19}$$

$$C_{F,t} = \left[\int_0^1 \left(C_{F,t}(i)\right)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{1-\varepsilon}} \tag{3.2.20}$$

The corresponding consumption maximization problem is given by:

$$\max_{C_{H,t}(i)} C_{H,t} = \left[\int_0^1 \left(C_{H,t}(i) \right)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{1-\varepsilon}} \tag{3.2.21}$$

subject to spending on a variety of differentiated goods (Equation (3.2.22))

$$P_{H,t} C_{H,t} = \int_0^1 P_{H,t}(i) C_{H,t}(i) di \tag{3.2.22}$$

where ε is the elasticity of substitution between differentiated goods. Rearranging the first-order conditions of the optimization problem provides the demand function for each differentiated good (both home-produced and imported goods) as follows:

$$C_{H,t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\varepsilon} C_{H,t} \tag{3.2.23}$$

$$C_{F,t}(i) = \left(\frac{P_{F,t}(i)}{P_{F,t}} \right)^{-\varepsilon} C_{F,t} \tag{3.2.24}$$

where the domestic and foreign good price indexes are defined by:

$$P_{H,t} = \left[\int_0^1 \left(P_{H,t}(i) \right)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{1-\varepsilon}} \tag{3.2.25}$$

$$P_{F,t} = \left[\int_0^1 \left(P_{F,t}(i) \right)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{1-\varepsilon}} \tag{3.2.26}$$

3.2.2.2 Investment and Government Spending Demand

Like the consumption demand, investment (I) and government spending (G) goods are a composite of both home-produced and imported goods. Hence, the same two-stage optimization problem applies to I and G. Accordingly, the corresponding de-

mand functions and price indexes are obtained for I and G:

$$I_t = \left[(w_I)^{\frac{1}{\mu_I}}(I_{H,t})^{\frac{\mu_I-1}{\mu_I}} + (1-w_I)^{\frac{1}{\mu_I}}(I_{F,t})^{\frac{\mu_I-1}{\mu_I}}\right]^{\frac{\mu_I}{\mu_I-1}} \tag{3.2.27}$$

$$G_t = \left[(w_G)^{\frac{1}{\mu_G}}(G_{H,t})^{\frac{\mu_G-1}{\mu_G}} + (1-w_G)^{\frac{1}{\mu_G}}(G_{F,t})^{\frac{\mu_G-1}{\mu_G}}\right]^{\frac{\mu_G}{\mu_G-1}} \tag{3.2.28}$$

Given that $P_{H,t} = P^C_{H,t} = P^I_{H,t}$ and $P_{F,t} = P^C_{F,t} = P^I_{F,t}$, maximizing Equation (3.2.27) subject to a given aggregate expenditure $P^I_t I_t = P_{H,t}I_{H,t} + P_{F,t}I_{F,t}$ yields the optimal allocation of investment demand as follows:

$$I_{H,t} = w_I \left(\frac{P_{H,t}}{P^I_t}\right)^{-\mu_I} I_t \tag{3.2.29}$$

$$I_{F,t} = (1-w_I) \left(\frac{P_{F,t}}{P^I_t}\right)^{-\mu_I} I_t \tag{3.2.30}$$

where the aggregate investment price, P^I_t (different from CPI) is given by:

$$P^I_t = \left(w_I P^{1-\mu_I}_{H,t} + (1-w_I)P^{1-\mu_I}_{F,t}\right)^{\frac{1}{1-\mu_I}} \tag{3.2.31}$$

Given that $P_{H,t} = P^C_{H,t} = P^I_{H,t} = P^G_{H,t}$ and $P_{F,t} = P^C_{F,t} = P^I_{F,t} = P^G_{F,t}$, maximizing Equation (3.2.28) subject to a given aggregate expenditure $P^G_t G_t = P_{H,t}G_{H,t} + P_{F,t}G_{F,t}$ yields the optimal allocation of government spending demand as follows:

$$G_{H,t} = w_G \left(\frac{P_{H,t}}{P^G_t}\right)^{-\mu_G} G_t \tag{3.2.32}$$

$$G_{F,t} = (1-w_G) \left(\frac{P_{F,t}}{P^G_t}\right)^{-\mu_G} G_t \tag{3.2.33}$$

where the aggregate government spending price, P^G_t (different from CPI) is given by:

$$P^G_t = \left(w_G P^{1-\mu_G}_{H,t} + (1-w_G)P^{1-\mu_G}_{F,t}\right)^{\frac{1}{1-\mu_G}} \tag{3.2.34}$$

where μ_I and μ_G are the respective elasticity of substitution between home-produced and imported investment and government spending goods. w_I and w_G are the respective home biases of investment and government spending goods. By the same analogy, similar results for the aforementioned part are computed for the RoW economy and results can be found in the appendix.

3.2.3 Firms

Firms are composed of intermediate and final good producers as well as capital producers as is the case in the standard New Keynesian DSGE literature.

3.2.3.1 Final good producer firms

The final good producers are retail firms operating in a perfectly competitive environment and assemble the differentiated wholesale goods into a basket of homogeneous goods for both home and RoW households (C_H, C_F), capital goods producers (I_H, I_F) and government (G_H, G_F). Assuming that preferences are symmetric in the home and the foreign economy, $\varepsilon = \varepsilon^*$, the CES aggregator for differentiated goods to households, capital goods producers and government is given by:

$$C_{H,t} = \left(\int_0^1 C_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \qquad C^*_{H,t} = \left(\int_0^1 C^*_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}$$

$$I_{H,t} = \left(\int_0^1 I_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \qquad I^*_{H,t} = \left(\int_0^1 I^*_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}$$

$$G_{H,t} = \left(\int_0^1 G_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \qquad G^*_{H,t} = \left(\int_0^1 G^*_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}$$

For each differentiated good j, home households choose $C_{H,t}(j)$ at a price $P_{H,t}(j)$ to maximize C_t given the total expenditure $\int_0^1 P_{H,t}(j) C_{H,t}(j) dj$. The same analogy for the RoW households, RoW capital goods producers, and government spending goods where the optimization provides the demand function for each differentiation good

by the aforementioned agents shown in the previous section. As is in Kimball (1995), the CES aggregator of output for the final good producer firms is given by:

$$Y_t = \left(\int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{3.2.35}$$

As the setting described under Appendix B.1.1, the optimal conditions result in an expression for the aggregate price level for home-produced goods.

$$P_{H,t} = \left(\int_0^1 P_{H,t}(j)^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}}$$

3.2.3.2 Intermediate good producer firms

A continuum of firms indexed by $j \in (0,1)$ face a perfectly competitive factor market and produce differentiated products $(Y_t(j))$ while operating in a monopolistically competitive market setup using a Cobb-Douglas technology where the technology process is common to all domestic producers. The available technology is given by:

$$Y_t(j) = F(Z_t, N_t, K_{t-1}) = K_{t-1}(j)^{\alpha} \left(Z_t N_t(j)\right)^{1-\alpha} \tag{3.2.36}$$

where α is the income share of capital, K is the capital resource and Z is an exogenous $AR(1)$ process technology. An intermediate good producer firm faces a dual problem of profit maximization (cost minimization) and price setting for each intermediate good. In the first problem, each firm aims to minimize the real cost of production in terms of home goods price given the production level and they face a perfectly competitive factor market. Defining $r_t^k = \frac{R_t^k}{P_{H,t}}$ as the real rental rate and real wage as $w_t = \frac{W_t}{P_{H,t}}$, the optimal condition of firm's cost minimization problem provides expressions for the optimal demand functions of the two inputs and the real marginal

cost function.

$$r_t^k \equiv \frac{R_t^k}{P_t} = \alpha \frac{Y_t}{K_{t-1}} mc_t \frac{P_{H,t}}{P_t} \tag{3.2.37}$$

$$w_t \equiv \frac{W_t}{P_t} = (1-\alpha) \frac{Y_t}{N_t} mc_t \frac{P_{H,t}}{P_t} \tag{3.2.38}$$

$$mc_t = \frac{1}{\frac{P_{H,t}}{P_t}} \left(\frac{r_t^k}{\alpha} \right)^{\alpha} \left(\frac{w_t}{(1-\alpha) Z_t} \right)^{1-\alpha} \tag{3.2.39}$$

The real marginal cost, mc_t (the same across firms) depends on $\frac{P_{H,t}}{P_t}$, r_t^k, w_t and Z_t which implies that the marginal cost in a small open economy is influenced by more factors than in the closed economy models.

3.2.3.3 Price setting

The second problem for an intermediate good producer firm j is setting prices subject to a quadratic adjustment cost as in Rotemberg (1982)[8]. Firm j maximizes the discounted present value of real profit (Ξ) subject to the final good producer's demand for an intermediate good and the optimal condition provides an expression for the New Keynesian Phillips curve.

$$\Pi_{H,t}(\Pi_{H,t} - 1) = \frac{\varepsilon}{\gamma_p} \left(mc_t M_t + \frac{1-\varepsilon}{\varepsilon} \right) + E_t \left[\Lambda_{t+1}^s \frac{Y_{t+1}}{Y_t} (\Pi_{H,t+1} - 1) \Pi_{H,t+1} \right] \tag{3.2.40}$$

Following the standard in New Keynesian literature, the Rotemberg price adjustment is considered a waste to the economy and hence is part of the national budget

[8] The quadratic price adjustment cost ($AC_t(j)$) is measured in terms of the final good as in (Basu and Bundick, 2017; Bonciani and Van Roye, 2016; Katayama and Kim, 2018; Leduc and Liu, 2016). $AC_t(j)$ scaled by aggregate output (Y_t) as in (Basu and Bundick, 2017; Bonciani and Van Roye, 2016; Katayama and Kim, 2018; Leduc and Liu, 2016) i.e., $AC_t(j) = \frac{\gamma_p}{2} \left(\frac{P_{H,t}(j)}{P_{H,t-1}(j)} - 1 \right)^2 Y_t$. where $\gamma_p \geq 0$ is the degree of nominal price rigidity (Rotemberg, 1982). To ensure a similar linear Phillips Curve as to the Calvo framework, γ_p is set as $\gamma_p = \frac{(\varepsilon-1)\theta_p}{(\Pi_H^2(1-\theta_p)(1-\beta\theta_p))}$ where θ_p is the Calvo price rigidity parameter.

constraint as is the capital adjustment cost.

The monopoly profit that will be distributed as dividends to Ricardian households is taxed by the government when received by households. The expression for dividend in real terms is given by:

$$d_t \equiv \frac{D_t}{P_t} = \frac{P_{H,t}}{P_t}\left(1 - mc_t - \frac{\gamma_p}{2}\left(\frac{P_{H,t}}{P_{H,t-1}} - 1\right)^2\right) Y_t \tag{3.2.41}$$

3.2.4 Capital producing firms

A continuum of perfectly competitive capital-producing firms takes the aggregate capital installed in the economy as given, purchases investment goods, and transforms it into new capital. The technology to produce new capital is given by $\eta_t\left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t$ where $S\left(\frac{I_t}{I_{t-1}}\right) = \frac{\phi_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 I_t$ is the investment adjustment cost firms face as of the form in Cooper and Haltiwanger (2006). At the steady-state, $S(.)$ has the following properties: $S'(.) > 0, s''(.) > 0, S(1) = S'(1) = 0$. Capital producers purchase investment goods from home and foreign retail firms at the real relative price of investment goods to home good ($\frac{P_t^I}{P_t}$) selling at real price q_t to maximize expected discounted profits as follows:

$$\max_{\{I_{t+j}\}_0^\infty} E_t \sum_{j=0}^{\infty} \Lambda_{t+j}\Pi_{t+j} = \max_{\{I_{t+j}\}_0^\infty} E_t \sum_{j=0}^{\infty} \Lambda_{t+j}\left\{\eta_{t+j}q_{t+j}\left(1 - S\left(\frac{I_{t+j}}{I_{t+j-1}}\right)\right) I_{t+j} - \frac{P_{t+j}^I}{P_{t+j}} I_{t+j}\right\} \tag{3.2.42}$$

where Λ_{t+j} is the stochastic discount factor and the motion of aggregate capital stock in the economy is given by:

$$K_t = (1-\delta)K_{t-1} + \eta_t\left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t \tag{3.2.43}$$

and

$$I_t = \left[(w_I)^{\frac{1}{\mu_I}} (I_{H,t})^{\frac{\mu_I - 1}{\mu_I}} + (1 - w_I)^{\frac{1}{\mu_I}} (I_{F,t})^{\frac{\mu_I - 1}{\mu_I}} \right]^{\frac{\mu_I}{\mu_I - 1}} \tag{3.2.44}$$

As is the case in Greenwood et al. (1988) and Fisher (2006), η_t can be interpreted as an investment-specific technology shock (or a shock to the production technology of capital goods), as well as a shock to the relative price of investment in terms of consumption goods.

$$\Pi = \eta_t q_t \left(1 - S\left(\frac{I_t}{I_{t-1}} \right) \right) I_t - \frac{P_t^I}{P_t} I_t + \max_{\{I_{t+j}\}_1^\infty} E_t \sum_{j=1}^{\infty} \Lambda_{t+j} \Pi_{t+j} \tag{3.2.45}$$

Each period, capital-producing firms choose the investment level to maximize the discounted flow of profit. The optimal condition expression takes the form:

$$\eta_t q_t \left(1 - S\left(\frac{I_t}{I_{t-1}} \right) - \frac{I_t}{I_{t-1}} X_t \right) + E_t \left(\Lambda_{t+1}^s \eta_{t+1} q_{t+1} X_{t+1} \frac{I_{t+1}^2}{I_t^2} \right) = \frac{P_t^I}{P_t} \tag{3.2.46}$$

where $X_t = \phi_I \left(\frac{I_t}{I_{t-1}} - 1 \right)$.

At this point, we can define the gross real return on capital (rr_t^k) net of depreciation and corporate profit tax (τ_t^k) as follows:

$$rr_t^k = \frac{(1 - \tau_t^k) r_t^k + (1 - \delta) q_t}{q_{t-1}} \tag{3.2.47}$$

Efficient financial intermediation within the SOE country implies the zero arbitrage condition and hence the discounted real gross rate of capital return equals the discounted gross real return of domestic bonds ($R_t \frac{P_t}{P_{t+1}} \equiv \frac{R_t}{E_t \Pi_{t+1}}$):

$$E_t(\Lambda_{t+1}^s rr_{t+1}^k) = E_t \left(\frac{\Lambda_{t+1}^s}{\Pi_{t+1}} \right) R_t = 1 \tag{3.2.48}$$

3.2.5 Commodity (Mineral) sector

Considering the economically substantial role that the phosphate mineral sector plays in the Moroccan economy, this export commodity sector (mineral) is treated as its output being exogenous constant endowment, Y_t^P. Following the approach used by Beidas-Strom and Poghosyan (2011) and Konebayev et al. (2020), a homogeneous commodity is produced by a single firm and is entirely exported and revenue is driven only by the price of the commodity $P_{p,t}^*$ denominated in foreign currency. Given the price of phosphate is determined by the international market, $P_{p,t}^*$ is assumed to be an AR(1) exogenous process. The commodity is produced as windfall production, and it is entirely exported where the only channel it affects the model is through the trade balance, government budget constraint, and RoT households budget constraint. The government is assumed to own τ_t^p fraction of the production and the $1 - \tau_t^p$ is transferred to RoT households where τ_t^p is calibrated at 0.6. The production of this sector is considered as a direct increase in domestic GDP since its production is a windfall gain.

$$Y_t^P = \kappa_p Y_t \tag{3.2.49}$$

where κ_p is the share of the export commodity sector to the total SOE production. Hence, GDP of Morocco is given by:

$$P_{H,t} GDP_t = S_t P_{p,t}^* Y_t^P + P_{H,t} Y_t$$

In real terms, the expressing takes the form:

$$GDP_t = \Omega_t \frac{1}{\frac{P_{H,t}}{P_t}} \frac{P_{p,t}^*}{P_t^*} Y_t^P + Y_t \tag{3.2.50}$$

where Ω_t is the real exchange rate.

3.2.6 Exchange rate pass-through

Assuming that export prices are set in the producer's currency Producer Currency Pricing (PCP), the nominal exchange rate (S_t) is defined as the price of foreign currency in terms of domestic currency and the Law of One Price (LOP) holds which implies:

$$P_{H,t} = S_t P^*_{H,t} \quad and \quad P_{F,t} = S_t P^*_{F,t} \tag{3.2.51}$$

Assuming that there exists a perfect exchange rate pass-through for imports to SOEs, $P^*_{F,t} = P^*_t, S_t P^*_t = P_{F,t}$. Then, the real exchange rate is given by:

$$\Omega_t = \frac{S_t P^*_t}{P_t} \equiv \frac{P_{F,t}}{P_t} \tag{3.2.52}$$

3.2.7 Terms of trade, Law of one price (LOP) and inflation

Terms of trade (Ψ) reflects the SOE's competitiveness in the international market. It is defined as the relative price of imported goods to domestic goods.[9]

$$\Psi_t = \frac{P_{F,t}}{P_{H,t}} \equiv \frac{S_t P^*_{F,t}}{P_{H,t}} \tag{3.2.53}$$

Similarly, terms of trade for the RoW block is $\Psi^*_t \equiv \frac{P^*_{H,t}}{P^*_{F,t}}$.

$$\Psi_t = \frac{P_{F,t}}{P_{H,t}} = \frac{S_t P^*_{F,t}}{S_t P^*_{H,t}} = \frac{P^*_{H,t}}{P^*_{F,t}} = \frac{1}{\Psi^*_t} \tag{3.2.54}$$

[9] This is an inverse of the conventional definition of terms of trade (the ratio of export price to import price). The inverse definition is considered to illustrate a positive shock in Ψ as a deterioration to the SOE's competitiveness in the international market and vice versa.

Gross inflation terms are given by:

$$\Pi_t = \frac{P_t}{P_{t-1}} \tag{3.2.55}$$

$$\Pi_{H,t} = \frac{P_{H,t}}{P_{H,t-1}} \tag{3.2.56}$$

$$\Pi_{F,t} = \frac{P_{F,t}}{P_{F,t-1}} \tag{3.2.57}$$

To illustrate the effect of Morocco's international trade competitiveness on its economy, an AR(1) process terms of trade shock (tot) is introduced

From $\Psi_t = \frac{P_{F,t}}{P_{H,t}}$, $\Psi_{t-1} = \frac{P_{F,t-1}}{P_{H,t-1}} \Rightarrow \frac{\Psi_t}{\Psi_{t-1}} = \frac{\Pi_{F,t}}{\Pi_{H,t}}$.
With the AR(1) process terms of trade shock takes the form:

$$\log\left(\frac{\Psi_t}{\Psi_{t-1}}\right) = \log\left(\frac{\Pi_{F,t}}{\Pi_{H,t}}\right) - \log\left(\frac{tot_t}{tot_{t-1}}\right) \tag{3.2.58}$$

As most of our expressions in the model involve relative price ratios, the expression in Equation 3.2.16 can be used to establish the following aggregate inflation expression:

$$\Pi_t = \left[w_C\left(\Pi_{H,t}\frac{P_{H,t-1}}{P_{t-1}}\right)^{1-\mu_C} + (1-w_C)\left(\Pi_{F,t}\frac{P_{F,t-1}}{P_{t-1}}\right)^{1-\mu_C}\right]^{\frac{1}{1-\mu_C}} \tag{3.2.59}$$

The same price and terms of trade ratio expressions are specified to simplify notations as described under Appendix B.2.

3.2.8 Export demand to the SOE

The foreign counterpart to consumption, investment, and government spending demand that represents the export demands to the SOE can be derived in the same

analogy as consumption demand and is given by:

$$C^*_{H,t} = (1-w^*_C)\left(\frac{P^*_{H,t}}{P^*_t}\right)^{-\mu^*_C} C^*_t \equiv (1-w^*_C)\left(\frac{\frac{1}{S_t}P_{H,t}}{\frac{1}{S_t}P_{F,t}}\right)^{-\mu^*_C} C^*_t \equiv (1-w^*_C)\left(\frac{1}{\Psi_t}\right)^{-\mu^*_C} C^*_t$$

$$I^*_{H,t} = (1-w^*_I)\left(\frac{P^*_{H,t}}{P^{*I}_t}\right)^{-\mu^*_I} I^*_t \equiv (1-w^*_I)\left(\frac{\frac{1}{S_t}P_{H,t}}{\frac{1}{S_t}P^I_t}\right)^{-\mu^*_I} I^*_t \equiv (1-w^*_I)\left(\frac{P_{H,t}}{P^I_t}\right)^{-\mu^*_I} I^*_t$$

$$G^*_{H,t} = (1-w^*_G)\left(\frac{P^*_{H,t}}{P^{*G}_t}\right)^{-\mu^*_G} G^*_t \equiv (1-w^*_G)\left(\frac{\frac{1}{S_t}P_{H,t}}{\frac{1}{S_t}P^G_t}\right)^{-\mu^*_G} G^*_t \equiv (1-w^*_G)\left(\frac{P_{H,t}}{P^G_t}\right)^{-\mu^*_G} G^*_t$$

Accordingly, the total (including the entirely exported phosphate production) export for the SOE is given by:

$$EX_t = C^*_{H,t} + I^*_{H,t} + G^*_{H,t} + Y^p_t \tag{3.2.60}$$

Since the RoW is assumed to be a closed economy[10], $C^*_{H,t} = I^*_{H,t} = G^*_{H,t} = 0$. However, the export for the SOE is different from zero. To ensure these conditions are satisfied at the steady state, the respective shares of consumption, investment, and government spending goods to the SOE's GDP are used to establish the steady state expressions. To determine these proportions for the SOE, we write the steady state as:

$$EX_t = cs_{ex}EX_{ss} + is_{ex}EX_{ss} + gs_{ex}EX_{ss} \tag{3.2.61}$$

Including the phosphate sector export:

$$EX_t = \left(cs_{ex} + is_{ex} + gs_{ex} + \frac{1}{\frac{P_{H,t}}{P_t}}\Omega_t \frac{P^*_{P,t}}{P^*_t}\frac{Y^P_t}{Y_t}\right) Y_t \tag{3.2.62}$$

where cs_{ex}, is_{ex}, and gs_{ex} are the respective GDP shares of consumption, investment,

[10]The RoW economy is considered a closed economy, despite the existing import of mineral production from the SOE. This is due to the fact that the RoW economy is too large and this import is infinitely small relative to the RoW economy..

and government spending export goods. The steady-state values for cs_{ex}, is_{ex}, and gs_{ex} are calibrated based on trade statistics from WITS.

3.2.9 Risk premium

A debt elastic risk premium is considered to absorb the international risk sharing element for SOEs. This plays a vital role in linking up domestic consumption with the rest of the world. Furthermore, it is a necessary condition for the stationarity of our model. Following Schmitt-Grohé and Uribe (2003) and Nguyen (2020), access to foreign assets is subject to a premium that depends on the SOE's exposure to total external debt. The risk premium takes the form:

$$\Phi_t(.) = exp\left(-\phi_B\left(\frac{B_{F,t}}{\frac{P_{H,t-1}}{P_t}Y_t}\right)\right) \tag{3.2.63}$$

where $B_{F,t}$ is the amount of SOE's external debt denominated in terms of the SOE's consumption units. $\phi_B > 0$ is the risk premium elasticity. $\Phi(0) = 0$, $\Phi'(.) < 0$.

3.2.10 Foreign asset position

The SOE's foreign asset position is given by:

$$B_{F,t} = \frac{\Pi_t^s}{\Pi_t}B_{F,t-1} + TB_t \tag{3.2.64}$$

where TB is the trade balance given by:

$$TB_t = \Omega_t\frac{P_{P,t}^*}{P_t^*}Y_t^P + \frac{P_{H,t}}{P_t}Y_t - C_t - \frac{P_t^I}{P_t}I_t - \frac{P_t^G}{P_t}G_t \tag{3.2.65}$$

3.2.11 Monetary Policy

A standard Taylor-type with an exchange rate target rule is employed for the SOE as the nominal interest rate R_t follows the nominal policy rule:

$$\log\left(\frac{R_t}{R}\right) = \rho_r \log\left(\frac{R_{t-1}}{R}\right) + (1-\rho_r)\left[\theta_{r,\Pi}\log\left(\frac{\Pi_{t-1}}{\Pi}\right) + \theta_{r,s}\log\left(\frac{\Pi_{s,t-1}}{\Pi_s}\right) + \theta_{r,y}\log\left(\frac{Y_t}{Y}\right)\right] + \epsilon_{r,t} \tag{3.2.66}$$

where ρ_r is the persistence term, $\theta_{r,\Pi}$, $\theta_{r,Y}$ and θ_{r,Π^s} respectively represents the monetary policy feedback parameters to inflation, output and exchange rate deviations from their steady state. ϵ_t is a monetary policy shock. The monetary policy rule in RoW however is the standard Taylor rule with inflation and output feedback responses.

3.2.12 Fiscal Authority

Government spending and lump sum transfer payments are financed through distortionary income taxes on labour and capital income, income from phosphate production, and newly issued debt. Accordingly, a balanced government budget constraint is given by:

$$\frac{P_t^G}{Pt}G_t + \frac{R_{t-1}}{\Pi_t}B_{GH,t-1} = T_t + B_{GH,t} + w_t N_t \tau_t^w + ((r_t^k - \delta q_t)K_{t-1} + d_t)\tau_t^k + \tau_t^p \Omega_t \frac{P_{p,t}^*}{P_t^*}Y_t^p$$

The fiscal authorities tax instruments are $\tau^w, \tau^{*w}, \tau^k, \tau^{*k}$. To reduce the number of fiscal policy instruments, the approach employed by Cantore et al. (2019) and Batini et al. (2021) is used and the number of tax and expenditure instruments can be reduced assuming that all the fiscal policy instruments deviate from their respective

steady state by the same proportion.

$$\tau_t^w = \tau_t \tau_{ss}^w, \quad \tau_t^k = \tau_t \tau_{ss}^k, \qquad T_t = g_t T_{ss}, \quad G_t = g_t G_{ss}$$

$$\log\left(\frac{\tau_t}{\tau_{ss}}\right) = \rho_\tau \log\left(\frac{\tau_{t-1}}{\tau_{ss}}\right) + \theta_{\tau,y} \log\left(\frac{Y_{t-1}}{Y_{ss}}\right) + \theta_{\tau,bg} \log\left(\frac{B_{GH,t-1}}{B_{GH,ss}}\right) + \epsilon_{\tau,t}$$

$$\log\left(\frac{g_t}{g_{ss}}\right) = \rho_g \log\left(\frac{g_{t-1}}{g_{ss}}\right) - \theta_{g,y} \log\left(\frac{Y_{t-1}}{Y_{ss}}\right) - \theta_{g,bg} \log\left(\frac{B_{GH,t-1}}{B_{GH,ss}}\right) + \epsilon_{g,t}$$

where ρ_τ and ρ_g govern the persistence of fiscal policy instruments while $\theta_{g,y}$ and $\theta_{\tau,y}$ are the instrument's responsiveness to the deviation of output from its steady state. Similarly $\theta_{g,bg}$ and $\theta_{\tau,bg}$ represent the instrument's responsiveness to the deviation of government debt from its steady state.

3.2.13 Market clearing conditions

3.2.13.1 Market clearing for public bond

The market equilibrium resource constraint condition is satisfied by:

$$Y_t = C_{H,t} + C_{H,t}^* + I_{H,t} + I_{H,t}^* + G_{H,t} + G_{H,t}^* + \frac{\gamma_p}{2}\left(\Pi_{H,t} - 1\right)^2 Y_t \tag{3.2.67}$$

3.2.14 Exogenous shock processes

A total of nine structural shocks are identified in the SOE model that includes, preference shock, total factor productivity shock, price markup shock, the marginal efficiency of investment shock, terms of trade shock, 2 fiscal policy stabilizer shocks, monetary policy shock, and phosphate price shock. Since the processes for monetary policy and fiscal policy are expressed in the section before, the processes for the

remaining shocks are presented below.

$$\log b_t - \log b = \rho_z(\log b_{t-1} - \log b) + \epsilon_{b,t} \tag{3.2.68}$$

$$\log Z_t - \log Z = \rho_z(\log Z_{t-1} - \log Z) + \epsilon_{z,t} \tag{3.2.69}$$

$$\log \eta_t - \log \eta = \rho_\eta(\log \eta_{t-1} - \log \eta) + \epsilon_{\eta,t} \tag{3.2.70}$$

$$\log M_t - \log M = \rho_M(\log M_{t-1} - \log M) + \epsilon_{m,t} \tag{3.2.71}$$

$$\log tot_t - \log tot = \rho_{tot}(\log tot_{t-1} - \log tot) + \epsilon_{tot,t} \tag{3.2.72}$$

$$\log P^*_{P,t} - \log P^*_P = \rho_{P^*_M}(\log P^*_{P,t-1} - \log P^*_P) + \epsilon_{P^*_{p,t}} \tag{3.2.73}$$

where ϵ_is are the respective shocks to the processes. For the RoW economy, terms of trade are not relevant.

The terms of trade shocks are introduced to capture changes in the purchasing power of the SOE and its ability to trade following fluctuations in the prices of internationally traded goods and services, while the phosphate price shock is introduced to capture how the volatility of the price of Morocco's main export commodity affects its economy. Consistent with the literature, preference, technology, investment, and price mark-up shocks are introduced to capture the respective effects of shifts in households' intertemporal choices, aggregate productivity, marginal efficiency of investment, and changes in firms' degree of market power on the Moroccan economy. Fiscal and monetary policy shocks are also included to capture the respective economic effects of government fiscal and central bank monetary policy operations.

3.3 Data and Estimation Strategy

3.3.1 Data and Choice of Observable

A set of observable variables is used to estimate the models for both the RoW and SOE economies. To overcome the stochastic singularity problem during estimation, the number of data series used is set to be equal to the number of shocks considered in the model. In particular, seven observables are used for the corresponding seven shocks in the RoW model block, while nine observables are used for the nine shocks in the SOE block. The choice of observable and prior distributions for the RoW is mainly based on the well-established literature (Smets and Wouters (2007b)). However, in the absence of a benchmark model in the context of the Moroccan economy, the choice of prior distributions is based on observations from the data and a combination of priors used in studies of other emerging economies.

To estimate the EU block model, data on observable variables of output, private consumption, private investment, consumer price, interest rate, hours of work, and wage rate are used. In contrast, the available data for Morocco is not as rich as the EU economy, and data on observable variables of output, private consumption, private investment, consumer price, interest rate, price of phosphate, exchange rate, terms of trade and domestic public debt are used to estimate the SOE model. All the series are seasonally adjusted and are in quarterly frequency that ranges from 1999:QI to 2019:QIV. Since there is no endogenous trend in the model and the model is expressed in per capita terms, the variables are transformed to fit the model properties. As a result, all nominal variables are deflated by the price index, and the first differences are applied to filter the raw data, except for inflation, exchange rate, and interest rates. For consumer price inflation, inflation of phosphate price, and exchange rates, log differences of the row data are used. Since the model is written in quarterly frequency and gross interest rate is used for estimation, the annualized gross interest

rate is transformed into quarterly frequency using the geometric mean approximation, $R_t^{obs} = \left(\frac{R_t^{data}}{4}\right)$. Given the detailed description of observable variables and data source under Tables B.1 and B.2 in the appendix, the construction of observable variables and the measurement equations are given below.

3.3.2 Observables and Measurement Equations

3.3.2.1 EU economy

Variables	Description	Construction
Y_t^{*obs}	Real GDP	$\ln\left(\frac{GDP_t^*/Pop_t^*}{PI_t^*}\right) * 100$
C_t^{*obs}	Real private consumption	$\ln\left(\frac{C_t^*/Pop_t^*}{PI_t^*}\right) * 100$
I_t^{*obs}	Real private investment	$\ln\left(\frac{I_t^*/Pop_t^*}{PI_t^*}\right) * 100$
R_t^{*obs}	Shadow rate	$\ln\left(\frac{R^*}{4*100}\right) * 100$
W_t^{*obs}	Real wage	$\ln\left(\frac{W^*}{PI_t^*}\right) * 100$
N_t^{*obs}	Labour supply	$\ln\left(\frac{N_t^*}{Pop_t^*}\right) * 100$
Π_t^{*obs}	Inflation	$\ln\left(\frac{PI_t^*}{PI_{t-1}^*}\right) * 100$

Table 3.1: Data transformation of observables for the EU economy

Using the respective steady state values of each variable denoted with a subscript 'ss', the measurement equations for estimation of the RoW model are given by:

$$\begin{bmatrix} Y_t^{*obs} \\ C_t^{*obs} \\ I_t^{*obs} \\ R_t^{*obs} \\ W_t^{*obs} \\ N_t^{*obs} \\ \Pi_t^{*obs} \end{bmatrix} = \begin{bmatrix} \left(\log\left(\frac{Y_t^*}{Y_{ss}^*}\right) - \log\left(\frac{Y_{t-1}^*}{Y_{ss}^*}\right)\right) * 100 \\ \left(\log\left(\frac{C_t^*}{C_{ss}^*}\right) - \log\left(\frac{C_{t-1}^*}{C_{ss}^*}\right)\right) * 100 \\ \left(\log\left(\frac{I_t^*}{I_{ss}^*}\right) - \log\left(\frac{I_{t-1}^*}{I_{ss}^*}\right)\right) * 100 \\ \left(\log\left(\frac{R_t^*}{R_{ss}^*}\right)\right) * 100 \\ \left(\log\left(\frac{W_t^*}{W_{ss}^*}\right) - \log\left(\frac{W_{t-1}^*}{W_{ss}^*}\right)\right) * 100 \\ \left(\log\left(\frac{N_t^*}{N_{ss}^*}\right) - \log\left(\frac{N_{t-1}^*}{N_{ss}^*}\right)\right) * 100 \\ \left(\log\left(\frac{\Pi_t^*}{\Pi_{ss}^*}\right)\right) * 100 \end{bmatrix} \tag{3.3.1}$$

3.3.2.2 Moroccan economy

Variables	Description	Construction
Y_t^{obs}	Real GDP	$\ln\left(\frac{GDP_t/Pop_t}{CPI_t}\right) * 100$
C_t^{obs}	Real private consumption	$\ln\left(\frac{C_t/Pop_t}{CPI_t}\right) * 100$
I_t^{obs}	Real private investment	$\ln\left(\frac{I_t/Pop_t}{CPI_t}\right) * 100$
D_t^{obs}	Real government debt	$\ln\left(\frac{D_t/Pop_t}{CPI_t}\right) * 100$
R_t^{obs}	Interest rate	$\ln\left(\frac{R_t}{4*100}\right) * 100$
$\Pi_{s,t}^{obs}$	Depreciation of exchange rate	$\ln\left(\frac{E_t}{E_{t-1}}\right) * 100$
$\Pi_{p,t}^{obs}$	Inflation of phosphate price	$\ln\left(\frac{PP_t}{PI_t^*}\right) * 100$
Ψ_t^{obs}	Terms of trade	$\ln\left(TOT_t\right) * 100$
Π_t^{obs}	Inflation	$\ln\left(\frac{CPI_t}{CPI_{t-1}}\right) * 100$

Table 3.2: Data transformation of observables for the Moroccan economy

Using the respective steady-state values of each variable denoted with a subscript 'ss', the measurement equations for estimation of the SOE model are given by:

$$\begin{bmatrix} Y_t^{obs} \\ C_t^{obs} \\ I_t^{obs} \\ D_t^{obs} \\ \Psi_{s,t}^{obs} \\ R_t^{obs} \\ \Pi_{s,t}^{obs} \\ \Pi_{p,t}^{obs} \\ \Pi_t^{obs} \end{bmatrix} = \begin{bmatrix} \left(\log\left(\frac{Y_t}{Y_{ss}}\right) - \log\left(\frac{Y_{t-1}}{Y_{ss}}\right)\right) * 100 \\ \left(\log\left(\frac{C_t}{C_{ss}}\right) - \log\left(\frac{C_{t-1}}{C_{ss}}\right)\right) * 100 \\ \left(\log\left(\frac{I_t}{I_{ss}}\right) - \log\left(\frac{I_{t-1}}{I_{ss}}\right)\right) * 100 \\ \left(\log\left(\frac{D_t}{D_{ss}}\right) - \log\left(\frac{D_{t-1}}{D_{ss}}\right)\right) * 100 \\ \left(\log\left(\frac{\Psi_t}{\Psi_{ss}}\right) - \log\left(\frac{\Psi_{t-1}}{\Psi_{ss}}\right)\right) * 100 \\ \left(\log\left(\frac{R_t}{R_{ss}}\right)\right) * 100 \\ \left(\log\left(\frac{\Pi_{s,t}}{\Pi_{s,ss}}\right)\right) * 100 \\ \left(\log\left(\frac{\Pi_{p,t}}{\Pi_{p,ss}}\right)\right) * 100 \\ \left(\log\left(\frac{\Pi_t}{\Pi_{ss}}\right)\right) * 100 \end{bmatrix} \tag{3.3.2}$$

3.3.3 Bayesian Estimation

The DSGE models for both SOE and RoW blocks are estimated using the Bayesian approach. This approach is widely employed since it is a useful way to use observed data and prior external information about parameters of interest. In its brief form, the approach involves the posterior distribution of parameters starting from the prior distribution and employs Bayes's theorem to continuously update the parameters using the observed data. Then, a Metropolis-Hastings algorithm is used to draw samples from the posterior distribution. Accordingly, inferences are made based on a sample generated from the posterior distribution using the Monte-Carlo-Markov-Chain Metropolis-Hastings (MCMC-MH) algorithm with two parallel chains of 200,000 draws each, and the first 25 percent have been discarded. The DYNARE toolbox of Adjemian et al. (2011) is used to conduct the MCMC algorithm.

3.3.4 Calibrated Parameters

Not all model parameters are estimated. Some structural parameters are calibrated for both SOE and RoW blocks using the standard business cycle literature and block-specific data. As presented in Table 3.3, structural parameters and steady-state values are set based on quarterly frequency. As employed by the literature, a classic discount factor ($\beta, \beta^* = 0.99$) is calibrated for both blocks of economies. Based on the average annual inflation level in the data, the long-run steady-state inflation is set at 2 percent (annually). The depreciation rate of capital is calibrated to $\delta = 0.25$ which matches a 10 percent annual depreciation of capital. Following Schmitt-Grohé and Uribe (2003), the price elasticity of substitution between intermediate goods is set at 6 to match a steady state markup price of 20 percent. The elasticity of substitution between home and imported goods is set at 1.5 following Adler et al. (2016). The respective share of domestic goods in the consumption, investment, and government spending goods of the Moroccan economy is set at $0.263, 0.731$, and 0.029 using import composition

Notation	Parameter	Range	Value/Target
β, β^*	Discount factor	[0.985, 0.995]	0.990
Π, Π^*	Steady state gross inflation	$[1.000, 1.030^{\frac{1}{4}}]$	$1.020^{\frac{1}{4}}$
δ, δ^*	Depreciation rate	[0.010, 0.040]	0.025
ε, ε^*	Price elasticity of substitution	[4.000, 12.000]	6.000
μ_j, μ_j^*, $j = C, I, G$	Elasticity of substitution (H/F)	[1.070, 2.500]	1.500
$1 - w_C, 1 - w_C^*$	Import share of consumption	[0.000, 1.000]	0.263, 0.000
$1 - w_I, 1 - w_I^*$	Import share of investment	[0.000, 1.000]	0.731, 0.000
$1 - w_G, 1 - w_G^*$	Import share of government spending	[0.000, 1.000]	0.029, 0.000
cs_{exp}	Consumption goods export GDP share	[0.100, 0.500]	0.444
is_{exp}	Investment goods export GDP share	[0.100, 0.400]	0.358
gs_{exp}	G spending goods export GDP share	[0.000, 0.200]	0.009
τ^k, τ^{*k}	Capital income tax rate tax	[0.100, 0.400]	0.200, 0.300
τ^w, τ^{*w}	Labour income tax rate	[0.200, 0.350]	0.300, 0.340
τ^p	Phosphate output gov't share	[0.300, 0.800]	0.600
κ_p	Phosphate output GDP share	[0.080, 0.300]	0.129
g_y, g_y^*	G to GDP ratio	[0.100, 0.250]	0.190, 0.210
b_g, b_g^*	Debt to GDP ratio	[0.500, 0.900]	4x0.610, 4x0.650
Z	SOE's home productivity	[2.500, 21.900]	$\varpi = \frac{Y^*}{Y} = 12.77$

Parameters without and with $*$ refers to the Morocco and EU economies respectively. Unless otherwise explicitly expressed, parameter values reflect quarterly values.

Table 3.3: Calibrated EU and Morocco Economy Parameters

data from the WB's - WITS. Since the RoW economy is considered to be a closed economy, the respective imported goods share to the consumption, investment, and government spending goods are set to zero. Morocco's statistical agency database is the main source used to calibrate the GDP share of phosphate production ($\kappa_p = 0.139$) and the government's ownership share of phosphate production ($\tau^p = 0.6$).

The WITS database is used to calibrate the respective GDP share of consumption and investment export goods at $cs_{exp} = 0.083$ and $is_{exp} = 0.035$. Then, the implied steady-state GDP share of government expenditure export goods is set at $gs_{exp} = 0.062$. To account for the size difference between the SOE and RoW, the SOE's level of productivity (Z) is calibrated based on the GDP per capita of the SOE and RoW blocks. Finally, the steady-state tax rates, share of government spending, and government debt to GDP are set based on data from the Moroccan statistical agency for the Moroccan economy and the Eurostat database for the EU economy.

3.3.5 Prior Information

In general, four types of prior distributions are employed in the estimation. For parameters where non-negativity constraint is necessary such as standard errors of shocks and SOE's risk premium elasticity, elasticity of substitution, and fiscal policy feedback parameters, a combination of gamma and inverse gamma distributions are used. The beta distribution is used for fractional parameters such as habit persistence, price indexation, shock persistence, the share of RoT households, and income share of capital parameters. Whenever the parameters range from $-\infty$ to ∞ and a more informative prior is required, a normal distribution is used.

3.3.6 Bayesian Estimated Results

Following Adolfson et al. (2007), the small open economy (Morocco) is assumed to be negligibly small compared to the rest of the world (EU) economy. Hence, the closed economy DSGE model for the RoW block is estimated separately from the SOE. Thus, in this paper, a total of 30 and 36 structural parameters are estimated for the RoW and SOE models respectively.

The estimated results for both RoW and SOE blocks are found to be in line with economic interpretations. In this regard, the data on observed variables is found to be informative to most of the estimated parameters. The estimated parameters prior distributions are found to be substantially different from their posterior distributions and the posterior distributions are well approximated around the posterior modes (see Appendix B.8.2 and Appendix B.8.3). However, it is worth noting that there are some exceptions where the prior and posterior distributions for some parameters are not significantly different. For instance, the observed data did not provide much to update the prior distributions of the Inverse Frisch elasticity parameters for the RoW model and fiscal policy feedback parameters for the SOE model.

As the results in Table 3.4 and Table 3.5 show, the estimated parameters are broadly in line with existing studies.

Parameter	Not.	Domain	Prior distribution			Posterior distribution		
			Dist.	Mean	S.d	Mean	S.d	95% HPDI
Preference and Technology Parameters								
Inverse EIS-RoT	σ_r^*	$\mathbb{R}^+$	Gamma	1.500	0.375	1.253	0.341	[0.867, 1.971]
Inverse EIS-S	σ_s^*	$\mathbb{R}^+$	Gamma	1.500	0.375	1.348	0.354	[0.835, 1.977]
Inv. Frisch ela.-RoT	φ_r^*	$\mathbb{R}^+$	Gamma	2.000	0.750	0.192	0.080	[0.091, 0.340]
Inv. Frisch ela.-S	φ_s^*	$\mathbb{R}^+$	Gamma	2.000	0.750	1.664	0.797	[0.769, 3.197]
Habit persistence	χ^*	$[0,1]$	Beta	0.700	0.100	0.532	0.054	[0.460, 0.635]
Inve. adj. cost	Φ_I^*	$\mathbb{R}^+$	Gamma	4.000	1.500	6.173	1.275	[4.310, 8.508]
Share of capital	α^*	$[0,1]$	Beta	0.300	0.050	0.300	0.030	[0.255, 0.352]
Share of RoT	λ^*	$[0,1]$	Beta	0.230	0.025	0.218	0.024	[0.179, 0.256]
Nominal Price Rigidity Parameters								
Price indexation	ι_p^*	$[0,1]$	Beta	0.500	0.175	0.075	0.099	[0.013, 0.299]
Price stickiness	γ_p^*	$\mathbb{R}^+$	Gamma	50.000	10.000	41.480	9.348	[30.446, 60.784]
Monetary Policy Parameters								
Int. rate AR coef.	ρ_r^*	$[0,1]$	Beta	0.500	2.000	0.726	0.049	[0.637, 0.794]
Int. rate Π feedback	$\theta_{r,\Pi}^*$	$\mathbb{R}$	Normal	1.500	0.250	1.782	0.201	[1.543, 2.206]
Int. rate Y feedback	$\theta_{r,Y}^*$	$\mathbb{R}^+$	Gamma	0.125	0.050	0.039	0.021	[0.019, 0.083]
Fiscal Rule - Labour and Capital Income Tax Parameters								
Tax AR coef.	ρ_τ^*	$[0,1]$	Beta	0.500	2.000	0.520	0.013	[0.498, 0.540]
Tax debt feedback	θ_{τ,B_f}^*	$\mathbb{R}^+$	Gamma	0.100	0.025	0.118	0.021	[0.085, 0.155]
Tax Y feedback	$\theta_{\tau,Y}^*$	$\mathbb{R}^+$	Gamma	0.100	0.025	0.073	0.020	[0.047, 0.110]
Fiscal Rule - Government spending (G) and Transfer (T) Parameters								
G/T AR coef.	ρ_g^*	$[0,1]$	Beta	0.500	2.000	0.510	0.012	[0.490, 0.530]
G/T debt feedback	θ_{g,B_f}^*	$\mathbb{R}^+$	Gamma	0.100	0.025	0.052	0.014	[0.034, 0.080]
G/T Y feedback	$\theta_{g,Y}^*$	$\mathbb{R}^+$	Gamma	0.100	0.025	0.102	0.026	[0.065, 0.150]
AR(1) parameters of other shocks/processes								
Preference	ρ_b^*	$[0,1]$	Beta	0.500	0.200	0.985	0.009	[0.968, 0.994]
Technology	ρ_z^*	$[0,1]$	Beta	0.500	0.200	0.966	0.024	[0.917, 0.991]
Price mark-up	ρ_m^*	$[0,1]$	Beta	0.500	0.200	0.416	0.110	[0.155, 0.517]
MEI	ρ_η^*	$[0,1]$	Beta	0.500	0.200	0.726	0.071	[0.578, 0.808]
Standard Deviation of shocks								
S.d. pref. shock	ϵ_b^*	$\mathbb{R}^+$	InvGamma	0.100	2.000	0.031	0.012	[0.018, 0.052]
S.d. tech. shock	ϵ_z^*	$\mathbb{R}^+$	InvGamma	0.100	2.000	0.011	0.001	[0.010, 0.013]
S.d. G/T shock	ϵ_g^*	$\mathbb{R}^+$	InvGamma	0.100	2.000	0.022	0.002	[0.020, 0.026]
S.d. mark-up shock	ϵ_m^*	$\mathbb{R}^+$	InvGamma	0.100	2.000	0.229	0.066	[0.172, 0.381]
S.d. MEI shock	ϵ_η^*	$\mathbb{R}^+$	InvGamma	0.100	2.000	0.078	0.018	[0.058, 0.117]
S.d. MP shock	ϵ_r^*	$\mathbb{R}^+$	InvGamma	0.100	2.000	0.009	0.001	[0.008, 0.011]
S.d. tax shock	ϵ_τ^*	$\mathbb{R}^+$	InvGamma	0.100	2.000	0.033	0.003	[0.029, 0.039]
Log data density						**708.52**		

Table 3.4: Prior and posterior distributions of estimated structural parameters for EU economy

Parameter	Not.	Domain	Prior distribution			Posterior distribution		
			Dist.	Mean	S.d	Mean	S.d	95% HPDI
Preference and Technology Parameters								
Inverse EIS-RoT	σ_r	$\mathbb{R}^+$	Gamma	1.500	0.375	0.309	0.043	[0.239, 0.379]
Inverse EIS-S	σ_s	$\mathbb{R}^+$	Gamma	1.500	0.375	1.829	0.374	[1.204, 2.421]
Inv. Frisch ela.-RoT	φ_r	$\mathbb{R}^+$	Gamma	2.000	0.750	3.202	0.403	[2.561, 3.880]
Inv. Frisch ela.-S	φ_s	$\mathbb{R}^+$	Gamma	2.000	0.750	1.652	0.605	[0.706, 2.598]
Habit persistence	χ	$[0,1]$	Beta	0.700	0.100	0.594	0.042	[0.528, 0.665]
Investment adj. cost	Φ_I	$\mathbb{R}^+$	Gamma	4.000	1.500	3.905	1.188	[2.072, 5.731]
Share of capital	α	$[0,1]$	Beta	0.300	0.050	0.311	0.043	[0.240, 0.383]
Share of RoT hhs	λ	$[0,1]$	Beta	0.230	0.025	0.259	0.021	[0.226, 0.295]
Risk prem. elas.	ϕ_B	$\mathbb{R}^+$	InvGamma	0.100	2.000	0.028	0.005	[0.020, 0.036]
Nominal Price Rigidity Parameters								
Price indexation	ι_p	$[0,1]$	Beta	0.500	0.175	0.646	0.147	[0.414, 0.889]
Price stickiness	γ_p	$\mathbb{R}^+$	Gamma	100.000	10.000	88.441	11.948	[68.352, 107.126]
Monetary Policy Parameters								
Int. rate AR coef.	ρ_r	$[0,1]$	Beta	0.500	2.000	0.598	0.079	[0.474, 0.726]
Int. rate Π feedback	$\theta_{r,\Pi}$	$\mathbb{R}$	Normal	1.500	0.250	2.022	0.205	[1.682, 2.359]
Int. rate Y feedback	$\theta_{r,Y}$	$\mathbb{R}^+$	Gamma	0.125	0.050	0.079	0.026	[0.036, 0.119]
Int. rate Π^s feedback	θ_{r,Π^s}	$\mathbb{R}^+$	Gamma	0.100	0.050	0.356	0.079	[0.228, 0.482]
Fiscal Rule - Labour and Capital Income Tax Parameters								
Tax ARcoef.	ρ_τ	$[0,1]$	Beta	0.500	2.000	0.126	0.065	[0.021, 0.222]
Tax debt feedback	θ_{τ,B_h}	$\mathbb{R}^+$	Gamma	0.100	0.025	0.101	0.025	[0.062, 0.141]
Tax Y feedback	$\theta_{\tau,Y}$	$\mathbb{R}^+$	Gamma	0.100	0.025	0.100	0.025	[0.060, 0.140]
Fiscal Rule - Government spending (G) and Transfer (T) Parameters								
G/T AR coefficient	ρ_g	$[0,1]$	Beta	0.500	2.000	0.668	0.071	[0.551, 0.781]
G/T debt feedback	θ_{g,B_h}	$\mathbb{R}^+$	Gamma	0.100	0.025	0.090	0.022	[0.055, 0.125]
G/T Y feedback	$\theta_{g,Y}$	$\mathbb{R}^+$	Gamma	0.100	0.025	0.095	0.024	[0.056, 0.132]
AR(1) parameters of other shocks/processes								
Preference	ρ_b	$[0,1]$	Beta	0.500	0.200	0.159	0.082	[0.028, 0.282]
Technology	ρ_z	$[0,1]$	Beta	0.500	0.200	0.725	0.079	[0.595, 0.853]
Price mark-up	ρ_m	$[0,1]$	Beta	0.500	0.200	0.489	0.199	[0.169, 0.818]
MEI	ρ_η	$[0,1]$	Beta	0.500	0.200	0.069	0.041	[0.009, 0.129]
Terms of trade	ρ_{tot}	$[0,1]$	Beta	0.500	0.200	0.881	0.032	[0.831, 0.932]
Phos. price	ρ_{pp}	$[0,1]$	Beta	0.500	0.200	0.387	0.091	[0.241, 0.538]
Standard Deviation of shocks								
S.d. pref. shock	ϵ_b	$\mathbb{R}^+$	InvGamma	0.1	2	0.024	0.003	[0.019, 0.029]
S.d. tech. shock	ϵ_z	$\mathbb{R}^+$	InvGamma	0.1	2	0.037	0.005	[0.030, 0.044]
S.d. G/T shock	ϵ_g	$\mathbb{R}^+$	InvGamma	0.1	2	0.113	0.009	[0.098, 0.128]
S.d. mark-up shock	ϵ_m	$\mathbb{R}^+$	InvGamma	0.1	2	0.083	0.052	[0.024, 0.149]
S.d. MEI shock	ϵ_η	$\mathbb{R}^+$	InvGamma	0.1	2	0.255	0.076	[0.137, 0.372]
S.d. mon. pol.	ϵ_r	$\mathbb{R}^+$	InvGamma	0.1	2	0.011	0.001	[0.009, 0.012]
S.d. tax shock	ϵ_τ	$\mathbb{R}^+$	InvGamma	0.1	2	0.520	0.045	[0.446, 0.590]
S.d. tot shock	ϵ_{tot}	$\mathbb{R}^+$	InvGamma	0.1	2	0.029	0.003	[0.024, 0.033]
S.d. phos. price	ϵ^*_{pp}	$\mathbb{R}^+$	InvGamma	0.1	2	0.135	0.011	[0.118, 0.153]
Log data density						**1,813.06**		

Table 3.5: Prior and posterior distributions of estimated structural parameters for Morocco economy

3.4 Analysis of Results

In this section, the key sources of Morocco's macroeconomic fluctuations, the importance of export commodity price shock, and the subsequent welfare implications are discussed in detail. To this effect, a simple statistical moment comparison between data and model results; illustration of impulse responses; and historical variance decomposition tools are utilized.

3.4.1 Business Cycle Moments

As a way to see how the estimated model results can mimic data on business cycle statistics, comparisons for the statistical moments of the real data and model for both models of the RoW and SOE economies are presented under the tables below (see Tables 3.6 and 3.7). Generally, the key real data business cycle stylized facts are well replicated by the estimated models for both blocks of economies. Consistent with the-

	$\Delta \log y^*$	$\Delta \log c^*$	$\Delta \log i^*$	$\Delta \log l^*$	$\Delta \log w^*$	Π^*_{def}	R^*
	Standard Deviation (σ^*_j)						
Data	0.5645	0.3651	1.9151	0.2579	0.6213	0.5849	0.8960
Model	0.9477	0.8459	3.7693	1.5165	3.2424	1.5584	1.9294
	Relative Standard Deviation with Output $(\frac{\sigma^*_j}{\sigma^*_y})$						
Data	1.0000	0.6469	3.3928	0.4569	1.1008	1.0362	1.5874
Model	1.0000	0.8926	3.9772	1.6002	3.4214	1.6444	2.0359
	Cross-correlation with Output $(\rho^*(j, \Delta \log y^*))$						
Data	1.0000	0.7650	0.4943	0.6177	-0.4152	0.4365	-0.0975
Model	1.0000	0.6733	0.5458	0.6727	-0.4814	0.0282	-0.2528
	Autocorrelations of order 1 (ρ^*_j)						
Data	0.6253	0.4981	0.1287	0.6110	0.1356	0.1764	0.9609
Model	0.1806	0.3161	0.6346	0.0230	0.1930	0.8038	0.8895

Table 3.6: Business cycle statistics of real data and model results for the RoW model

ory and empirical evidence, the countercyclicality of interest rate is confirmed together

with higher volatility of investment over consumption and output. It is worthwhile noting that SOEs output volatility is higher than the developed economies as it is ascertained by both data and model results. Looking at the co-movement between output growth and phosphate price inflation in Morocco, the positive correlations are confirmed by both data and model results. Although the model closely mimicked the

	$\Delta \log y$	$\Delta \log c$	$\Delta \log i$	$\Delta \log B_{GH}$	R	Π_{cpi}	Π^s	$\Delta \log \Psi$	Π_{pp}
	Standard Deviation (σ_j)								
Data	1.6839	2.7186	6.5083	4.6612	0.2542	0.6365	1.4915	2.2290	20.9660
Model	2.7943	3.3397	6.1818	5.6842	1.1673	1.1777	2.9193	3.8573	14.6187
	Relative Standard Deviation with Output ($\frac{\sigma_j}{\sigma_y}$)								
Data	1.0000	1.6145	3.8651	2.7681	0.1510	0.3780	0.8858	1.3237	12.4510
Model	1.0000	1.1952	2.2123	2.0342	0.4177	0.4215	1.0447	1.3804	5.2317
	Cross-correlation with Output ($\rho(j, \Delta \log y)$)								
Data	1.0000	0.0440	0.5759	0.3597	-0.0753	-0.3539	-0.0881	-0.0245	0.0895
Model	1.0000	0.0851	0.0720	0.1646	-0.0807	-0.1342	0.0844	0.2837	0.3004
	Autocorrelations of order 1 (ρ_j)								
Data	0.4251	0.0516	0.2116	0.6858	0.8935	0.6480	0.7036	0.8516	0.8012
Model	0.1442	0.0340	0.0492	-0.1531	0.1749	0.6724	0.3174	0.0793	0.3866

Table 3.7: Business cycle statistics of real data and model results for the SOE model

business cycle statistics of the Moroccan economy, including cross-correlations, there are a few exceptions that deserve to be highlighted. Firstly, the model overestimates the volatility of interest rates and inflation compared to the actual data. Secondly, the low cross-correlation of output growth with investment and consumption growth is a striking result that seems puzzling for the Moroccan economy. One possible explanation for this is that Morocco's economy is heavily dependent on external factors such as global economic conditions, commodity prices (especially for imports such as oil), or remittances from Moroccans living abroad. As a result, changes in these external factors could weaken the correlation between GDP growth and domestic consumption/investment.

3.4.2 Impulse Response Functions

Responses of selected macroeconomic aggregates to selected domestic and external shocks are presented in this section. The responses to more structural shocks can be found in Appendix B.8. The macroeconomic aggregates in the Moroccan economy respond notably to the various estimated structural shocks and the responses are all of the expected signs. For instance, the demand side domestic shocks such as preference, monetary, and fiscal policy shocks move output and inflation in the same direction. On the other hand, output and inflation respond in an opposite direction following the domestic supply shocks such as productivity, price markup, and the marginal efficiency of investment shocks.

The introduction of RoT households is found to be a viable transmission channel to illustrate the rise in consumption in response to an increase in government spending. In this regard, the results are consistent with the literature as in Galí et al. (2007) (refer to Figure B.1). The responses also showed significant distributional effects of shocks between RoT and Ricardian households. To illustrate the distributional effects, a welfare indicator using consumption equivalence is computed for RoT and Ricardian households. Accordingly, the consumption equivalence of RoT households less of the Ricardian households is used as a welfare gap indicator[11]. Furthermore, the responses are temporary as most of the macroeconomic aggregates return to their steady state fairly quickly except for interest rate which experiences a more persistent effect in response to most shocks.

[11] To illustrate the welfare gain or loss associated with a one percent change in consumption, consumption equivalence for the respective households is computed as follows: $CE_t = \frac{U_t(1.01C_t,N_t)-U_t(C_t,N_t)}{1-\beta}$) (see Mirfatah et al., 2021, for details). Accordingly, for a convenient direct distributional comparison following the considered structural shocks, the welfare gap between RoT and Ricardian households is computed as $CE_t^{RoT} - CE_t^{R}$.

3.4.2.1 A domestic technology shock

In keeping with the empirical evidence and theoretical literature, a positive total factor productivity shock results in an expansion to output, export, and consumption to both RoT and Ricardian households. In Figure 3.1, inflation responds negatively due to the lower cost of production. The positive productivity shock is an improvement in technology that allows firms to produce the same level of output using fewer hours of labour. Consequently, the demand for labour falls which creates an excess labour supply over demand that leads to an inward shift of the labour demand curve and hence a downward push to real wage. However, the sticky price faced by firms leads to a lesser expansion of output compared to the flexible price case.

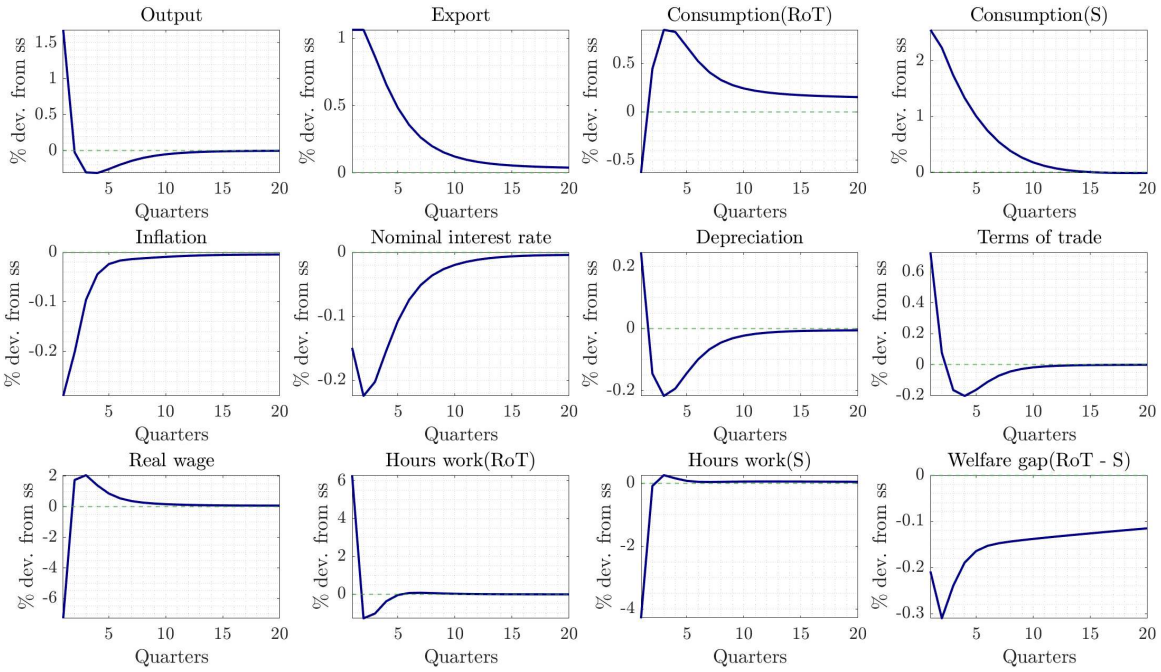

Figure 3.1: Responses to a positive productivity shock

The decline in real wage leads to a contraction in aggregate hours of work which confirms the introduction of RoT households produce a result in line with empirical evidence as in Francis and Ramey (2005), Furlanetto and Seneca (2012) and Thomet and Wegmueller (2021). Though consumption increases for both RoT and Ricardian households, the response of consumption delays slightly due to the habit persistence

in preferences, as is in De Walque et al. (2005). In line with the literature with RoT households, the wage decline induces RoT households to increase their hours of work to compensate the lost wage since their consumption has increased and they consume out of their wage ($C_t^r = w_t(1-\tau_t^w)N_t^r + (1-\tau^p)\Omega_t \frac{P_{p,t}^*}{P_t^*} Y_t^p - T_t$) while they have no saving as an outlet to smooth consumption. In contrast, Ricardinan households react by working fewer hours following the decline in real wages. However, the aggregate hours of work shrinks since the size of Ricardian households is higher than RoT's.

Following the downward response of inflation, the nominal interest rate declines via monetary authorities' reaction to the decline of inflation which is higher than the limited expansion to output. The lower interest rate set by the monetary authorities leads to the depreciation of the domestic currency and hence an increase in terms of trade and export for Morocco. At this point, the small open economy results differ from what would have happened to a closed economy model in such a way that the export sector creates an additional channel for expansion in output.

As a result of Morocco's interaction with the rest of the world, a depreciation of domestic currency creates two possible effects. On the one hand, export demand rises since exports are relatively cheaper. On the other hand, depreciation of the domestic currency leads to a decline in imports since imports are expensive and hence a shift from foreign to domestically produced goods. These two effects together result in a further expansion of output. Therefore, though the output expansion through the original technology shock is limited by price rigidity, the export sector channel results in a higher expansion in output compared to what would have happened in a closed economy case. In addition, a positive technology shock leads to a deterioration in the terms of trade (positive terms of trade response) and an increase in the price of imports, which leads to an increase in output. As a result, the expansion to output is significantly higher than the aggregate consumption.

About the distributional effects of a productivity shock, though it comes as a welfare boost to both RoT and Ricardian households, the welfare gap between the two households declines implying the technology improvement benefiting RoT households more.

3.4.2.2 A phosphate price shock

The impulse responses to phosphate price shock can be considered as an external supply-side shock to the Moroccan economy. The results share certain similar features with a domestic supply shock as a disturbance to phosphate price drives output and inflation in an opposite direction. More importantly, a rise in phosphate price results in an expansion of output and consumption while it leads to a decline in inflation (see Figure 3.2). Furthermore, a positive shock to phosphate prices induces a higher transfer income to RoT households and hence a rise in their consumption and fewer hours of work.

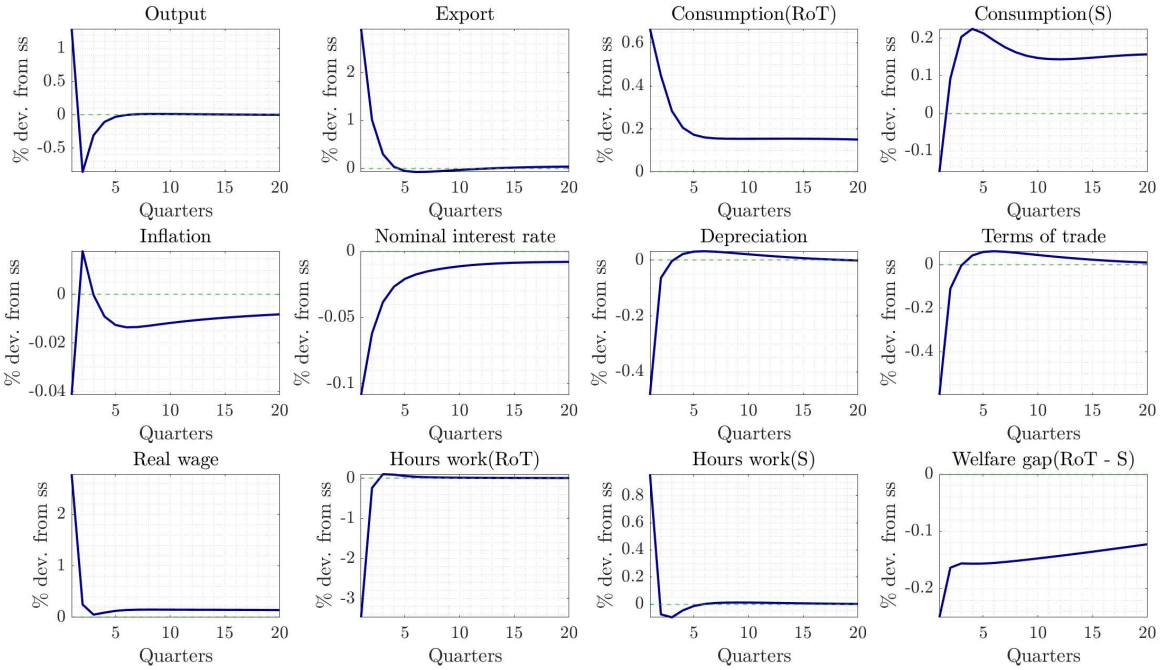

Figure 3.2: Responses to a positive phosphate price shock

Following the added flow of foreign exchange to the domestic economy because of a

positive phosphate price shock, the domestic currency appreciates leading to a downward interest rate response via the policy rate. Appreciation of the domestic currency implies a cheap import price and hence a downward push to aggregate inflation. The positive phosphate price shock provides an economic incentive to expand output and export. However, the expansion in output induces an excess demand for labour that leads to a rise in real wages. As a result, the hours of work for RoT's shrinks while Ricardian households supply more hours of work. Finally, a positive phosphate price shock tends to induce more welfare gain to RoT households as the welfare gap declines and the result is persistent.

The slight contraction of output after the initial expansion can be explained by two factors. First, the appreciation of the domestic currency makes the SOE's exports less competitive, which in turn can lead to a contraction in output. Second, the higher wage response induced by the positive phosphate price shock slowly translates into higher production costs for firms, which may lead to output contraction after some time.

3.4.2.3 A RoW monetary policy shock

To illustrate the monetary policy spillover effects from the external economy, a result of responses to a foreign (EU) monetary tightening is presented in Figure 3.3. The SOEs macroeconomic variables respond to an estimated contractionary monetary policy shock from the RoW economy. Accordingly, a rise in the foreign interest rate results in the depreciation of the domestic currency and a rise in terms of trade. As a result, exports of the SOE turn out to be cheaper and hence an expansion of export.

Depreciation of domestic currency induces a higher imported inflation for the SOE that leads to a higher interest rate reaction of the monetary authorities via the policy rate. The results also produce substantially different responses of hours of work for

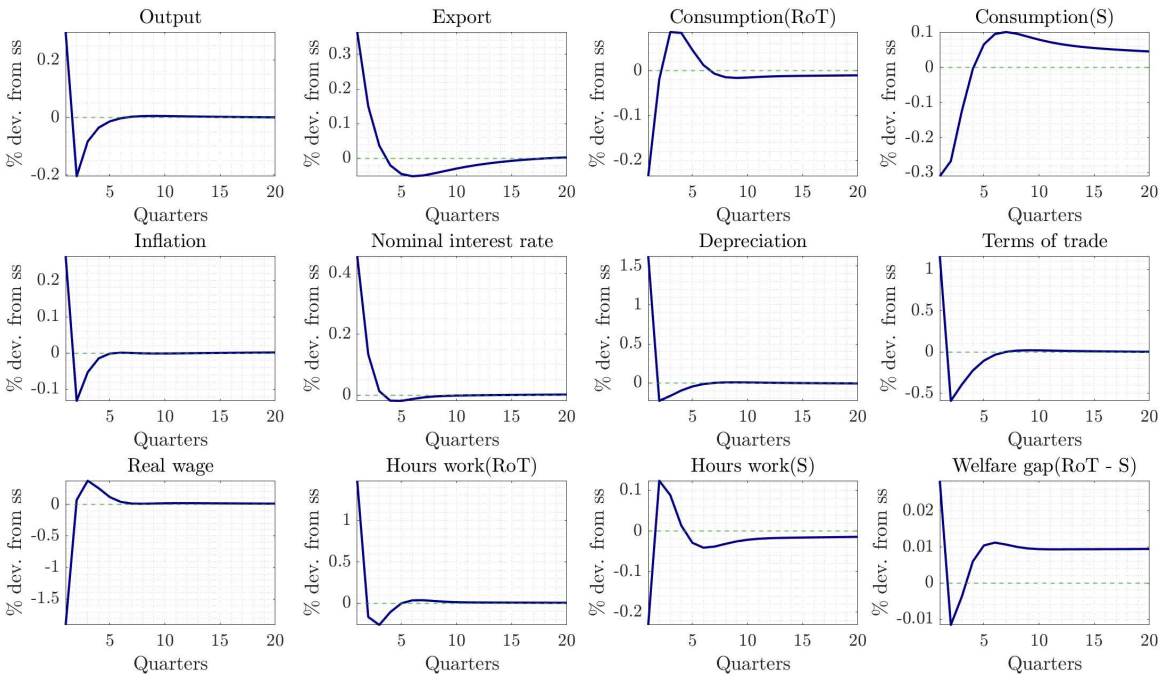

Figure 3.3: Responses to a contractionary RoW monetary policy shock

the RoT and Ricardian households leading to a worse welfare condition for the RoT households. All in all, an economically viable spillover transmission of the RoW's monetary policy is reflected by the results.

3.4.3 Historical Decomposition

In this section, the results of historical decomposition analysis are presented to highlight the contribution of various domestic and external shocks to explain the dynamics of selected macroeconomic aggregates for the period 1999: QI - 2019: QIV. As one of the useful tools for understanding the role of various structural shocks, historical decomposition can be used to decompose data into the sum of a baseline forecast and the contribution of all shocks. As a result, how the data would have evolved if a shock or a combination of shocks were shut down is analyzed in this section.

Since several structural shocks of domestic and external origin are included in the model, the contributions of these shocks are grouped into smaller subgroups. There-

fore, in what follows, external shock is an aggregated sum of foreign-based shocks including preference, investment-specific technology, markup, productivity, monetary policy, and fiscal policy shocks. Domestic productivity, investment-specific technology, terms of trade, and mark-up shocks are grouped to form a domestic supply shock. Similarly, monetary policy, fiscal policy, and preference shocks of domestic origin are grouped to compose a domestic demand shock. A shock to phosphate price is presented independently to highlight its contribution in isolation. Accordingly, the gray shaded area represents recession periods of the EU economy while the black line is the deviation of the smoothed value of the corresponding macroeconomic variable from its steady-state level for Morocco.

The role of external shocks to the Moroccan economy is found to be more relevant for nominal variables (inflation and exchange rate) than their contribution to real output growth. However, phosphate price shock has a profound contribution to Morocco's real output growth fluctuation.

3.4.3.1 Output Growth

Figure 3.4 presents the historical decomposition of structural shocks to the fluctuations of output for the period 1999:QI - 2019:QIV. Though Morocco's real GDP has experienced both upward trajectories and slowdowns over the years, the economy has not been pushed into a recession since 1995. More importantly, the 2007 global financial crisis can be considered as a cut-off point as the real GDP growth has experienced more slowdowns in the aftermath of the crisis compared to the pre-2007 recession periods.

Over the years, Morocco's economy has been hit by several shocks that led to some periods of booms and slumps. Among the few significant spikes in Morocco's real GDP growth, the period between 2008 and 2010 is marked by the strong contribution

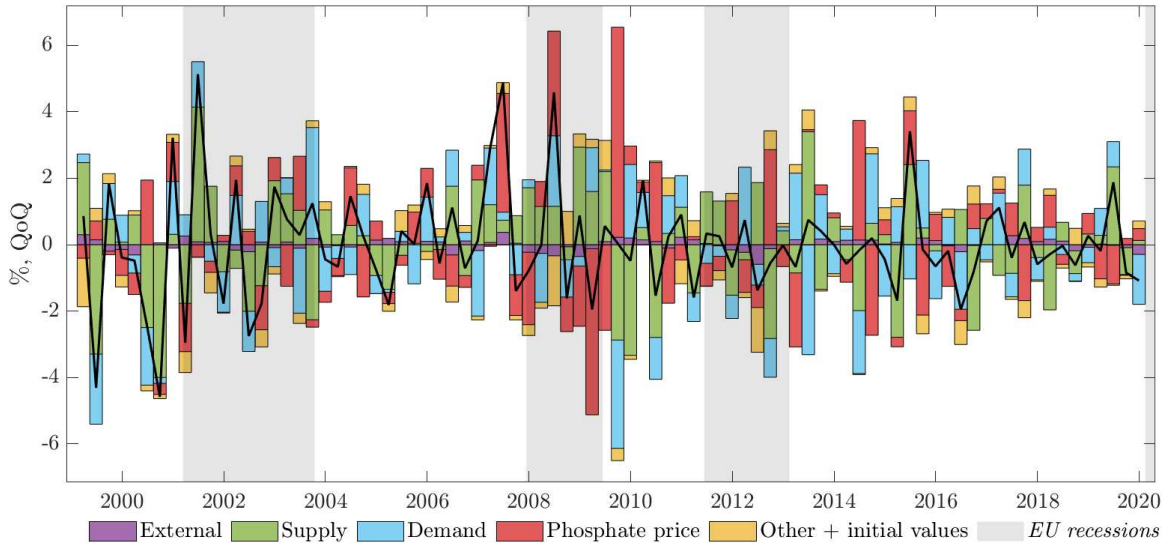

Figure 3.4: Historical decomposition of real output growth, 1999:QI - 2019:QIV.

of phosphate price shocks. This is because the price of phosphate has been highly volatile between those periods where positive shocks lifted real GDP while negative shocks dragged down real GDP. Phosphate price shocks have been among the key factors driving real output growth implying the frequent volatile nature of its price and the subsequent sensitivity of Morocco's economy to these shocks. Supply-side shocks, while taking the lion's share of explaining real output fluctuations, contributed to most of the pre-2007 booms and their contribution has been mixed between booms and slumps since then. Though their behaviour is not consistent over the years, demand shocks have a sizeable contribution to real output fluctuation. Overall, except for the phosphate price shock, the contribution of the other external shocks to Morocco's output fluctuations is minimal. Additionally, consistent with the theory on emerging small open economies, domestic supply factors are more important than demand shocks to output fluctuation.

3.4.3.2 CPI Inflation

With the exceptions of few spikes during the early 2000s and late 2007, Morocco's inflation has been fairly fluctuating around its steady state (see Figure 3.5). Various

shocks have distinctively contributed to inflation dynamics over the years while the contribution of phosphate price inflation is found to be minimal. In this regard, external shocks are important contributors of driving inflation upwards consistently. During the periods between 2005 and 2012, external shocks together explained a third of inflation's fluctuation. Domestic demand and supply shocks are also important as their direction of contribution is reversed before and after 2007. The pre-2007 periods are marked by supply shocks pushing inflation upwards while demand shocks dragged it down. Following the 2007 financial crisis, domestic demand and supply shocks reversed directions and remained as important factors explaining inflation dynamics.

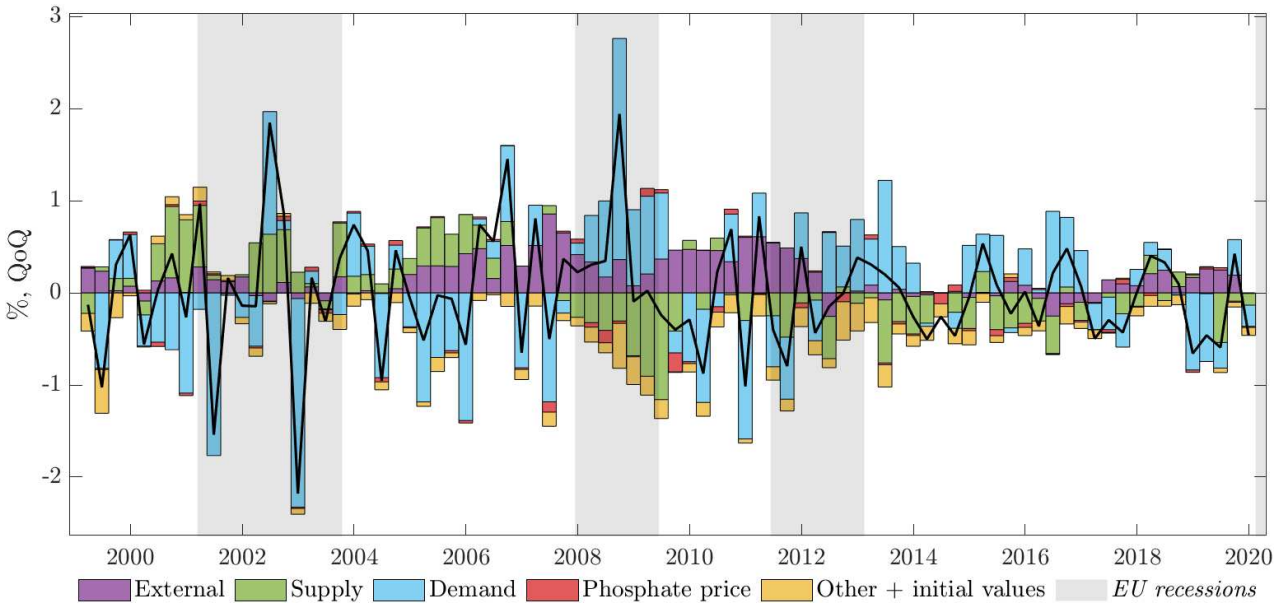

Figure 3.5: Historical decomposition of inflation, 1999:QI - 2019:QIV.

3.4.3.3 Nominal Exchange Rate

As reported in Figure 3.6, exchange rate fluctuation is among the prevalent features of Moroccan economy. As such, several shocks of domestic and external origin accounted for its fluctuation over the years. Among the domestic shocks, monetary policy shocks are the main drivers of exchange rate movements in Morocco. Though domestic

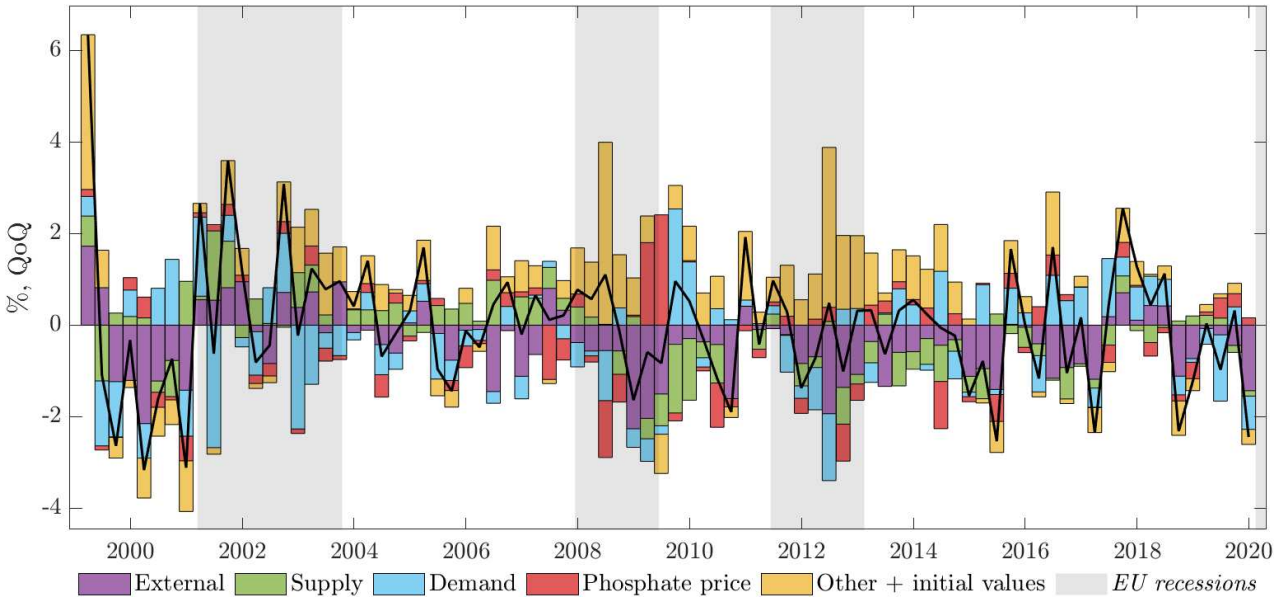

Figure 3.6: Historical decomposition of nominal exchange rate, 1999:QI - 2019:QIV.

demand shocks, domestic supply shocks, and phosphate price shocks have an equal contribution to exchange rate fluctuation, their role has been consistently reversed over the periods. Like the dynamics of inflation, the main drivers of exchange rate fluctuation (ranging between 20 - 50 percent) are external shocks. External shocks contributed to the fluctuation of the nominal exchange rate and consistently led to the depreciation of Morocco's domestic currency, Dirham.

3.5 Sensitivity Analysis

Frequent swings in exchange rates are among the economic hurdles emerging economies must deal with. An exchange rate depreciation for emerging economies not only subdues their capital and intermediate goods import but also can easily find itself to induce inflationary pressure through high prices of import. It can also be a source for a rise in foreign currency-denominated liabilities of SOE emerging economies.

Large fluctuations in exchange rates can destabilize emerging economies since it is a core determinant of the nominal anchor in emerging economies and it is central to

what central banks are meant to do, preserve the value of money and price stability. Cognizant of this understanding, the Taylor rule monetary policy of the benchmark model is customized in a way that the central bank responds to not only the classical inflation and output gap movements but also to exchange rate movements. However, the question of why central banks in emerging economies care so much about exchange rates is not fully out of sight, especially by flexible exchange rate proponents. A standard Taylor rule monetary policy with and without exchange rate targeting is compared to illustrate whether exchange rate targeting of Bank Al-Maghrib (BAM)'s monetary policy has economic merit or not.

Under the alternative scenario, the monetary authorities do not target exchange rate fluctuations and hence the standard Taylor rule is given by:

$$\log\left(\frac{R_t}{R}\right) = \rho_r \log\left(\frac{R_{t-1}}{R}\right) + (1-\rho_r)\left[\theta_{r,\Pi}\log\left(\frac{\Pi_{t-1}}{\Pi}\right) + \theta_{r,y}\log\left(\frac{Y_t}{Y}\right)\right] + \epsilon_{r,t} \tag{3.5.1}$$

To compare the two cases, the benchmark model's estimated parameters posteriors are used to run simulations without an exchange rate targeting monetary policy. Accordingly, the responses of selected macroeconomic variables to an external shock (external monetary tightening) are presented below for the Moroccan economy.

As the results in Figure 3.7 can attest, the response of output, consumption, inflation, depreciation, and terms of trade is significantly lower under the benchmark model. The result, with the appropriate choice of parameters, supports the argument that emerging economies can utilize exchange rate-targeting monetary policy to partially offset the undesirable effects of external shocks and stabilize their economy.

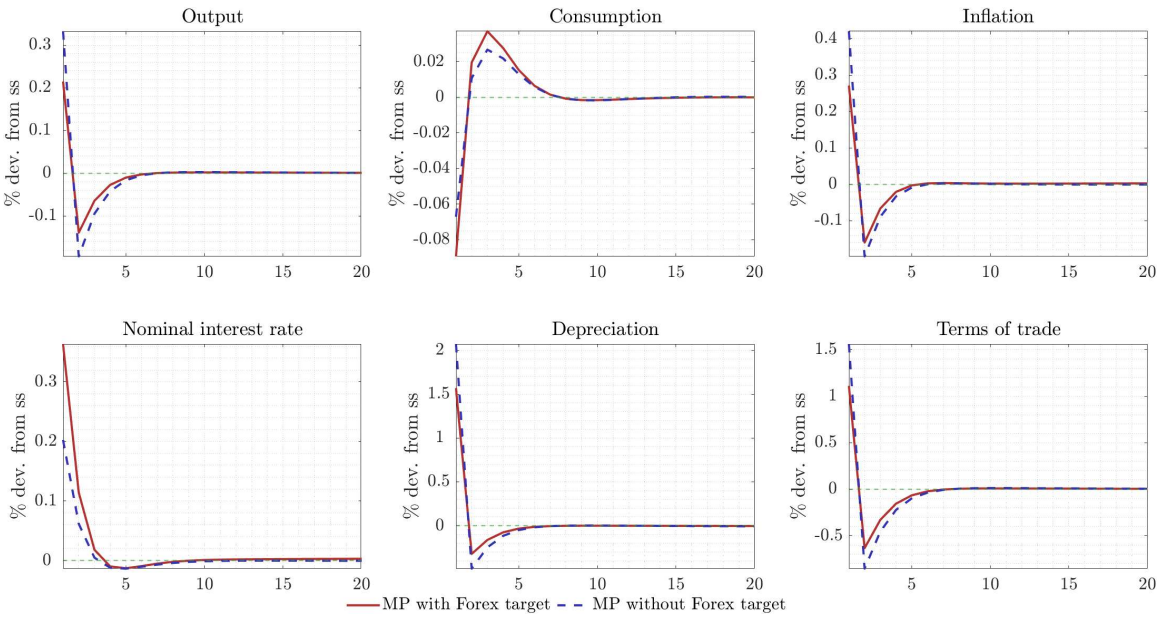

Figure 3.7: Responses to a foreign monetary tightening - FX target Vs No FX Target

3.5.1 Welfare Implications of Exchange Rate Targeting

As per the results in Section 3.5, monetary policy exchange rate targeting is proven to be important to ease the magnitude of external shocks' effect on emerging economies. However, the follow-up question is whether this partially shielding monetary policy practice of emerging economies is truly welfare-improving or not. Accordingly, a counterfactual exercise is conducted to explore the possible welfare implications of emerging economy's exchange rate targeting in their monetary policy operations.

In what follows, the estimated parameters of the benchmark model are used, and alternative monetary policy regimes along the different monetary policy exchange rate feedback parameter space (θ_{r,Π^s}) are undertaken to illustrate a welfare comparison. For this purpose, both conditional and unconditional welfare are employed using the approach in Carlstrom et al. (2017) and Born and Pfeifer (2020). The recursive steady-state utility (U) function that involves evaluating welfare at a particular point in the state space produces the conditional welfare ($V = \frac{1}{1-\beta}U$) while unconditional

welfare results are produced by averaging welfare with shocks. The steady-state Consumption Equivalence (CE) value, $CE_{ss} = 1.172$, is used to compute the welfare gain or loss based on Consumption Equivalenct Variation (CEV) across the θ_{r,Π^s} parameter space as follows:

$$CEV = \frac{V_{\Pi^s,\Pi,Y} - V_{\Pi,Y}}{CE_{ss}} \tag{3.5.2}$$

where V is either the conditional or unconditional welfare across the parameter space of θ_{r,Π^s}. Based on this counterfactual exercise, the results are presented below.

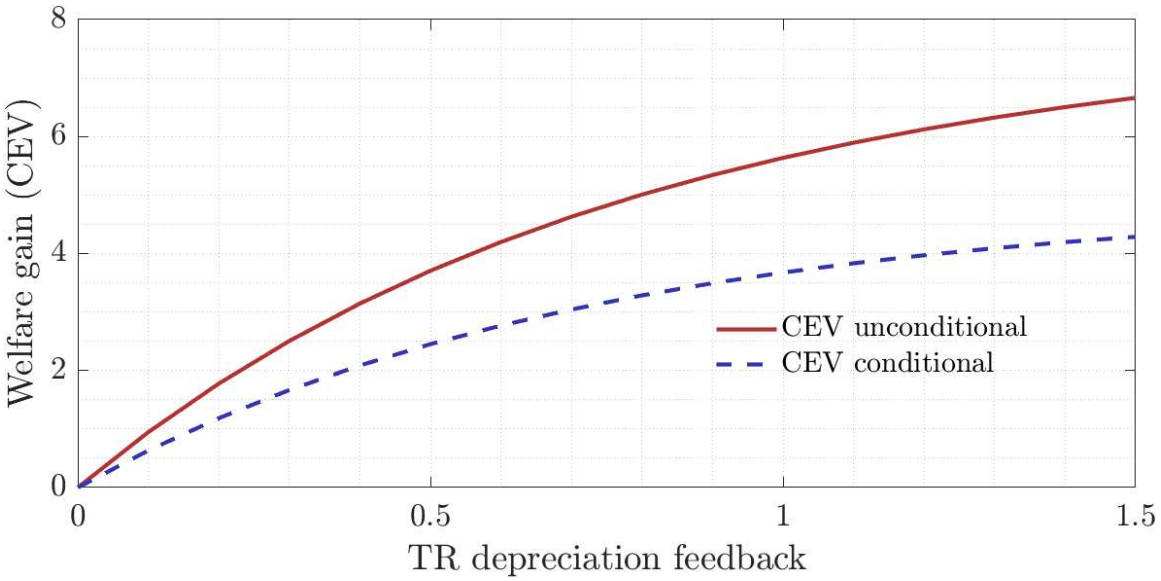

Figure 3.8: Welfare gain (loss) of alternative monetary policy regime

Though it is important to recognize the common criticism labeled at using unconditional welfare criterion as a welfare comparison,[12] the results of both unconditional and conditional welfare based CEV (Figure 3.8) clearly shows how the welfare gain is a positive function of θ_{r,Π^s} which supports the argument for BAM's monetary policy targeting of exchange rate fluctuation. This counterfactual exercise highlights the importance of monetary authorities in SOEs to target exchange rate fluctuations as part

[12]Using unconditional welfare criterion is criticized since it may neglect the welfare effects during the transition period from one steady state to another (Born and Pfeifer, 2020; Kim and Kim, 2018; Lombardo and Vestin, 2008; Woodford, 2002)

of their monetary policy operations. Therefore, targeting exchange rate fluctuations during monetary policy operations has positive welfare implications for the Moroccan economy.

3.6 Conclusion

Using Adolfson et al. (2007) and Mirfatah et al. (2021) as a benchmark, a small open economy DSGE model is estimated for the Moroccan economy. Considering the EU economy as the relevant RoW block and the phosphate mineral sector as the key export commodity sector to the Moroccan economy, the model is estimated using the Bayesian estimation procedure. Accordingly, observed data on real GDP, price of phosphate, nominal interest rate, inflation, real government debt, real investment, real consumption, terms of trade, and nominal exchange rate of the Moroccan economy are used for estimation. Similarly, EU economy observed data on real GDP, inflation, the shadow interest rate, real investment, real consumption, hours of work, and real wage are employed to estimate parameters of the EU economy. In doing so, the study shows that in addition to other external and domestic structural shocks, a shock to the price of Morocco's main export commodity (phosphate) is an important transmission channel of external shocks to the Moroccan economy. More importantly, disturbances to the export commodity sector's price have a strong economic effect on output, inflation, and the welfare gap between RoT and Ricardian households.

To my knowledge, the estimated comprehensive model is the first of its kind for the Moroccan economy. This study provided a result and guidance that can be used as a springboard for further research on emerging economies. In this regard, there are various possible ways this research can be extended. First, the TANK model employed with RoT households can be extended into a full-fledged Kaplan et al. (2018) Hetrogenous Agent New Keynesian (HANK) model and results can be compared against

a representative agent-based model. Second, though a mineral export commodity sector is considered in this study, similar extensions can be conducted for other emerging economies with the appropriate export commodity sector. Furthermore, the simple endowment-based commodity sector considered in this study can be extended into other functional forms such as search and extraction functional forms.

Third, though the New Keynesian DSGE models have come a long way and progressed to include some salient features of emerging economies, there are still key structural features that need to be considered for these models' applicability to emerging economies. Therefore, a step-by-step introduction of features such as dependency on remittances, foreign exchange constraint, imperfect access to the international financial market, and labour market informalities as identified in Senbeta (2011) can be applied to this study. Finally, there is room to extend the model by considering other alternative Taylor rule fiscal and monetary policy targeting rules.

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APPENDIX A

THE ROLE OF EXTERNAL SHOCKS TO MACROECONOMIC FLUCTUATIONS Of EMERGING ECONOMIES: EXPLORING THE EXPORT COMMODITY PRICE CHANNEL

A.1 Impulse responses under an alternative prior specification

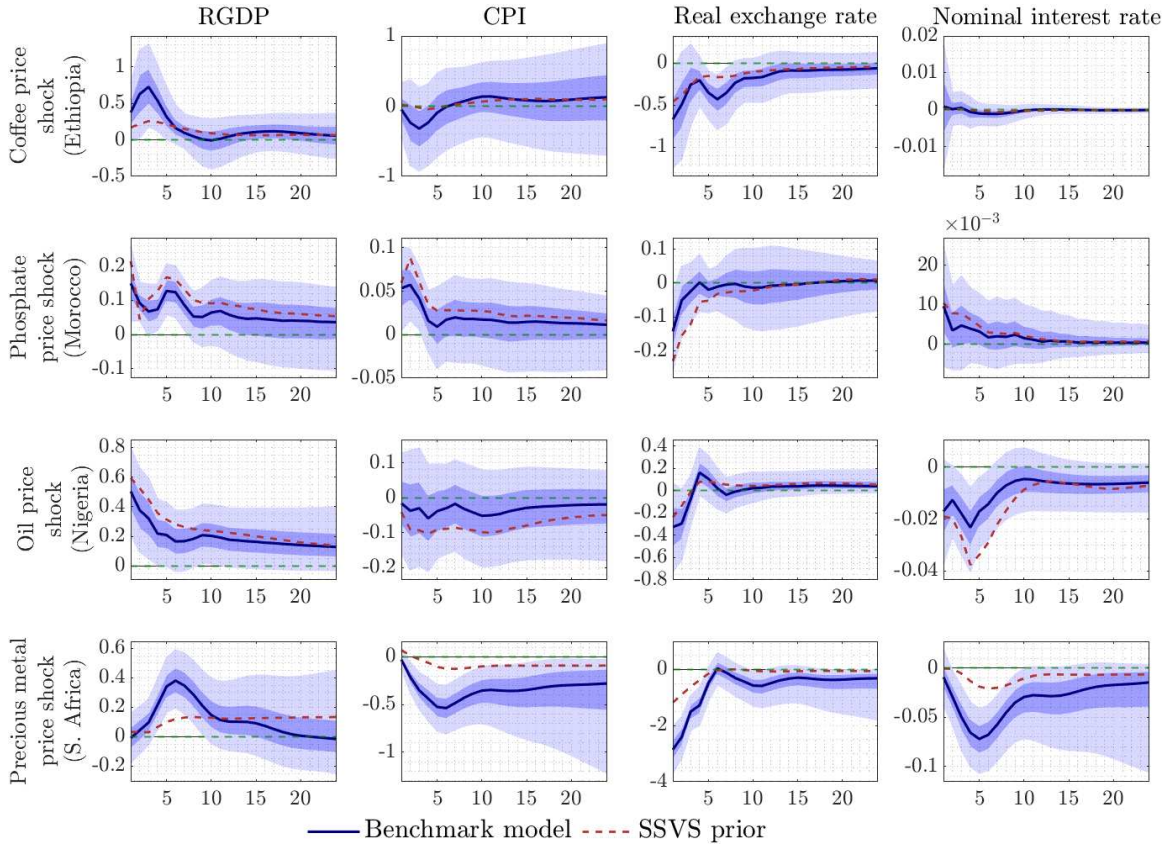
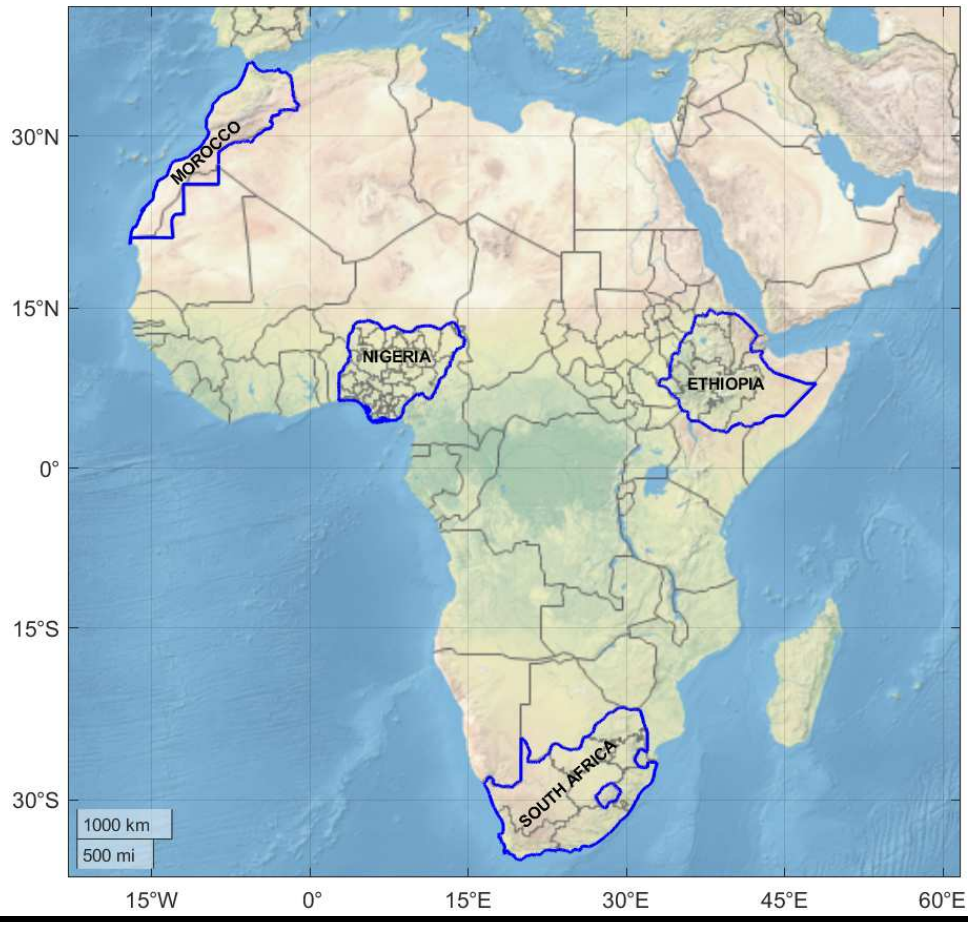


Figure A.1: Responses to a 10 percent positive export commodity price shock

A.2 Economies selected for the study



	Ethiopia	Morocco	Nigeria	South Africa
Relative GDP (% of Africa's GDP)	5.32	7.15	24.85	21.54
Main Export (% of total export)	Coffee (37.37)	Phosphate (23.55)	Crude Oil (92.78)	Precious Metal (32.51)
Export to EU (% of total export)	37.02	75.41	34.32	38.24
Trade openness (% of GDP)	41.94	60.69	37.40	52.57
Remittances received (% of GDP)	1.10	6.11	4.20	0.23

Source: Author's computation using data from the WB - WITS (2022) and WDI (2022).

Table A.1: Key features of four African economies selected for the study over the period, 1998 - 2019.

A.3 Measurement of variables and data source

Variables	Description of Variables	Measurement of Variables	Data Source
Y^*	Real gross domestic product (GDP) of the EU	$100 * \log$ of quarterly EU GDP deflated by EU CPI	Eurostat database
PI^c	Price of export commodity (Coffee, Phosphate fertilizer, Oil and Precious metal)	$100 * \log$ of quarterly price of each commodity deflated by EU CPI	Federal Reserve Economic Data (FRED) database
R^*	Nominal interest rate of the EU	$100 * \log$ of quarterly shadow rate of the EU	Wu and Xia (2020) and Eurostat database
A^*	Real aid to GDP ratio of each selected economy	$100 * \log$ of quarterly share of real aid to GDP	National Banks and Statistical Agency databases
Y	Real GDP of each selected economy	$100 * \log$ of quarterly real GDP for each economy	National Banks and Statistical Agency databases
CPI	Consumer price index of each economy	$100 * \log$ of quarterly CPI for each economy	National Banks and Statistical Agency databases
E	Exchange rate of domestic currency for each economy	$100 * \log$ of quarterly exchange rate/euro	National Banks and Statistical Agency databases
R	Nominal interest rate of each economy	$100 * \log$ of quarterly interest rate of central banks	National Banks and Statistical Agency databases

Note: Whenever data is found to be not seasonally adjusted from the source, seasonal adjustments are conducted with the help of Eviews' X-13 filter.

Table A.2: Description, measurement of variables and data source

APPENDIX B

EXTERNAL SHOCKS, MACROECONOMIC FLUCTUATIONS AND WELFARE IMPLICATIONS: A SMALL OPEN ECONOMY NEW KEYNESIAN DSGE MODEL WITH AN EXPORT COMMODITY SECTOR

B.1 Optimal conditions for firms

B.1.1 Final good producing firms

Profit maximization of a final good producer firm follows:

$$P_{H,t} = \left(\int_0^1 P_{H,t}(j)^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}}$$

$$\begin{aligned} \max_{Y_t(j)} \Pi_{H,t} &= P_{H,t} Y_t - \int_0^1 P_{H,t}(j) Y_t(j) dj \qquad s.t \quad \textit{Equation 3.2.35} \\ &= P_{H,t} \left(\int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} - \int_0^1 P_{H,t}(j) Y_t(j) dj \end{aligned} \tag{B.1.1}$$

Simplifying the optimal conditions results in an expression for the aggregate price level for home produced goods.

$$P_{H,t} = \left(\int_0^1 P_{H,t}(j)^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}}$$

B.2 Price and terms of trade ratios

$$\frac{\Psi_t tot_t}{\Psi_{t-1} tot_{t-1}} = \frac{\Pi_{F,t}}{\Pi_{H,t}}$$

$$\frac{P_t}{P_{H,t}} = \left(w_C + (1-w_C)\Psi_t^{1-\mu_C}\right)^{\frac{1}{1-\mu_C}} \Rightarrow \frac{P_{H,t}}{P_t} = 1 \Big/ \left(w_C + (1-w_C)\Psi_t^{1-\mu_C}\right)^{\frac{1}{1-\mu_C}}$$

$$\frac{P_t}{P_{F,t}} = \left(w_C \Psi_t^{\mu_C - 1} + (1-w_C)\right)^{\frac{1}{1-\mu_C}} \Rightarrow \frac{P_{F,t}}{P_t} = 1 \Big/ \left(w_C \Psi_t^{\mu_C - 1} + (1-w_C)\right)^{\frac{1}{1-\mu_C}}$$

$$\frac{P_t^I}{P_{H,t}} = \left(w_I + (1-w_I)\Psi_t^{1-\mu_I}\right)^{\frac{1}{1-\mu_I}} \Rightarrow \frac{P_{H,t}}{P_t^I} = 1 \Big/ \left(w_I + (1-w_I)\Psi_t^{1-\mu_I}\right)^{\frac{1}{1-\mu_I}}$$

$$\frac{P_t^I}{P_{F,t}} = \left(w_I \Psi_t^{\mu_I - 1} + (1-w_I)\right)^{\frac{1}{1-\mu_I}} \Rightarrow \frac{P_{F,t}}{P_t^I} = 1 \Big/ \left(w_I \Psi_t^{\mu_I - 1} + (1-w_I)\right)^{\frac{1}{1-\mu_I}}$$

$$\frac{P_t^G}{P_{H,t}} = \left(w_G + (1-w_G)\Psi_t^{1-\mu_G}\right)^{\frac{1}{1-\mu_G}} \Rightarrow \frac{P_{H,t}}{P_t^G} = 1 \Big/ \left(w_G + (1-w_I)\Psi_t^{1-\mu_I}\right)^{\frac{1}{1-\mu_I}}$$

$$\frac{P_t^G}{P_{F,t}} = \left(w_G \Psi_t^{\mu_G - 1} + (1-w_G)\right)^{\frac{1}{1-\mu_G}} \Rightarrow \frac{P_{F,t}}{P_t^G} = 1 \Big/ \left(w_G \Psi_t^{\mu_I - 1} + (1-w_G)\right)^{\frac{1}{1-\mu_G}}$$

$$\frac{P_t^I}{P_t} \equiv \frac{P_t^I}{P_{H,t}} \Big/ \frac{P_t}{P_{H,t}} \equiv \frac{1}{\frac{P_{H,t}}{P_t^I}} \Big/ \frac{1}{\frac{P_{H,t}}{P_t}} \equiv \frac{P_{H,t}}{P_t} \Big/ \frac{P_{H,t}}{P_t^I}$$

$$\frac{P_t^G}{P_t} \equiv \frac{P_t^G}{P_{H,t}} \Big/ \frac{P_t}{P_{H,t}} \equiv \frac{1}{\frac{P_{H,t}}{P_t^G}} \Big/ \frac{1}{\frac{P_{H,t}}{P_t}} \equiv \frac{P_{H,t}}{P_t} \Big/ \frac{P_{H,t}}{P_t^G}$$

B.2.1 Price setting

Intermediate firms have a price setting problem where firm j set prices subject to a quadratic adjustment cost as in Rotemberg (1982). Firm j maximizes the discounted present value of real profit (Ξ) subject to final good producer's demand for an intermediate good.

$$\max_{\{P_{H,t}(j)\}_0^\infty} E_t \sum_{s=0}^{\infty} \Lambda_{t+s}^s \Xi_{t+s}$$

$$\max_{\{P_{H,t}(j)\}_0^\infty} E_t \sum_{s=0}^{\infty} \Lambda_{t+s}^s \left\{ \left(\frac{P_{H,t+s}(j)}{P_{H,t+s}} - mc_{t+s} M_{t+s} \right) Y_{t+s}(j) - \frac{\gamma_p}{2} \left(\frac{P_{H,t+s}(j)}{P_{H,t+s-1}(j)} - 1 \right)^2 Y_{t+s} \right\} \tag{B.2.1}$$

s.t

$$Y_{t+s}(j) = \left(\frac{P_{H,t+s}(j)}{P_{H,t+s}}\right)^{-\varepsilon} Y_{t+s} \tag{B.2.2}$$

$\Lambda^s_{t+s} \equiv \beta \frac{U^s_{C,t+s}}{U^s_{C,t+s-1}}$ is the stochastic discount factor [13] and M_t is an exogenous AR(1) process markup shock similar to Oh (2019) and $\frac{P_{H,t}}{mc_t}$ is the average markup. Substituting Equation B.2.2 into subsection B.2.1, the discounted pricing problem can be expressed as:

$$\Xi = \Big(\frac{P_{H,t}(j)}{P_{H,t}}\Big)^{1-\varepsilon} Y_t - mc_t M_t \Big(\frac{P_{H,t}(j)}{P_{H,t}}\Big)^{-\varepsilon} Y_t - \frac{\gamma_p}{2}\Big(\frac{P_{H,t}(j)}{P_{H,t-1}(j)} - 1\Big)^2 Y_t + \max_{\{P_{H,t}(j)\}_1^\infty} E_t \sum_{s=1}^{\infty} \Lambda^s_{t+s} \Xi_{t+s} \tag{B.2.3}$$

Each period, firms choose the price level to maximize the discounted flow of profit. The first order condition can be expressed as:

$$(1-\varepsilon)\Big(\frac{P_{H,t}(j)}{P_{H,t}}\Big)^{-\varepsilon} \frac{Y_t}{P_{H,t}} + (\varepsilon) mc_t M_t \Big(\frac{P_{H,t}(j)}{P_{H,t}}\Big)^{-(1+\varepsilon)} \frac{Y_t}{P_{H,t}} - \gamma_p \Big(\frac{P_{H,t}(j)}{P_{H,t-1}(j)} - 1\Big) \frac{Y_t}{P_{H,t-1}(j)} + \gamma_p E_t \Big[\Lambda^s_{t+1} \Big(\frac{P_{H,t+1}(j)}{P_{H,t}(j)} - 1\Big) \left(\frac{P_{H,t+1}(j)}{(P_{H,t}(j))^2}\right) Y_{t+1}\Big] = 0$$

All firms face this price setting problem and they behave identically at equilibrium and hence they will charge the same price and produce the same output i.e., $P_{H_t}(j) = P_{H,t}$ and $Y_t(j) = Y_t$. Once we impose this symmetry condition and multiply both sides by $\frac{P_{H,t}}{Y_t}$, the first order condition takes the form:

$$(1-\varepsilon) + (\varepsilon) mc_t M_t - \gamma_p \Big(\frac{P_{H,t}}{P_{H,t-1}} - 1\Big) \frac{P_{H,t}}{P_{H,t-1}} + \gamma_p E_t \Big[\Lambda^s_{t+1} \Big(\frac{P_{H,t+1}}{P_{H,t}} - 1\Big) \frac{P_{H,t+1}}{P_{H,t}} \frac{Y_{t+1}}{Y_t}\Big] = 0$$

Define $\Pi_{H,t} \equiv P_{H,t}/P_{H,t-1}$ as domestic gross inflation. Substituting this definition above provides the New Keynesian Phillips curve:

$$\Pi_{H,t}(\Pi_{H,t} - 1) = \frac{\varepsilon}{\gamma_p}\Big(mc_t M_t + \frac{1-\varepsilon}{\varepsilon}\Big) + E_t\Big[\Lambda^s_{t+1} \frac{Y_{t+1}}{Y_t} (\Pi_{H,t+1} - 1)\Pi_{H,t+1}\Big] \tag{B.2.4}$$

[13] This particular stochastic discount factor is used since the wholesale sector intermediate good producing firms are assumed to be owned by patient households (see Galí et al., 2007, for details)

B.3 Model solutions and equilibrium conditions - Moroccan economy

B.3.1 Households

$$U_t^s = \frac{\left(C_t^s - \chi C_{t-1}^s\right)^{1-\sigma_s}}{1-\sigma_s} \exp\left((\sigma_s - 1)\frac{N_t^{s(1+\varphi_s)}}{1+\varphi_s}\right) \tag{B.3.1}$$

$$U_t^r = \frac{\left(C_t^r - \chi C_{t-1}^r\right)^{1-\sigma_r}}{1-\sigma_r} \exp\left((\sigma_r - 1)\frac{N_t^{r(1+\varphi_r)}}{1+\varphi_r}\right) \tag{B.3.2}$$

$$V_t^s = E_t\left[\sum_{i=0}^{\infty} \beta^{t+i} U_{t+i}^s\right] = U_t^s + \beta E_t U_{t+1}^s \tag{B.3.3}$$

$$V_t^r = E_t\left[\sum_{i=0}^{\infty} \beta^{t+i} U_{t+i}^s\right] = U_t^r + \beta E_t U_{t+1}^r \tag{B.3.4}$$

$$U_t = \lambda U_t^r + (1-\lambda) U_t^s \tag{B.3.5}$$

$$V_t = \lambda V_t^r + (1-\lambda) V_t^s \tag{B.3.6}$$

$$CE_t^r = (1.01^{(1-\sigma_r)} - 1)U_t^r + \beta CE_{(t+1)}^r; \tag{B.3.7}$$

$$CE_t^s = (1.01^{(1-\sigma_s)} - 1)U_t^s + \beta CE_{(t+1)}^s; \tag{B.3.8}$$

$$CE_t = \lambda CE_t^r + (1-\lambda) CE_t^s; \tag{B.3.9}$$

$$w_t(1-\tau_t^w) = \frac{(C_t^s - \chi C_{t-1}^s)(N_t^s)^{\varphi_s}}{1 - \beta\chi \frac{U_{t+1}^s}{U_t^s} \frac{C_t^s - \chi C_{t-1}^s}{C_{t+1}^s - \chi C_t^s}} \tag{B.3.10}$$

$$1 = E_t\Big[\frac{\Lambda_{t+1}^s}{\Pi_{t+1}}\Big] R_t \tag{B.3.11}$$

$$1 = E_t\Big[\Lambda_{t+1}^s \frac{\Pi_{t+1}^S}{\Pi_{t+1}}\Big] \Phi_t(.) R_t^* \tag{B.3.12}$$

$$\Lambda_{t+1}^s \equiv \beta \frac{U_{C,t+1}^s}{U_{C,t}^s} \tag{B.3.13}$$

$$U_{C,t}^s = \left(C_t^s - \chi C_{t-1}^s\right)^{-\sigma_s} \exp\left((\sigma_s - 1)\frac{N_t^{s(1+\varphi_s)}}{1+\varphi_s}\right) \tag{B.3.14}$$

$$E_t\left[\frac{\Lambda_{t+1}}{\Pi_{t+1}}\right] R_t = R_t^* \Phi_t(.) E_t\left[\Lambda_{t+1}\frac{\Pi_{t+1}^S}{\Pi_{t+1}}\right] \tag{B.3.15}$$

$$C_t^r = w_t(1-\tau_t^w)N_t^r + (1-\tau^p)\Omega_t \frac{P_{p,t}^*}{P_t^*} Y_t^p - T_t \tag{B.3.16}$$

$$w_t(1-\tau_t^w) = \frac{(C_t^r - \chi C_{t-1}^r)(N_t^r)^{\varphi_r}}{1 - \beta\chi \frac{U_{t+1}^r}{U_t^r} \frac{C_t^r - \chi C_{t-1}^r}{C_{t+1}^r - \chi C_t^r}} \tag{B.3.17}$$

$$C_t = \lambda C_t^r + (1-\lambda) C_t^s \tag{B.3.18}$$

$$N_t = \lambda N_t^r + (1-\lambda) N_t^s \tag{B.3.19}$$

$$C_{H,t} = w_C \left(\frac{P_{H,t}}{P_t} \right)^{-\mu_C} C_t \tag{B.3.20}$$

$$C_{F,t} = (1 - w_C) \left(\frac{P_{F,t}}{P_t} \right)^{-\mu_C} C_t \tag{B.3.21}$$

$$I_{H,t} = w_I \left(\frac{P_{H,t}}{P_t^I} \right)^{-\mu_I} I_t \tag{B.3.22}$$

$$I_{F,t} = (1 - w_I) \left(\frac{P_{F,t}}{P_t^I} \right)^{-\mu_I} I_t \tag{B.3.23}$$

$$G_{H,t} = w_G \left(\frac{P_{H,t}}{P_t^G} \right)^{-\mu_G} G_t \tag{B.3.24}$$

$$G_{F,t} = (1 - w_G) \left(\frac{P_{F,t}}{P_t^G} \right)^{-\mu_G} G_t \tag{B.3.25}$$

B.3.2 Firms

$$Y_t = K_{t-1}^{\alpha} \left(Z_t N_t \right)^{1-\alpha} \tag{B.3.26}$$

$$r_t^k \equiv \frac{R_t^k}{P_t} = \alpha \frac{Y_t}{K_{t-1}} mc_t \frac{P_{H,t}}{P_t} \tag{B.3.27}$$

$$w_t \equiv \frac{W_t}{P_t} = (1 - \alpha) \frac{Y_t}{N_t} mc_t \frac{P_{H,t}}{P_t} \tag{B.3.28}$$

$$mc_t = \frac{1}{\frac{P_{H,t}}{P_t}} \left(\frac{r_t^k}{\alpha} \right)^{\alpha} \left(\frac{w_t}{(1 - \alpha) Z_t} \right)^{1-\alpha} \tag{B.3.29}$$

$$\Pi_{H,t}(\Pi_{H,t} - 1) = \frac{\varepsilon}{\gamma_p} \Big(mc_t M_t + \frac{1 - \varepsilon}{\varepsilon} \Big) + E_t \Big[\Lambda_{t+1}^s \frac{Y_{t+1}}{Y_t} (\Pi_{H,t+1} - 1) \Pi_{H,t+1} \Big] \tag{B.3.30}$$

$$\Gamma = \frac{\gamma_p}{2}\left(\frac{P_{H,t}}{P_{H,t-1}} - 1\right)^2 Y_t \tag{B.3.31}$$

$$d_t \equiv \frac{D_t}{P_t} = \frac{P_{H,t}}{P_t}\left(1 - mc_t - \frac{\gamma_p}{2}\left(\frac{P_{H,t}}{P_{H,t-1}} - 1\right)^2\right) Y_t \tag{B.3.32}$$

$$K_t = (1-\delta)K_{t-1} + \eta_t\left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t \tag{B.3.33}$$

$$I_t = \left[(w_I)^{\frac{1}{\mu_I}}(I_{H,t})^{\frac{\mu_I - 1}{\mu_I}} + (1-w_I)^{\frac{1}{\mu_I}}(I_{F,t})^{\frac{\mu_I - 1}{\mu_I}}\right]^{\frac{\mu_I}{\mu_I - 1}} \tag{B.3.34}$$

$$\eta_t q_t\left(1 - S\left(\frac{I_t}{I_{t-1}}\right) - \frac{I_t}{I_{t-1}}X_t\right) + E_t\left(\Lambda^s_{t+1}\eta_{t+1}q_{t+1}X_{t+1}\frac{I^2_{t+1}}{I^2_t}\right) = \frac{P^I_t}{P_t} \tag{B.3.35}$$

$$SX_t(.) = \frac{\phi_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \tag{B.3.36}$$

$$X_t = \phi_I\left(\frac{I_t}{I_{t-1}} - 1\right) \tag{B.3.37}$$

$$rr^k_t = \frac{(1-\tau^k_t)r^k_t + (1-\delta)q_t}{q_{t-1}} \tag{B.3.38}$$

$$E_t(\Lambda^s_{t+1} rr^k_{t+1}) = E_t\left(\frac{\Lambda^s_{t+1}}{\Pi_{t+1}}\right) R_t = 1 \tag{B.3.39}$$

$$Y^P_t = \kappa_p Y_t \tag{B.3.40}$$

$$GDP_t = \Omega_t \frac{1}{\frac{P_{H,t}}{P_t}} \frac{P^*_{P,t}}{P^*_t} Y^P_t + Y_t \tag{B.3.41}$$

$$P_{H,t} = S_t P^*_{H,t} \quad and \quad P_{F,t} = S_t P^*_{F,t} \tag{B.3.42}$$

$$\Omega_t = \frac{S_t P^*_t}{P_t} \equiv \frac{P_{F,t}}{P_t} \tag{B.3.43}$$

$$\Psi_t = \frac{P_{F,t}}{P_{H,t}} \equiv \frac{S_t P^*_{F,t}}{P_{H,t}} \tag{B.3.44}$$

$$\Psi_t = \frac{P_{F,t}}{P_{H,t}} = \frac{S_t P^*_{F,t}}{S_t P^*_{H,t}} = \frac{P^*_{H,t}}{P^*_{F,t}} = \frac{1}{\Psi^*_t} \tag{B.3.45}$$

B.3.3 Inflation and relative prices

$$\Pi_t = \frac{P_t}{P_{t-1}} \tag{B.3.46}$$

$$\Pi_{H,t} = \frac{P_{H,t}}{P_{H,t-1}} \tag{B.3.47}$$

$$\Pi_{F,t} = \frac{P_{F,t}}{P_{F,t-1}} \tag{B.3.48}$$

$$\Pi_t = \left[w_C \left(\Pi_{H,t} \frac{P_{H,t-1}}{P_{t-1}} \right)^{1-\mu_C} + (1 - w_C) \left(\Pi_{F,t} \frac{P_{F,t-1}}{P_{t-1}} \right)^{1-\mu_C} \right]^{\frac{1}{1-\mu_C}} \tag{B.3.49}$$

$$\frac{\Psi_t tot_t}{\Psi_{t-1} tot_{t-1}} = \frac{\Pi_{F,t}}{\Pi_{H,t}}$$

$$\frac{P_t}{P_{H,t}} = \left(w_C + (1-w_C)\Psi_t^{1-\mu_C}\right)^{\frac{1}{1-\mu_C}} \Rightarrow \frac{P_{H,t}}{P_t} = 1 \Big/ \left(w_C + (1-w_C)\Psi_t^{1-\mu_C}\right)^{\frac{1}{1-\mu_C}}$$

$$\frac{P_t}{P_{F,t}} = \left(w_C \Psi_t^{\mu_C - 1} + (1-w_C)\right)^{\frac{1}{1-\mu_C}} \Rightarrow \frac{P_{F,t}}{P_t} = 1 \Big/ \left(w_C \Psi_t^{\mu_C - 1} + (1-w_C)\right)^{\frac{1}{1-\mu_C}}$$

$$\frac{P_t^I}{P_{H,t}} = \left(w_I + (1-w_I)\Psi_t^{1-\mu_I}\right)^{\frac{1}{1-\mu_I}} \Rightarrow \frac{P_{H,t}}{P_t^I} = 1 \Big/ \left(w_I + (1-w_I)\Psi_t^{1-\mu_I}\right)^{\frac{1}{1-\mu_I}}$$

$$\frac{P_t^I}{P_{F,t}} = \left(w_I \Psi_t^{\mu_I - 1} + (1-w_I)\right)^{\frac{1}{1-\mu_I}} \Rightarrow \frac{P_{F,t}}{P_t^I} = 1 \Big/ \left(w_I \Psi_t^{\mu_I - 1} + (1-w_I)\right)^{\frac{1}{1-\mu_I}}$$

$$\frac{P_t^G}{P_{H,t}} = \left(w_G + (1-w_G)\Psi_t^{1-\mu_G}\right)^{\frac{1}{1-\mu_G}} \Rightarrow \frac{P_{H,t}}{P_t^G} = 1 \Big/ \left(w_G + (1-w_I)\Psi_t^{1-\mu_I}\right)^{\frac{1}{1-\mu_I}}$$

$$\frac{P_t^G}{P_{F,t}} = \left(w_G \Psi_t^{\mu_G - 1} + (1-w_G)\right)^{\frac{1}{1-\mu_G}} \Rightarrow \frac{P_{F,t}}{P_t^G} = 1 \Big/ \left(w_G \Psi_t^{\mu_I - 1} + (1-w_G)\right)^{\frac{1}{1-\mu_G}}$$

$$\frac{P_t^I}{P_t} \equiv \frac{P_t^I}{P_{H,t}} \Big/ \frac{P_t}{P_{H,t}} \equiv \frac{1}{\frac{P_{H,t}}{P_t^I}} \Big/ \frac{1}{\frac{P_{H,t}}{P_t}} \equiv \frac{P_{H,t}}{P_t} \Big/ \frac{P_{H,t}}{P_t^I}$$

$$\frac{P_t^G}{P_t} \equiv \frac{P_t^G}{P_{H,t}} \Big/ \frac{P_t}{P_{H,t}} \equiv \frac{1}{\frac{P_{H,t}}{P_t^G}} \Big/ \frac{1}{\frac{P_{H,t}}{P_t}} \equiv \frac{P_{H,t}}{P_t} \Big/ \frac{P_{H,t}}{P_t^G}$$

B.3.4 External sector

$$C_{H,t}^* = (1-w_C^*)\left(\frac{1}{\Psi_t}\right)^{-\mu_C^*} C_t \tag{B.3.50}$$

$$I_{H,t}^* = (1-w_I^*)\left(\frac{P_{H,t}}{P_t^I}\right)^{-\mu_I^*} I_t^* \tag{B.3.51}$$

$$G_{H,t}^* = (1-w_G^*)\left(\frac{P_{H,t}}{P_t^G}\right)^{-\mu_G^*} G_t^* \tag{B.3.52}$$

$$\tag{B.3.53}$$

$$EX_t = \left(cs_{ex} + is_{ex} + gs_{ex} + \frac{1}{\frac{P_{H,t}}{P_t}} \Omega_t \frac{P_{P,t}^*}{P_t^*} \frac{Y_t^P}{Y_t}\right) Y_t \tag{B.3.54}$$

$$\Phi_t(.) = exp\left(-\phi_B\left(\frac{B_{F,t}}{\frac{P_{H,t}}{P_t}Y_t}\right)\right) \tag{B.3.55}$$

$$B_{F,t} = \frac{\Pi_t^s}{\Pi_t}B_{F,t-1} + TB_t \tag{B.3.56}$$

$$TB_t = \Omega_t\frac{P_{P,t}^*}{P_t^*}Y_t^P + \frac{P_{H,t}}{P_t}Y_t - C_t - \frac{P_t^I}{P_t}I_t - \frac{P_t^G}{P_t}G_t \tag{B.3.57}$$

B.3.5 Market clearing condition

$$Y_t = C_{H,t} + C_{H,t}^* + I_{H,t} + I_{H,t}^* + G_{H,t} + G_{H,t}^* + \frac{\gamma_p}{2}\left(\Pi_H - 1\right)^2 Y_t \tag{B.3.58}$$

B.4 Monetary policy

$$\log\left(\frac{R_t}{R}\right) = \rho_r \log\left(\frac{R_{t-1}}{R}\right) + (1-\rho_r)\left[\theta_{r,\Pi}\log\left(\frac{\Pi_{t-1}}{\Pi}\right) + \theta_{r,s}\log\left(\frac{\Pi_{s,t-1}}{\Pi_s}\right) + \theta_{r,y}\log\left(\frac{Y_t}{Y}\right)\right] + \epsilon_{r,t} \tag{B.4.1}$$

B.4.1 Fiscal policy

$$\frac{P_t^G}{Pt}G_t + \frac{R_{t-1}}{\Pi_t}B_{GH,t-1} = T_t + B_{GH,t} + w_t N_t \tau_t^w + (r_t^k - \delta q_t)K_{t-1} + d_t)\tau_t^k + \tau_t^p \Omega_t \frac{P_{p,t}^*}{P_t^*}Y_t^p$$

$$\tau_t^w = \tau_t \tau_{ss}^w, \quad \tau_t^k = \tau_t \tau_{ss}^k, \qquad T_t = g_t T_{ss}, \quad G_t = g_t G_{ss}$$

$$\log\left(\frac{\tau_t}{\tau_{ss}}\right) = \rho_\tau \log\left(\frac{\tau_{t-1}}{\tau_{ss}}\right) + \theta_{\tau,y}\log\left(\frac{Y_{t-1}}{Y_{ss}}\right) + \theta_{\tau,bg}\log\left(\frac{BG_{t-1}}{BG_{ss}}\right) + \epsilon_{\tau,t}$$

$$\log\left(\frac{g_t}{g_{ss}}\right) = \rho_g \log\left(\frac{g_{t-1}}{g_{ss}}\right) - \theta_{g,y}\log\left(\frac{Y_{t-1}}{Y_{ss}}\right) - \theta_{g,bg}\log\left(\frac{BG_{t-1}}{BG_{ss}}\right) + \epsilon_{g,t}$$

B.4.2 Exogenous process

$$\log b_t - \log b = \rho_z(\log b_{t-1} - \log b) + \epsilon_{b,t} \tag{B.4.2}$$

$$\log Z_t - \log Z = \rho_z(\log Z_{t-1} - \log Z) + \epsilon_{z,t} \tag{B.4.3}$$

$$\log \eta_t - \log \eta = \rho_\eta(\log \eta_{t-1} - \log \eta) + \epsilon_{\eta,t} \tag{B.4.4}$$

$$\log M_t - \log M = \rho_M(\log M_{t-1} - \log M) + \epsilon_{m,t} \tag{B.4.5}$$

$$\log tot_t - \log \Psi = \rho_{tot}(\log tot_{t-1} - \log tot) + \epsilon_{tot,t} \tag{B.4.6}$$

$$\log P^*_{P,t} - \log P^*_P = \rho_{P^*_M}(\log P^*_{P,t-1} - \log P^*_P) + \epsilon_{P^*_{p,t}} \tag{B.4.7}$$

B.5 Deterministic zero growth, non-zero net inflation steady state - SOE

At the steady state, all expectation operators and it is true that $X_t = X_{t+1} = X$ and all the stochastic shocks do not exist. The productivity gap ($\varpi = \frac{Y^*}{\frac{Y}{\Omega}}$) between the SOE and the RoW model is used to compute Z^*. ϖ is calibrated using real GDP per capita of the SOE and the RoW. A non-zero constant net steady state gross inflation rate is set at $\Pi = \bar{\Pi}$. Relative prices are set to 1 and hence and real exchange rate, $\Omega = 1$. The labour supply equations are used to compute the steady state hours of work for the two households using a solver function. The rest of the steady state is computed as follows recursively.

$$\Omega = 1 \tag{B.5.1}$$

$$Z = 1 \tag{B.5.2}$$

$$M = 1 \tag{B.5.3}$$

$$q = 1 \tag{B.5.4}$$

$$\eta = 1 \tag{B.5.5}$$

$$\bar{\Pi} = 1.02^{1/4} \tag{B.5.6}$$

$$\Pi = \Pi^* = \Pi_F = \Pi_H = \bar{\Pi} = \bar{\Pi} \tag{B.5.7}$$

$$\Pi^s = 1 \tag{B.5.8}$$

$$\Lambda = \beta \tag{B.5.9}$$

$$\Psi = 1 \tag{B.5.10}$$

$$\tau_k = 0.28 \tag{B.5.11}$$

$$\tau_w = 0.30 \tag{B.5.12}$$

$$\tau = 1 \tag{B.5.13}$$

$$tot = 1 \tag{B.5.14}$$

$$SX(.) = 0 \tag{B.5.15}$$

$$X = 0 \tag{B.5.16}$$

$$R = \frac{\bar{\Pi}}{\beta} \tag{B.5.17}$$

$$rr^k = \frac{R}{\Pi} \tag{B.5.18}$$

$$mc = \frac{\varepsilon - 1}{\varepsilon} \tag{B.5.19}$$

$$\frac{Y}{K} = \frac{r^k}{\alpha mc} \tag{B.5.20}$$

$$K = \frac{Z^{\frac{1}{1-\alpha}}}{\frac{Y}{K}} \tag{B.5.21}$$

$$Y = K^{\alpha}(ZN)^{1-\alpha} \tag{B.5.22}$$

$$Y_p = \kappa_p Y \tag{B.5.23}$$

$$GDP = Y^p + Y \tag{B.5.24}$$

$$w = (1-\alpha)mc\frac{Y}{N} \tag{B.5.25}$$

$$I = \delta K \tag{B.5.26}$$

$$I_H = w_I I \tag{B.5.27}$$

$$I_F = (1 - w_I)I \tag{B.5.28}$$

$$\Gamma = 0 \tag{B.5.29}$$

$$d = \frac{P_H}{P}(1 - mc)Y - \Gamma \tag{B.5.30}$$

$$B_{GF} = 4bgGDP \tag{B.5.31}$$

$$G = gyGDP \tag{B.5.32}$$

$$G_H = w_G G \tag{B.5.33}$$

$$G_F = (1 - w_G)G \tag{B.5.34}$$

$$\Phi = \frac{1}{\Lambda}\frac{1}{R^*}\frac{\Pi}{\Pi^s} \tag{B.5.35}$$

$$B_F = \frac{Y \log(\Phi)}{-\phi_B} \tag{B.5.36}$$

$$TB = BF(1 - R^*\Phi\frac{\Pi^s}{\Pi}) \tag{B.5.37}$$

$$T = G + B_{GH}(\frac{R}{\Pi} - 1) - wN\tau_w - ((r^k - \delta q)K + d)\tau^k - \tau^p Y^p \tag{B.5.38}$$

$$C = Y^p + Y - I - G - TB \tag{B.5.39}$$

$$N^r = \frac{1}{\lambda}(N - (1 - \lambda)N^s) \tag{B.5.40}$$

$$C^r = N^r w(1 - \tau^w) + (1 - \tau^p)Y^p - T \tag{B.5.41}$$

$$C^s = \frac{C}{(1 - \lambda)} - C^r\frac{\lambda}{(1 - \lambda)} \tag{B.5.42}$$

$$C_H = w_C C \tag{B.5.43}$$

$$C_F = (1 - w_C)C \tag{B.5.44}$$

$$EX = GDP - I - G - C + C_F + I_F + G_F + \Gamma \tag{B.5.45}$$

$$cs_{ex} = \frac{EX}{Y} - is_{ex} - gs_{ex} - \frac{Y^p}{Y} \tag{B.5.46}$$

$$U^s = U^s(C^s, N^s) \tag{B.5.47}$$

$$U^r = U^r(C^r, N^r) \tag{B.5.48}$$

$$U = \lambda U^r + (1 - \lambda)U^s \tag{B.5.49}$$

$$CE^s = \frac{U^s(1.01^{1-\sigma_s} - 1)}{(1 - \beta)} \tag{B.5.50}$$

$$CE^r = \frac{U^r(1.01^{1-\sigma_r} - 1)}{(1 - \beta)} \tag{B.5.51}$$

$$CE = \lambda CE^r + (1 - \lambda)CE^s \tag{B.5.52}$$

B.6 Model solutions and equilibrium conditions - RoW

B.6.1 Households

$$U_t^{*s} = \frac{\left(C_t^{*s} - \chi C_{t-1}^{*s}\right)^{1-\sigma_s^*}}{1-\sigma_s^*} \exp\left(^*(\sigma_s^* - 1)\frac{N_t^{*s(1+\varphi_s^*)}}{1+\varphi_s^*}\right) \tag{B.6.1}$$

$$U_t^{*r} = \frac{\left(C_t^{*c} - \chi C_{t-1}^{*c}\right)^{1-\sigma_r^*}}{1-\sigma_r^*} \exp\left((\sigma_r^* - 1)\frac{N_t^{*r(1+\varphi_r^*)}}{1+\varphi_r^*}\right) \tag{B.6.2}$$

$$U_t^* = \lambda^* U_t^{*r} + (1-\lambda^*)U_t^{*s} \tag{B.6.3}$$

$$V_t^{*s} = E_t\left[\sum_{i=0}^{\infty} \beta^{*(t+i)} U_{t+i}^{*s}\right] = U_t^{*s} + \beta^* E_t U_{t+1}^{*s} \tag{B.6.4}$$

$$V_t^{*r} = E_t\left[\sum_{i=0}^{\infty} \beta^{*(t+i)} U_{t+i}^{*r}\right] = U_t^{*r} + \beta^* E_t U_{t+1}^{*r} \tag{B.6.5}$$

$$V_t^* = \lambda^* V_t^{*r} + (1-\lambda^*)V_t^{*s} \tag{B.6.6}$$

$$CE_t^{*r} = (1.01^{(1-\sigma_r^*)} - 1)U_t^{*r} + \beta^* CE_{(t+1)}^{*r}; \tag{B.6.7}$$

$$CE_t^{*s} = (1.01^{(1-\sigma_s^*)} - 1)U_t^{*s} + \beta^* CE_{(t+1)}^{*s}; \tag{B.6.8}$$

$$CE_t^* = \lambda^* CE_t^{*r} + (1-\lambda^*)CE_t^{*s}; \tag{B.6.9}$$

$$w_t^*(1-\tau_t^{*w}) = \frac{(C_t^{*s} - \chi C_{t-1}^{*s})(N_t^{*s})^{\varphi_s^*}}{1 - \beta^* \chi^* \frac{U_{t+1}^{*s}}{U_t^{*s}} \frac{C_t^{*s} - \chi^* C_{t-1}^{*s}}{C_{t+1}^* - \chi^* C_t^{*s}}} \tag{B.6.10}$$

$$1 = E_t\Big[\frac{\Lambda_{t+1}^{*s}}{\Pi_{t+1}^*}\Big] R_t^* \tag{B.6.11}$$

$$\Lambda_{t+1}^{*s} = \beta^* \frac{U_{C,t+1}^{*s}}{U_{C,t}^{*s}} \tag{B.6.12}$$

$$U_{C,t}^{*s} = \left(C_t^{*s} - \chi C_{t-1}^{*s}\right)^{-\sigma_s^*} \exp\left((\sigma_s^* - 1)\frac{N_t^{*s(1+\varphi_s^*)}}{1+\varphi_s^*}\right) \tag{B.6.13}$$

$$C_t^{*r} = w_t^r(1-\tau_t^{*w})N_t^{*r} - T_t^* \tag{B.6.14}$$

$$w_t^*(1-\tau_t^{*w}) = \frac{(C_t^{*r} - \chi C_{t-1}^{*r})(N_t^{*r})^{\varphi_r^*}}{1 - \beta^* \chi^* \frac{U_{t+1}^{*r}}{U_t^{*r}} \frac{C_t^{*r} - \chi^* C_{t-1}^{*r}}{C_{t+1}^* - \chi^* C_t^{*r}}} \tag{B.6.15}$$

$$C_t^* = \lambda^* C_t^{*r} + (1-\lambda^*) C_t^{*s} \tag{B.6.16}$$

$$N_t^* = \lambda^* N_t^{*r} + (1-\lambda^*) N_t^{*s} \tag{B.6.17}$$

$$C_{F,t}^* = w_C^* \left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\mu_C^*} C_t^* \tag{B.6.18}$$

$$C_{H,t}^* = (1-w_C^*) \left(\frac{P_{F,t}^*}{P_t^*}\right)^{-\mu_C^*} C_t^* \tag{B.6.19}$$

$$I^*_{F,t} = w^*_I \left(\frac{P^*_{H,t}}{P^{*I}_t}\right)^{-\mu^*_I} I^*_t \tag{B.6.20}$$

$$I^*_{H,t} = (1 - w^*_I) \left(\frac{P^*_{H,t}}{P^{*I}_t}\right)^{-\mu^*_I} I^*_t \tag{B.6.21}$$

$$G^*_{F,t} = w^*_G \left(\frac{P^*_{F,t}}{P^{*G}_t}\right)^{-\mu^*_G} G^*_t = w^*_G \left(\frac{P_{F,t}}{P^G_t}\right)^{-\mu^*_G} G^*_t \tag{B.6.22}$$

$$G^*_{H,t} = (1 - w^*_G) \left(\frac{P^*_{H,t}}{P^{*G}_t}\right)^{-\mu^*_G} G^*_t = (1 - w^*_G) \left(\frac{P_{H,t}}{P^G_t}\right)^{-\mu^*_G} G^*_t \tag{B.6.23}$$

B.6.2 Firms

$$Y^*_t = K^{*\alpha^*}_{t-1} \left(Z^*_t N^*_t\right)^{1-\alpha^*} \tag{B.6.24}$$

$$r^{*k}_t = \alpha^* \frac{Y^*_t}{K^*_{t-1}} mc^*_t \frac{P^*_{F,t}}{P^*_t} \tag{B.6.25}$$

$$w^*_t = (1 - \alpha^*) \frac{Y^*_t}{N^*_t} mc^*_t \frac{P^*_{F,t}}{P^*_t} \tag{B.6.26}$$

$$mc^*_t = \frac{1}{\frac{P^*_{F,t}}{P^*_t}} \left(\frac{r^{*k}_t}{\alpha^*}\right)^{\alpha^*} \left(\frac{w^*_t}{(1 - \alpha^*) Z^*_t}\right)^{1-\alpha^*} \tag{B.6.27}$$

$$\Pi^*_{F,t}(\Pi^*_{F,t} - 1) = \frac{\varepsilon^*}{\gamma^*_p}\left(mc^*_t M^*_t + \frac{1 - \varepsilon^*}{\varepsilon^*}\right) + E_t\left[\Lambda^{*s}_{t+1} \frac{Y^*_{t+1}}{Y^*_t} (\Pi^*_{F,t+1} - 1)\Pi^*_{F,t+1}\right] \tag{B.6.28}$$

$$\Gamma^* = \frac{\gamma^*_p}{2} \left(\frac{P^*_{F,t}}{P^*_{F,t-1}} - 1\right)^2 Y^*_t \tag{B.6.29}$$

$$d_t^* = \frac{P_{F,t}^*}{P_t^*}\left(1 - mc_t^* - \frac{\gamma_p^*}{2}\left(\frac{P_{F,t}^*}{P_{F,t-1}^*} - 1\right)^2\right) Y_t^* \tag{B.6.30}$$

$$K_t^* = (1-\delta^*)K_{t-1}^* + \eta_t^*\left(1 - S^*\left(\frac{I_t^*}{I_{t-1}^*}\right)\right) I_t^* \tag{B.6.31}$$

$$\eta_t^* q_t^*\left(1 - S^*\left(\frac{I_t^*}{I_{t-1}^*}\right) - \frac{I_t^*}{I_{t-1}^*}X_t^*\right) + E_t\left(\Lambda_{t+1}^{*s}\eta_{t+1}^* q_{t+1}^* X_{t+1}^* \frac{I_{t+1}^{*2}}{I_t^{*2}}\right) = \frac{P_t^{*I}}{P_t^*} \tag{B.6.32}$$

$$SX_t^*(.) = \frac{\phi_I^*}{2}\left(\frac{I_t^*}{I_{t-1}^*} - 1\right)^2 \tag{B.6.33}$$

$$X_t^* = \phi_I^*\left(\frac{I_t^*}{I_{t-1}^*} - 1\right) \tag{B.6.34}$$

$$rr_t^{*k} = \frac{(1-\tau_t^{*k})r_t^{*k} + (1-\delta^*)q_t^*}{q_{t-1}^*} \tag{B.6.35}$$

$$E_t(\Lambda_{t+1}^{*s} rr_{t+1}^{*k}) = E_t\left(\frac{\Lambda_{t+1}^{*s}}{\Pi_{F,t+1}^*}\right) R_t^* = 1 \tag{B.6.36}$$

B.6.3 Inflation and relative prices

$$\Pi_t^* = \frac{P_t^*}{P_{t-1}^*} \tag{B.6.37}$$

$$\Pi_{F,t}^* = \frac{P_{F,t}^*}{P_{F,t-1}^*} \tag{B.6.38}$$

$$\Pi_{H,t}^* = \frac{P_{H,t}^*}{P_{H,t-1}^*} \tag{B.6.39}$$

$$\Pi_t^* = \left[w_C^* \left(\Pi_{F,t}^* \frac{P_{F,t-1}^*}{P_{t-1}^*} \right)^{1-\mu_C^*} + (1 - w_C^*) \left(\Pi_{H,t}^* \frac{P_{H,t-1}^*}{P_{t-1}^*} \right)^{1-\mu_C^*} \right]^{\frac{1}{1-\mu_C^*}} \tag{B.6.40}$$

$$\frac{\Psi_t^*}{\Psi_{t-1}^*} = \frac{\Pi_{H,t}^*}{\Pi_{F,t}^*} \tag{B.6.41}$$

$$\frac{P_t^*}{P_{H,t}^*} = \left(w_C^* \Psi_t^{*\mu_C^*-1} + (1-w_C^*)\right)^{\frac{1}{1-\mu_C^*}} \Rightarrow \frac{P_{H,t}^*}{P_t^*} = 1 \Big/ \left(w_C^* \Psi_t^{*\mu_C^*-1} + (1-w_C^*)\right)^{\frac{1}{1-\mu_C^*}} \tag{B.6.42}$$

$$\frac{P_t^*}{P_{F,t}^*} = \left(w_C^* + (1-w_C^*)\Psi_t^{*\mu_C^*-1}\right)^{\frac{1}{1-\mu_C^*}} \Rightarrow \frac{P_{F,t}^*}{P_t^*} = 1 \Big/ \left(w_C^* + (1-w_C^*)\Psi_t^{*1-\mu_C^*}\right)^{\frac{1}{1-\mu_C^*}} \tag{B.6.43}$$

$$\frac{P_t^{*I}}{P_{H,t}^*} = \left(w_I^* \Psi_t^{*\mu_I^*-1} + (1-w_I^*)\right)^{\frac{1}{1-\mu_I^*}} \Rightarrow \frac{P_{H,t}^*}{P_t^{*I}} = 1 \Big/ \left(w_I^* \Psi_t^{*\mu_I^*-1} + (1-w_I^*)\right)^{\frac{1}{1-\mu_I^*}} \tag{B.6.44}$$

$$\frac{P_t^{*I}}{P_{F,t}^*} = \left(w_I^* + (1-w_I^*)\Psi_t^{*1-\mu_I^*}\right)^{\frac{1}{1-\mu_I^*}} \Rightarrow \frac{P_{F,t}^*}{P_t^{*I}} = 1 \Big/ \left(w_I^* + (1-w_I^*)\Psi_t^{*1-\mu_I^*}\right)^{\frac{1}{1-\mu_I^*}} \tag{B.6.45}$$

$$\frac{P_t^{*G}}{P_{H,t}^*} = \left(w_G^* \Psi_t^{*\mu_G^*-1} + (1-w_G^*)\right)^{\frac{1}{1-\mu_G^*}} \Rightarrow \frac{P_{H,t}^*}{P_t^{*G}} = 1 \Big/ \left(w_G^* \Psi_t^{*\mu_G^*-1} + (1-w_G^*)\right)^{\frac{1}{1-\mu_G^*}} \tag{B.6.46}$$

$$\frac{P_t^{*G}}{P_{F,t}^*} = \left(w_G^* + (1-w_G^*)\Psi_t^{*1-\mu_G^*}\right)^{\frac{1}{1-\mu_G^*}} \Rightarrow \frac{P_{F,t}^*}{P_t^{*G}} = 1 \Big/ \left(w_G^* + (1-w_G^*)\Psi_t^{*1-\mu_G^*}\right)^{\frac{1}{1-\mu_G^*}} \tag{B.6.47}$$

$$\frac{P_t^{*I}}{P_t^*} \equiv \frac{P_t^{*I}}{P_{F,t}^*} \Big/ \frac{P_t^*}{P_{F,t}^*} = \frac{1}{\frac{P_{F,t}^*}{P_t^{*I}}} \Big/ \frac{1}{\frac{P_{F,t}^*}{P_t^*}} = \frac{P_{H,t}^*}{P_t^*} \Big/ \frac{P_{H,t}^*}{P_t^{*I}} \tag{B.6.48}$$

$$\frac{P_t^{*G}}{P_t^*} \equiv \frac{P_t^{*G}}{P_{F,t}^*} \Big/ \frac{P_t^*}{P_{F,t}^*} = \frac{1}{\frac{P_{F,t}^*}{P_t^{*G}}} \Big/ \frac{1}{\frac{P_{F,t}^*}{P_t^*}} = \frac{P_{F,t}^*}{P_t^*} \Big/ \frac{P_{F,t}^*}{P_t^{*G}} \tag{B.6.49}$$

B.6.4 External sector

$$EX_t^* = 0 \tag{B.6.50}$$

$$TB_t = 0 \tag{B.6.51}$$

B.6.5 Market clearing condition

$$Y_t^* = C_{F,t}^* + I_{F,t}^* + G_{F,t}^* + \frac{\gamma_p^*}{2}\left(\Pi_F^* - 1\right)^2 Y_t^* \tag{B.6.52}$$

B.6.6 Monetary policy

$$\log\left(\frac{R_t^*}{R^*}\right) = \rho_r^* \log\left(\frac{R_{t-1}^*}{R^*}\right) + (1-\rho_r^*)\left[\theta_{r,\pi}^* \log\left(\frac{\Pi_{t-1}^*}{\Pi^*}\right) + \theta_{r,y}^* \log\left(\frac{Y_t^*}{Y^*}\right)\right] + \epsilon_{ms,t}^*$$

B.6.7 Fiscal policy

$$\frac{P_t^{*G}}{P_t^*} G_t^* + \frac{R_{t-1}^*}{\Pi_t^*} B_{GF,t-1}^* = T_t^* + B_{GF,t}^* + w_t^* N_t^* \tau_t^{*w} + (r_t^{*k} - \delta^* q_t^*) K_{t-1}^* + d_t^*) \tau_t^{*k}$$

$$\tau_t^{*w} = \tau_t^* \tau_{ss}^{*w}, \quad \tau_t^{*k} = \tau_t^* \tau_{ss}^{*k}, \quad T_t^* = g_t^* T_{ss}^*, \quad G_t^* = g_t^* G_{ss}^*$$

$$\log\left(\frac{\tau_t^*}{\tau_{ss}^*}\right) = \rho_\tau^* \log\left(\frac{\tau_{t-1}^*}{\tau_{ss}^*}\right) + \theta_{\tau,y}^* \log\left(\frac{Y_{t-1}^*}{Y_{ss}^*}\right) + \theta_{\tau,bg}^* \log\left(\frac{B_{GF,t-1}^*}{B_{GF,ss}^*}\right) + \epsilon_{\tau,t}^*$$

$$\log\left(\frac{g_t^*}{g_{ss}^*}\right) = \rho_g^* \log\left(\frac{g_{t-1}^*}{g_{ss}^*}\right) - \theta_{g,y}^* \log\left(\frac{Y_{t-1}^*}{Y_{ss}^*}\right) - \theta_{g,bg}^* \log\left(\frac{B_{GF,t-1}^*}{B_{GF,ss}^*}\right) + \epsilon_{g,t}^*$$

B.6.8 Exogenous process

$$\log b_t^* - \log b^* = \rho_z(\log b_{t-1}^* - \log b^*) + \epsilon_{b,t}^* \tag{B.6.53}$$

$$\log Z_t^* - \log Z^* = \rho_z(\log Z_{t-1}^* - \log Z^*) + \epsilon_{z,t}^* \tag{B.6.54}$$

$$\log \eta_t^* - \log \eta^* = \rho_\eta^*(\log \eta_{t-1}^* - \log \eta^*) + \epsilon_{\eta,t}^* \tag{B.6.55}$$

$$\log M_t^* - \log M^* = \rho_M^*(\log M_{t-1}^* - \log M^*) + \epsilon_{m,t}^* \tag{B.6.56}$$

$$\tag{B.6.57}$$

B.7 Deterministic zero growth, non-zero net inflation steady state - RoW

A non-zero constant net steady state gross inflation rate is set at $\Pi = \bar{\Pi}$. Relative prices are set to 1. The labour supply equations are used to compute the steady state hours of work for the two households using a solver function. The rest of the steady state is computed as follows recursively.

$$\Omega = 1 \tag{B.7.1}$$

$$Z* = \varpi Z \tag{B.7.2}$$

$$M^* = 1 \tag{B.7.3}$$

$$q^* = 1 \tag{B.7.4}$$

$$\eta^* = 1 \tag{B.7.5}$$

$$\bar{\Pi}^* = 1.02^{1/4} \tag{B.7.6}$$

$$\Pi^* = \Pi^* = \bar{\Pi}^* \tag{B.7.7}$$

$$\Lambda^* = \beta^* \tag{B.7.8}$$

$$\Psi^* = 1 \tag{B.7.9}$$

$$\tau_k^* = 0.30 \tag{B.7.10}$$

$$\tau_w^* = 0.34 \tag{B.7.11}$$

$$\tau^* = 1 \tag{B.7.12}$$

$$SX^*(.) = 0 \tag{B.7.13}$$

$$X^* = 0 \tag{B.7.14}$$

$$R^* = \frac{\bar{\Pi}^*}{\beta^*} \tag{B.7.15}$$

$$rr^{*k} = \frac{R^*}{\Pi^*} \tag{B.7.16}$$

$$mc^* = \frac{\varepsilon^* - 1}{\varepsilon^*} \tag{B.7.17}$$

$$\frac{Y^*}{K^*} = \frac{r^{*k}}{\alpha^* mc^*} \tag{B.7.18}$$

$$K^* = \frac{Z^{* \frac{1}{1-\alpha^*}}}{\frac{Y^*}{K^*}} \tag{B.7.19}$$

$$Y^* = K^{\alpha}(Z^* N^*)^{1-\alpha^*} \tag{B.7.20}$$

$$w = (1 - \alpha^*) mc^* \frac{Y^*}{N^*} \tag{B.7.21}$$

$$I^* = \delta^* K^* \tag{B.7.22}$$

$$I_H^* = w_I^* I^* \tag{B.7.23}$$

$$I_F^* = (1 - w_I^*) I^* \tag{B.7.24}$$

$$\Gamma^* = 0 \tag{B.7.25}$$

$$d^* = (1 - mc^*) Y^* - \Gamma^* \tag{B.7.26}$$

$$B_{GF}^* = 4bg^* Y^* \tag{B.7.27}$$

$$G^* = gy^* Y^* \tag{B.7.28}$$

$$G_H^* = w_G^* G^* \tag{B.7.29}$$

$$G_F^* = (1 - w_G^*)G^* \tag{B.7.30}$$

$$TB = 0 \tag{B.7.31}$$

$$T^* = G^* + B_{GF}^*(\frac{R^*}{\Pi^*} - 1) - w^* N^* \tau_w^* - ((r^{*k} - \delta^* q^*)K^* + d^*)\tau^{*k} \tag{B.7.32}$$

$$C^* = Y^* - I^* - G^* - TB^* \tag{B.7.33}$$

$$N^{*r} = \frac{1}{\lambda^*}(N^* - (1 - \lambda^*)N^{*s}) \tag{B.7.34}$$

$$C^{*r} = N^{*r} w^* (1 - \tau^{*w}) - T^* \tag{B.7.35}$$

$$C^{*s} = \frac{C^*}{(1 - \lambda^*)} - C^{*r} \frac{\lambda^*}{(1 - \lambda^*)} \tag{B.7.36}$$

$$C_H^* = w_C^* C^* \tag{B.7.37}$$

$$C_F^* = (1 - w_C^*)C^* \tag{B.7.38}$$

$$EX = 0 \tag{B.7.39}$$

$$U^{*s} = U^{*s}(C^{*s}, N^{*s}) \tag{B.7.40}$$

$$U^{*r} = U^{*r}(C^{*r}, N^{*r}) \tag{B.7.41}$$

$$U^* = \lambda^* U^{*r} + (1 - \lambda^*)U^{*s} \tag{B.7.42}$$

$$CE^{*s} = \frac{U^{*s}(1.01^{1-\sigma_s^*} - 1)}{(1 - \beta^*)} \tag{B.7.43}$$

$$CE^{*r} = \frac{U^{*r}(1.01^{1-\sigma_r^*} - 1)}{(1 - \beta^*)} \tag{B.7.44}$$

$$CE^* = \lambda CE^{*r} + (1 - \lambda^*)CE^{*s} \tag{B.7.45}$$

B.8 Impulse responses to additional structural shocks in the model

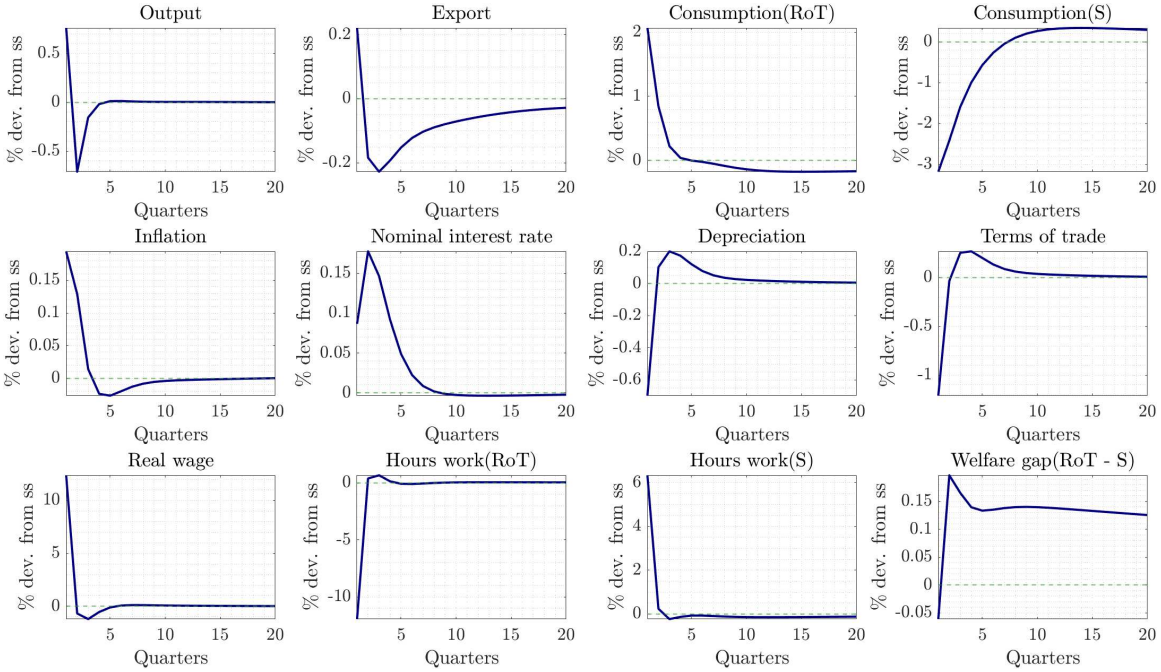


Figure B.1: Responses to a positive government spending shock

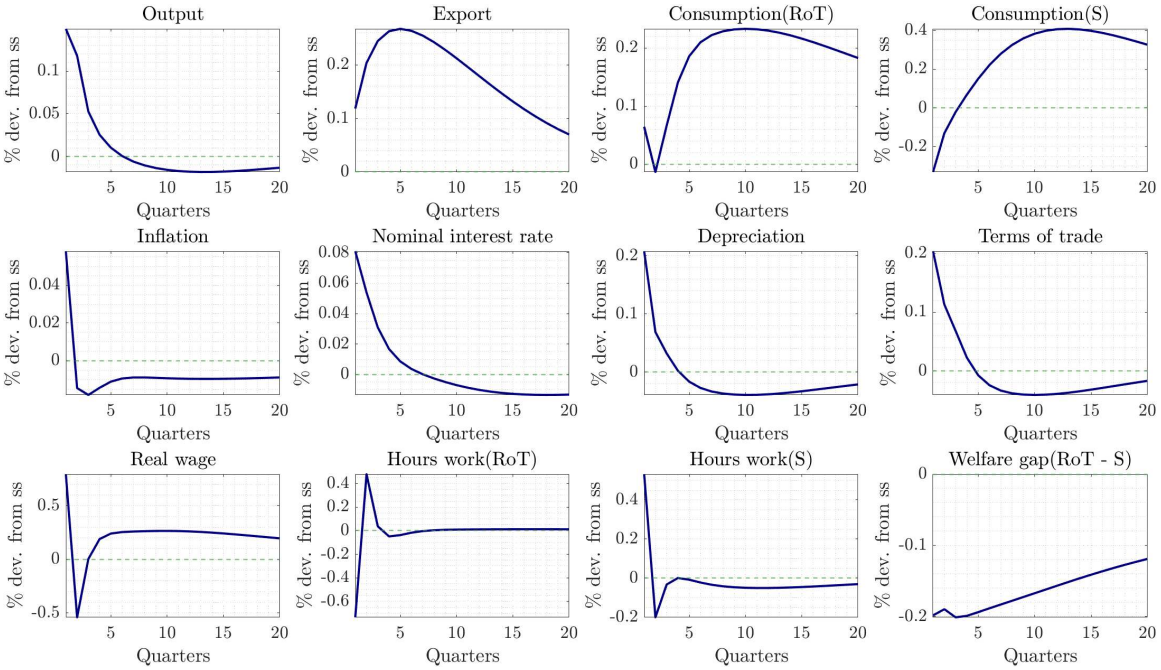


Figure B.2: Responses to a positive marginal efficiency of investment shock

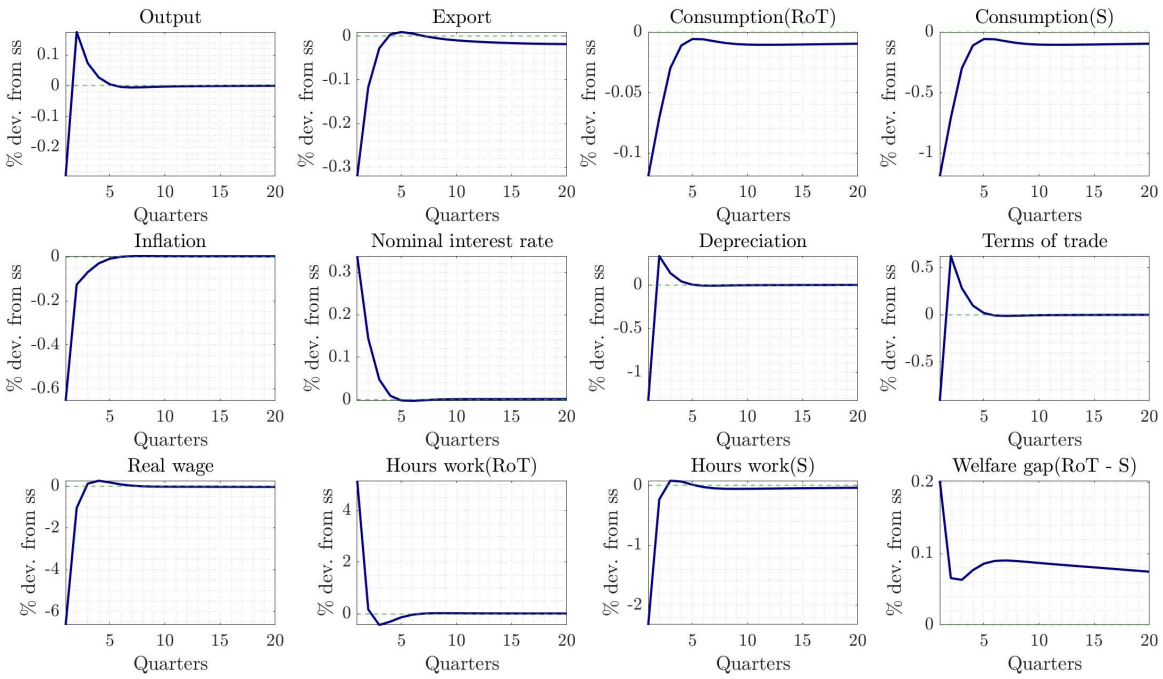


Figure B.3: Responses to a domestic contractionary monetary policy shock

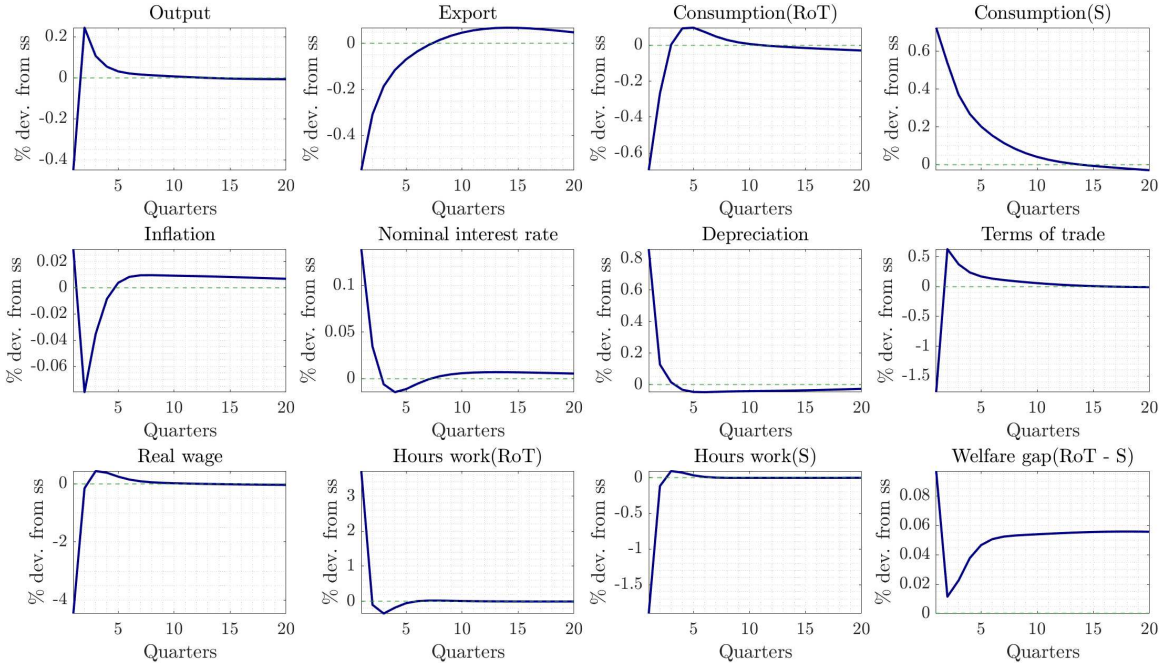


Figure B.4: Responses to a positive terms of trade shock

B.8.1 Description of variables and data source

B.8.1.1 EU economy

Variables	Description of Variables	Data Source	Reference Series
GDP^*	Nominal GDP	Eurostat	Table namq_10_gdp
PI^*	GDP deflator	Eurostat	Table prc_hicp_midx
C^*	Nominal households and NPISH final consumption expenditure	Eurostat	Table namq_10_gdp
I^*	Nominal gross fixed capital formation	Eurostat	Table namq_10_gdp
R^*	Shadow rate	Wu and Xia (2017) and Eurostat	Table irt_st_q and shadowrate_ECB
W^*	Nominal wage rate	Eurostat	Table lc_lci_r2_q
N^*	Labour supply	OECD	Table stlabour
Pop^*	Working age population	Eurostat	Table lfsq_pganws

Note: Whenever data is found to be not seasonally adjusted from the source, seasonal adjustments are conducted with the help of Eviews' X-13 filter.

Table B.1: Description of variables and data source for the EU economy

Variables	Description of Variables	Data Source	Reference Series
GDP	Nominal GDP	HCP	Table REMPibTrimVal
CPI	Consumer Price Index	HCP	Table BKAM
C	Nominal households and NPISH final consumption expenditure	HCP	Table DCFMTrimVal
I	Nominal gross fixed capital formation	HCP	Table FBCTrimVal
D	Nominal total government debt	HCP	Table dette-tresor-trimestriel
R	Nominal interest rate	BAM	Table série+taux+débiteurs_fr
E	Nominal exchange rate against euro	BAM	Table Cours virement moyen de fin de mois
PP	Price of phosphate	FRED	Table PCU325312325312
TOT	Terms of trade	IMF	Author's computation
Pop	Working age population	HCP	Table Matrices-emploi

Note: Whenever data is found to be not seasonally adjusted from the source, seasonal adjustments are conducted with the help of Eviews' X-13 filter.

Table B.2: Description of variables and data source for Moroccan economy

B.8.2 Prior and posteriors distributions for the EU model

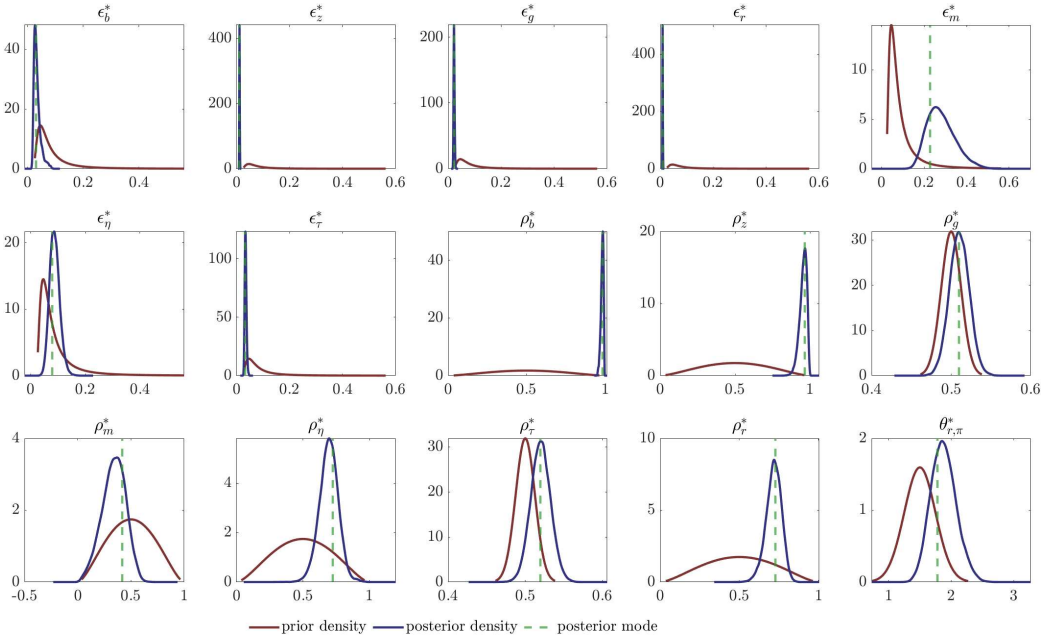


Figure B.5: EU economy, prior and posterior distributions of estimated parameters

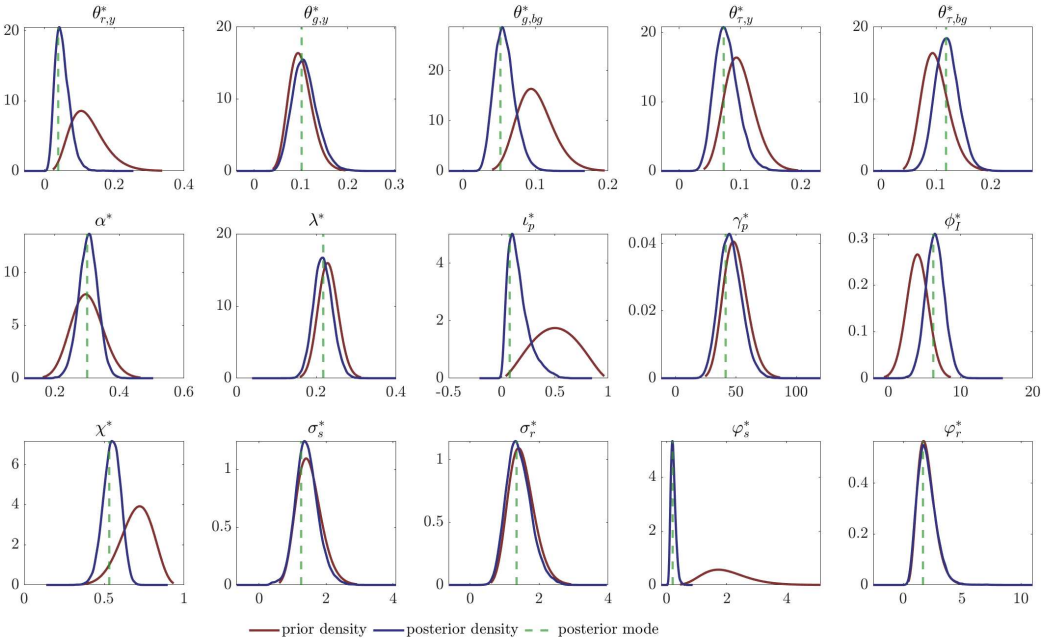


Figure B.6: EU economy, prior and posterior distributions of estimated parameters

B.8.3 Prior and posteriors distributions for the SOE model

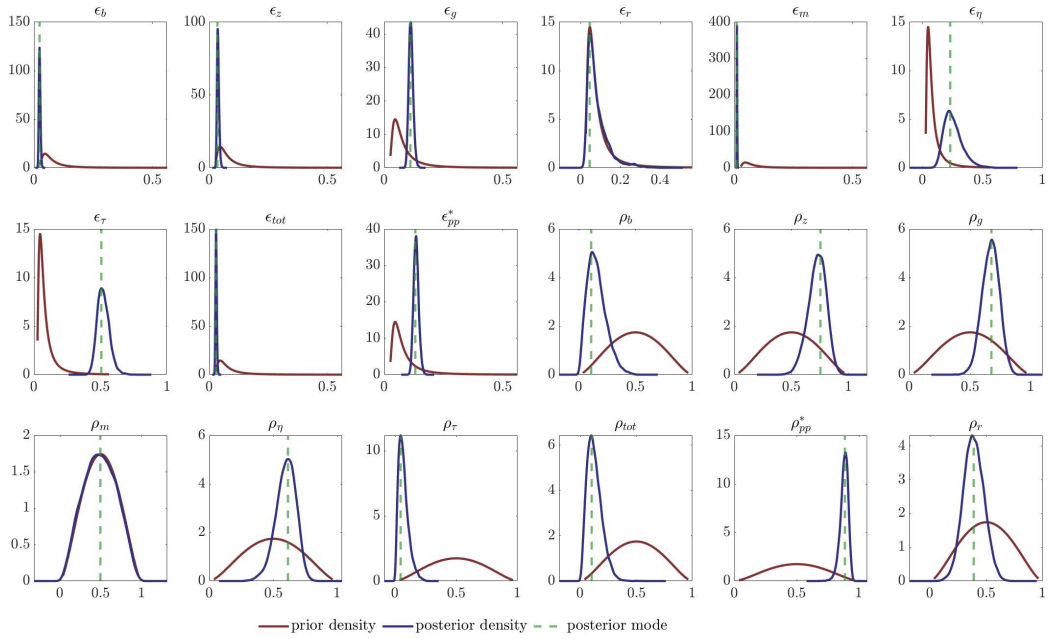


Figure B.7: Moroccan economy, prior and posterior distributions of estimated parameters

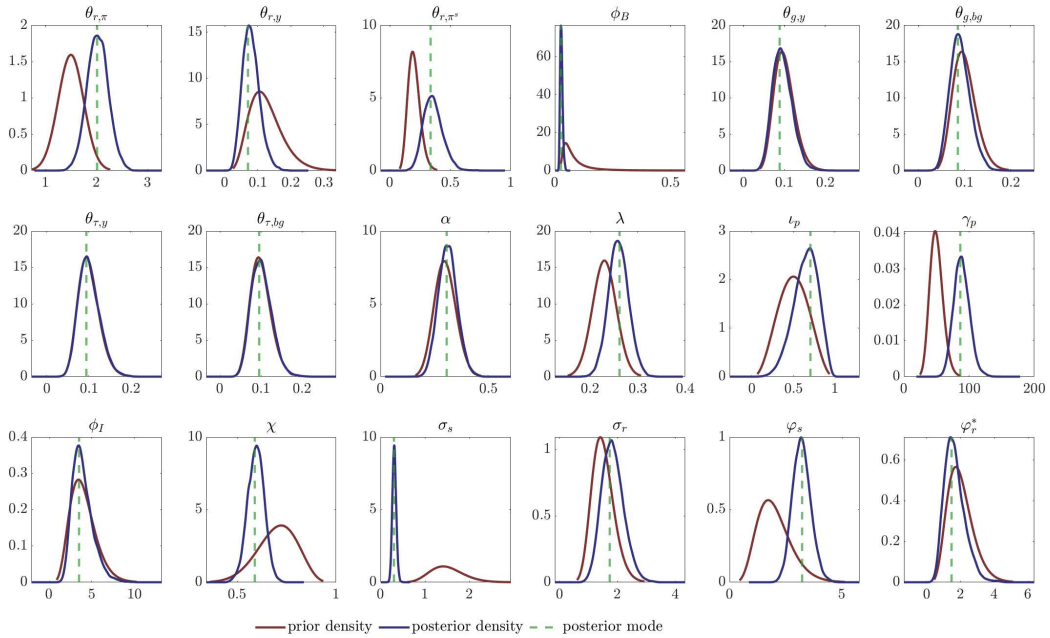


Figure B.8: Moroccan economy, prior and posterior distributions of estimated parameters