UNIVERSITAT DE BARCELONA

Essays on Fiscal and Monetary Policies

Ivan Hajdukovic

2021

PhD in Economics

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PhD in Economics | Ivan Hajdukovic

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PhD in Economics

Thesis title:

Essays on Fiscal and Monetary Policies

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Date:
April 2021

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To my family

Acknowledgements

A PhD programme is a marathon requiring a lot of effort, commitment and perseverance. During this phase of my life, I learned a lot, both in the scientific area and on a personal level. The completion of this doctoral thesis was done in company and with the support of different people around me. This first section is dedicated to recognize all the persons that were part of my PhD journey.

First and foremost, I would like to express my sincere gratitude to my thesis supervisor Raúl Ramos. I am very grateful to him for his guidance, involvement and continuous support at all stages of the thesis. His expertise in macroeconomic analysis and technical support were determinant in the completion of this thesis. Since the beginning of our collaboration, Raúl has always been very clear and honest with me, and encouraged me to develop my own ideas and go beyond the limits. I should also stress that he was always very responsive, including the periods during which I was not present at the University of Barcelona, to help me with all the questions and doubts that I encountered during my research. Moreover, I really appreciated the flexibility he gave me and the trust he has shown in me since the first days. Raúl is not only a great supervisor, but he is also a very good person. In other words, I could not have had a better supervisor for the completion of my thesis.

I would like to mention the good job done by the University of Barcelona School of Economics and the continued efforts of the director of the PhD programme Elisabet Viladecans-Marsal and the programme coordinator Jordi Roca Solanelles to improve the programme. In particular, I am very grateful to Jordi for his support at all stages of the administrative process of the PhD.

I also want to show my sincere gratitude to the Department of Econometrics, Statistics and Applied Economics of the University of Barcelona and the Regional Quantitative Analysis Group (AQR-IREA) for providing me with all the support and equipment I needed to complete my thesis. I appreciated participating in the department's activities and the very interesting discussions I had with all the members of the department.

Next, I am very grateful to all my friends and colleagues from the PhD programme for having shared academic and non-academic experience during the last three years. In particular, I thank my fellow PhD students: Akin Ayberk

Cilekoglu, Arianna Garofalo, Bongha Shin, Cynthia Armas, Filippo Tassinari, Florencia Saravia, Georgios Tsiachtsiras, Ghizlen Ouasbaa, Henry Bernard Moscoso, Jessica Pesantez-Narvaez, Liliana Cuccu, Marianna Sebö, Michel Philippe Lioussis, Stefano Fusaro, Viviana Zarate, as well as all the others. It goes without saying that the great atmosphere and the mutual support were determinant and motivated me to do my best during my research period. I also want to thank Nicola Rubino for his very useful comments on the fourth chapter of the thesis during my presentation at the AQR-IREA seminar.

I also thank all my close friends outside of the university for their continued support during this journey. Without the presence and encouragement of all my friends, this phase of my life would not have been the same. Their presence was very important, in both good and difficult times.

The completion of this thesis also benefited from my research stay in the Trade and Environment Division of the World Trade Organization in 2019. During this period, I wrote a research paper assessing the impact of international trade on the price of solar photovoltaic modules. The research stay allowed me to deepen my knowledge in environmental economics, which helped me to complete the fourth chapter of this thesis. I am grateful to all my colleagues of the division and in particular to my internship's supervisor Karsten Steinfatt.

Since May 2020, I am working in parallel as a data analyst - Federation-wide Databank and Reporting System (FDRS) at the International Federation of Red Cross and Red Crescent Societies (IFRC) under a 12-month fixed-term contract. The main tasks consist in supporting data collection, validation and analysis, as well as working with FDRS focal points in 192 National Societies and IFRC regional and county offices. The work includes collecting data on the activities of National Societies on an annual basis and the financial and programmatic indicators data relating to National Societies' response to COVID-19, as well as supporting the development of the *Everyone Counts Report 2021*. I would like to thank all my colleagues and in particular my manager Rania Alerksoussi for giving me the opportunity to work in a very stimulating environment.

Finally, the completion of this doctoral thesis would not have been possible without the support of my family. In particular, I would like to thank my parents, Ljiljana and Dragan, and my sister Anja, who were always close to me and encouraged me to overcome obstacles. I dedicate this thesis to my family.

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Chapter 1: Introduction

1.1 Background and Motivation

The global financial crisis of 2008 hit countries and affected financial systems all over the world. This led many governments to implement large-scale fiscal interventions in an attempt to stimulate private activity and avoid a prolonged recession. Many countries experienced high sovereign risk associated with high level of public debt and were forced to undertake large consolidation plans by cutting spending and raising taxes. In fact, when discretionary fiscal policy is used either as stimulative tool or as a debt consolidation, there is a lot of uncertainty about the effectiveness in terms of the domestic absorption of the policy benefits. The latter critically depends on the composition of fiscal policy and the reaction of the exchange rate and the trade balance to fiscal shocks (Lane and Perotti, 1998). This is particularly important for open economies, in which international trade represents a significant share of economic activity. As a result, it seems essential to examine the domestic and external transmission channels of unexpected changes in tax revenue and government spending components. From this perspective, a relevant question that arises is which fiscal instruments are the most effective in stimulating economic activity.

Monetary policy can affect economic activity through various transmission channels, including interest rates, exchange rates, asset prices, consumer confidence and credit (e.g., Bernanke and Gertler, 1995; Mishkin, 1995; Cushman and Zha, 1997; Debes et al., 2014). To respond the global financial crisis, central banks initially lowered their reference policy rate until it has reached the effective zero lower bound. These policy measures were aimed to reduce the cost of borrowing for households and businesses, thus encouraging spending and investment. Despite these unprecedent measures, they alone were not sufficient to stimulate economic activity and maintain price stability. This situation forced central banks to implement large-scale asset purchases, commonly known as quantitative easing, to improve the economic conditions. These operations changed the relative supply of short-term and long-term bonds, and other assets, which consequently affected their prices and the flow of funds in the economy. The main objective of such unconventional measures was to lower long-term interest rates in order to ease financing conditions and stimulate economic activity. Monetary policy decisions have an impact on financing conditions and market expectations, which in turn can lead to changes in asset

prices and consumer confidence, thus amplifying their effects on the economy. It therefore seems essential to examine the potential role of asset prices and consumer expectations in the transmission of monetary policy.

From a different perspective, concerns about the environment and climate change have raised over the past two centuries. Economic activities affect the environment in several ways. Common effects like increased pollution and greenhouse gas emissions, depletion of natural resources and contribution to global climate change have been recognized as the greatest negative externalities of today's global economy. Many scientific studies have been argued that climate change may in turn negatively affect economic growth and output levels (e.g., Dell et al., 2009, 2012). Renewable and non-renewable energy resources are major inputs for production, meaning that their availability will directly affect future production capabilities and economic activities. The energy sector is a particularly interesting case study since it represents by far the largest source of anthropogenic greenhouse gas emissions (International Energy Agency, 2009). Despite improvements in some countries, the level of global emissions emanating from the energy sector has little changed over the past decades (International Energy Agency, 2017). Macroeconomic policies are usually used for the purpose of stabilizing economic activity and maintain price stability. In response to the crisis, many governments have employed expansionary fiscal and monetary policies to support the recovery of their economy, subsequently affecting economic aggregates and global welfare. The implementation of macroeconomic policies might also affect the quality of the environment through their specific effects on economic activity and energy consumption. Thus, the overall impact of these policies on environmental quality is not certain.

1.2 Objectives and Structure of the Thesis

The general objective of this doctoral thesis is to evaluate the effects of macroeconomic policies on the economy and the environment. Chapter 2 examines the composition of fiscal policy and its transmission mechanisms on various macroeconomic aggregates in open economies. Chapter 3 examines the transmission mechanisms of conventional and unconventional monetary policies on the macroeconomic aggregates in open economies. Chapter 4 explores the interactions among macroeconomic policies, the energy market and environmental quality. The conducted research on the evaluation of these policies is presented in the following three chapters. The thesis also contains a final chapter with the concluding remarks and future lines of research.

The analysis of the effects of fiscal and monetary policies on the economy and the environment is conducted using the structural vector autoregressive (VAR) methodology. This procedure is suitable when the variables of interest are endogenous, which is typically the case with macroeconomic and environmental variables. Structural VAR models have the advantage of being flexible regarding the assumptions required for the identification of structural shocks. In fact, they have become the standard econometric tool for estimating fiscal and monetary policy shocks. However, this approach poses several challenges. First, the identification of exogenous and unanticipated fiscal policy shocks is not straightforward, especially when using disaggregated fiscal data. Second, the responses of macroeconomic aggregates to monetary policy shocks are sensitive to the model specification and the information included in the analysis about central bank's operating procedures. It therefore seems essential to take into account all transmission channels and to control for global economic shocks in order to provide a comprehensive analysis of the effects of fiscal and monetary policies. Finally, in the literature, there is a lack of theoretical models examining the underpinnings of the relationship between macroeconomic policies, economic growth and environmental quality. As a result, this makes empirical modelling particularly challenging and interesting from the perspective of setting the ground for theoretical and empirical approaches to this issue.

The objective of **Chapter 2** is to examine the composition of fiscal policy and its transmission mechanisms on various macroeconomic aggregates in open economies. A body of literature analyses the effects of fiscal policy within a closed economy framework (e.g., Fatas and Mihov, 2001; Blanchard and Perotti, 2002; Caldara and Kamps, 2008; Mountford and Uhlig, 2009). However, the benefits of fiscal instruments depend on the reaction of the exchange rate and the trade balance to fiscal policy shocks. Yet, the effects of discretionary fiscal policy on the exchange rate and international trade still remain controversial (e.g., Kim and Roubini, 2008; Monacelli and Perotti, 2010; Ravn et al., 2012). From a different perspective, a large body of literature has examined the effects of tax shocks on the output and other real economic variables (e.g., Blanchard and Perotti, 2002; Perotti, 2005; Caldara and Kamps, 2008; Mountford and Uhlig, 2009). However, the study of the effects of tax shocks on the exchange rate and the trade balance has received less attention. In addition, most of the literature on fiscal policy does not distinguish between different types of government spending. Many studies assess the impact of total government spending as a single fiscal instrument, without investigating the potential distinct

effects that may arise from shocks to different types of expenditure. Research on the effects of disaggregated government spending has proliferated over the past decades and has not yet provided robust stylized facts (e.g., Lane and Perotti, 1998; Giordano et al., 2007; Perotti, 2008; Pappa, 2009). Nevertheless, the literature devoted to disaggregated fiscal policy analysis in open economies is relatively limited (e.g., Lane and Perotti, 1998; Bénétrix and Lane, 2009).

This chapter contributes further to this direction of research by examining the transmission mechanisms of fiscal policy components in open economies. We evaluate the effects of shocks to tax revenue and government spending components on the macroeconomic aggregates in two Anglo-Saxon countries, the United States and the United Kingdom, over the period 1964-2017. These countries conduct independent fiscal policies and are characterized by the low levels of government regulation, the small shares of the public sector and by free markets. Although they are relatively homogenous, the United Kingdom has comparatively higher levels of taxation and spending on the welfare state and shares some common features with European continental economic models that diverge from those of Anglo-American economic models (Davtyan, 2016). While research on fiscal policy has been substantial, the study of the transmission mechanisms and effects of government spending components in open economies has received less attention. This approach is particularly complex since government decisions to adjust its spending levels on various categories may benefit only to a small group of individuals and have negligible effects on others. As a result, the transmission mechanisms and the effects of shocks to government spending components on the real economy are uncertain and may be very small. However, in our view, this approach can complement the analysis of aggregate fiscal policy by providing more informative conclusions on the ways in which policy decisions can influence macroeconomic conditions.

The empirical analysis is conducted through structural VAR models. The effects of shocks to government non-wage consumption, government wage consumption, public investment and tax revenue are assessed by the impulse response functions and the variance decomposition. This chapter contributes to the literature on the disaggregated analysis of fiscal policy in open economies. We examine the composition of fiscal policy by asking whether government spending disaggregation matters for the transmission of fiscal policy on the macroeconomic aggregates. While there is some evidence for the United States economy, to the best of our knowledge, no other previous study has conducted such an empirical analysis of shocks to government non-wage and wage

consumption for the United Kingdom. In addition, this chapter explores the role of the exchange rate and the trade balance in the transmission of shocks to tax revenue and government spending components.

The objective of **Chapter 3** is to examine the transmission mechanisms of conventional and unconventional monetary policies on various macroeconomic aggregates in open economies. The literature generally provides consistent findings as regards the effects of conventional monetary policy on the national income and its components (e.g., Mojon and Peersman, 2001; Christiano et al., 2005). However, a large part of the literature does not consider asset prices and consumer expectations that represent two potential channels for the transmission of monetary policy (e.g., Mishkin, 1995; Brissimis and Magginas, 2006). Monetary policy decisions have an impact on financing conditions and market expectations, which can lead to adjustments of asset prices. The consumer confidence indicator contains important information used by central banks about consumer expectations as regards future economic conditions. The omission of these two variables may result in an important loss of information in the analysis. A few studies analyse the effects of consumer confidence on the real economy (e.g., Ludvigson, 2004; Barsky and Sims, 2012). However, very little is known about its role in the transmission of monetary policy. Debes et al. (2014) is the first study to show that conventional monetary policy can be operative via a consumer confidence channel from an empirical and theoretical perspective. Consequently, this implies the need to explore how monetary policy can affect macroeconomic aggregates along the business cycle and the specific role of asset prices and consumer confidence as potential transmission channels.

Unconventional monetary policy can affect the real economy through different transmission channels, including signaling, portfolio balance, exchange rates and asset prices (e.g., Mishkin, 1995; Gagnon et al., 2011; Joyce et al., 2011; Bauer and Rudebusch, 2014; Christensen and Krogstrup, 2019). A body of literature has mainly focused on the effects of unconventional monetary policy measures on the financial market. Specifically, a number of studies analyse the effects of large-scale asset purchases on long-term interest rates and other asset prices (e.g., Gagnon et al., 2010; Joyce et al., 2011; Hamilton and Wu, 2012). A few studies go one step further and examine the short-run macroeconomic effects of unconventional monetary policy shocks (e.g., Lenza et al., 2010; Peersman, 2011; Chung et al., 2012). A potential caveat concerning these studies is that they rely on models estimated over sample periods covering also the pre-

crisis period, which may not be appropriate for assessing the transmission of unconventional monetary policy in a liquidity trap. Moreover, central banks' quantitative easing policies before the crisis were usually not aimed at influencing macroeconomic conditions (Gambacorta et al., 2014). Another possible limitation of these studies is that they often neglect the role of the stock market as a potential transmission channel. Gambacorta et al. (2014) reveal the importance of analysing the effects of unconventional monetary policy within a framework based on a combination of macroeconomic and financial variables.

This chapter contributes to filling this gap by exploring the role of stock prices and consumer expectations in the transmission of monetary policy for European countries that have adopted a flexible exchange rate regime. The effects of conventional and unconventional monetary policies are evaluated for two non-EMU countries, Switzerland and the United Kingdom, over the period 1990-2017. While research has been substantial for the euro area and the United States, very few studies have analysed the effects of monetary policy in other open economies outside the euro area. These countries also represent unique case studies on the transmission mechanisms of unconventional monetary policy, as they were the only non-EMU countries to implement quantitative easing in response to the global financial crisis. This chapter proposes two distinct structural VAR models based on a novel specification. The baseline model for the evaluation of the effects of conventional monetary policy covers the pre-2009 period and is estimated using quarterly data, while the baseline model for the evaluation of the effects of unconventional monetary policy covers the post-2009 period and is estimated using monthly data. The analysis is explicitly made on sub-periods since the implementation of quantitative easing may be viewed as a new monetary policy regime. If the central banks are forward looking, the monetary policy instrument cannot be properly identified unless expectations are taken into account. The modelling approach consists in augmenting the structural VAR model with a forward-looking informational variable of near-term development in economic activity and several foreign exogenous variables to control for global supply and demand shocks. For the case of conventional monetary policy, the consumer confidence indicator is used since it contains important information used by central banks about consumer expectations as regards future economic conditions. For the case of unconventional monetary policy, the long-term government bond yields are used to capture consumer expectations about future short-term interest rates. The effects of conventional and unconventional monetary policy shocks are assessed by the impulse response functions and the variance decomposition.

The objective of **Chapter 4** is to explore the interactions among macroeconomic policies, the energy market and environmental quality[1]. Theoretical modelling of the relationships between macroeconomic policies, economic growth and environmental quality is still underdeveloped. However, empirical analysis can help achieve a better understanding of the complex links between them. The environmental Kuznets curve hypothesis predicts that economic growth initially leads to a deterioration of environmental quality, followed by an improvement of environmental quality once the economy has reached a certain level. Depending on the relationship between macroeconomic policies and economic growth and according to the shape of the environmental Kuznets curve, expansionary fiscal and monetary policies may lead to greater use of natural resources and greenhouse gas emissions in some levels of the gross domestic product. Moreover, the potential impact of macroeconomic policies on environment quality can generate interactions between macroeconomic and environmental policies. As a result, this implies the need to explore how fiscal and monetary policies can affect the quality of the environment along the business cycle and the specific role of energy markets as transmission channels.

Several studies have recently suggested that fiscal policy may be a determinant of environmental quality (e.g., Lopez et al., 2011; Halkos and Paizanos, 2013, 2016; Lopez and Palacios, 2014). The relationship between fiscal policy and environmental quality depends critically on the type of government spending. For instance, if spending is largely used for improvements in renewable energy, then increases in government consumption and public investment could be associated with lower emissions. In contrast, we would expect the opposite relationship if spending is targeted towards non-renewable energy. Fiscal policy measures have been predominantly implemented to moderate climate change issues (e.g., Kosonen and Nicodème, 2009). It has been commonly admitted that since the central banks' main objectives of inflation and output stabilization are primarily short term, their influence on a long-term process such as climate change is relatively weak (Economides and Xepapadeas, 2018). However, the very probable impact of climate change on the financial market, economic growth and future output levels might require more involvement of monetary policy (Matikainen et al. 2017; Dafermos et al., 2018; Economides and Xepapadeas, 2018). Therefore, central banks may also be required to support climate change policies, which would imply the need to address long-term and

[1] The chapter has been published in *Environmental Economics and Policy Studies* as an online first article (https://doi.org/10.1007/s10018-021-00305-x).

short-term issues. Matikainen et al. (2017) suggest that the environmental impact of the central bank's unconventional monetary policy depends on government commitment to support low-carbon activities through direct spending. Thus, monetary policy may not be energy-neutral.

This chapter contributes to this direction of research by examining the interactions and channels among macroeconomic policies, economic growth, the energy market and environmental quality. We propose two distinct structural VAR models based on a macroeconomic framework including the energy market. The chapter considers one baseline model for the evaluation of the effects of fiscal and conventional monetary policy and one baseline model for the evaluation of the effects of unconventional monetary policy. Due to the lack of data availability, we consider aggregate levels of government spending components and central bank's reserve asset purchases, being this a clear limitation of our analysis that, however, in our view does not invalidate the interest of this approach. This chapter sheds light on the implications of fiscal and monetary policies on the environmental sustainability for European countries that have adopted a flexible exchange rate regime. The empirical analysis is conducted for Switzerland and the United Kingdom over the period 1990-2016. Apart of maintaining independent fiscal and monetary policies, the analysis of these specific countries is relevant in the context of environmental issues. Switzerland, as an Alpine country, is particularly affected by global warming (Beniston, 2012). On the other hand, the United Kingdom is a coastal country and is seriously threatened by rising sea levels due to the global climate change (de la Vega-Leinert and Nicholls, 2008). This chapter examines for the first time how the implementation of macroeconomic policies, that aim to stimulate the economy, may also affect the quality of the environment along the business cycle and the specific role of energy markets as transmission channels. On the one hand, the chapter evaluates the implications of macroeconomic policies on the price of non-renewable energy and the use of both renewable and non-renewable energy. On the other hand, it assesses the influence of fiscal policy components, conventional and unconventional monetary policies on greenhouse gas emissions generated by the energy sector. The impulse response functions and the variance decomposition are used as empirical tools to assess the effects of policy shocks. We aim to provide some policy recommendations that can help support the achievement of environmental sustainability.

Chapter 5 provides a summary of all the obtained results of the thesis and the policy implications. This final section also contains the future lines of research.

Chapter 2: Fiscal Policy Composition and its Transmission Mechanisms in Open Economies

2.1 Introduction

After the global financial crisis of 2008, governments had drastically increased their public spending in an attempt to stimulate private activity and avoid a prolonged recession. Massive bailouts of financial institutions and other expansionary fiscal and monetary policies had been employed to prevent a potential collapse of the world financial system. Many countries experienced high sovereign risk associated with high level of public debt and were forced to undertake large consolidation plans by cutting spending and raising taxes. Since the beginning of the crisis, the United States engaged in unprecedented fiscal expansions to rescue the financial sector and stimulate economic activity. Several other countries like Japan experienced during decades interest rates close to zero and applied large fiscal expansions in an attempt to escape their liquidity trap. Fiscal policy is also important for member states of the European Union, since it is the only national stabilization instrument in presence of asymmetric macroeconomic shocks. All of this makes fiscal policy one of the most important tools used by the government to influence economic conditions. Nevertheless, there is a lot of uncertainty about the effectiveness in terms of the domestic absorption of the benefits of discretionary fiscal policy, when used to stimulate the economy or stabilize the debt. The latter critically depends on the composition of fiscal policy and the reaction of the exchange rate and the trade balance to fiscal shocks (Lane and Perotti, 1998). A relevant question that arises is which fiscal instruments are the most effective in stimulating economic activity.

In this context, this chapter examines the transmission mechanisms of fiscal policy by focusing on its components in an open economy framework. The VAR methodology has become the main econometric tool used to study the effects of fiscal policy shocks. Yet, the empirical literature using VAR models to assess the effects of fiscal policy shocks often disagrees on the quantitative and qualitative response of key macroeconomic aggregates to government spending and tax shocks. Various reasons such as the differences in the specification (including sample period, choice of endogenous variables, deterministic terms and lag length) and the lack of comparability of fiscal policy experiments have been proposed to explain the absence of stylized facts. The empirical studies in this literature distinguish themselves by the approach used

to identify fiscal policy shocks. Four main identification approaches have been used. First, the recursive approach introduced by Sims (1980) and applied to the study of fiscal policy effects by Fatas and Mihov (2001). Second, the Blanchard-Perotti approach proposed by Blanchard and Perotti (2002) and further extended in Perotti (2005). Third, the sign-restrictions approach developed by Uhlig (2005) and applied to fiscal policy analysis by Mountford and Uhlig (2009). Fourth, the so-called "narrative" or "dummy" methodology has been used to identify fiscal shocks due to events such as war episodes by Ramey and Shapiro (1998) and Eichenbaum and Fisher (2005). All approaches use different identification schemes, that either explicitly or implicitly impose restrictions on the systematic response of tax and spending policies to changes in output. Caldara and Kamps (2017) show how different assumptions on the fiscal rule have a strong implication on the sign and size of fiscal multipliers, which would account for the wide range of estimates in the existing literature.

The common feature of these studies is that they all analyse the effects of fiscal policy within a closed economy framework. In other words, they implicitly assume that the transmission of fiscal policy occurs exclusively through the domestic channel. However, the benefits of fiscal instruments strongly depend on the reaction of the exchange rate and the trade balance, which is particularly important for open economies, in which international trade represents a significant share of economic activity. Yet, the effects of discretionary fiscal policy on the exchange rate and international trade still remain controversial. The standard Mundell-Fleming model predicts that following a fiscal expansion, the trade balance deteriorates through the appreciation of the domestic currency. As trade openness increases, a sufficiently large fiscal stimulus will propagate abroad through higher imports and prices, thus reducing the impact of the fiscal multiplier on the output. Nevertheless, the latter relationship between fiscal policy and international trade is not always observed empirically. VAR studies like Monacelli and Perotti (2010) and Ravn et al. (2012) find that after a fiscal expansion, the real exchange rate depreciates and the trade balance deteriorates. Moreover, Kim and Roubini (2008) reveal that a deficit-financed fiscal expansion leads to a real depreciation and an improvement of the current account. From a different perspective, a large body of literature has examined the effects of tax shocks on the output and other real economic variables (e.g., Blanchard and Perotti, 2002; Perotti, 2005; Caldara and Kamps, 2008; Mountford and Uhlig, 2009). However, the study of the effects of tax shocks on the exchange rate and the trade balance has received less attention.

Most of the literature on fiscal policy does not distinguish between different types of government spending. A number of studies assess the impact of total government spending as a single fiscal instrument, without investigating the potential distinct effects that may arise from shocks to different types of expenditure. Government spending includes all government consumption, investment and transfer payments, and not all induce the same effect on the economy. Government consumption can be in turn decomposed into its non-wage and wage components. Wage and salary payments of public sector workers represent a large share of public expenditure in most countries. Research on the effects of disaggregated government spending has developed over the past decades. To the best of our knowledge, the first studies to use disaggregated data for government spending are Lane and Perotti (1998), Giordano et al. (2007), Perotti (2008) and Pappa (2009). Nevertheless, research devoted to the disaggregated analysis of fiscal policy in open economies is relatively limited. Bénétrix and Lane (2009) contribute to this literature by analysing the effects of government non-wage consumption, government wage consumption and public investment shocks on the Irish exchange rate. Lane and Perotti (1998) evaluate the impact of fiscal policy components on international trade in OECD countries. It therefore seems essential to examine the transmission channels and the effects of unexpected changes in the components of government spending on the economic variables in an open economy framework.

In this chapter, we undertake a detailed empirical examination on the composition of fiscal policy and its transmission mechanisms on various macroeconomic aggregates in two Anglo-Saxon countries, the United States and the United Kingdom, over the period 1964-2017. These countries conduct independent fiscal policies and are characterized by the low levels of government regulation, the small shares of the public sector and by free markets. Although they are relatively homogenous, the United Kingdom has comparatively higher levels of taxation and spending on the welfare state and shares some common features with European continental economic models that diverge from those of Anglo-American economic models (Davtyan, 2016). While research on fiscal policy has been substantial, the study of the transmission mechanisms and effects of government spending components in open economies has received less attention. This approach is particularly complex since government decisions to adjust its spending levels on various categories may benefit only to a small group of individuals and have negligible effects on others. As a result, the transmission mechanisms and the effects of shocks to government spending

components on the macroeconomics aggregates are uncertain and may be very small. In this chapter, we consider disaggregated levels of government spending components. In our view, this approach can complement the analysis of aggregate fiscal policy by providing more informative conclusions on the ways in which policy decisions can influence macroeconomic conditions.

The empirical analysis is conducted through structural VAR models based on a novel specification, including all relevant variables in the transmission mechanisms of fiscal policy components in open economies. We estimate the effects of disaggregated fiscal policy shocks on the macroeconomic aggregates. Using the recursive approach, we identify a tax revenue and a government spending component shock that rotates between (i) government non-wage consumption (ii) government wage consumption (iii) public investment. The baseline VAR model is composed of the government spending component, the output, the inflation rate, tax revenue, the interest rate, the trade balance and the real effective exchange rate. To have a better sense of what changes in fiscal policy induce on the economy, we estimate four alternative specifications in which we replace the inflation rate by switching in turn private consumption, private investment, private wages and the employment rate. The effects of fiscal policy shocks are assessed by the impulse response functions and the variance decomposition. This chapter contributes to the literature on the disaggregated analysis of fiscal policy in open economies. We examine the composition of fiscal policy by asking whether government spending disaggregation matters for the transmission of fiscal policy on the macroeconomic aggregates. Besides, this chapter explores the role of the exchange rate and the trade balance in the transmission of shocks to tax revenue and government spending components. The analysis conducted in this chapter reveals that the disaggregation of fiscal policy matters since each fiscal instrument implies different transmission channels and effects on the real economy. There are also some differences in the obtained results for the United States and the United Kingdom that can be attributed to the different features shared by each country. In addition, our findings indicate that fiscal policy can be operative, besides the interest rate channel, via an exchange rate and trade balance channels.

The rest of the chapter is organized as follows. Section 2.2 reviews the theory of fiscal policy and the related empirical literature. Section 2.3 presents the econometric methodology. Section 2.4 describes the data and their properties. Section 2.5 provides the results of the VAR estimation. Finally, section 2.6 contains concluding remarks and policy implications.

2.2 Theory and Literature Review

The study of the transmission mechanisms of fiscal policy has received particular attention. In this regard, many studies in the literature have employed the VAR methodology. Apart from differences in the specification of the reduced-form model, the studies distinguish themselves by the approach used to identify fiscal policy shocks. There is often a disagreement on the quantitative and qualitative response of key economic variables to government spending and tax shocks. Subsection 2.2.1 provides a brief review of the fiscal policy theory. Subsection 2.2.2 discusses the related empirical literature on the transmission channels and effects of aggregate and disaggregated fiscal policy shocks.

2.2.1 Theoretical Literature

According to the classical literature, fiscal policy has no effect on the real economy in the long run, since wages and prices are fully flexible and the aggregate supply curve is inelastic. The classical view suggests that the real output is determined by supply-side factors. On the other hand, the Keynesian framework, represented by the traditional IS-LM and the extended Mundell-Fleming models, predicts that a fiscal stimulus will increase employment and private consumption, due to wage and price rigidities. The Keynesian theory advocates that the tax multiplier is usually lower than the spending multiplier given that part of the disposable income will not be spent, but saved, depending on the marginal propensity to consume. In an open economy, the effects of discretionary fiscal policy depend on the adopted exchange rate regime and the degree of trade openness (Lane and Perotti, 1998). Under a flexible exchange rate regime, an expansionary fiscal shock increases the output, interest rate and demand for money. The higher interest rate attracts foreign capital, which flows into the economy, causing the domestic nominal exchange rate to appreciate. Given that prices are rigid in the short run, the nominal appreciation translates into a real appreciation. The stronger domestic currency discourages exports and encourages imports, causing the trade balance to deteriorate and thus partially offsetting the positive effect of fiscal policy (e.g., Beetsma and Giuliodori, 2011). Under a fixed exchange rate regime, an expansionary fiscal policy forces the monetary authority to increase the money supply in order to maintain the exchange rate parity, which leads to a greater fiscal multiplier impact on the economy. The Keynesian theory suggests that fiscal policy decisions taken locally can affect the economic conditions of foreign trading partners through the exchange rate and trade balance channels.

The literature modelling the effects of fiscal policy using general equilibrium models has evolved into two different streams. The real business cycle model builds on the assumption that private consumption and real wages react negatively and employment positively to an expansion of government spending. In this framework, an exogenous rise in government spending financed by lump-sum taxes reduces the wealth of the economic agent, leading the agent to consume less and work more, which in turn exerts downward pressure on real wages (e.g., Burnside et al., 2004; Eichenbaum and Fisher, 2005). The New Keynesian dynamic stochastic general equilibrium (DSGE) model incorporates nominal rigidities and monopolistic competition. It builds on the assumption that private consumption, real wages and employment react positively to an increase in government spending (e.g., Ravn et al., 2006; Galí et al., 2007). The expanded output leads firms to hire more and thus increases real wages and employment, providing consumers with more income to spend and invest.

2.2.2 Empirical Literature

2.2.2.1 Government Spending and Taxes

The literature generally provides mixed evidence as regards the effects of tax shocks on the economy. In most studies assessing the effects of tax shocks in the United States, a contractionary tax shock has negative effects on the output and other real economic variables, as found in Blanchard and Perotti (2002), Mountford and Uhlig (2009) and Romer and Romer (2010). Moreover, Ramos and Roca-Sagales (2008) provide evidence that tax cuts increase the output in the United Kingdom. On the other hand, Perotti (2005) suggests that the effect of taxes on the output is relatively small in the United Kingdom. Giordano et al. (2007) and Tenhofen et al. (2010) also find that tax revenue shocks have weak effects on the macroeconomic aggregates in Italy and Germany. Caldara and Kamps (2008) propose an explanation to this disagreement on the effects of tax shocks by showing that they depend on the identification approach used and the size of automatic stabilizers. In relation to the monetary aggregates, these authors find that the interest rate increases after a contractionary tax revenue shock, while inflation does not react in the United States. Mountford and Uhlig (2009) find positive responses of the interest rate and prices. As regards the labor market variables, Caldara and Kamps (2008) find that real wages increase after a contractionary shock, while employment declines. In contrast, Mountford and Uhlig (2009) find that real wages decline after a government revenue shock.

A large body of literature has investigated the effects of government spending shocks on the macroeconomic aggregates. Using a structural VAR model based on the recursive approach, Fatas and Mihov (2001) examine the response of key macroeconomic variables to changes in government spending in the United States. These authors find that government spending shocks lead to an increase in output, private consumption, real interest rate, manufacturing wages and employment. Blanchard and Perotti (2002) assess the effects of shocks to government spending and taxes on the Unites States economy in the post-war period. These authors use a structural VAR approach relying on institutional information about the tax and transfer systems and the timing of tax collections to achieve the identification of the automatic response of taxes and government spending to economic activity. Their findings indicate that a government spending shock is associated with an increase in output and private consumption. In contrast, an increase in government spending has a strong negative impact on private investment. Burriel et al. (2010) find a similar result for private investment in the United States. Mountford and Uhlig (2009) impose theory-motivated sign-restrictions to identify government spending and revenue shocks using United States data. These authors find that government spending expansions lead to a weak increase in output and private consumption, as well as a decline in non-residential investment. On the other hand, Perotti (2005) finds that the output declines in Canada and the United Kingdom after an expansionary shock in the post-1980 sample. Ramos and Roca-Sagales (2008) obtain similar results for the United Kingdom.

The responses of monetary and labor market variables to fiscal policy shocks have also been subject to some disagreement. Caldara and Kamps (2008) and Burriel et al. (2010) provide evidence that inflation increases in response to a government spending shock in the United States. In contrast, Fatas and Mihov (2001) and Mountford and Uhlig (2009) find a negative effect of government spending on prices or inflation. Perotti (2008) provides evidence that real and nominal interest rates increase in the United Kingdom and decline in the United States after a government spending shock. However, these findings are not consistent with Caldara and Kamps (2008) for the United States. Turning on the response of labor market variables, Perotti (2008) finds that real wages rise steadily, while employment does not react in the United States. These findings are also supported by Caldara and Kamps (2008). On the other hand, Fatas and Mihov (2001) provide evidence that employment increases, while the overall wage level does not change. Moreover, Burnside et al. (2004) find that real wages decline persistently, while employment follows the opposite dynamics.

Several empirical studies attempt to establish the relationship between discretionary fiscal policy and the open economy variables, without obtaining robust stylized facts. VAR studies like Monacelli and Perotti (2010) and Ravn et al. (2012) find that the real exchange rate depreciates and the trade balance deteriorates after a government spending expansion in a group of four Anglo-Saxon countries composed of Australia, Canada, the United States and the United Kingdom. In contrast, Kim and Roubini (2008) provide evidence that a deficit-financed fiscal expansion leads to a depreciation of the real exchange rate and an improvement of the current account in the United States. Beetsma and Giuliodori (2011) employ a panel VAR for a group of fourteen European country using annual data over the period 1970-2004. Their findings indicate that government spending shocks lead to an expansion of economic activity by increasing private consumption and private investment. These movements in the components of national income are associated with an appreciation of the real exchange rate, as well as a deterioration of public and trade balances.

2.2.2.2 Government Spending Components

Research on the effects of disaggregated government spending shocks has developed over the past decades. Lane and Perotti (1998) evaluate the short-run effects of movements in different components of fiscal policy on the trade balance for a panel of OECD countries over the period 1960-1995. Above all, their findings reveal that the composition of a change in fiscal policy and the exchange rate regime matter for its transmission to the external account. These authors find that an increase in government wage consumption causes a deterioration of the trade balance, especially under flexible exchange rates. Using the structural VAR modelling, Giordano et al. (2007) analyse the effects of shocks to fiscal policy components in Italy. These authors find that a government consumption shock has positive effects on the output, private consumption, private investment and employment. Moreover, Giordano et al. (2007) provide evidence that an increase in public wages has a negative impact on employment, while it has no significant impact on the output. Using a VAR model based on the recursive approach, Bénétrix and Lane (2009) evaluate the effects of shocks to government spending components on the Irish exchange rate. These authors show that the impact of government spending critically depends on the nature of the fiscal shock. They find that shocks to government non-wage consumption imply a real depreciation, while shocks to public investment and government wage consumption imply a real appreciation.

Several other studies in this literature analyse the effects of disaggregated government spending shocks in a closed economy framework using structural VAR models. Ramos and Roca-Sagales (2008) find that the estimated long-term effects of increases in current expenditure and public investment on the output are negative. Pappa (2009) reveals that shocks to government consumption and public investment lead to an increase in real wages and employment in the United States. Tenhofen et al. (2010) find that public investment increases have a persistent positive effect on the output in Germany. In contrast, their findings indicate that increases in government wage consumption are not effective in stimulating the economy. In another relevant work, Bermperoglou et al. (2017) estimate the effects of public wage expenditures on private activity in the United States. These authors find that government wage consumption shocks induce a weak increase in output, a fall in private employment and investment, as well as an increase in private wages and unemployment. Moreover, Bermperoglou et al. (2017) reveal that government wage consumption increases have different effects on the macroeconomic aggregates when they are disaggregated by government levels. Using a DSGE model with a public good providing both productive and utility-enhancing services, search and matching functions, and endogenous labor force participation, these authors show how the sign of the response of the output depends on the complementarity between public goods and private consumption in the aggregate consumption bundle of the household. Their theoretical framework demonstrates that public wage policies could be expansionary only if the increases in wages are associated with the production of public goods that strongly complements private consumption.

Brückner and Pappa (2012) analyse the effects of shocks to government spending in ten OECD countries. For the United Kingdom, these authors find evidence that an expansion of government consumption leads to an increase in output, private consumption and real wages, as well as a decline in employment. For the United States, they find that the output and private consumption increase slightly, while the responses of employment and real wages are slightly positive initially before turning insignificant. Afonso and Aubyn (2018) study the effects of public investment in seventeen OECD countries through a VAR analysis over the period 1960-2014. Their findings reveal that an increase in public investment has a positive effect on the output in twelve countries and a negative effect in the five remaining countries. These authors find that public investment shocks have expansionary effect on the output by crowding in private investment in the United States, whereas they have contractionary effect on the output by crowding out private investment in the United Kingdom.

2.3 Econometric Methodology

This section presents the structural vector autoregressive methodology used for the examination of the transmission mechanisms of fiscal policy. This analysis enables to take into account the feedback and the reciprocal causality that exist among the variables in the system both in the short term and in the long term. Structural VAR models are suitable when the variables of interest are endogenous and have the advantage of not requiring too many variables. A key challenge in this framework is the identification of exogenous and unexpected fiscal policy shocks[2]. To recover government spending components and tax revenue shocks, we use the recursive identification approach, commonly adopted in the structural VAR literature, as in Fatas and Mihov (2001) and Caldara and Kamps (2008). The model specification is such to consider all relevant variables in the transmission mechanisms of fiscal policy components in open economies[3]. The chapter considers one baseline VAR model (A) and four alternative specifications (B, C, D and E). Subsection 2.3.1 presents the specification of the VAR model and subsection 2.3.2 describes the identification approach.

2.3.1 VAR Specification

The reduced VAR form model contains a constant, a linear time trend and seven endogenous variables: the log of real per capita government spending component (g), the log of real per capita output (y), the inflation rate (π), the log of real per capita tax revenue (t), the real interest rate (r), the trade balance (tb) and the log of the real effective exchange rate (rer). The government spending component (g) rotates between the log of real per capita government non-wage consumption (gc), the log of real per employee government wage consumption (gw) and the log of real per capita public investment (pi). In the alternative specifications, we replace the inflation rate by switching in turn the log of real

[2] One frequent criticism to the identification of fiscal policy shocks with quarterly data is that fiscal decisions are mainly taken on year-by-year basis as embedded in the budget. This may potentially be problematic as changes in various spending categories can often be anticipated, due to prior announcements. However, while recognizing that the yearly budget includes important policy measures, discretionary fiscal policy measures are widely used within the year and have been commonplace throughout most of the sample period considered.

[3] The VAR specification often results from a compromise between parsimony and avoiding omitted variables bias. We choose the latter strategy since we need a number of variables to examine the domestic and external transmission channels of fiscal policy. The drawback of such a strategy is that it requires estimating a large number of parameters. To minimize the loss of degrees of freedom, we consider sufficiently long series using quarterly data.

per capita private consumption (c), the log of real per capita private investment (i), the log of real per employee private wage (w) and the employment rate (e)[4].

The estimated baseline VAR (p) has the following reduced form:

$$Y_t = \mu_0 + \mu_1\tau + A_1Y_{t-1} + A_2Y_{t-2} + \cdots + A_pY_{t-p} + u_t \qquad (2.1)$$

Where $Y_t = (y_{1t},\ldots,y_{kt})'$ is a k-dimensional vector of endogenous variables, μ_0 is a constant, τ is a linear time trend, A_i (i=1,…,p) are (k x k) matrices of coefficients and $u_t = (u_{1t},\ldots,u_{kt})'$ is a k-dimensional vector of reduced form shocks with $E(u_t) = 0$, $E(u_tu_t') = \Omega_u$ and $E(u_tu_s') = 0$ for $t \neq s$.

The shocks of this reduced form do not generally have a meaningful economic interpretation since they are linear combinations of structural shocks. Moreover, they are not likely to occur in isolation in practice and are generally correlated, meaning that the impulse response functions do not describe how the variables in the system react over time to an innovation in a variable, holding everything else constant. Therefore, it is necessary to transform the reduced form model into a structural model.

We pre-multiply the equation (2.1) by the matrix A of order k, which refers to the contemporaneous relations among variables in the vector Y_t. This enables us to obtain the structural VAR (p) representation:

$$AY_t = V_0 + V_1\tau + \Gamma_1Y_{t-1} + \Gamma_2Y_{t-2} + \cdots + \Gamma_pY_{t-p} + Be_t \qquad (2.2)$$

Where $\Gamma_i = AA_i$, $V_j = A\mu_j$ (for j = 0,1) and $e_t = (e_{1t},\ldots,e_{kt})'$ is the k-dimensional vector of exogenous structural shocks with a standardized identity variance-covariance matrix, that is, $E(e_te_t') = \Omega_e = I_k$. Using the Lth-order lag operator A(L), the process (2.2) can be equivalently expressed as:

$$A\left(Y_t - A_1Y_{t-1} - A_2Y_{t-2} - \cdots - A_pY_{t-p}\right) = V_0 + V_1\tau + Be_t \qquad (2.3)$$

[4] We switch the additional variables in turn with the objective of minimizing the loss of degrees of freedom. The alternative specifications B, C, D, E refer respectively to the specification with private consumption, private investment, private wages and the employment rate. The model specifications are summarized in table A.2.2.1.

Which can be rewritten in a more compact form as:

$$AA(L)Y_t = V_t + Be_t \tag{2.4}$$

Where $A(L) = I_k - A_1L - A_2L^2 - \ldots - A_pL^p$ and $V_t = V_0 + V_1\tau$. Ignoring the deterministic terms, the relationship between the vector of reduced form shocks and the vector of exogenous structural shocks can be expressed as:

$$Au_t = Be_t \tag{2.5}$$

This is known as the AB model in the literature. These transformations of the innovations allow us to analyse the dynamics of the system in terms of a change to an element of e_t. Structural VAR models based on the recursive approach use the Cholesky decomposition to orthogonalize the disturbances and thereby obtain structurally interpretable impulse response functions.

The model estimation requires more identifying restrictions since A and B involve many more parameters to estimate. Given a sample of size T, the free parameters in A and B are estimated by maximizing the concentrated log-likelihood function:

$$\ell(A,B) = constant + \frac{T}{2}\log\det(A)^2 - \frac{T}{2}\log\det(B)^2 - \frac{T}{2}tr(A'\,B'^{-1}\,B^{-1}A\widehat{\Omega}_u) \tag{2.6}$$

The resulting estimators have the usual asymptotic properties of maximum likelihood estimators (e.g., Lütkepohl, 2005), and, thus, asymptotic inference can be proceeded in the usual way.

2.3.2 Identification: The Recursive Approach

The chapter applies the recursive approach originally proposed by Sims (1980) to identify the structural shocks. This identification scheme imposes a causal ordering from the top variables to the bottom variables based on the economic theory. The matrix A represents the contemporaneous effects of changes in observed variables and unobserved shocks, while the matrix B scales the innovations to have a unit variance. Thus, the recursive approach requires B to be an identity matrix and A to be a lower triangular matrix with unit diagonal. Because there are $2k^2$ total parameters in A and B, the identification requires that at least $2k^2 - k(k-1)/2$ are placed on those parameters. Therefore, one has

to impose k(k-1)/2 restrictions on the matrix A. The relationship between the vector of reduced form shocks and the vector of structural shocks is given by:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{yg} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{\pi g} & a_{\pi y} & 1 & 0 & 0 & 0 & 0 \\ a_{tg} & a_{ty} & a_{t\pi} & 1 & 0 & 0 & 0 \\ a_{rg} & a_{ry} & a_{r\pi} & a_{rt} & 1 & 0 & 0 \\ a_{tbg} & a_{tby} & a_{tb\pi} & a_{tbt} & a_{tbr} & 1 & 0 \\ a_{rerg} & a_{rery} & a_{rer\pi} & a_{rert} & a_{rerr} & a_{rertb} & 1 \end{bmatrix} \begin{bmatrix} u_t^g \\ u_t^y \\ u_t^{\pi} \\ u_t^t \\ u_t^r \\ u_t^{tb} \\ u_t^{rer} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e_t^g \\ e_t^y \\ e_t^{\pi} \\ e_t^t \\ e_t^r \\ e_t^{tb} \\ e_t^{rer} \end{bmatrix} \quad (2.7)$$

The baseline model is specified with the particular order of: the government spending component, the output, the inflation rate, tax revenue, the real interest rate, the trade balance and the real effective exchange rate. We impose short-run restrictions, which prevent a structural shock from affecting an endogenous variable contemporaneously. The model specification is an extension of the model proposed by Caldara and Kamps (2008) in an open economy framework. The particular ordering of the variables has the following implications: (i) The government spending component is not affected contemporaneously by structural shocks to other variables in the system. (ii) The output does not react simultaneously to all structural shocks but is affected by shocks to the government spending component within the same quarter. (iii) The inflation rate does not react simultaneously to shocks to tax revenue, interest rate, trade balance and real effective exchange rate, but is affected within the same quarter by shocks to government spending component and output. (iv) Tax revenue does not react simultaneously to shocks to interest rate, trade balance and real effective exchange rate but is affected within the same quarter by shocks to government spending component, output and inflation rate. (v) The interest rate is affected contemporaneously by all variables in the system, except by shocks to trade balance and real effective exchange rate. (vi) The trade balance is affected contemporaneously by all variables in the system except by shocks to the real effective exchange rate. (vii) The real effective exchange rate is assumed to react simultaneously to all structural shocks in the system. Note that after the initial period, the variables are allowed to interact freely.

When using quarterly data, it is plausible to assume that public spending decisions cannot be revised and implemented within a quarter, and thus cannot react to current economic conditions. This implicitly means that the automatic stabilizers of government spending components are equal to zero. Ordering the output and inflation before taxes can be justified by the fact that shocks to these

two variables have an immediate impact on the tax base, thus affecting simultaneously tax revenue. In addition, this particular ordering of the variables captures the effects of automatic stabilizers of tax revenue but prevents the contemporaneous impact of discretionary tax revenue changes on the output and inflation. The interest rate is ordered after all these variables and before the real effective exchange rate. This can be rationalized on the grounds that the interest rate is the main tool of the central bank's monetary policy whose objective is to stabilize the output gap and maintain price stability. Monetary policy is one of the main determinants of the exchange rate and is therefore ordered before it. Ordering tax revenue before the interest rate can be justified on the grounds that tax revenue is not very sensitive to interest rate changes since it is defined as net of interest payments. The trade balance is ordered before the real effective exchange rate since it takes time for demand for exports and imports to change in response to a movement in currency. Finally, the real effective exchange rate is ordered last since it is the most endogenous variable of the system, being affected by both domestic and foreign structural shocks.

In the alternative model specifications, we assess the dynamics effects of disaggregated fiscal policy shocks on national income components and labor market variables. The relationship between the vector of reduced form shocks and the vector of structural shocks is given by:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{zg} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{yg} & a_{yz} & 1 & 0 & 0 & 0 & 0 \\ a_{tg} & a_{tz} & a_{ty} & 1 & 0 & 0 & 0 \\ a_{rg} & a_{rz} & a_{ry} & a_{rt} & 1 & 0 & 0 \\ a_{tbg} & a_{tbz} & a_{tby} & a_{tbt} & a_{tbr} & 1 & 0 \\ a_{rerg} & a_{rerz} & a_{rery} & a_{rert} & a_{rerr} & a_{rertb} & 1 \end{bmatrix} \begin{bmatrix} u_t^g \\ u_t^z \\ u_t^y \\ u_t^t \\ u_t^r \\ u_t^{tb} \\ u_t^{rer} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e_t^g \\ e_t^z \\ e_t^y \\ e_t^t \\ e_t^r \\ e_t^{tb} \\ e_t^{rer} \end{bmatrix} \quad (2.8)$$

Where z = c, i, w, e. The components of national income and labor market variables are all ordered second in the VAR model before the output. The particular ordering of private consumption and private investment can be justified on the grounds that innovations in these components of national income have immediate effects on the output. Moreover, economic agents are not perfectly rational and do not react simultaneously to changes in current economic conditions and policy decisions on government revenue and monetary policy. Because of the possible existence of labor market rigidities, employment and private wages are assumed not to be very sensitive to changes in the other macroeconomic variables of the system within the same quarter.

2.4 Data

2.4.1 Data Description

We use quarterly seasonally adjusted data for the United States and the United Kingdom over the period 1964-2017. The appendix A.2.1 provides details on definitions and data sources for all variables used in this chapter. The components of national income and of various fiscal series are in real terms and were obtained by dividing them by the GDP deflator. They are expressed in their per capita terms[5]. Monthly series were aggregated and converted into quarterly series using arithmetic average. For the United States, the series used were obtained from two main sources. The components of national income and of various fiscal series are drawn from NIPA tables published by the Bureau of Economic Analysis (BEA). The interest rate, the real effective exchange rate, the employment rate and private wages series come from Federal Reserve Bank of St. Louis (FRED). For the United Kingdom, the series are obtained from four main sources. The output, government consumption, private consumption, the real effective exchange rate and the trade balance series come from FRED. The inflation rate, government wage consumption, tax revenue, private wages and the employment rate[6] series are obtained from the Office for National Statistics (ONS). Public investment and private investment series are taken from the annual macro-economic database of the European Commission (AMECO)[7] and the interest rate series comes from the Bank of England (BoE) database. Finally, the global oil price series is drawn from FRED.

Our definitions of fiscal and other endogenous variables closely follow the existing literature. Due to the differences in availability of data, we use different definitions for certain variables. Government consumption refers to consumption expenditures for the United States and the consumption of goods and services for the United Kingdom. Government wage consumption corresponds to the compensation of general government employees. Public investment refers to gross government investment for the United States and

[5] However, as mentioned in subsection 2.3.1, public and private wages are expressed in their per employee terms. For the United Kingdom, we had to use the log of real per capita government wage consumption and the log of real per capita private wage, due to the absence of sufficiently long series for public and private employees.
[6] For the United Kingdom, the longest available series for the employment rate is 1972-2017.
[7] These two series have been obtained converting data from annual to quarterly frequency using the Denton method as implemented in EVIEWS version 10.

gross fixed capital formation of the public sector for the United Kingdom. Government non-wage consumption is defined as government consumption minus government wage consumption. Government spending is defined as the sum of government consumption and public investment. Net tax revenue is defined as government current receipts minus current transfers and interest payments[8]. The output refers to the gross domestic product (GDP). The inflation rate is defined as the growth rate of the GDP deflator. The real interest rate refers to the effective federal funds rate for the United States and the official bank rate for the United Kingdom[9], both adjusted for inflation. The trade balance corresponds to real net exports of goods and services as a percentage of GDP. The real effective exchange rate is the real narrow effective exchange rate, and an increase means real appreciation in the domestic currency against the rest of the world. Private investment corresponds to gross private domestic investment for the United States and gross fixed capital formation of the private sector for the United Kingdom. Private consumption is defined as personal consumption expenditures for the United States and private final consumption expenditure for the United Kingdom. Private wages are defined as the compensation of employees in private industries for the United States and wages and salaries resources for the United Kingdom. The employment rate is the ratio of employed under the labor force, for all persons aged between 15 and 64. The global oil price refers to the West Texas Intermediate spot crude oil price.

2.4.2 Data Properties

This subsection provides a preliminary examination of the data properties. Tables 2.1 and 2.2 provide descriptive statistics of fiscal policy variables. Figures 2.1 and 2.2 show the evolution of government spending components and tax revenue as share of GDP and in real terms for the United States and the United Kingdom over the period 1964-2017. From figure 2.1, it can be noted that the components of government spending present different cyclical behaviors, whereas tax revenue tends to decrease during recessions. Figure 2.2 shows that government non-wage and wage consumption have a clear positive trend, while public investment fluctuates more during booms and recessions.

[8] For the United Kingdom, we follow Perotti (2005) and define net tax revenue as compulsory social contributions plus current receipts from taxes on income and wealth plus current receipts from taxes on production plus other current taxes minus current expenditure.

[9] Since the official bank rate series is not available for the entire sample period, we constructed the interest rate series by combining the three-month treasury securities (1964-1974) series and the official bank rate (1975-2017) series.

Figure 2.1: Government spending components and tax revenue as share of GDP

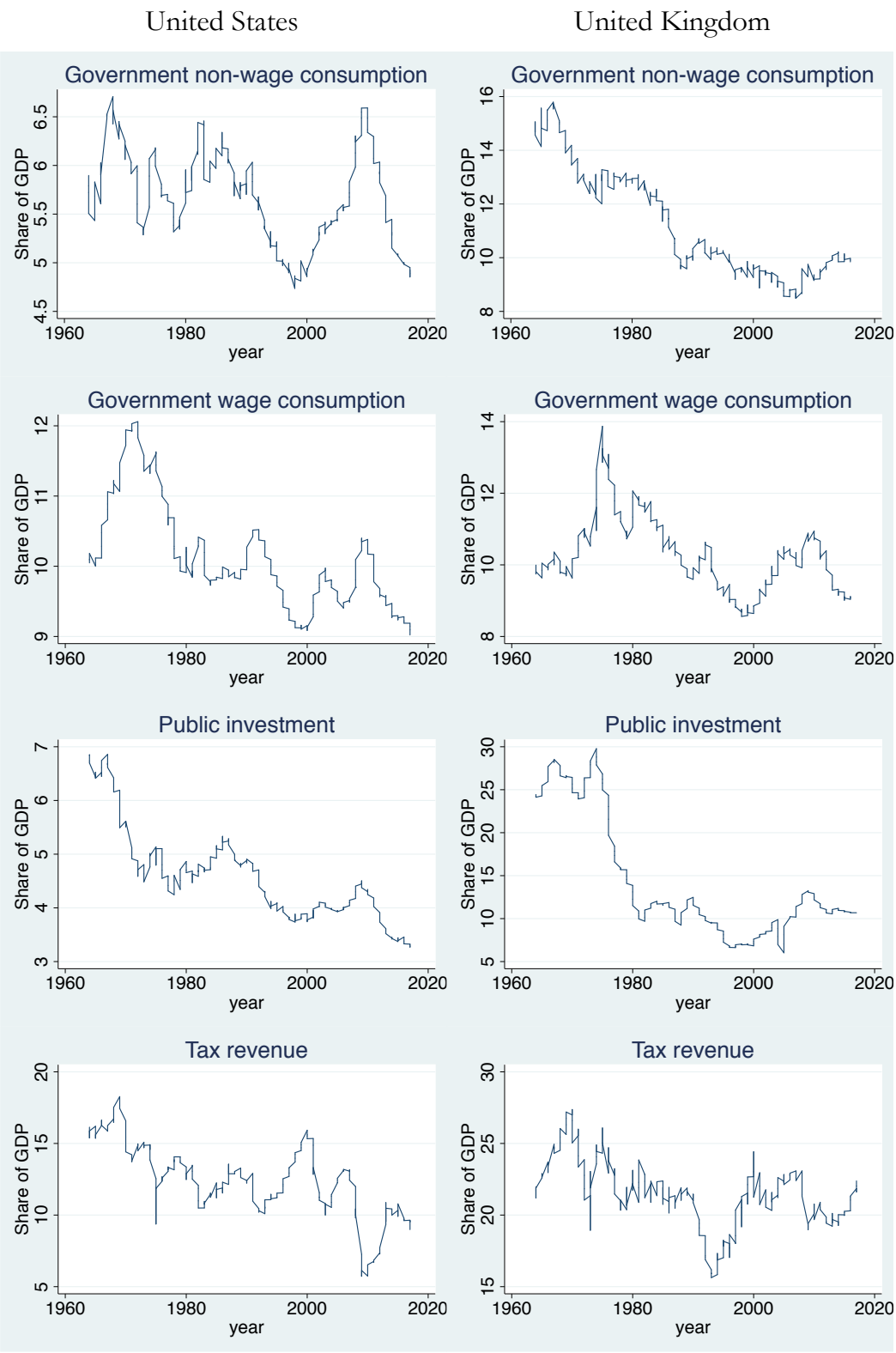


Figure 2.2: Government spending components and tax revenue in real terms

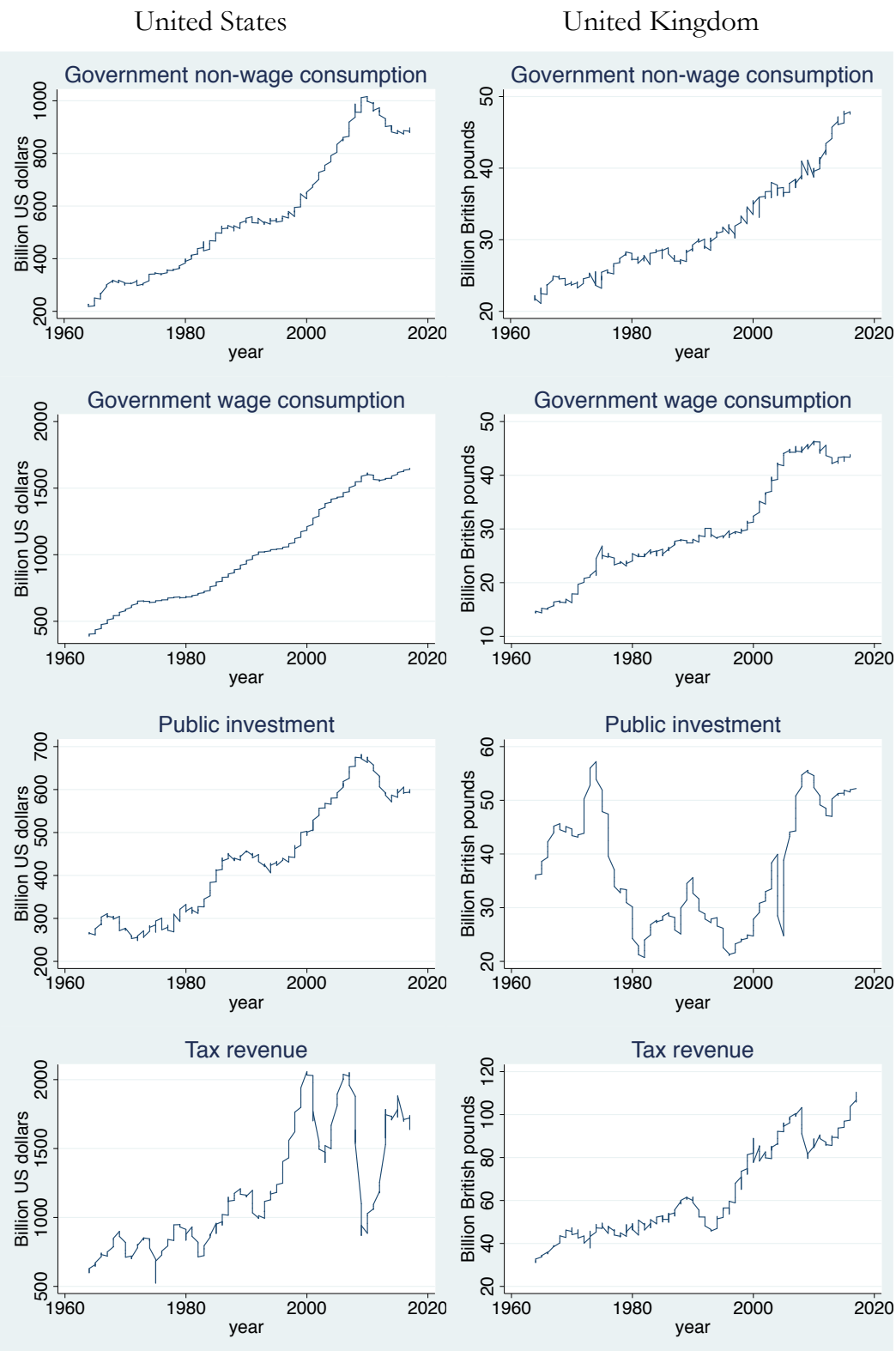
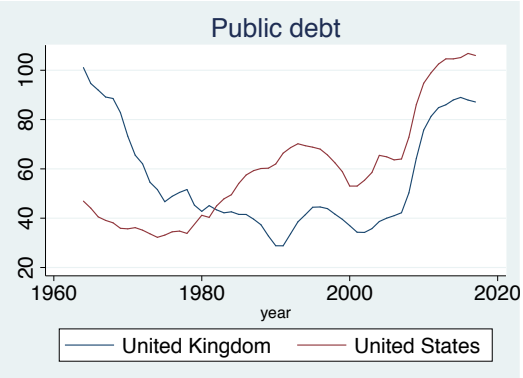
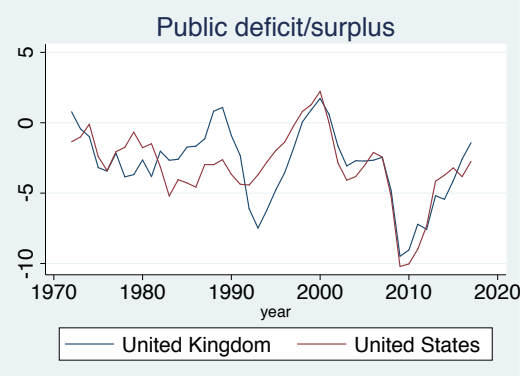


Figure 2.3: Public debt as share of GDP



Source: International Monetary Fund (2020)

Figure 2.4: Public deficit/surplus as share of GDP



Source: World Bank (2020)

Table 2.1: Descriptive statistics of fiscal policy variables (United States)

Variables (Billion US dollars)	Mean	Std. dev	Min.	Max.
Government non-wage consumption	568.37	234.62	218.42	1016.03
Government wage consumption	1005.18	388.97	386.96	1647.96
Public investment	435.63	134.27	248.43	681.69
Tax revenue	1182.03	424.45	523.65	2057.99
Government spending	2009.18	753.12	877.41	3298.42

Table 2.2: Descriptive statistics of fiscal policy variables (United Kingdom)

Variables (Billion British pounds)	Mean	Std. dev	Min.	Max.
Government non-wage consumption	31.24	6.85	21.10	47.95
Government wage consumption	29.74	9.52	14.36	46.35
Public investment	37.19	10.77	20.71	57.21
Tax revenue	63.17	21.39	31.11	110.46
Government spending	98.02	21.72	71.42	143.17

Figures 2.3 and 2.4 show the evolution of public debt and deficit as share of GDP. It can be seen that the United States and the United Kingdom experienced relatively high public debt and deficit during the global financial crisis, which increased concerns about the sustainability of their debt. The evolution of macroeconomic aggregates is presented in figures 2.5 and 2.6. There is a visible structural change in the early 1980s for most of the series, with the exception of the series for the output, private consumption and private wages. We then check the order of integration of the series with the augmented Dickey-Fuller test. The null hypothesis that the series has a unit root is tested against its stationarity. The test is carried out for the levels of the variables, as well as for their first differences. The results are provided in tables A.2.3.1 to A.2.3.4 and show that all the series are not stationary and that they are integrated of order one.

2.4.3 Analysis of the Cyclical Components of the Series

The examination of the cyclical components of the series can be meaningful to complement the analysis of fiscal policy. This subsection presents the main regularities of business cycles observed in the United States and the United Kingdom over the period 1964-2017. For a policymaker, it is fundamental to understand how economic variables move during booms and recessions before implementing policies. Business cycles are characterized by a set of statistics that we care about in that type of analysis. We are interested in the co-movements of the series since we want to know how correlated are cyclical fluctuations in various macroeconomic aggregates with the cycle. We also care about the volatility of series, measured by standard deviations, which indicates us how big is the magnitude of cyclical fluctuations. The variables of interest are those that can create fluctuations in output from its long-run trend. All original series have been detrended by the Hodrick-Prescott filter with $\lambda = 1600$ to get their cyclical components. The main business cycle statistics are summarized in table 2.3.

The analysis reveals that the disaggregation of government spending into its main components enables to capture differences in terms of co-movements of fiscal variables with the cycle. Government spending is procyclical in the United Kingdom and acyclical in the United States. Let us now describe the cyclical behavior of the main components of government spending. Public investment is positively correlated with the cycle and is therefore procyclical. Government non-wage consumption is weakly procyclical in the United Kingdom and countercyclical in the United States. Government wage consumption is countercyclical in the United Kingdom and acyclical in the United States.

Figure 2.5: Evolution of macroeconomic aggregates (United States)

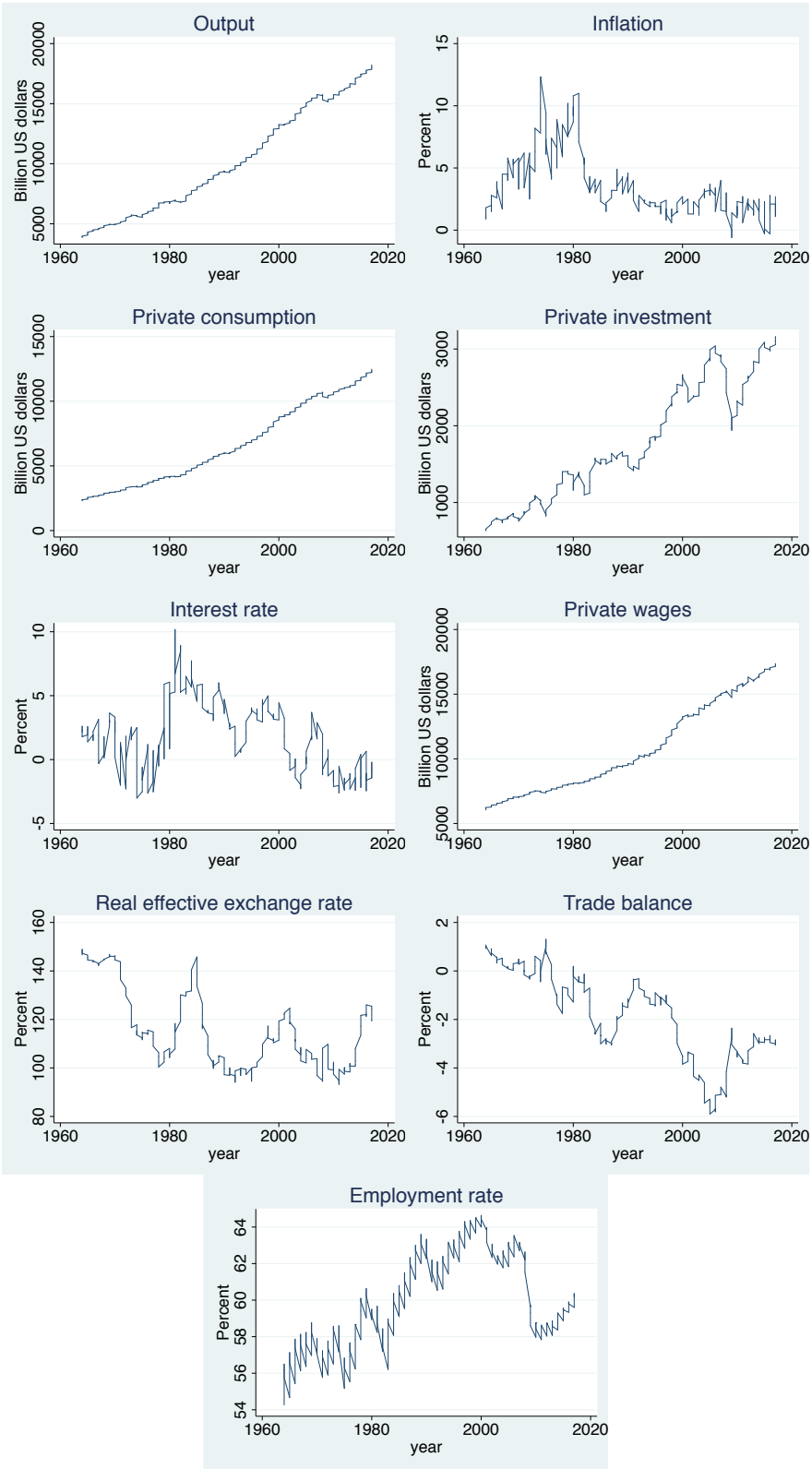
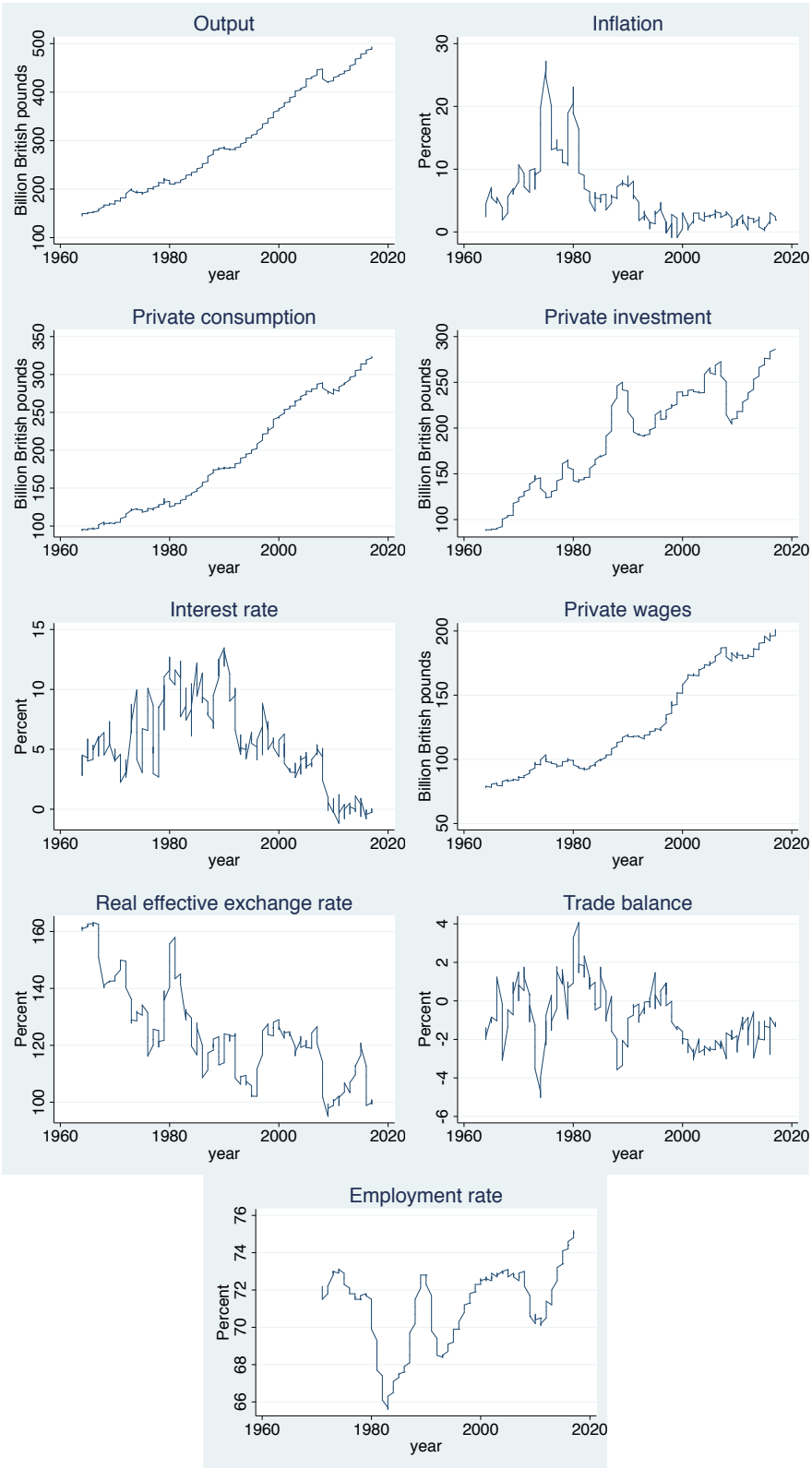


Figure 2.6: Evolution of macroeconomic aggregates (United Kingdom)



Tax revenue is countercyclical, meaning that taxes increase during booms and decrease during recessions. As regards the macroeconomic aggregates, private consumption, private investment, private wages and the employment rate are all procyclical. In particular, national income components and employment increase sharply during booms and decrease sharply during recessions. On the other hand, the interest rate and the trade balance are countercyclical. Moreover, the present analysis indicates that the real effective exchange rate and the inflation rate have different cyclical behaviors. From table 2.3, it can be noted that tax revenue is generally more volatile than government spending and its main components. The real effective exchange rate, public investment and private investment are very volatile, while other macroeconomic aggregates have standard deviations comprised between 0.41 and 2.33.

Table 2.3: Cyclical components statistics

	United States		**United Kingdom**	
Variables[a]	Std.dev	Correlation with output	Std.dev	Correlation with output
Government non-wage consumption	2.39	-0.20	2.29	0.12
Public investment	2.87	0.19	7.19	0.26
Government wage consumption	0.93	-0.05	2.35	-0.31
Government spending	1.33	0.03	2.85	0.21
Tax revenue	10.41	0.69	4.66	0.26
Output	1.48	1.00	1.50	1.00
Private consumption	1.17	0.90	1.52	0.85
Private investment	6.60	0.90	4.68	0.83
Trade balance	0.41	-0.50	0.83	-0.28
Real effective exchange rate	3.67	-0.27	4.65	0.04
Inflation rate	1.14	0.20	2.33	-0.22
Interest rate	1.30	0.31	1.45	0.24
Private wages	0.89	0.54	1.65	0.45
Employment rate	0.78	0.63	0.64	0.59

[a] The cyclical components are obtained by detrending each series by the Hodrick-Prescott filter with $\lambda = 1600$.

2.5 Empirical Analysis

This section presents the results from the empirical analysis. Before proceeding with the VAR estimation, we first have to check whether the baseline model and the alternative specifications are correctly specified. Different specification tests are performed, including residual autocorrelation, residual normality and cointegration tests. We then present the results of the VAR estimation based on the dynamic effects of shocks to fiscal policy components on the macroeconomic aggregates. We interpret the results of the orthogonalized impulse response functions and the variance decomposition analysis. The figures show the responses of the endogenous variables to a one standard deviation shock to tax revenue and government spending components[10]. The impulse response functions are reported for a horizon of five years with the 68 percent confidence interval[11]. The results of the variance decomposition analysis are reported for the first three years following the structural shocks. In addition, we estimate the effects of total government spending shocks on the macroeconomic aggregates to see whether aggregation is relevant or misleading. We finally check whether the results are sensitive to the inclusion of the global oil price as a critical exogenous variable. Subsection 2.5.1 presents the results of the specification tests and subsection 2.5.2 the results of the VAR estimation. Finally, subsection 2.5.3 discusses the obtained findings and their implications for the analysis of fiscal policy.

2.5.1 Specification Tests

The first step is to select the appropriate number of lags for the baseline VAR model and the alternative specifications. For this purpose, we consider three different criteria (AIC, HQIC and BIC) and refer to the residual autocorrelation test conclusions. Tables A.2.4.1 and A.2.4.2 present the results of the lag length selection and specification tests. The three criteria usually select

[10] The impulse responses are symmetrical, so an expansionary or contractionary shock yields the same absolute values.

[11] 68% error bands are commonly used in the VAR literature (e.g., Giordano et al., 2007; Caldara and Kamps, 2008; Mountford and Uhlig, 2009). Although it is a common practice, there is no formal theoretical justification for this choice. Sims and Zha (1999) pointed out that error bands corresponding to 0.68 probability are often more useful than 0.95 bands since they provide a measure of shape uncertainty and a more precise estimate of the true coverage probability. We use the 16th and 84th percentiles of the distribution of impulse responses to follow the literature and facilitate the comparison of responses between model specifications.

two lags for the United Kingdom and between one and four lags for the United States. We need to ensure that there is no residual autocorrelation in the reduced VAR form for the corresponding number of lags selected, which is a fundamental condition for the inference. For this purpose, we perform the Breusch-Godfrey Lagrange Multiplier test to check whether the residuals are serially correlated when using one, two, three and four lags. The results indicate that the test conclusion is sensitive to the number of lags used. For the United Kingdom, no serial correlation is detected in the baseline VAR model and in the alternative specifications when using two lags. In contrast, the null hypothesis of no serial correlation is often rejected for the United States when using two lags. As a result, the number of lags is set to two, three or four, depending on the model specification, when they provide serially uncorrelated residuals[12]. We also carry out the residual normality test to check whether the residuals are normally distributed. The test generally rejects the null hypothesis of normal distribution for both countries. Although normality of the residuals is not required for the validity of hypothesis tests related to VAR models, non-normality may suggest nonlinear relationships between the variables and potential existence of structural change (Lütkepohl, 2011). Models that can incorporate regime changes and nonlinearities, such as Markov Switching and Threshold VAR could be relevant for examining such patterns. For comparison purposes, we follow most of the empirical literature using linear models to examine the relationships between fiscal and economic variables.

The series are then analysed to detect possible cointegration relations among them. Johansen procedure (Johansen, 1995) is performed within the vector error-correction model (VECM) representation of the VAR model to check whether the series are cointegrated. The order of VECM is one less than the corresponding VAR model and is therefore equal to one for the United Kingdom, and varies between one and three, depending on the model specification, for the United States. The results of the Johansen cointegration test with constant and linear trend are presented in table A.2.5.1. They all indicate that the series are cointegrated and that one or more cointegration relationships are present in the different model specifications. Therefore, the estimation of

[12] Several specifications do not provide serially uncorrelated residual regardless of the number of lags used. However, the impulse response functions generally yield very similar results to those of the baseline model and thereby do not seem affected by possible misspecification bias. For these specifications, we choose the number of lags according to HQIC or the number of lags corresponding to the highest p-value.

VAR models in levels provides consistent estimates (Sims et al., 1990; Lütkepohl and Reimers, 1992). Since the cointegration structure is unknown and we want to assess the short-run and medium-run effects of discretionary fiscal policy shocks, we prefer to use VAR models rather than VECMs. The VECM approach is also less appropriate when disaggregated time series are used, as it becomes more difficult to define cointegration relations among them.

2.5.2 Empirical Results

The empirical analysis is carried out for evaluating the effects of shocks to government non-wage consumption, government wage consumption, public investment and tax revenue. The obtained results reveal that the disaggregation of fiscal policy matters since each fiscal instrument implies different transmission channels and effects on the real economy[13]. There are some differences in the obtained results for the United Kingdom and the United States. This could be explained on the grounds that the United Kingdom shares some common features with European continental economic models, with a taxation and spending system comparatively more devoted to the welfare state than the United States. The results of the analysis are presented in subsections 2.5.2.1 to 2.5.2.6. Figures 2.7 to 2.22 show the impulse response functions of macroeconomic aggregates to shocks to tax revenue and government spending components. Tables 2.4 and 2.5 report the results of the variance decomposition analysis. For the case of total government spending, figures A.2.6.1 to A.2.6.4 display the impulse response functions and tables A.2.6.1 and A.2.6.2 contain the results of the variance decomposition analysis. Tables A.2.7.1 to A.2.7.4 provide additional details on the results described in this section.

2.5.2.1 The Dynamic Effects of Government Non-wage Consumption Shocks

The empirical analysis reveals that increases in the non-wage component of government consumption have contractionary effects on the United States economy. After a government non-wage consumption shock, tax revenue decreases sharply, indicating a deficit financed spending. As regards the national

[13] In the analysis, the various model specifications generally yield very similar results to those of the baseline model, with only a few small differences in magnitude of the impulse responses. As a robustness check, we have estimated a variant of the presented models by including the global oil price as a critical exogenous variable to control for global supply and demand effects. Overall, the results remain very similar to those of the original model specifications.

accounts, the decline in output is accompanied by a persistent fall in private consumption and private investment. The initial increase in aggregate demand after a fiscal expansion is more than offset by the crowding out effect in the private sector. Turning on the monetary variables, the interest rate and inflation decrease persistently, which can be justified by the decline in aggregate demand. The negative response of inflation has also been found in studies using aggregate spending data like Fatas and Mihov (2001) and Mountford and Uhlig (2009). In the labor market, employment declines steadily, while private wages do not react after a government non-wage consumption shock. The decline in aggregate demand can be partly rationalized by the fall in employment. In relation to the open economy variables, the real effective exchange rate depreciates slightly, while net exports decline slightly before increasing insignificantly after three quarters. In a relevant work but for aggregate spending shocks, Monacelli and Perotti (2010) find that government spending shocks lead to a real depreciation and a deterioration of the trade balance in the United States. However, the comparison between these studies is not straightforward since the fiscal policy variables used in the analysis are not the same.

We proceed with the description of the impulse response functions of the United Kingdom macroeconomic aggregates to government non-wage consumption shocks. After a positive innovation, tax revenue increases insignificantly. An unexpected increase in government non-wage consumption has contractionary effects on the real economy by crowding out private consumption and private investment. The negative response of the output is consistent with the finding of Ramos and Roca-Sagales (2008) for the United Kingdom, although these authors use a more aggregated spending variable as a policy instrument. In the money market, inflation increases temporarily after two quarters, while the interest rate does not react. The positive response of inflation can be justified by its countercyclical behavior. Turning on the labor market variables, employment increases initially before declining insignificantly after one year, while private wages do not react after an expansion of government non-wage consumption. Nevertheless, the initial slight increase in employment is not sufficient to offset the decline in aggregate demand due to lower private activity. Finally, a government non-wage consumption shock leads to a slight real appreciation and an improvement of the trade balance. However, it can be noted that the deviation of the real effective exchange rate from its trend is mostly insignificant across the entire impulse response horizon.

Figure 2.7: Impulse response functions to a government non-wage consumption shock (Baseline model, United States)

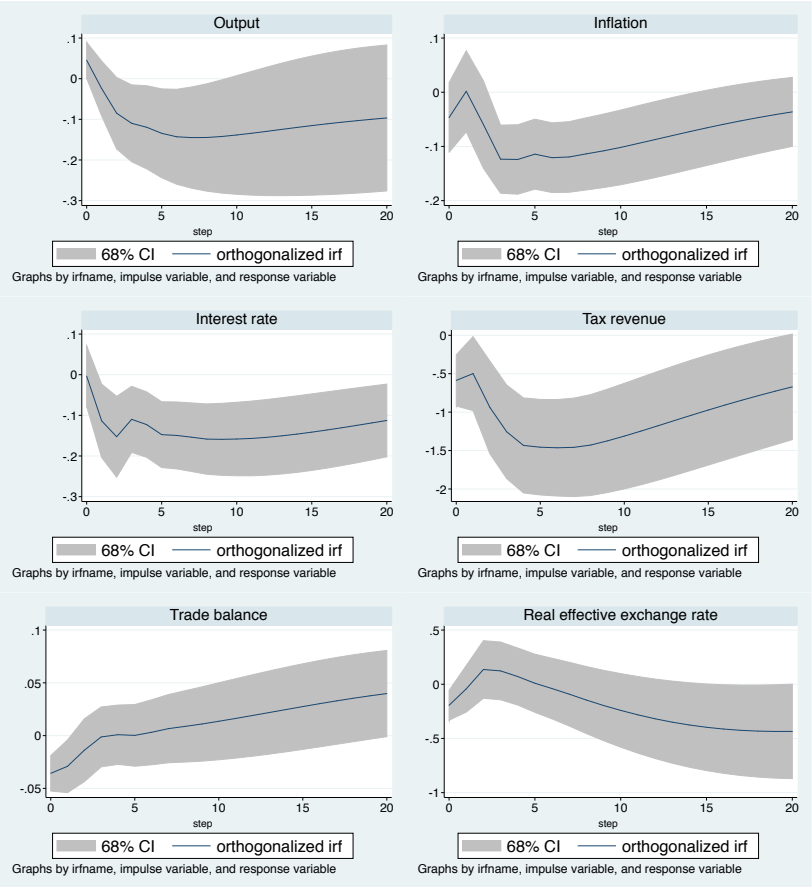


Figure 2.8: Impulse response functions to a government non-wage consumption shock (Alternative specifications, United States)

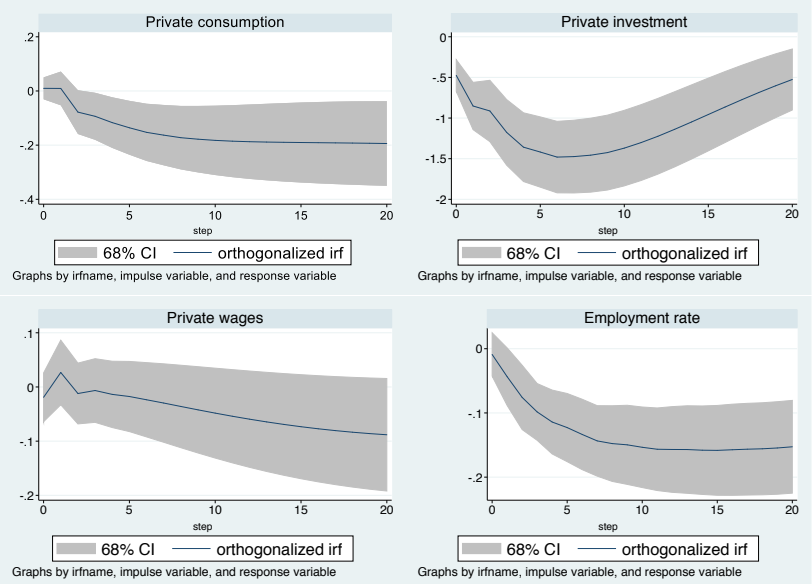


Figure 2.9: Impulse response functions to a government non-wage consumption shock (Baseline model, United Kingdom)

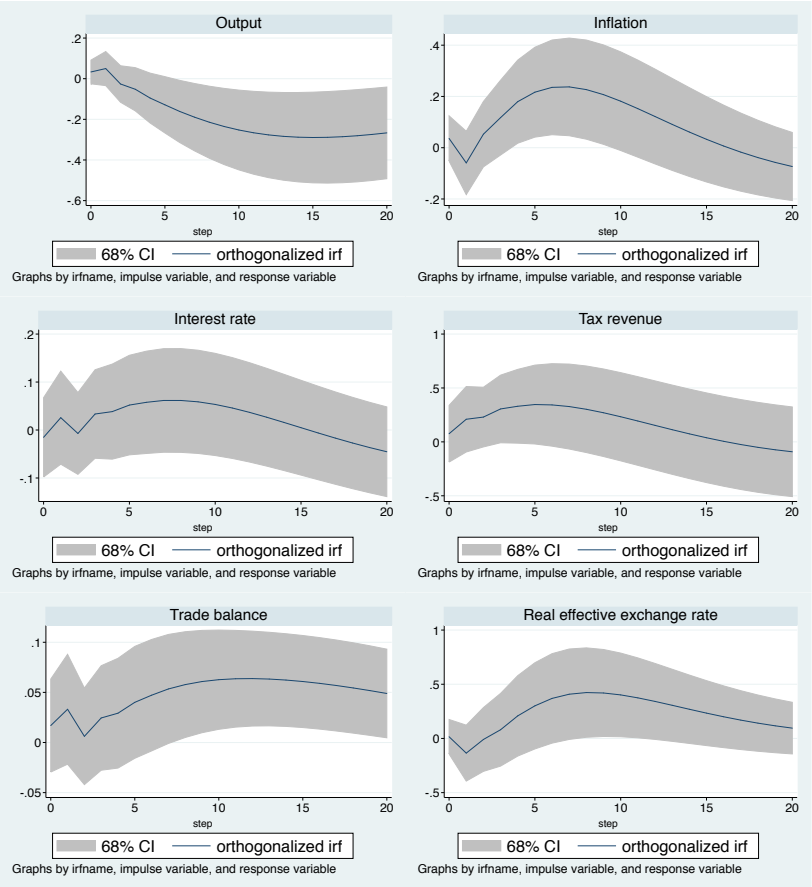
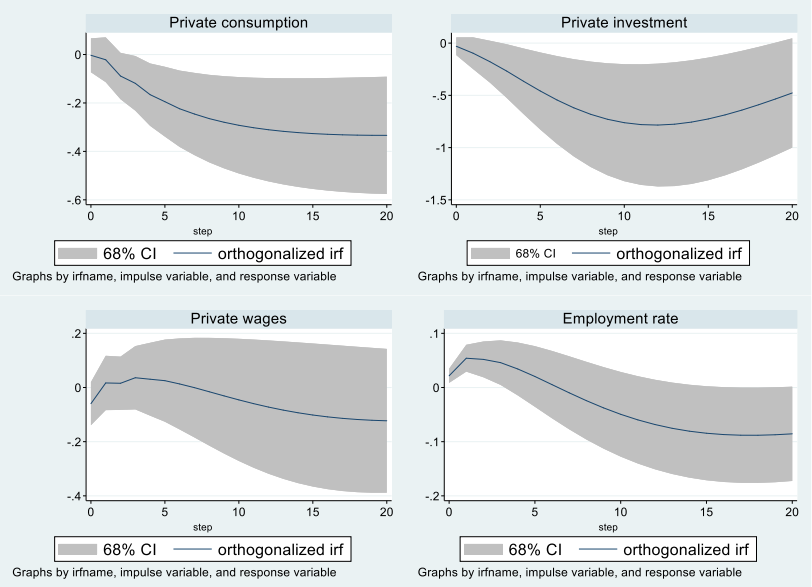


Figure 2.10: Impulse response functions to a government non-wage consumption shock (Alternative specifications, United Kingdom)



2.5.2.2 The Dynamic Effects of Government Wage Consumption Shocks

The empirical analysis reveals that government wage consumption shocks have a mostly insignificant effect on the output in the United States. After an expansionary shock, tax revenue does not react significantly. As regards the national accounts, private consumption and private investment decline steadily in response to an expansion of government wage consumption. In the money market, inflation declines during approximately three years, while the interest rate increases initially before declining after one year. The response of inflation is a little counterintuitive as we would expect higher wage costs to lead to higher aggregate price level. In the labor market, a government wage consumption shock leads to spillovers on the private sector average wage, inducing a negative labor demand effect and thus a sharp decline in employment. Despite the increase in private wages, private consumption falls steadily. The responses of private investment and labor market variables are consistent with Bermperoglou et al. (2017) for the United States. Their theoretical framework shows that public wage policies could be expansionary only if the increases in wages are associated with the production of public goods that strongly complements private consumption. In other words, public wage policies can have crowding in effect on private consumption depending on the complementarity of the latter with the public good in the aggregate consumption bundle. However, we can reasonably assume that the complementarity between them is weak at the government level. This means that the wage spillover in the private sector might predominate, thus leading to a decline in employment and private activity. Finally, an increase in government wage consumption implies a real appreciation during two years, although it does not have a significant impact on net exports.

In the United Kingdom, after a government wage consumption shock, the response of tax revenue is positive on impact before turning insignificant. Public wage shocks lead to spillover effects on the private sector wage, inducing a negative labor demand effect and a steady decline in employment. At the same time, the increase in private wages induces a temporary positive response of private consumption, which results in a slight increase in output on impact. Nevertheless, the initial positive effect on economic growth is mitigated by the decline in employment over time. Moreover, our findings indicate that private investment does not react after an expansion of government wage consumption. To the best of our knowledge, no other previous study has examined the effects of shocks to government wage consumption on the United Kingdom economy.

Figure 2.11: Impulse response functions to a government wage consumption shock (Baseline model, United States)

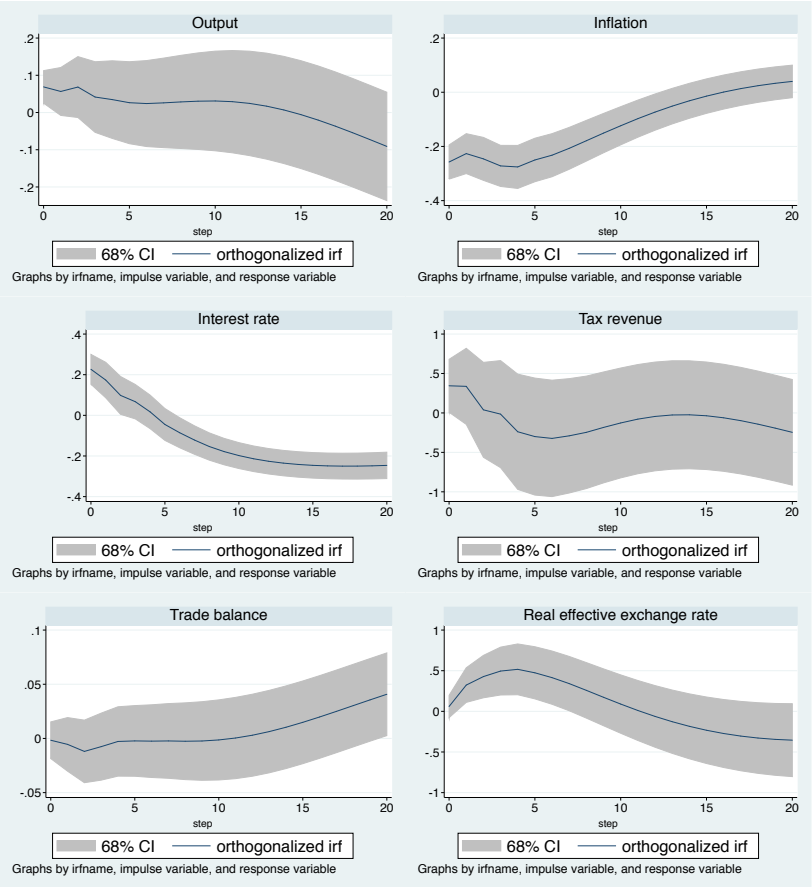


Figure 2.12: Impulse response functions to a government wage consumption shock (Alternative specifications, United States)

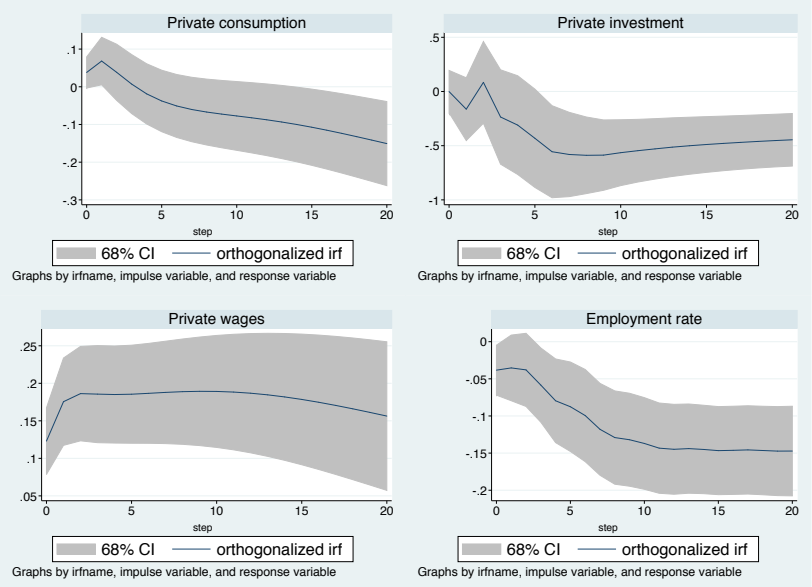


Figure 2.13: Impulse response functions to a government wage consumption shock (Baseline model, United Kingdom)

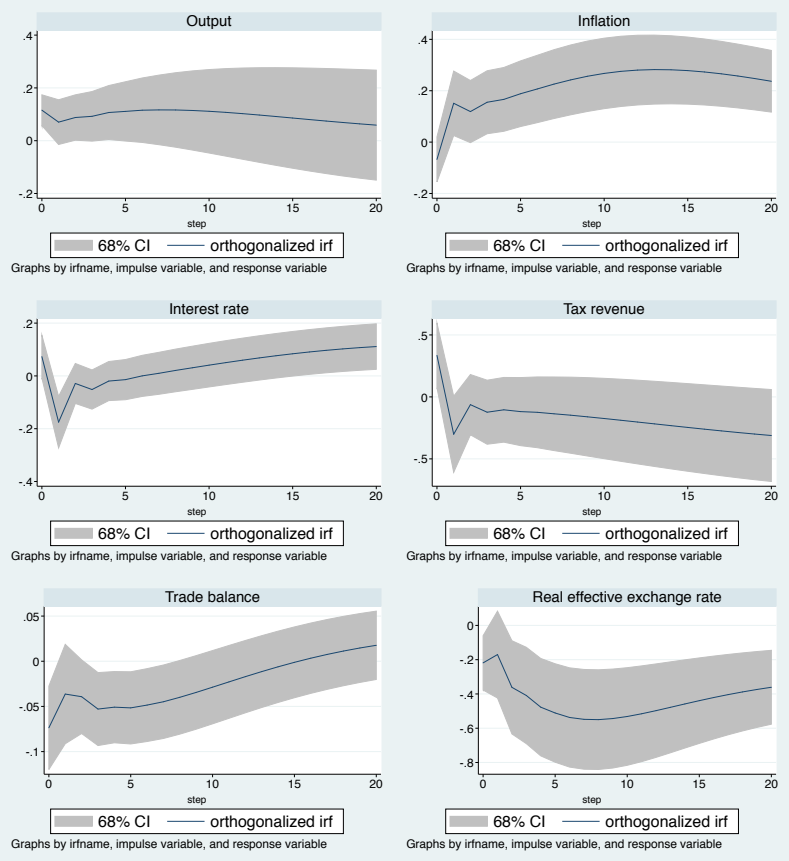
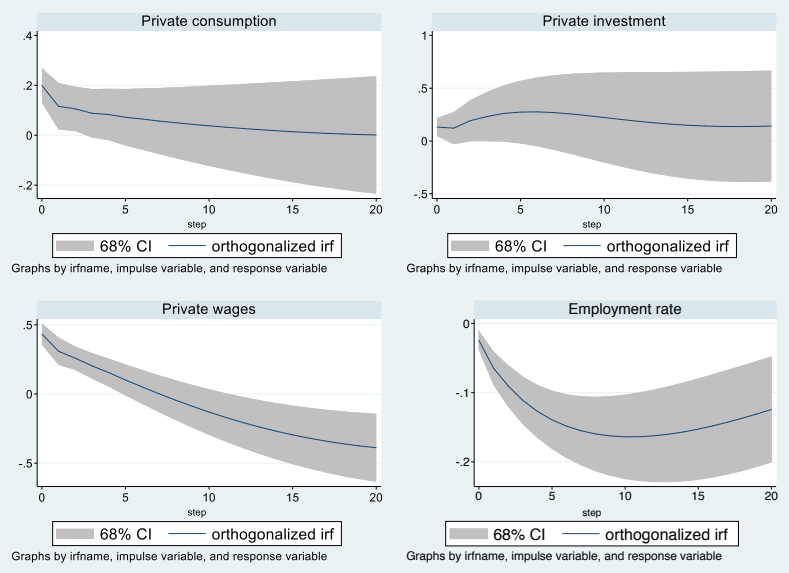


Figure 2.14: Impulse response functions to a government wage consumption shock (Alternative specifications, United Kingdom)



In a similar framework, Giordano et al. (2007) and Tenhofen et al. (2010) find that an increase in public sector wages has weak effects on the output in Italy and Germany. In the money market, the interest rate declines initially before rising slightly after two years, while inflation increases steadily. Finally, an unexpected increase in government wage consumption leads to a sharp depreciation of the real effective exchange rate and a decline in net exports during two years. The deterioration of the trade balance suggests that the loss of international competitiveness caused by rising prices and labor costs could exceed the competitiveness gain resulting from the real depreciation.

2.5.2.3 The Dynamic Effects of Public Investment Shocks

In the United States, after a public investment shock, tax revenue increases initially before decreasing sharply after two quarters. An expansion of public investment leads to an increase in output during approximately three quarters. However, the response of output becomes slightly negative after one year. Private consumption increases during one year, while private investment is crowded out with a minimum of one percent after three years. These findings suggest that after the initial expansion of economic activity, the crowding out effect in the private sector predominates, thus leading to a slight decline in economic growth. In a relevant work, Afonso and Aubyn (2018) find that public investment shocks imply an increase in output by having a crowding in effect on private investment in the United States. One possible explanation for these different findings could be that these authors use a different measure of public and private investment by defining them as general government gross fixed capital formation and gross fixed capital formation of the private sector. In the money market, the interest rate and inflation increase initially in response to improving economic conditions, before declining slightly and persistently after approximately one year. In the labor market, private wages increase steadily and employment is temporarily stimulated, although it declines slightly after six quarters. The initial positive response of labor market variables can be explained by the output dynamics. The observed rise in private wages might reflect higher productivity and can be justified by the increase in labor demand, resulting from expanded output. The short-run response of labor market variables is in line with Pappa (2009) for the United States. Finally, a public investment shock implies a slight real depreciation, with net exports initially falling and then rising very little after three quarters. However, it can be noted that the deviations from their trends are mostly insignificant across the entire impulse response horizon.

Figure 2.15: Impulse response functions to a public investment shock (Baseline model, United States)

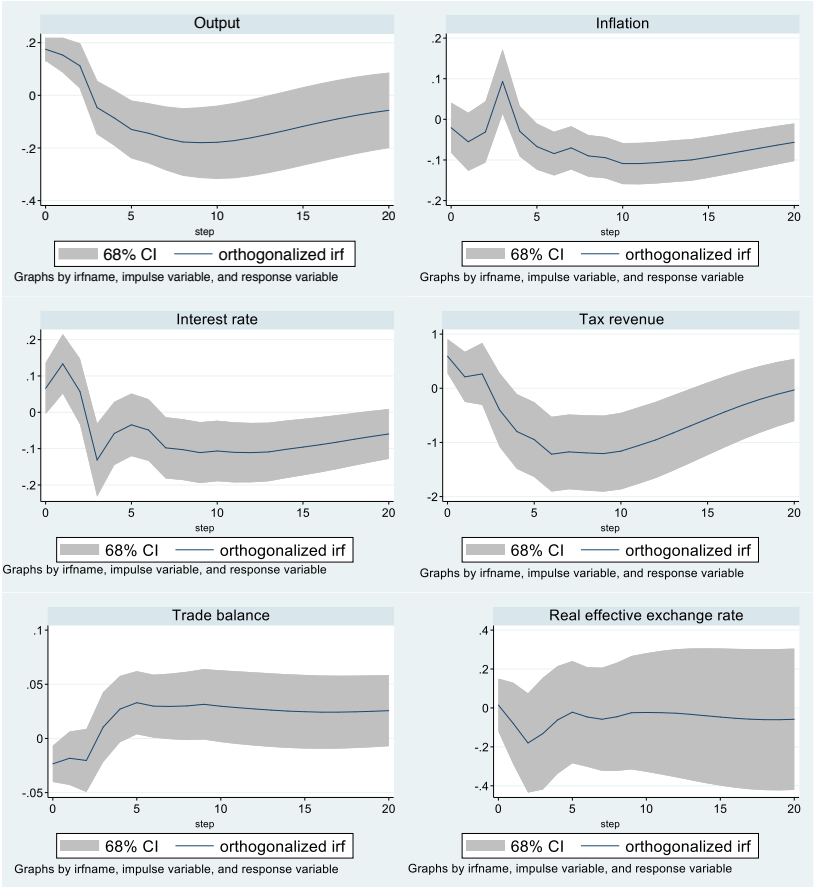


Figure 2.16: Impulse response functions to a public investment shock (Alternative specifications, United States)

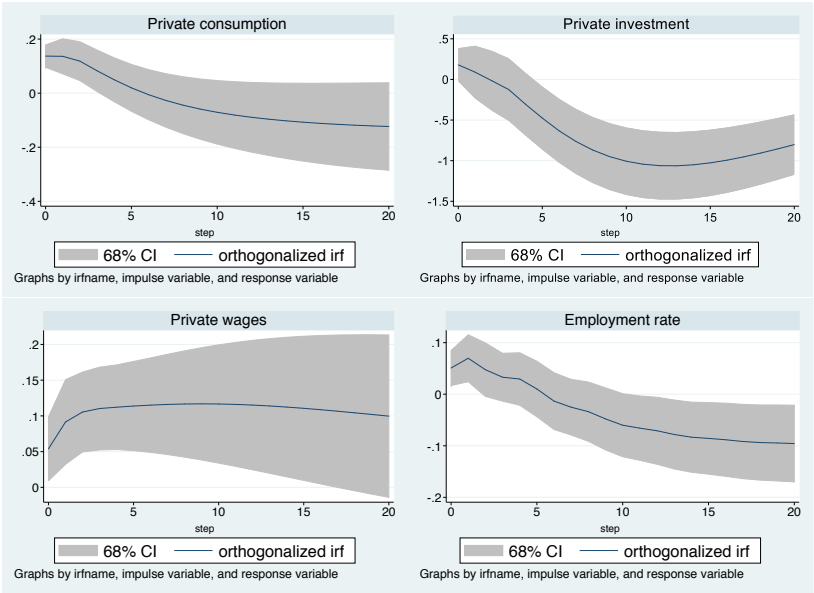


Figure 2.17: Impulse response functions to a public investment shock (Baseline model, United Kingdom)

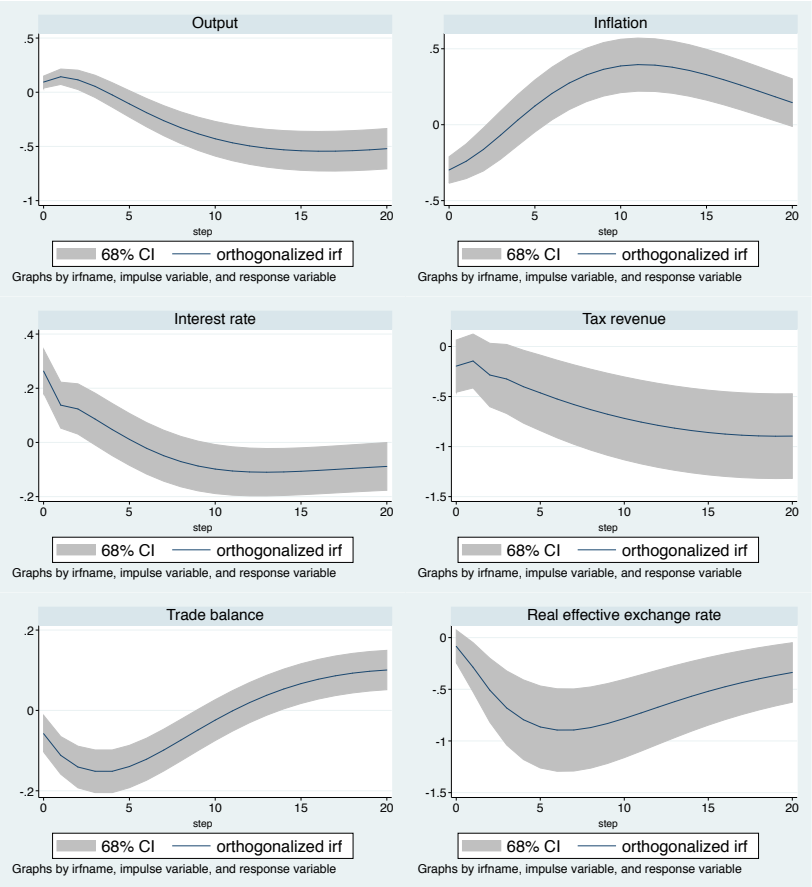
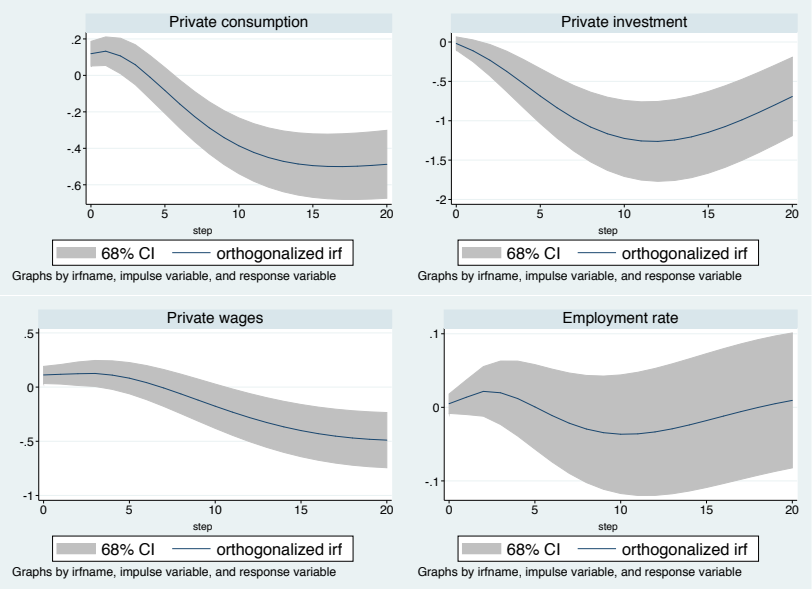


Figure 2.18: Impulse response functions to a public investment shock (Alternative specifications, United Kingdom)



In the United Kingdom, an unexpected increase in public investment implies a steady decline in tax revenue, which can be interpreted as a deficit financed spending. After a positive innovation, the output declines after approximately one year with a minimum of 0.5 percent. Private consumption and private investment are strongly crowded out, which can explain the decline in economic growth. The negative response of tax revenue can be justified by its countercyclical behavior. Our findings as regards the response of output and private investment are consistent with Afonso and Aubyn (2018) for the United Kingdom. Ramos and Roca-Sagales (2008) also find a negative effect of public investment increases on the output. The response of the interest rate is initially positive before turning slightly negative after five quarters, while the response of inflation follows exactly the opposite dynamics. The sharp decline in private investment may be partly rationalized by the initial rise in interest rates, which increases the cost of borrowing. In relation to the labor market variables, private wages decline after approximately six quarters, while the level of employment does not react. Moreover, a public investment shock induces a sharp real depreciation and a deterioration of the trade balance during two years.

2.5.2.4 The Dynamic Effects of Tax Revenue Shocks

The impulse response functions of macroeconomic aggregates to a contractionary tax revenue shock are similar in the baseline model when using different components of government spending[14]. In the United States, after a positive innovation, government non-wage consumption and public investment decline, which can be interpreted as a deficit reducing tax increase policy. On the other hand, the response of government wage consumption is initially slightly negative before turning positive after approximately two years. An unexpected increase in tax revenue leads to a decline in output with a minimum of 0.2 percent after ten quarters. The decline in economic growth is accompanied by a temporary fall in private consumption and private investment. The negative impact on private activity can be explained by the reduction in household disposable income. These findings are generally consistent with Blanchard and Perotti (2002), Mountford and Uhlig (2009) and Romer and Romer (2010) for the United States. In the money market, inflation falls steadily, while the response of the interest rate is positive before turning slightly negative after ten quarters.

[14] The impulse response functions are those of the baseline model specification with government non-wage consumption.

Figure 2.19: Impulse response functions to a tax revenue shock (Baseline model, United States)

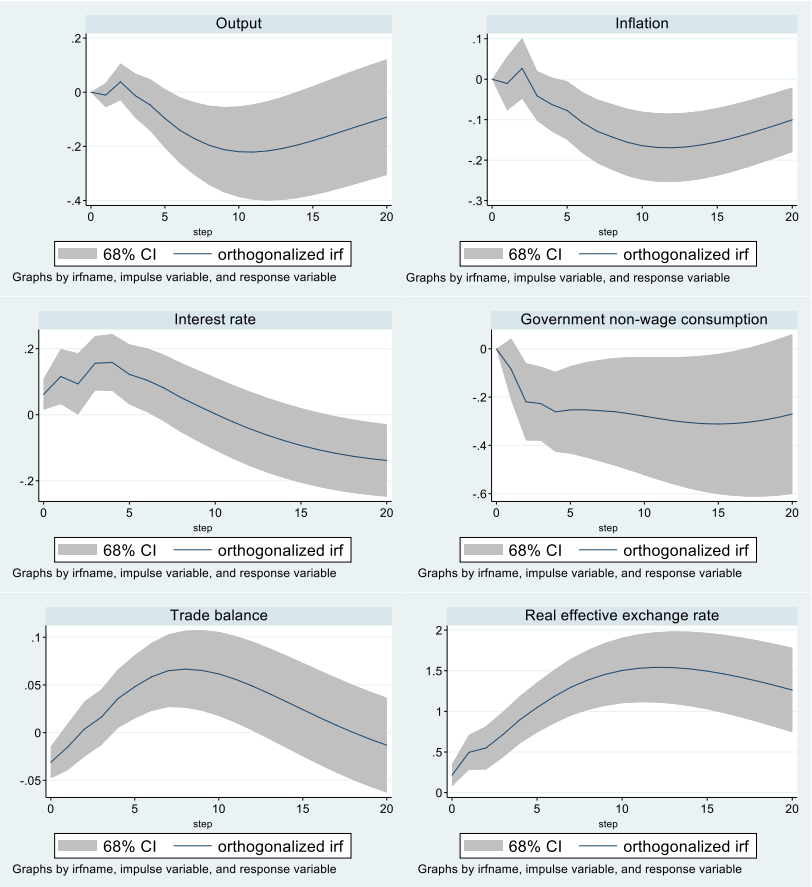


Figure 2.20: Impulse response functions to a tax revenue shock (Alternative specifications, United States)

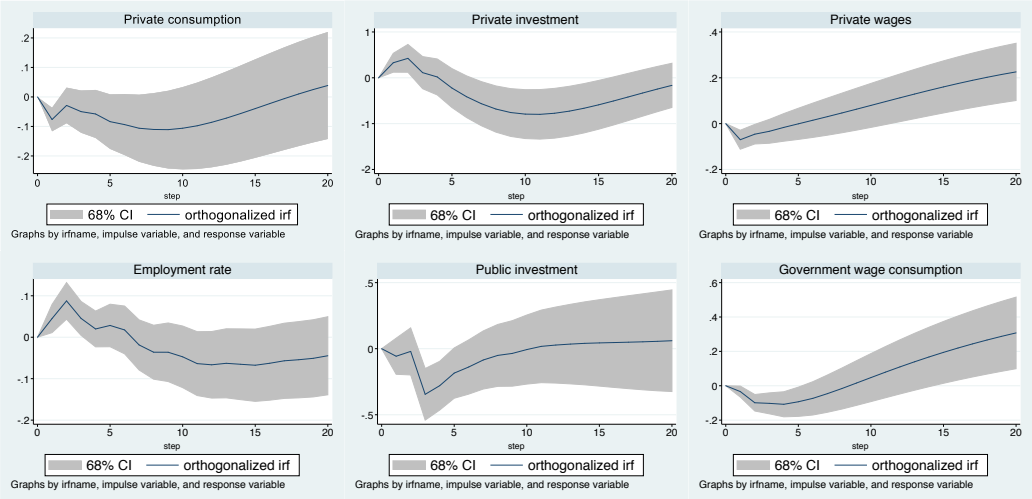


Figure 2.21: Impulse response functions to a tax revenue shock (Baseline model, United Kingdom)

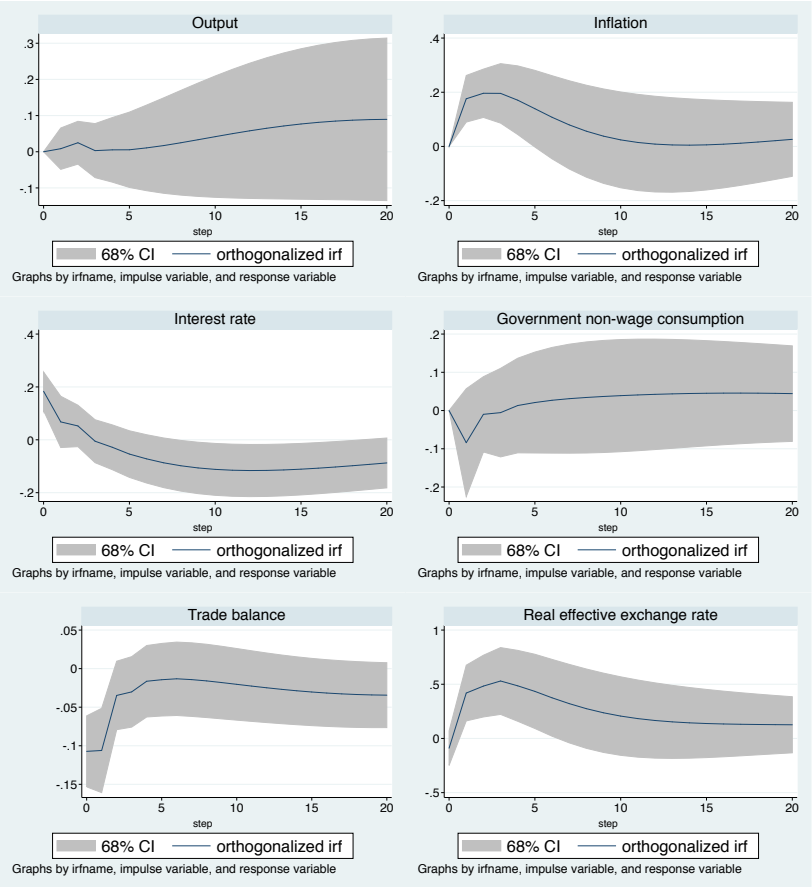
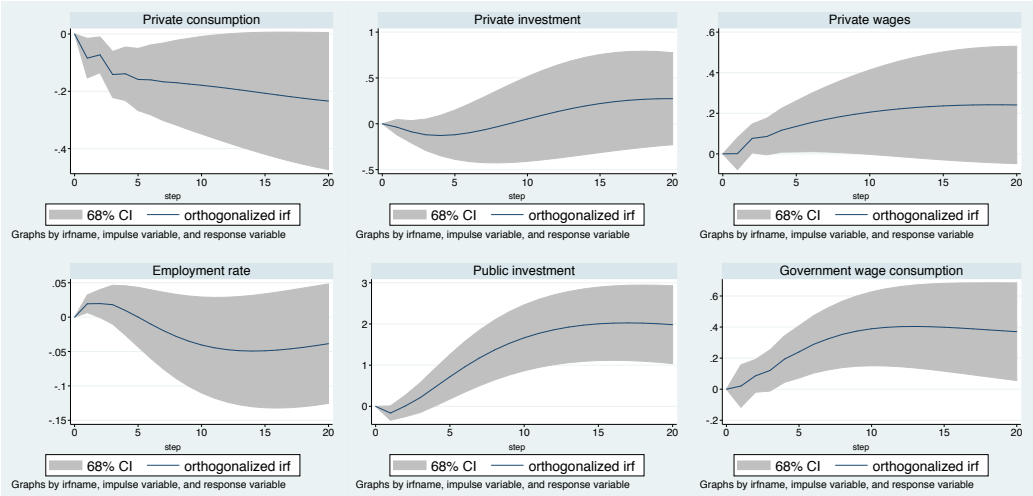


Figure 2.22: Impulse response functions to a tax revenue shock (Alternative specifications, United Kingdom)



The latter result is counterintuitive as we would expect an increase in taxation to lead to lower prices and interest rates, due to the reduction of the demand for money. Nevertheless, the positive response of the interest rate is consistent with the findings of Caldara and Kamps (2008) and Mountford and Uhlig (2009). The response of private wages is initially negative before turning positive after two years, while employment increases slightly during one year. The temporary increase in employment can be rationalized by the government action. The government might use tax revenue to create new jobs in the public sector, thus increasing public employees that represent an important portion of total employees in the United States. Finally, an unanticipated increase in tax revenue leads to a sharp real appreciation and an improvement of the trade balance.

The empirical results reveal that tax revenue shocks have little distortionary effects on the United Kingdom economy. An unexpected change in tax revenue has different effects on the government spending components. The response of government non-wage consumption is not significant, which can be interpreted as a deficit reducing tax increase policy. On the contrary, government wage consumption and public investment increase steadily after a tax revenue shock, which can be interpreted as tax financed spending policy. Tax revenue expansions have mostly insignificant effects on the output and private investment. The government relies on taxation to finance the welfare state, and thus, heavily depends on tax revenues. If an increase in government spending in welfare is financed by increases in taxes, some people are worse off from the tax increase, but others will increase their spending due to higher welfare payments. As a result, there may not be an overall fall in spending, which could keep aggregate demand unchanged and thus partly explain the ineffectiveness of tax revenue changes in the United Kingdom. This finding is consistent with Perotti (2005), while it contrasts with the negative effect of tax increases on the output found by Ramos and Roca-Sagales (2008). In addition, a tax revenue shock leads to a decline in private consumption, which can be rationalized by reduced disposable income caused by increased taxation. The responses of monetary variables are characterized by a temporary rise in the interest rate and the aggregate price level. Turning on the labor market variables, private wages increase slightly, while employment does not react. The increase in wages can be justified on the grounds that they are defined as gross wages, which include labor taxes and social contributions. Finally, the temporary real appreciation is accompanied by a deterioration of the trade balance during two quarters. A stronger currency makes exports less attractive and thus decreases net exports.

2.5.2.5 The Dynamic Effects of Government Spending Shocks

To investigate whether aggregation is important or misleading, we estimate the effects of government spending shocks on the macroeconomic aggregates. The corresponding impulse response functions are reported in figures A.2.6.1 to A.2.6.4. In the United States, a positive shock to government spending leads to a sharp decline in tax revenue. The output and private consumption increase temporarily, while private investment is strongly crowded out. In comparison with the analysis of disaggregated government spending shocks, the crowding out effect on private investment does not predominates and the real economy is temporarily stimulated. In the money market, the interest rate and inflation decline significantly. These findings are generally consistent with Mountford and Uhlig (2009). Turning on the labor market variables, private wages increase during two years, while employment declines steadily. Moreover, a positive innovation leads to a real depreciation and an improvement of the trade balance after one year. In the United Kingdom, a government spending shock causes a steady decline in tax revenue. The responses of output and private consumption are positive during one year before turning negative. In contrast, private investment is crowded out. In relation to the monetary aggregates, the effect of an expansion of government spending on the interest rate is positive initially before turning insignificant after two quarters. The response of inflation is initially negative before turning positive after one year. In the labor market, private wages increase during six quarters, while employment does not react. Finally, the real effective exchange rate depreciates sharply and the trade balance deteriorates during two years. The responses of open economy variables are in line with the findings of Monacelli and Perotti (2010) for the United Kingdom.

2.5.2.6 Variance Decomposition Analysis

In order to assess the relative importance of fiscal policy shocks, the variance decomposition analysis is implemented. It provides informative conclusions about the effectiveness of the respective policies. The results are presented in tables 2.4 and 2.5 for the first three years following the structural shocks.

In the United States, government non-wage consumption shocks have a significant contribution to the variability of tax revenue. In contrast, the shares of the variance of tax revenue resulting from government wage consumption and public investment shocks are modest. In the United Kingdom, tax revenue

is little sensitive to unexpected changes in the components of government spending. On the other hand, the contribution of tax revenue shocks to the variability of government spending components is modest in both countries. In the United States, government wage consumption shocks explain a meaningful part of the variability of the interest rate and inflation. However, the shares of fluctuations in monetary variables explained by changes in the other components of fiscal policy are moderate. In the United Kingdom, public investment shocks explain a significant part of the variability of the interest rate and inflation.

Public investment shocks explain a meaningful part of the variability of the output in both countries. However, the output is little sensitive to innovations in tax revenue and in the components of government consumption. In the United States, government non-wage consumption and public investment shocks explain a significant part of the variability of private investment. In contrast, the share of the variance of private consumption resulting from shocks to fiscal policy components is generally small. In the United Kingdom, the contribution of government non-wage consumption and public investment shocks to the variability of private consumption and private investment increases over time. However, these national income components are little sensitive to unexpected changes in government wage consumption and tax revenue. Government wage consumption shocks explain a meaningful part of the variability of employment and private wages in both countries. In contrast, labor market variables are little sensitive to innovations in public investment and tax revenue. In the United States, the contribution of government non-wage consumption shocks to fluctuations in employment is also significant. The real effective exchange rate is highly sensitive to unexpected changes in tax revenue in the United States. However, shocks to government spending components generally have a low contribution to the variability of the real effective exchange rate and net exports. In the United Kingdom, public investment innovations explain a significant part of the variability of the real effective exchange rate and net exports. In contrast, the contribution of shocks to other fiscal instruments to their variance is modest.

The results of the variance decomposition analysis for the case of total government spending are presented in tables A.2.6.1 and A.2.6.2. They reveal that total government spending shocks generally explain a greater part of the variability of macroeconomic aggregates than shocks to the components of government spending. In the United States, the contribution of government spending shocks to the variability of the output is significant on impact and that to the variability of private investment increases progressively over time.

Table 2.4: Variance decomposition (United States)

Shock	Quarter	1	4	8	12
Government non-wage consumption shock					
y		0.485	0.853	1.544	1.783
π		0.245	1.148	3.022	4.109
r		0.001	1.740	3.185	4.724
t		1.432	2.685	5.704	7.365
tb		2.068	0.894	0.494	0.452
rer		0.923	0.342	0.225	0.509
c		0.026	0.692	1.890	2.889
i		2.741	6.778	12.710	17.308
w		0.083	0.085	0.122	0.320
e		0.033	2.443	5.697	8.391
Government wage consumption shock					
y		1.143	0.660	0.379	0.297
π		7.442	13.318	17.850	18.875
r		4.326	3.980	4.062	8.092
t		0.487	0.205	0.294	0.290
tb		0.005	0.096	0.060	0.046
rer		0.088	2.536	3.432	2.603
c		0.390	0.396	0.411	0.694
i		0.143	0.195	1.302	2.562
w		3.481	7.856	9.892	11.257
e		0.601	1.047	3.157	6.087
Public investment shock					
y		7.682	2.932	2.462	2.819
π		0.053	0.849	1.479	3.086
r		0.404	1.757	1.493	2.195
t		1.607	0.569	2.281	3.535
tb		0.873	0.562	1.134	1.403
rer		0.000	0.292	0.193	0.139
c		4.933	2.761	1.452	1.251
i		0.346	0.103	1.621	5.424
w		0.673	2.366	3.348	3.933
e		1.031	1.474	0.843	1.152
Tax revenue shock					
y		0.000	0.068	1.019	2.506
π		0.000	0.141	1.559	4.737
r		0.321	1.815	2.621	2.284
gc		0.000	1.101	2.295	3.046
gw		0.000	1.352	1.081	0.747
pi		0.000	1.090	1.405	0.963
tb		1.573	0.576	2.659	4.230
rer		1.087	5.145	15.521	26.229
c		0.000	0.424	0.778	1.097
i		0.000	0.642	0.937	2.847
w		0.000	0.552	0.366	0.868
e		0.000	1.654	0.926	1.074

Table 2.5: Variance decomposition (United Kingdom)

Shock	Quarter	1	4	8	12
Government non-wage consumption shock					
y		0.153	0.209	1.266	2.759
π		0.079	0.327	1.896	2.585
r		0.016	0.066	0.307	0.496
t		0.039	0.586	1.276	1.396
tb		0.063	0.206	0.769	1.726
rer		0.005	0.076	0.878	1.891
c		0.000	0.590	2.467	4.118
i		0.060	0.654	2.109	3.703
w		0.266	0.130	0.074	0.084
e		1.478	2.117	0.974	1.087
Government wage consumption shock					
y		1.851	1.002	1.080	1.065
π		0.279	0.992	2.109	3.879
r		0.383	1.251	0.921	0.899
t		0.779	0.657	0.542	0.602
tb		1.196	1.145	1.650	1.720
rer		0.897	1.198	2.892	4.680
c		3.833	1.860	1.134	0.777
i		1.142	0.710	0.765	0.693
w		14.046	9.714	4.879	3.300
e		1.976	7.507	11.374	13.173
Public investment shock					
y		1.338	1.690	2.883	9.179
π		5.348	2.753	3.039	6.775
r		4.869	3.787	3.063	3.494
t		0.264	0.721	2.293	4.600
tb		0.749	6.448	10.618	9.876
rer		0.135	2.565	7.371	10.853
c		1.440	1.429	2.012	6.711
i		0.023	1.324	5.361	9.776
w		0.938	1.422	0.863	1.171
e		0.076	0.290	0.171	0.361
Tax revenue shock					
y		0.000	0.021	0.016	0.060
π		0.000	1.647	1.555	1.279
r		2.329	1.320	1.321	2.023
gc		0.000	0.086	0.086	0.124
gw		0.000	0.207	1.661	3.438
pi		0.000	0.097	1.825	5.478
tb		2.527	2.538	2.069	1.913
rer		0.151	2.107	2.595	2.659
c		0.000	0.850	1.621	2.012
i		0.000	0.136	0.127	0.090
w		0.000	0.317	1.013	1.551
e		0.000	0.283	0.165	0.443

In contrast, private consumption is little sensitive to innovations in government spending. The shares of the variance of the interest rate, inflation and tax revenue explained by unexpected changes in government spending are significant after two years. In contrast, labor market and open economy variables are little sensitive to fiscal shocks. In the United Kingdom, a positive innovation has a moderate contribution to the variability of national income and its components. Government spending shocks explain a meaningful part of the variability of monetary aggregates and private wages, while their contribution to fluctuations in employment is very low. Finally, the real effective exchange rate and net exports are highly sensitive to innovations in government spending.

2.5.3 Implications of the Results for the Analysis of Fiscal Policy

The obtained results reveal that the disaggregation of government spending is important for the analysis of the transmission mechanisms and effects of fiscal policy. The expansion of government spending generally has different effects on the macroeconomic aggregates than the increase of its main components. For instance, a positive shock to government non-wage consumption induces a real depreciation in the United States, while a positive shock to government wage consumption induces a real appreciation. In contrast, an expansion of government spending implies a real depreciation. As a result, it seems essential to further disaggregate government spending and its components to uncover significant and different patterns that an aggregated analysis cannot reveal. This can be explained on the grounds that the effects of each fiscal policy instrument are not the same for every group. When a government decides to adjust a category of its spending, it may affect only one specific group of people. For instance, a decision to build a new road or bridge will give work and more income to hundreds of construction workers. Thus, a spending decision may benefit only to a small group of individuals, which would not necessarily contribute to increase aggregate employment levels. Public wage policies targeting employees that work in public education or the public health system could be expansionary because they are associated with the production of goods and services that complements private consumption (Bermperoglou et al., 2017). However, an increase in defense spending could be contractionary since it does not enhance directly the utility of households (Perotti, 2014). Depending on the political orientations and goals of the policymakers, a tax cut could affect more the middle class and less the wealthier upper class. Therefore, the aggregation of government spending into one single fiscal instrument can lead to an important loss of information for the analysis of fiscal policy.

2.6 Conclusions and Policy Implications

This chapter provides a detailed empirical examination on the composition of fiscal policy and its transmission mechanisms for two Anglo-Saxon countries, the United States and the United Kingdom, over the period 1964-2017. The review of the empirical literature makes it clear how the quantitative and qualitative response of key macroeconomic aggregates are difficult to reconcile, due to the differences in the specification and the lack of comparability of fiscal policy experiments. We propose a structural VAR model based on a novel specification, including all relevant macroeconomic variables in the transmission mechanisms of fiscal policy components in an open economy. We estimate the effects of disaggregated fiscal policy shocks on the macroeconomic aggregates. Using the recursive approach, we identify a tax revenue and a government spending component shock that rotates between (i) government non-wage consumption (ii) government wage consumption (iii) public investment.

The empirical analysis reveals that the disaggregation of fiscal policy matters since each fiscal instrument implies different transmission channels and effects on the real economy. The results show that the components of government spending generally have different effects on the macroeconomic aggregates than aggregate fiscal policy. It therefore seems essential to disaggregate government spending into its main components to uncover significant and different patterns that an aggregated analysis cannot reveal. However, as expected, the effects of government spending components on certain economic variables are weak and insignificant. The conducted analysis reveals that the components of government spending generally have smaller effects on the economic variables than aggregate fiscal policy. In addition, our findings suggest that fiscal policy can be operative, besides the interest rate channel, via an exchange rate and trade balance channels. Considering an open economy framework is therefore essential since a part of the fiscal stimulus propagates abroad through external channels. There are also some differences in the obtained results for the United States and the United Kingdom. This could be explained by the divergence between the United Kingdom and the Anglo-American economic models.

The obtained results reveal that government non-wage consumption shocks can have contractionary effects in both countries by crowding out private consumption and private investment. Government wage consumption shocks seem to have little effect on the output, but lead to spillovers on private sector

wages, that could induce a negative labor demand effect and decrease employment as a result. Public investment shocks have clear and strong expansionary short-run effects on the United States economy by increasing private consumption, private wages and employment. Nevertheless, private investment is crowded out. Our findings suggest that after the initial expansion of economic activity, the crowding out effect in the private sector predominates, thus leading to a slight decline in economic growth. In the United Kingdom, the economic slowdown is accompanied by contractionary effects on private activity. In addition, the obtained results indicate that the expansion of all government spending components increases inflation in the United Kingdom, while they reduce all inflation in the United States. Tax revenue increases lead to a decline in output and its components in the United States, while they have little distortionary effects on the United Kingdom economy.

The empirical analysis provides mixed evidence as regards the impact of government spending components on the open economy variables. Government non-wage consumption shocks have a relatively weak impact on the real effective exchange rate and lead to a slight increase in net exports. Government wage consumption shocks imply a real appreciation in the United States and a real depreciation in the United Kingdom. These movements are accompanied by a decline in net exports in the United Kingdom, while they do not react significantly in the United States. Public investment shocks lead to a real depreciation, associated with an increase in the United States net exports and a decline in the United Kingdom net exports. Finally, tax revenue increases imply a real appreciation in both countries, accompanied by an increase in the United States net exports and a decline in the United Kingdom net exports. The responses of economic variables to shocks to tax revenue and government spending components are generally difficult to reconcile with most macroeconomic theories. Thus, while we do not attempt to provide an explanation in this chapter, we believe they certainly deserve further investigation.

The results occurring from this chapter have several policy implications. First, government non-wage consumption increases could have contractionary effects on the real economy as observed in the countries and the period considered in our analysis. Our findings also indicate that, as expected, public wage policies have a greater impact on the labor market than changes in the other components of government spending, while they have a relatively small effect on the output. Moreover, government efforts to stimulate the real economy

through the increase in public investment should be accompanied by other types of macroeconomic policy instruments in order to offset the crowding out effect on private activity. The analysis of the composition of government spending seems essential to establish how different spending categories can influence macroeconomic aggregates. However, as expected, changes in the components of government spending are not by themselves capable of sufficiently improving economic conditions and other supportive policies need to be implemented jointly. Besides, the examination of tax revenue reveals different implications. In the United States, tax revenue cuts can stimulate economic activity and increase prices in the short run. In contrast, tax revenue cuts do not seem to be effective in stimulating the United Kingdom economy.

Appendix 2

A.2.1 Data Sources and Variable Definitions

United States

Government consumption: Consumption expenditures, Item 21, Table 3.1. Source: Bureau of Economic Analysis.

Public investment: Gross government investment, Item 39, Table 3.1. Source: Bureau of Economic Analysis.

Government wage consumption: Compensation of general government employees, Item 4, Table 3.10.5. Source: Bureau of Economic Analysis.

Government non-wage consumption: Government consumption minus government wage consumption.

Government spending: Government consumption plus public investment.

Output: Gross domestic product, Item 1, Table 1.1.5. Source: Bureau of Economic Analysis.

Private consumption: Personal consumption expenditures, Item 2, Table 1.1.5. Source: Bureau of Economic Analysis.

Private investment: Gross private domestic investment, Item 7, Table 1.1.5. Source: Bureau of Economic Analysis.

Private wages: Compensation of employees (wages and salaries): Private industries, Code: A132RC1Q027SBEA. Source: Federal Reserve Bank of St. Louis.

Inflation rate: GDP implicit price deflator percent change from preceding period, Item 28, Table 1.1.7. Source: Bureau of Economic Analysis.

GDP deflator: GDP implicit price deflator, Item 1, Table 1.1.9. Source: Bureau of Economic Analysis.

Real effective exchange rate: Real narrow effective exchange rate, Code: RNUSBIS. Source: Federal Reserve Bank of St. Louis.

Real interest rate: Effective federal funds rate minus inflation rate, Code: FEDFUNDS. Source: Federal Reserve Bank of St. Louis.

Employment rate: Employment rate for all persons aged between 16 and 64, Code: LREM64TTUSQ156N. Source: Federal Reserve Bank of St. Louis.

Trade balance: Net exports of goods and services as a percentage of GDP, Item 15, Table 1.1.5. Source: Bureau of Economic Analysis.

Net tax revenue: Government current receipts (Item 1) minus current transfer payments (Item 22) minus interest payments (Item 27), Table 3.1. Source: Bureau of Economic Analysis.

Global oil price: West Texas Intermediate spot crude oil price, Code: WTISPLC. Source: Federal Reserve Bank of St. Louis.

Population: Resident population plus armed forces overseas, Code: POPTHM. Source: Federal Reserve Bank of St. Louis.

Public employment: All employees: Government (covers only civilian employees; military personnel are excluded), Code: USGOVT. Source: Federal Reserve Bank of St. Louis.

Private employment: All employees: Total private industries, Code: USPRIV. Source: Federal Reserve Bank of St. Louis.

United Kingdom

Government consumption: Real government consumption of goods and services, Code: RGCGASUKQ. Source: Federal Reserve Bank of St. Louis.

Public investment: Gross fixed capital formation: Public sector. Source: Annual macro-economic database of the European Commission.

Government wage consumption: Compensation of general government employees, Code: NMXS. Source: Office for National Statistics.

Government non-wage consumption: Government consumption minus government wage consumption.

Government spending: Government consumption plus public investment.

Output: Gross domestic product, Code: UKNGDP. Source: Federal Reserve Bank of St. Louis.

Private consumption: Private final consumption expenditure, Code: GBRPFCEQDSMEI. Source: Federal Reserve Bank of St. Louis.

Private investment: Gross fixed capital formation: Private sector. Source: Annual macro-economic database of the European Commission.

Private wages: Wages and salaries: Resources, Code: RPCG. Source: Office for National Statistics.

Inflation rate: GDP implicit price deflator: Quarter on quarter previous year growth, Code: IHYU. Source: Office for National Statistics.

GDP deflator: GDP implicit price deflator, Code: GBRGDPDEFQISMEI. Source: Federal Reserve Bank of St. Louis.

Real effective exchange rate: Real narrow effective exchange rate, Code: RNGBBIS. Source: Federal Reserve Bank of St. Louis.

Real interest rate: Three-month or 90-day rates and yields: Treasury Securities (1964-1974), Code: IR3TTS01GBQ156N. Source: Federal Reserve Bank of St. Louis. Official bank rate (1975-2017) minus inflation rate, Code: IUQABEDR. Source: Bank of England.

Employment rate: Employment rate for all persons aged between 16 and 64, Code: LF24. Source: Office for National Statistics.

Trade balance: Net exports of goods and services as a percentage of GDP. Exports of goods and services (Code: GBREXPORTQDSMEI) minus imports of goods and services (Code: GBRIMPORTQDSMEI). Source: Federal Reserve Bank of St. Louis.

Net tax revenue: Compulsory social contributions (Code: ANBO) plus current receipts from taxes on income and wealth (Code: ANSO) plus current receipts from taxes on production (Code: NMYE) plus other current taxes (Code: MJBC) minus current expenditure (net social benefits) (Code: ANLY). Source: Office for National Statistics.

Global oil price: West Texas Intermediate spot crude oil price, Code: WTISPLC. Source: Federal Reserve Bank of St. Louis.

Population: Resident population: Mid-year estimates (quarterly data interpolated), Code: EBAQ. Source: Office for National Statistics.

A.2.2 Model Specifications

Table A.2.2.1: Model specifications

Specification	Endogenous variables							Period
A	g[a]	y	π	t	r	tb	rer	1964-2017
B	g	c	y	t	r	tb	rer	1964-2017
C	g	i	y	t	r	tb	rer	1964-2017
D	g	w	y	t	r	tb	rer	1964-2017
E	g	e	y	t	r	tb	rer	1964-2017[b]

[a] The government spending component (g) rotates between government non-wage consumption (gc), government wage consumption (gw) and public investment (pi).

[b] For the United Kingdom, the estimation of the model specification E covers the period 1972-2017.

Table A.2.2.2: Summary of variables

Variables	Notation
Government non-wage consumption	gc
Government wage consumption	gw
Public investment	pi
Tax revenue	t
Government spending	gs
Output	y
Inflation rate	π
Interest rate	r
Trade balance	tb
Real effective exchange rate	rer
Private consumption	c
Private investment	i
Private wages	w
Employment rate	e
Global oil price	op*

A.2.3 Results from Unit Root Tests

Table A.2.3.1: Augmented Dickey-Fuller test (Variables in levels, United States)

		Critical Values			
Variables	Test Values[a]	1%	5%	10%	P-Values
gc	-2.087	-3.472	-2.882	-2.572	0.2497
pi	-1.248	-3.475	-2.883	-3.573	0.6527
gw	-0.498	-3.473	-2.883	-2.573	0.8923
gs	-1.473	-3.474	-2.883	-2.753	0.5468
t	-2.830	-3.473	-2.883	-2.573	0.0542
y	-1.795	-3.473	-2.883	-2.573	0.3827
c	-1.704	-3.473	-2.883	-2.573	0.4290
i	-1.822	-3.472	-2.882	-2.572	0.3698
tb	-1.732	-3.472	-2.882	-2.572	0.4147
rer	-2.349	-3.472	-2.882	-2.572	0.1567
π	-2.060	-3.473	-2.883	-2.573	0.2607
r	-2.156	-3.473	-2.883	-2.573	0.2227
w	-0.346	-3.472	-2.882	-2.572	0.9801
e	-1.661	-3.475	-2.883	-2.573	0.4515

[a] The series has an unit root under the null hypothesis.

Table A.2.3.2: Augmented Dickey-Fuller test (Variables in first differences, United States)

		Critical Values			
Variables	Test Values[a]	1%	5%	10%	P-Values
gc	-4.654	-3.473	-2.883	-2.573	0.0001
pi	-3.808	-3.476	-2.883	-2.573	0.0028
gw	-3.514	-3.475	-2.883	-2.573	0.0076
gs	-4.177	-3.475	-2.883	-2.573	0.0007
t	-6.420	-3.474	-2.883	-2.573	0.0000
y	-7.031	-3.474	-2.883	-2.573	0.0000
c	-6.622	-3.474	-2.883	-2.573	0.0000
i	-6.872	-3.474	-2.883	-2.573	0.0000
tb	-6.635	-3.474	-2.883	-2.573	0.0000
rer	-5.531	-3.474	-2.883	-2.573	0.0000
π	-7.305	-3.474	-2.883	-2.573	0.0000
r	-8.165	-3.474	-2.883	-2.573	0.0000
w	-5.481	-3.474	-2.883	-2.573	0.0000
e	-4.501	-3.476	-2.883	-2.573	0.0002

[a] The series has an unit root under the null hypothesis.

Table A.2.3.3: Augmented Dickey-Fuller test (Variables in levels, United Kingdom)

		Critical Values			
Variables	Test Values[a]	1%	5%	10%	P-Values
gc	-0.073	-3.474	-2.883	-2.773	0.9521
pi	-1.744	-3.475	-2.883	-2.573	0.4086
gw	-2.098	-3.475	-2.883	-2.573	0.2452
gs	-1.216	-3.474	-2.883	-2.573	0.6669
t	-1.104	-3.472	-2.882	-2.572	0.7133
y	-1.472	-3.473	-2.883	-2.573	0.5473
c	-1.078	-3.473	-2.883	-2.573	0.7238
i	-2.091	-3.473	-2.883	-2.573	0.2481
tb	-3.004	-3.472	-2.882	-2.572	0.0345
rer	-2.351	-3.472	-2.882	-2.572	0.1561
π	-1.944	-3.475	-2.883	-2.573	0.3119
r	-1.823	-3.472	-2.882	-2.572	0.3691
w	-0.447	-3.472	-2.882	-2.572	0.9020
e	-2.388	-3.484	-2.885	-2.575	0.1453

[a] The series has an unit root under the null hypothesis.

Table A.2.3.4: Augmented Dickey-Fuller test (Variables in first differences, United Kingdom)

		Critical Values			
Variables	Test Values[a]	1%	5%	10%	P-Values
gc	-5.730	-3.475	-2.883	-2.573	0.0000
pi	-4.725	-3.476	-2.883	-2.573	0.0001
gw	-3.261	-3.476	-2.883	-2.573	0.0167
gs	-5.728	-3.476	-2.883	-2.573	0.0000
t	-4.145	-3.474	-2.883	-2.573	0.0008
y	-4.001	-3.474	-2.883	-2.573	0.0014
c	-4.049	-3.474	-2.883	-2.573	0.0012
i	-5.472	-3.475	-2.883	-2.573	0.0000
tb	-6.853	-3.474	-2.883	-2.573	0.0000
rer	-6.988	-3.474	-2.883	-2.573	0.0000
π	-6.546	-3.476	-2.883	-2.573	0.0000
r	-6.898	-3.474	-2.883	-2.573	0.0000
w	-4.835	-3.473	-2.883	-2.573	0.0000
e	-3.677	-3.485	-2.885	-2.575	0.0044

[a] The series has an unit root under the null hypothesis.

A.2.4 VAR Model: Lag Length Selection and Specification tests

Table A.2.4.1: Residual autocorrelation test and lag length selection (United States)

	Residual autocorrelation[a]				Lag length selection			
Lags Specification	1	2	3	4	AIC	BIC	HQIC	No. lags selected[b]
A								
gc	0.00385	0.00010	0.16563	0.19922	3	1	1	3
pi	0.03105	0.00891	0.00686	0.39929	7	1	1	4
gw	0.01776	0.00085	0.05690	0.04172	2	1	2	3
gs	0.00181	0.00214	0.04263	0.56542	7	1	1	4
B								
gc	0.00461	0.00495	0.15388	0.03857	2	1	2	3
pi	0.00885	0.25373	0.00704	0.17684	2	1	2	2
gw	0.00004	0.00023	0.00307	0.02079	3	1	2	2
gs	0.01635	0.01966	0.03411	0.04896	2	1	2	4
C								
gc	0.01007	0.00243	0.30936	0.05461	2	1	1	3
pi	0.00474	0.00682	0.00055	0.01408	2	1	2	2
gw	0.02187	0.01531	0.03908	0.07478	3	1	2	4
gs	0.00790	0.01515	0.02985	0.02087	2	1	2	2
D								
gc	0.07486	0.07355	0.09104	0.36308	2	1	1	2
pi	0.12861	0.07759	0.00183	0.45931	2	1	2	2
gw	0.00344	0.00147	0.04087	0.01468	3	1	2	2
gs	0.06448	0.14077	0.01177	0.36090	2	1	2	2
E								
gc	0.00000	0.00000	0.21804	0.00000	5	1	5	3
pi	0.00000	0.00001	0.00409	0.00000	7	1	5	3
gw	0.00000	0.00000	0.04099	0.00000	5	1	5	3
gs	0.00000	0.00001	0.03495	0.00000	7	1	5	3

[a] Residual autocorrelation test (p-value) is based on the residuals from the reduced VAR form. Reported p-values are from the Breusch-Godfrey Lagrange Multiplier test. No serial correlation under the null hypothesis.

[b] When the optimal number of lags indicated by the criteria provides serially correlated residuals, we refer to the residual autocorrelation test conclusions to select the appropriate number of lags. In several specifications, the residuals are serially correlated regardless of the number of lags used. For these specifications, we select the number of lags according to HQIC or the highest p-value.

Table A.2.4.2: Residual autocorrelation test and lag length selection (United Kingdom)

	Residual autocorrelation[a]				Lag length selection			
Lags Specification	1	2	3	4	AIC	BIC	HQIC	No. lags selected
A								
gc	0.65895	0.53409	0.00029	0.00000	6	1	2	2
pi	0.60077	0.27624	0.00677	0.00000	6	1	2	2
gw	0.52856	0.21865	0.00261	0.00000	6	1	1	2
gs	0.32343	0.16245	0.00720	0.00000	6	1	2	2
B								
gc	0.02948	0.16575	0.03775	0.01036	2	1	2	2
pi	0.05546	0.09255	0.17927	0.00000	2	1	2	2
gw	0.04504	0.09233	0.04491	0.00013	2	1	2	2
gs	0.02099	0.11128	0.08532	0.00720	2	1	2	2
C								
gc	0.26420	0.56942	0.08118	0.00093	2	2	2	2
pi	0.18600	0.12600	0.30386	0.00000	2	2	2	2
gw	0.23099	0.24729	0.14124	0.00002	2	2	2	2
gs	0.11236	0.22995	0.37838	0.00003	2	2	2	2
D								
gc	0.88550	0.57979	0.01415	0.01160	2	1	1	2
pi	0.89548	0.25711	0.15307	0.00000	2	1	2	2
gw	0.88792	0.39144	0.05654	0.00138	2	1	1	2
gs	0.79017	0.29058	0.07950	0.01778	2	1	1	2
E								
gc	0.04123	0.95979	0.00267	0.01244	2	1	2	2
pi	0.03139	0.66836	0.01465	0.00000	2	2	2	2
gw	0.17908	0.75127	0.01877	0.00167	2	1	2	2
gs	0.01648	0.43171	0.04139	0.00179	2	1	2	2

[a] Residual autocorrelation test (p-value) is based on the residuals from the reduced VAR form. Reported p-values are from the Breusch-Godfrey Lagrange Multiplier test. No serial correlation under the null hypothesis.

Table A.2.4.3: Residual normality test

Residual Normality[a]						
	United States			United Kingdom		
Specification	Jarque-Bera test	Skewness test	Kurtosis test	Jarque-Bera test	Skewness test	Kurtosis test
A						
gc	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
pi	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
gw	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
gs	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
B						
gc	0.00000	0.00000	0.00000	0.00000	0.00025	0.00000
pi	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
gw	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
gs	0.00000	0.00000	0.00000	0.00000	0.00442	0.00000
C						
gc	0.00000	0.59682	0.00000	0.00000	0.00000	0.00000
pi	0.00000	0.68673	0.00000	0.00000	0.00000	0.00000
gw	0.00000	0.27147	0.00000	0.00000	0.00000	0.00000
gs	0.00000	0.88838	0.00000	0.00000	0.00000	0.00000
D						
gc	0.00000	0.15093	0.00000	0.00000	0.00000	0.00000
pi	0.00000	0.20466	0.00000	0.00000	0.00000	0.00000
gw	0.00000	0.18611	0.00000	0.00000	0.00000	0.00000
gs	0.00000	0.25985	0.00000	0.00000	0.00000	0.00000
E						
gc	0.00000	0.17766	0.00000	0.00000	0.00151	0.00000
pi	0.00000	0.19400	0.00000	0.00000	0.00000	0.00000
gw	0.00000	0.12539	0.00000	0.00000	0.00440	0.00000
gs	0.00000	0.36263	0.00000	0.00000	0.00402	0.00000

[a] Reported p-values are from Jarque-Bera, Skewness and Kurtosis tests. Normally distributed residuals under the null hypothesis.

A.2.5 Johansen Cointegration Maximum Eigenvalue Test

Table A.2.5.1: Johansen cointegration maximum eigenvalue test

	United States		United Kingdom	
	Hypothesized number of cointegrating vectors	**Hypothesized number of cointegrating vectors**	**Hypothesized number of cointegrating vectors**	**Hypothesized number of cointegrating vectors**
Specification	**Constant**	**Trend**	**Constant**	**Trend**
A				
gc	1	1	1	1
pi	1	2	2	2
gw	1	1	1	1
gs	1	1	3	3
B				
gc	1	1	1	1
pi	1	1	2	2
gw	2	2	1	1
gs	1	2	2	2
C				
gc	1	2	2	1
pi	1	2	3	2
gw	2	3	2	1
gs	2	2	3	3
D				
gc	1	1	1	1
pi	1	1	1	2
gw	1	1	1	1
gs	1	1	1	1
E				
gc	1	1	1	1
pi	1	1	2	1
gw	1	1	2	1
gs	1	2	2	1

A.2.6 The Dynamic Effects of Government Spending Shocks

Figure A.2.6.1: Impulse response functions to a government spending shock (Baseline model, United States)

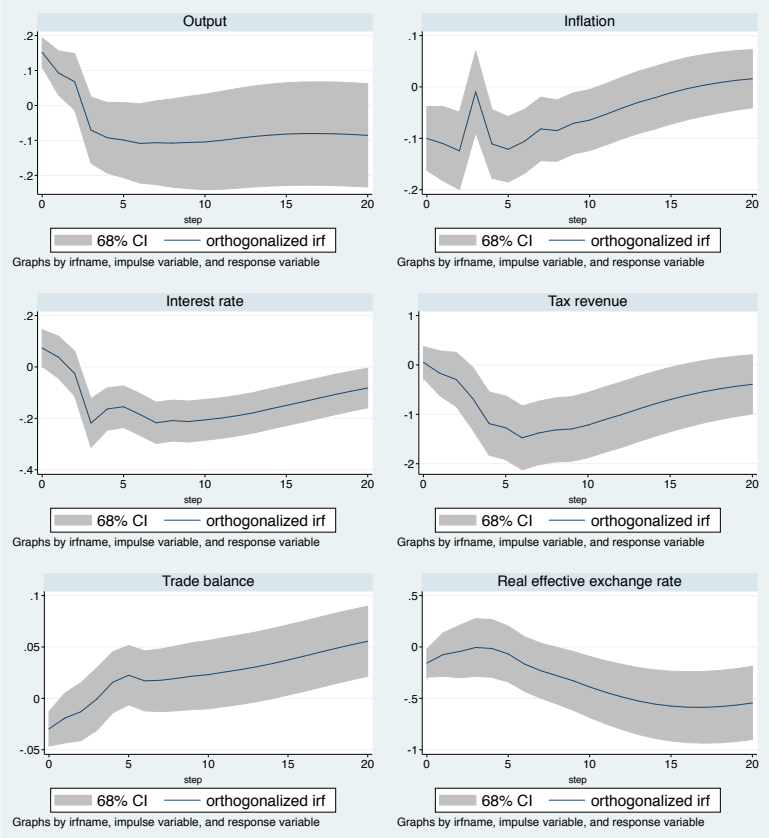


Figure A.2.6.2: Impulse response functions to a government spending shock (Alternative specifications, United States)

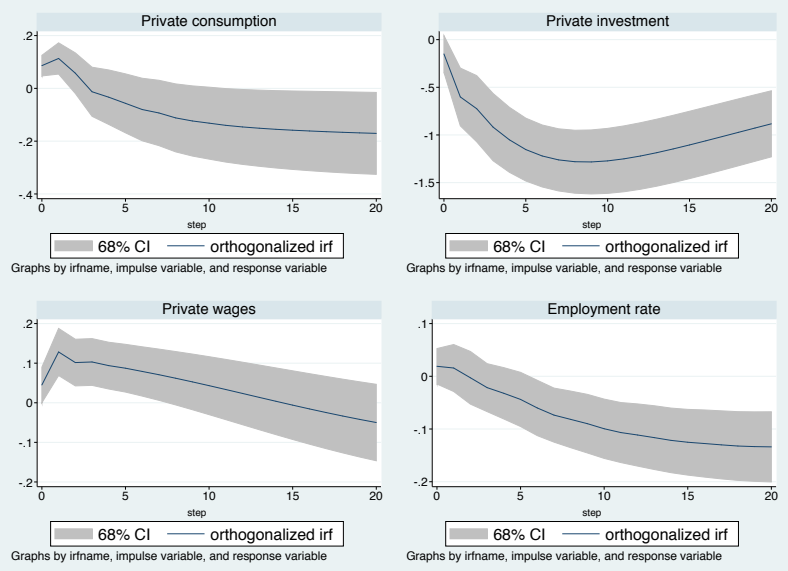


Figure A.2.6.3: Impulse response functions to a government spending shock (Baseline model, United Kingdom)

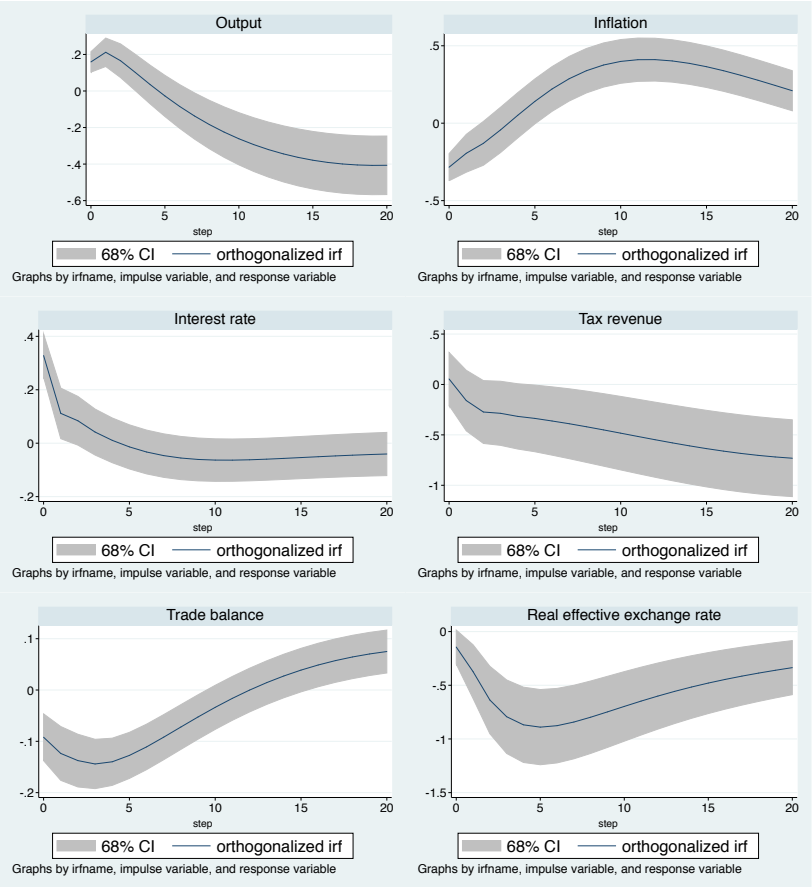


Figure A.2.6.4: Impulse response functions to a government spending shock (Alternative specifications, United Kingdom)

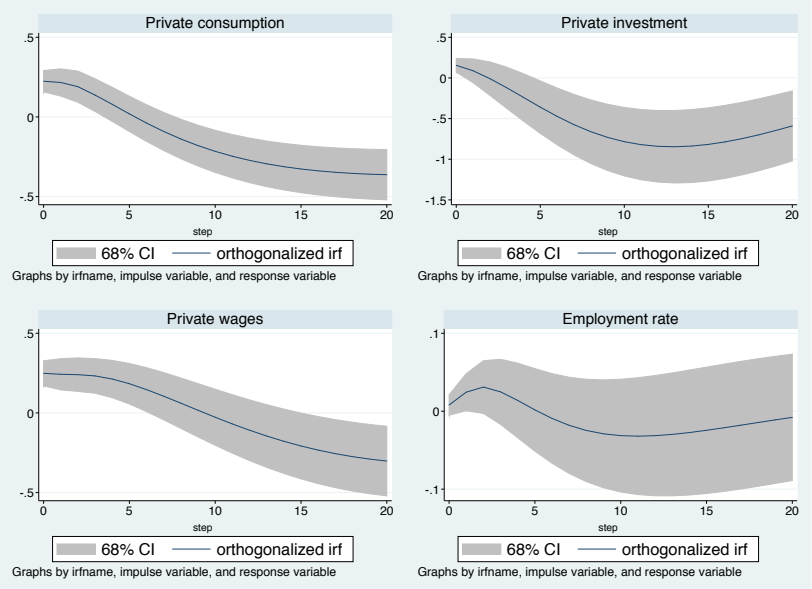


Table A.2.6.1: Variance decomposition (United States)

Shock	Quarter	1	4	8	12
Government spending shock					
	y	6.065	1.854	1.491	1.366
	π	1.203	2.315	3.430	3.616
	r	0.500	2.381	5.035	7.839
	t	0.012	0.578	3.959	5.257
	tb	1.467	0.596	0.630	0.763
	rer	0.617	0.160	0.332	1.277
	c	2.242	1.166	0.824	1.279
	i	0.280	3.902	9.915	15.249
	w	0.462	2.665	2.570	2.134
	e	0.147	0.157	0.929	2.432

Table A.2.6.2: Variance decomposition (United Kingdom)

Shock	Quarter	1	4	8	12
Government spending shock					
	y	3.762	3.821	2.321	4.182
	π	4.864	2.169	3.020	7.576
	r	7.554	4.382	3.445	3.369
	t	0.020	0.537	1.267	2.262
	tb	1.912	6.905	10.216	9.606
	rer	0.391	3.766	8.144	10.744
	c	5.112	4.614	2.648	3.487
	i	1.607	0.298	1.641	3.733
	w	4.605	5.683	3.782	2.306
	e	0.202	0.633	0.276	0.347

A.2.7 Summary of the Results

Table A.2.7.1: Summary of the results (United States)

Shock	Quarter	1	4	8	12	20
Government non-wage consumption shock						
y		0	-	-	0	0
π		0	-	-	-	0
r		0	-	-	-	-
t		-	-	-	-	0
tb		-	0	0	0	0
rer		0	0	0	0	0
c		0	-	-	-	-
i		-	-	-	-	-
w		0	0	0	0	0
e		0	-	-	-	-
Government wage consumption shock						
y		0	0	0	0	0
π		-	-	-	-	0
r		+	0	-	-	-
t		0	0	0	0	0
tb		0	0	0	0	0
rer		+	+	0	0	0
c		0	0	0	0	-
i		0	0	-	-	-
w		+	+	+	+	+
e		0	-	-	-	-

The sign shows the direction of the impact, and 0 means that the null hypothesis of no effect cannot be rejected at the 0.32 level of significance.

Table A.2.7.2: Summary of the results (United States)

Shock Quarter	1	4	8	12	20
Public investment shock					
y	+	0	-	-	0
π	0	0	-	-	0
r	+	0	-	-	0
t	0	-	-	-	0
tb	0	0	0	0	0
rer	0	0	0	0	0
c	+	0	0	0	0
i	0	0	-	-	-
w	+	+	+	+	0
e	+	0	0	-	-
Tax revenue shock					
y	0	0	-	-	0
π	0	0	-	-	-
r	+	+	0	0	-
gc	0	-	-	-	0
gw	0	-	0	0	+
pi	0	-	0	0	0
tb	0	0	+	+	0
rer	+	+	+	+	+
c	-	0	0	0	0
i	+	0	-	-	0
w	-	0	0	0	+
e	+	0	0	0	0

The sign shows the direction of the impact, and 0 means that the null hypothesis of no effect cannot be rejected at the 0.32 level of significance.

Table A.2.7.3: Summary of the results (United Kingdom)

Shock	Quarter	1	4	8	12	20
Government non-wage consumption shock						
	y	0	0	-	-	-
	π	0	+	+	0	0
	r	0	0	0	0	0
	t	0	0	0	0	0
	tb	0	0	+	+	+
	rer	0	0	+	0	0
	c	0	-	-	-	-
	i	0	-	-	-	0
	w	0	0	0	0	0
	e	+	0	0	0	0
Government wage consumption shock						
	y	0	0	0	0	0
	π	+	+	+	+	+
	r	-	0	0	0	+
	t	0	0	0	0	0
	tb	-	-	0	0	0
	rer	0	-	-	-	-
	c	+	0	0	0	0
	i	0	0	0	0	0
	w	+	+	0	0	-
	e	-	-	-	-	-

The sign shows the direction of the impact, and 0 means that the null hypothesis of no effect cannot be rejected at the 0.32 level of significance.

Table A.2.7.4: Summary of the results (United Kingdom)

Shock Quarter	1	4	8	12	20
Public investment shock					
y	+	0	-	-	-
π	-	0	+	+	0
r	+	0	0	-	0
t	0	-	-	-	-
tb	-	-	0	0	+
rer	-	-	-	-	-
c	+	0	-	-	-
i	0	-	-	-	-
w	+	0	0	-	-
e	0	0	0	0	0
Tax revenue shock					
y	0	0	0	0	0
π	+	+	0	0	0
r	+	0	0	-	0
gc	0	0	0	0	0
gw	0	+	+	+	+
pi	0	0	+	+	+
tb	-	0	0	0	0
rer	+	+	0	0	0
c	-	-	-	0	0
i	0	0	0	0	0
w	0	0	0	0	0
e	+	0	0	0	0

The sign shows the direction of the impact, and 0 means that the null hypothesis of no effect cannot be rejected at the 0.32 level of significance.

Chapter 3: Transmission Mechanisms of Conventional and Unconventional Monetary Policies in Open Economies

3.1 Introduction

In response to the global financial crisis of 2008, many central banks started to conduct unconventional monetary policies in parallel with conventional policy measures. Monetary policy consists in a set of actions of the monetary authority, which are generally targeted to ensure price stability and sustain economic growth. The short-term interest rate is the conventional tool used by central banks to implement their monetary policy. Its transmission mechanism starts from the money market and the effects are transmitted to the real economy through different channels, including interest rates, exchange rates, asset prices, consumer confidence and credit (e.g., Bernanke and Gertler, 1995; Mishkin, 1995; Cushman and Zha, 1997; Debes et al., 2014). During the global recession, many central banks reduced their reference rates close to zero. Lower interest rates reduce the cost of borrowing and make cheaper for households and businesses to borrow money, thus encouraging spending and investment. During the liquidity trap period, the conventional monetary policy instrument had reached its limit, which forced central banks to implement large-scale asset purchases, commonly known as quantitative easing, to improve the economic conditions. These operations changed the relative supply of short-term and long-term bonds, and other assets, which consequently affected their prices and the flow of funds in the economy. The main objective of such unconventional measures was to lower long-term interest rates in order to ease financing conditions, thereby stimulating aggregate demand and economic activity.

In this context, this chapter analyses the transmission mechanisms of conventional and unconventional monetary policies on various macroeconomic aggregates in open economies. The VAR methodology has become the main econometric tool used to study the effects of monetary policy shocks. A body of literature evaluates the differences in the transmission mechanism of monetary policy across countries of the euro area (e.g., Barran et al., 1996; Ramaswamy and Sløk, 1998) and in the euro area as a whole (e.g., Peersman and Smets, 2001). However, despite the differences in monetary policy regime of each country, they impose the same identification scheme of monetary policy shocks across countries (Mojon and Peersman, 2001). In addition, very few studies have attempted to evaluate the effects of monetary policy in countries outside the euro area. Studies like Kugler and Rich (2002) and Assenmacher-Wesche (2008)

contribute to this literature by assessing the effects of conventional monetary policy measures in Switzerland. Similar contributions can be found for Norway in Bjørnland (2008) and for the United Kingdom in Cloyne and Hürtgen (2016).

Through different applications, the literature has reached a consensus on how monetary policy can affect economic variables in closed economies (e.g., Leeper et al., 1996; Christiano et al., 2005). Nevertheless, empirical studies relying on an open economy framework have posed a few puzzles concerning the effects on the exchange rate and prices. In addition, a number of studies do not include foreign variables, meaning that they neglect the possible existence of spillovers across countries. Dornbusch's (1976) exchange rate overshooting hypothesis predicts that the exchange rate instantaneously appreciates after a contractionary monetary policy shock. However, VAR studies have often found that if the exchange rate appreciates, it does so for a prolonged period. Another recurrent puzzle is the observed rise in the aggregate price level in response to a contractionary shock. Sims (1992) suggests that the price puzzle could be explained on the grounds that interest rate innovations partly reflect policy responses to inflationary pressures. This counterintuitive response is often viewed as evidence of a misspecification problem due to the inadequate description of central bank's operating procedures and the insufficient amount of information incorporated in the VAR model (Brissimis and Magginas, 2006). Several studies proposed ways to solve this puzzle by including variables such as commodity prices (e.g., Sims, 1992) or the output gap (e.g., Giordani, 2004).

The literature generally provides consistent findings as regards the effects of conventional monetary policy on the national income and its components (e.g., Mojon and Peersman, 2001; Christiano et al., 2005). However, a large body of existing literature does not consider asset prices and consumer expectations that represent two potential channels for the transmission of monetary policy (e.g., Mishkin, 1995; Brissimis and Magginas, 2006). Monetary policy decisions have an impact on financing conditions and market expectations, which can lead to adjustments of asset prices. The consumer confidence indicator contains important information used by central banks about consumer expectations as regards future economic conditions. The omission of these two variables may result in an important loss of information in the analysis. A few studies analyse the effects of consumer confidence on the real economy (e.g., Ludvigson, 2004; Barsky and Sims, 2012). However, very little is known about its role in the transmission of monetary policy. Debes et al. (2014) is the first study to show that conventional monetary policy can be operative via a consumer confidence

channel from an empirical and theoretical perspective. As a result, this implies the need to explore how monetary policy can affect macroeconomic aggregates in open economies along the business cycle and the specific role of asset prices and consumer confidence as potential transmission channels.

Unconventional monetary policy can affect the real economy through different transmission channels, including signaling, portfolio balance, exchange rates and asset prices (e.g., Mishkin, 1995; Gagnon et al., 2011; Joyce et al., 2011; Bauer and Rudebusch, 2014; Christensen and Krogstrup, 2019). A body of literature has mainly focused on the effects of unconventional monetary policy measures on the financial market. Specifically, there are a number of studies analysing the effects of large-scale asset purchases on long-term interest rates and other asset prices (e.g., Gagnon et al., 2010; Joyce et al., 2011; Hamilton and Wu, 2012; Christensen and Krogstrup, 2019). A few studies go one step further and examine the short-run macroeconomic effects of unconventional monetary policy shocks (e.g., Lenza et al., 2010; Peersman, 2011; Chung et al., 2012; Baumeister and Benati, 2013). A potential caveat concerning these studies is that they rely on models estimated over sample periods covering also the pre-crisis period, which may not be appropriate for assessing the transmission of unconventional monetary policy in a liquidity trap. Moreover, central banks' quantitative easing policies before the crisis were usually not aimed at influencing macroeconomic conditions (Gambacorta et al., 2014). Another possible limitation of these studies is that they often neglect the role of the stock market as a potential transmission channel. Recent work in that direction can be found in Gambacorta et al. (2014). These authors focus on the period after the onset of the crisis and estimate a panel VAR model using a combination of macroeconomic and financial variables. Their findings reveal that the inclusion of stock market variables is of key importance in determining the effects of unconventional monetary policy. On the other hand, despite the focus on the macroeconomic effects of quantitative easing measures has increased in the last years, their impact on the labor market has been much less documented.

In this chapter, we employ the structural VAR modelling and use quarterly and monthly data from two non-EMU countries, Switzerland and the United Kingdom, over the period 1990-2017. This chapter contributes to the empirical research on the transmission mechanisms of monetary policy instruments for European countries that have adopted a flexible exchange rate regime and conduct independent monetary policy. While research has been substantial for the euro area and the United States, very few studies have analysed the effects

of monetary policy in the open economies outside the euro area, with Switzerland and the United Kingdom as compelling examples. In addition, these countries represent unique case studies on the transmission mechanisms of unconventional monetary policy, as they were the only non-EMU countries to implement quantitative easing in response to the global financial crisis. The Bank of England purchased private and public sector assets, the majority of which were medium to long-term government securities (gilts) (Joyce et al., 2011). In contrast to the measures adopted in the United Kingdom, the Swiss National Bank policy measures involved an unprecedented expansion in reserves, achieved without any purchase of long-term debt securities, which has left the supply of long-term government bonds unchanged. Thus, Switzerland represents a very interesting case study of the transmission of quantitative easing. Moreover, considering these countries makes the assumptions on small open economies more realistic than in the cases of the euro area and the United States. In particular, it enables to control for global economic shocks, which provides a more comprehensive analysis of the transmission of monetary policy.

We propose two distinct structural VAR models based on a new specification, which capture the effects of monetary policy on the real economy that occur through changes in stock prices and consumer expectations in an open economy framework. Using the recursive approach, we identify two policy shocks: (i) the official bank policy rate (ii) the central bank's reserve assets. We explicitly separate the pre-crisis period and the post-crisis period since the implementation of quantitative easing may be viewed as a new monetary policy regime. The baseline model for the case of conventional monetary policy covers the pre-2009 period and is estimated using quarterly data on the consumer confidence indicator, the output, the inflation rate, the official bank policy rate, the real effective exchange rate and the stock price index. The model contains the global oil price, the euro area short-term interest rate, the euro area consumer price index and the euro area stock price index as critical exogenous variables. To have a better sense of what changes in monetary policy induce on the economy, we estimate five augmented specifications in which we include in turn private consumption, private investment, the trade balance, the nominal wage and the unemployment rate. The baseline model for the case of unconventional monetary policy covers the post-2009 period and is estimated using monthly data on the industrial production index, the consumer price index, the central bank's reserve assets, the long-term government bond yields, the real effective exchange rate and the stock price index. The model includes the euro area reserve assets, the euro area consumer price index and the euro area stock price index as critical exogenous

variables. We estimate five alternative specifications in which we replace the industrial production index, by switching in turn private consumption, private investment, the trade balance, the nominal wage and the unemployment rate. The effects of conventional and unconventional monetary policy shocks are assessed by the impulse response functions and the variance decomposition.

This chapter contributes to the literature by investigating the role of stock prices and consumer expectations in the transmission of monetary policy. First, we ask whether conventional monetary policy is operative, besides other well-known channels, via a stock price and consumer confidence channels. We then examine the role of long-term interest rates, exchange rates and stock prices in the transmission of unconventional monetary policy. The inclusion of stock prices is of key importance since monetary policy decisions have an impact on financing conditions and market expectations, thus leading to adjustments of asset prices. If central banks are forward looking, the monetary policy instrument cannot be properly identified unless expectations are taken into account. Our modelling approach consists in augmenting the VAR model with a forward-looking informational variable of near-term development in economic activity and several foreign exogenous variables to control for international spillovers. For the case of conventional monetary policy, the consumer confidence indicator is included since it contains important information used by central banks about consumer expectations as regards future economic conditions. To the best of our knowledge, no other previous study has explored the role of consumer confidence in the transmission of conventional monetary policy in an open economy framework. For the case of unconventional monetary policy, the long-term government bond yields are used to capture consumer expectations about future short-term interest rates. The analysis reveals that the inclusion of a forward-looking informational variable of near-term development in economic activity and a financial variable such as the stock prices are of key importance for the monetary policy assessment. We provide evidence for the existence of a consumer confidence channel in the transmission of conventional monetary policy. Our findings also reveal that conventional and unconventional monetary policies were effective in providing temporary stimulus to the economies of Switzerland and the United Kingdom during the considered periods.

The rest of the chapter is organized as follows. Section 3.2 discusses the transmission channels of monetary policy and the related empirical literature. Section 3.3 presents the econometric methodology and section 3.4 describes the data. Section 3.5 provides the results. Section 3.6 contains concluding remarks.

3.2 Theory and Literature Review

The study of the transmission mechanisms and effects of conventional and unconventional monetary policies has received particular attention over the past decades. One of the main challenges in the empirical monetary policy analysis is to identify exogenous and unexpected monetary policy shocks. In this regard, many studies in the existing literature have employed the VAR methodology. Subsection 3.2.1 reviews the theory on the transmission channels of conventional and unconventional monetary policies. Subsection 3.2.2 discusses the related empirical literature.

3.2.1 Transmission Channels of Monetary Policy

3.2.1.1 Conventional Monetary Policy

The transmission mechanisms of conventional monetary policy can be defined as the channels through which monetary policy decisions affect the real economy and the general price level. Mishkin (1995) classifies four such channels, which are also considered by other authors (e.g., Bernanke and Gertler, 1995; Cushman and Zha, 1997). These channels are the following:

1. *Interest rate channel*: Changes in the official bank's interest rate directly affect money market interest rates and indirectly lending and deposit rates, which are set by banks to their customers. An expansionary monetary policy lowers interbank rates and generates an expansion of lending between individual banks. As a result, the liquidity in the market increases, which exerts pressure on prices and lower real interest rates. This in turn affects the intertemporal choice of households in favor of consumption rather than savings, thus stimulating aggregate demand.

2. *Exchange rate channel*: In the perspective of an expansionary conventional monetary policy, the nominal interest rate decreases and leads to a negative differential between the domestic and foreign interest rates. Assuming perfect capital mobility and perfect substitutability of financial assets, the demand for domestic currency decreases in the forex market, thus leading to a depreciation of the exchange rate. If the Marshall-Lerner condition is satisfied, the trade balance improves and generates an increase in economic growth.

3. *Asset prices (stock prices) channel:* Monetary policy decisions have an impact on financing conditions and market expectations, which can lead to asset price adjustments. An expansionary monetary policy may imply a rise in stock prices, which according to the Tobin's q, increases the market price of firms relative to the replacement cost of their capital. Since firms can buy a lot of new investment goods with a small issue of new stock of capital and at a lower cost, their investment activities increase, which in turn can lead to higher levels of output.

4. *Credit channel*: In the perspective of an expansionary monetary policy, lower interest rates decrease the risk of borrowers to be unable to pay back their loans. As a result, this situation can directly affect the supply of credits. Lower interest rates can give an incentive to banks to increase the amount of funds they lend to households and firms, which in turn can lead to increased consumption and investment.

3.2.1.2 Unconventional Monetary Policy

The main objective of unconventional monetary policy measures is to raise the inflation rate and stimulate economic activity. Central banks' reserve asset purchases influence macroeconomic aggregates via different channels, including signaling, portfolio balance, exchange rates and assets prices (e.g., Mishkin, 1995; Gagnon et al., 2011; Joyce et al., 2011; Bauer and Rudebusch, 2014; Christensen and Krogstrup, 2019). The literature has mainly emphasized on how central banks' reserve asset purchases can lower long-term government bond yields through the signaling and portfolio balance channels (e.g., Gagnon et al., 2011; Bauer and Rudebusch, 2014; Christensen and Krogstrup, 2019). The long-term government bond yields can be decomposed into a risk-neutral part that represents the average of the expected future short-term interest rates until maturity and a term premium which compensates investors for the added risk they take when investing in a government bond of a given maturity instead of investing the same amount in another similar asset. The long-term government bond yields can be expressed in the following simplified form:

$$lr_t(\tau) = \frac{1}{\tau}\int_t^{t+r} E_t^P\,[\tau_s]ds + TP_t(\tau) \qquad (3.1)$$

Where t is time and r is time until maturity. The first term is the risk-neutral component of the long-term government bond yields and corresponds to the

average of the expected one-year interest rate over the t + r years. The second term is the term premium, which captures macroeconomic risks related to uncertainty regarding growth, inflation and changes in issuer-specific risks such as credit and liquidity risks. It also contains a premium due to supply and demand factors in the government bond market, with the presence of market imperfections. The policy signaling affects the risk-neutral component of the long-term government bond yields, while the portfolio balance effects affect the term premium since they are specific to the bond. These two transmission channels of unconventional monetary policy can be described as follows:

1. *Signaling channel*: An expansion of central bank's reserve assets represents a signal of future monetary policy. When the central bank announces that it plans to purchase assets, different market agents could interpret this as a signal of low monetary policy rates to come over a prolonged period. The policy signaling has a negative effect on the risk-neutral component of the long-term government bond yields, which would continue to decline, thus having a positive impact on general financing conditions and credit demand. This can in turn stimulate aggregate demand and increase the general price level.

2. *Portfolio balance channel*: Central bank's reserve asset purchases can affect long-term government bond yields by reducing the amount of government bonds in private sector portfolios. As asset purchases reduce the supply of long-term government bonds, private investors need to adjust their portfolios towards assets of similar characteristics. This rises the price of the purchased bonds and lower their yields, thus encouraging higher spending and consumption.

The literature has evidenced two other transmission channels of unconventional monetary policy (e.g., Mishkin, 1995; Joyce et al., 2011):

3. *Exchange rate channel*: An expansion of central bank's reserve assets causes the yields of assets denominated in domestic currency to fall compared to those denominated in foreign currency. Domestic assets become less attractive for foreign investors, which leads to a decline in demand for domestic currency. This creates downward pressure on the domestic currency, thus causing a depreciation of the exchange rate. A weaker currency makes exports of domestic goods and services cheaper

for foreign consumers and imports of such products more expensive, which leads to an increase in net exports and economic growth.

4. *Asset prices (stock prices) channel*: The liquidity injected in the markets lowers long-term interest rates, which affects the stock market through two different mechanisms. First, lower borrowing costs for firms translate into higher profitability and a higher propensity to invest. Then, the low return offered in the bond market leads to a move of investors away from it and towards the stock market. These two mechanisms can generate an increase in stock prices and aggregate demand.

3.2.2 Empirical Literature

3.2.2.1 Conventional Monetary Policy

One recurrent puzzle in the VAR literature is the positive response of prices or inflation to a contractionary monetary policy shock. Several studies proposed different ways to solve it. Sims (1992) shows that the price puzzle disappears when the VAR model is extended to include a commodity price index as an important variable to forecast inflation. Giordani (2004) proposes an alternative explanation, proving that the omission of a measure of output gap (or potential output) produces the price puzzle. Various theoretical and empirical studies generally argue that an expansionary (contractionary) conventional monetary policy has a positive (negative) impact on the national income and its main components (e.g., Mojon and Peersman, 2001; Christiano et al., 2005). In a relevant work, Cushman and Zha (1997) find that the output and prices decline after a contractionary monetary policy shock in Canada. Mojon and Peersman (2001) analyse the effects of monetary policy in ten countries of the euro area. Their results reveal that a contractionary monetary policy shock leads to a decline in output, prices, consumption and investment for all countries. Using a DSGE model incorporating nominal rigidities and a structural VAR model, Christiano et al. (2005) find that an expansionary monetary policy shock has positive effects on the United States economy by increasing output, consumption, investment, employment and real wages. Peersman and Smets (2001) study the effects of monetary policy in the euro area as a whole over the period 1980-1998. These authors find that an increase in interest rates leads to a temporary decline in output, with prices decreasing only after a few lags. Similar results for the euro area are obtained in Lütkepohl and Netsunajev (2018).

A few studies have analysed the effects of conventional monetary policy in countries outside the euro area. Using a cointegrated vector autoregressive model, Assenmacher-Wesche (2008) evaluates the transmission of monetary policy shocks for Switzerland over the period 1974-2006. The author finds that the output and inflation decline after a contractionary shock. Other Swiss studies such as Kugler and Rich (2002) and Kugler and Jordan (2004) assess the effects of monetary policy shocks using structural VAR models based on short-run and long-run restrictions. These studies provide similar findings as regards the response of output and inflation. For the United Kingdom, Cloyne and Hürtgen (2016) use real-time forecast data and employ the Romer-Romer approach to identify monetary policy shocks. These authors find that an increase in the official bank rate leads to a decline in output and inflation. These findings are also in line with Bjørnland (2008) for Norway. On the other hand, the impact of conventional monetary policy on the labor market has received less attention. Using a structural VAR model with the combination of both short-run and long-run restrictions, Bjørnland (2008) finds that unemployment increases and nominal wages decrease after a contractionary shock.

The relationship between conventional monetary policy and the stock market has received increasing attention over the past decades. Using a structural VAR model, Bjørnland and Leitemo (2009) find that a contractionary shock reduces real stock prices in the United States. A body of literature examines the link between monetary policy in the euro area and the stock market. Using a cointegrated structural vector autoregressive model, Lütkepohl and Netsunajev (2018) provide evidence that a contractionary shock leads to a persistent decline in real stock prices. The latter finding is consistent with Kholodilin et al. (2009). On the other hand, a part of the literature evaluates the effects of consumer confidence on macroeconomic aggregates (e.g., Ludvigson, 2004; Barsky and Sims, 2012), but very little is known about its role in the transmission of monetary policy. Debes et al. (2014) is the first study to provide evidence for the existence of a consumer confidence channel in the transmission of conventional monetary policy in the United States. Their findings reveal that consumer confidence drops substantially after a contractionary shock and amplifies the impact of monetary policy on aggregate consumption.

The responses of the exchange rate and the trade balance to monetary policy shocks are quite controversial in the empirical open economy macroeconomics literature. Dornbusch's (1976) exchange rate overshooting hypothesis predicts

that a contractionary monetary policy shock leads to a large initial appreciation due to price stickiness in the short run, followed by a depreciation until the initial steady state level is reached. Cushman and Zha (1997) and Bjørnland (2008) find evidence of exchange rate overshooting. However, this hypothesis is not supported by Eichenbaum and Evans (1995) who find that an expansionary shock to monetary policy leads to persistent real and nominal depreciations in the United States. Mojon and Peersman (2001) provide mixed evidence for the response of the exchange rate in euro area countries. Moreover, Assenmacher-Wesche (2008) finds that the exchange rate depreciates on impact in Switzerland after a contractionary shock, providing further evidence for the existence of an exchange rate puzzle. In contrast, Natal (2002, 2004) do not obtain an exchange rate puzzle for Switzerland, which may be explained on the grounds that the author includes credit variables in the VAR model. Focusing on European countries, Kim (2001) finds that an expansionary monetary policy leads to a depreciation of the exchange rate and an increase in net exports in France, Italy and the United Kingdom. The J-curve hypothesis predicts that the trade balance of a country deteriorates initially following a depreciation of the national currency, before it recovers to a higher level than where it was in the initial equilibrium. Empirical evidence on the J-curve effect is mixed. Cushman and Zha (1997) find evidence for the J-curve hypothesis, while other studies like Moffett (1989) and Kim (2001) find little evidence for J-curve effects.

3.2.2.2 Unconventional Monetary Policy

The study of the transmission channels and effects of unconventional monetary policy has received particular attention over the past decade. A body of existing literature has mainly focused on the financial market effects of unconventional monetary policy measures using high-frequency financial data. Specifically, there are a number of studies analysing the effects of large-scale asset purchases on long-term interest rates and other asset prices (e.g., Gagnon et al., 2010; Joyce et al., 2011; Hamilton and Wu, 2012; Christensen and Krogstrup, 2019). Overall, these studies provide evidence that such policies were effective in reducing financial market risk spreads or yields.

Several studies go one step further and analyse the short-run macroeconomic effects of unconventional monetary policy shocks (e.g., Lenza et al., 2010; Peersman, 2011; Chung et al., 2012; Baumeister and Benati, 2013). Lenza et al. (2010) evaluate the macroeconomic effects of non-standard policy measures in

the euro area by conducting counterfactual exercises based on assumptions regarding how money market spreads would have evolved with and without the measures. These authors find that the introduction of unconventional measures helped stabilize the financial sector and economy after the collapse of Lehman Brothers in September 2008, even if they were not sufficient to avoid a significant decline in economic and financial activity. On the other hand, Chung et al. (2012), using a set of structural and time series statistical models, find that the Federal Reserve's asset purchases have been effective in improving macroeconomic conditions in the United States at the zero lower bound.

Peersman (2011) proposes a structural VAR model to examine the macroeconomic effects of unconventional monetary policy shocks on the euro area economy over the period 1999-2009. The author finds that these measures had a significant impact on economic activity and inflation. Baumeister and Benati (2013) estimate a time-varying structural VAR model and find evidence that unconventional monetary policy measures avoided significant risks both of deflation and of large output collapses in the United States and in the United Kingdom, comparable to those that occurred during the Great Depression. Using Japanese data over the zero lower bound period, Schenkelberg and Watzka (2013) find that quantitative easing shocks have positive effects on industrial production and consumer prices. Their findings also reveal that long-term interest rates decline, while the exchange rate does not react significantly.

A few empirical studies consider the transmission channel of unconventional monetary policy that occurs through the stock market. Gambacorta et al. (2014) estimate a panel VAR model with monthly data from eight advanced economies over the period 2008-2011. These authors find that an expansion of central bank balance sheets leads to a temporary increase in economic activity and consumer prices. Their results for individual countries suggest that the macroeconomic effects of unconventional monetary policy are similar across countries, despite the heterogeneity of measures that were taken. In another relevant work, Meinusch and Tillmann (2016) provide evidence that unconventional monetary policy measures were effective in influencing economic conditions in the United States during the global financial crisis. These authors find that an expansionary policy leads to an increase in output, inflation and stock prices. Moreover, their findings indicate that long-term interest rates decline.

3.3 Empirical Methodology

This section presents the structural vector autoregressive methodology used for the examination of the transmission mechanisms of conventional and unconventional monetary policies. The structural shocks are recovered using the recursive identification approach, commonly adopted in the structural VAR literature, as in Sims (1980) and Christiano et al. (2005). The chapter considers one baseline VAR model (A) and five alternative specifications (B, C, D, E and F) for the evaluation of the effects of conventional and unconventional monetary policy shocks. The choice of variables in the baseline model reflects the theoretical set-up of a new-Keynesian small open economy model (e.g., Svensson, 2000; Clarida et al., 2001). If the central banks are forward looking, the monetary policy instrument cannot be properly identified unless expectations are taken into account. The modelling approach consists in augmenting the structural VAR model with a forward-looking informational variable of near-term development in economic activity and several foreign exogenous variables to control for international spillovers. The official bank policy rate and central bank's reserve assets are used as instruments for conventional and unconventional monetary policy. Subsection 3.3.1 presents the specification of the VAR models and subsection 3.3.2 describes the identification approach.

3.3.1 VAR Specification

The considered baseline VAR form model has the following reduced form:

$$Y_t = \mu_0 + A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + \beta X_t + u_t \qquad (3.2)$$

Where $Y_t = (y_{1t},\ldots,y_{kt})'$ is a k-dimensional vector of endogenous variables, $X_t = (x_{1t},\ldots,x_{qt})'$ is a q-dimensional vector of exogenous variables, A_i (i=1,…,p) are (k x k) matrices of coefficients and $u_t = (u_{1t},\ldots,u_{kt})'$ is a k-dimensional vector of reduced form shocks with $E(u_t) = 0$, $E(u_t u_t') = \Omega_u$ and $E(u_t u_s') = 0$ for $t \neq s$.

The shocks of the reduced form (3.2) do not generally have a meaningful economic interpretation since they are linear combinations of structural shocks. Therefore, it is necessary to transform the reduced form model into a structural model. The underlying structural model is obtained by pre-multiplying the reduced VAR form by the matrix A of order k, which refers to the

contemporaneous relations among variables in the vector Y_t. The structural VAR (p) has the following representation:

$$AY_t = V_0 + \Gamma_1 Y_{t-1} + \Gamma_2 Y_{t-2} + \cdots + \Gamma_p Y_{t-p} + bX_t + Be_t \qquad (3.3)$$

Where $\Gamma_i = AA_i$, $V_0 = A\mu_0$, $b = A\beta$ and $e_t = (e_{1t},\ldots,e_{kt})'$ is the k-dimensional vector of exogenous structural shocks with a standardized identity variance-covariance matrix, that is, $E(e_t e_t') = \Omega_e = I_k$. These transformations of the innovations allow us to analyse the dynamics of the system in terms of a change to an element of e_t. Structural VAR models based on the recursive approach use the Cholesky decomposition to orthogonalize the disturbances and obtain structurally interpretable impulse response functions.

3.3.1.1 Model for Conventional Monetary Policy

In the baseline case for the analysis of conventional monetary policy, the vector of endogenous variables Y_t contains the consumer confidence indicator (ci), the log of real per capita output (y), the inflation rate (π), the official bank policy rate (r), the log of the real effective exchange rate (rer) and the log of the stock price index (sp). The specification of the model enables to capture all important transmission channels, including interest rates, exchange rates, stock prices and consumer confidence[15]. The consumer confidence indicator contains important information used by central banks about consumer expectations with respect to the general state of the economy, their financial situation and the development of prices. The vector of exogenous variables X_t contains the following variables: the global oil price (op*), the euro area short-term nominal interest rate (r*), the euro area consumer price index (cpi*) or the global commodity price index (cp*), and the euro area stock price index (sp*). These variables are used to control for global supply and demand shocks, as well as

[15] Since our empirical analysis is carried out on sub-periods and requires estimating a large number of parameters, including an additional variable would considerably lower the number of degrees of freedom. Although the credit channel is usually recognized as a potential channel of monetary policy in the literature (e.g., Bernanke and Gertler, 1995; Mishkin, 1995), most empirical studies neglect it. In normal times, banking system distress and significant disruptions in the supply of bank loans are relatively rare in developed banking sectors, as in Switzerland and in the United Kingdom. Thus, the bank lending credit channel may be relatively infrequent. For this reason, we do not consider it in the analysis of the transmission mechanisms of conventional monetary policy. However, this assumption is not likely to hold during periods of crisis and may therefore represent a potential limitation for the analysis of the transmission mechanisms of unconventional monetary policy.

for the evolution of prices in the world and the euro area. The global oil price is an asset price that the central bank wants to respond, as a higher oil price will induce inflationary pressures through the cost channel. The inclusion of the euro area short-term interest rate allows to control for spillovers emanating from foreign monetary policy innovations. The euro area consumer price index or the global commodity price index is used to control for the evolution of the global level of prices[16]. Finally, the euro area stock price index allows to control for financial and economic uncertainty in the euro area. In the augmented specifications, we add in turn the log of real per capita private consumption (c), the log of real per capita private investment (i), the trade balance (tb), the unemployment rate (u) and the log of nominal per capita wage (w)[17].

3.3.1.2 Model for Unconventional Monetary Policy

The baseline VAR model describing the transmission mechanisms of unconventional monetary policy contains the log of the industrial production index (ip), the log of the consumer price index (cpi), the log of the central bank's reserve assets (ra), the long-term government bond yields (lr), the log of the real effective exchange rate (rer) and the log of the stock price index (sp). The specification of the baseline model is such to capture the exchange rate and stock prices channels. The inclusion of the long-term government bond yields is of key importance since it enables to control for signaling and portfolio balance effects. The risk-neutral component of the long-term government bond yields allows to capture economic agents' expectations about the future short-term interest rates. The risk premium component enables to capture risks related to uncertainty regarding growth, inflation and changes in issuer-specific risks. It also contains a premium due to supply and demand factors in the government bond market. The model contains three critical exogenous variables: the euro area reserve assets (ra*), the euro area consumer price index (cpi*) and the euro area stock price index (sp*). In the alternative specifications, we replace the industrial production index by switching in turn the log of real per capita private consumption, the log of real per capita private investment, the trade balance, the unemployment rate and the nominal wage.

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[16] Since the European Union is Switzerland's largest trading partner, the euro area consumer price index can be considered as a reasonable indicator of future inflation rates in the VAR model. Given the size and the specific characteristics of the United Kingdom economy, we follow the existing literature and use the global commodity price index as it contains more information about the evolution of the global level of prices (e.g., Sims, 1992).

[17] The model specifications are summarized in table A.3.2.1.

3.3.2 Identification: The Recursive Approach

The chapter applies the recursive approach to identify the structural shocks. This identification scheme imposes a causal ordering from the top variables to the bottom variables based on the economic theory. For the baseline model of conventional monetary policy, the relationship between the vector of reduced form shocks and the vector of structural shocks is given by:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ a_{yci} & 1 & 0 & 0 & 0 & 0 \\ a_{\pi ci} & a_{\pi y} & 1 & 0 & 0 & 0 \\ a_{rci} & a_{ry} & a_{r\pi} & 1 & 0 & 0 \\ a_{rerci} & a_{rery} & a_{rer\pi} & a_{rerr} & 1 & 0 \\ a_{spci} & a_{spy} & a_{sp\pi} & a_{spr} & a_{sprer} & 1 \end{bmatrix} \begin{bmatrix} u_t^{ci} \\ u_t^{y} \\ u_t^{\pi} \\ u_t^{r} \\ u_t^{rer} \\ u_t^{sp} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e_t^{ci} \\ e_t^{y} \\ e_t^{\pi} \\ e_t^{r} \\ e_t^{rer} \\ e_t^{sp} \end{bmatrix} \quad (3.4)$$

The baseline model (A) is specified with the particular order of: the consumer confidence indicator, the output, the inflation rate, the official bank policy rate, the real effective exchange rate and the stock price index. We impose short-run restrictions, which prevent a structural shock from affecting an endogenous variable contemporaneously. The particular ordering of the variables has the following implications: (i) The domestic macroeconomic aggregates such as the output and the inflation rate do not react contemporaneously to the conventional monetary policy shock. The fact that monetary policy decisions affect domestic variables with a lag is in line with the transmission mechanism of monetary policy emphasized in the theoretical set-up in Svensson (1997). (ii) The simultaneous reaction of conventional monetary policy to consumer expectations and the macroeconomic environment is allowed by placing the consumer confidence indicator, the output and the inflation rate above the official bank policy rate in the ordering. This can be rationalized on the grounds that the interest rate is the main tool of central bank's monetary policy whose objective is to stabilize the output gap and maintain price stability. Allowing for a contemporaneous response of monetary policy to the consumer confidence indicator is plausible in the view of the importance of this variable as a policy target. (iii) The real effective exchange rate and stock prices react simultaneously to the conventional monetary policy shock. Monetary policy is one of the main determinants of the exchange rate and is therefore ordered before it. The stock price index is ordered last since it is the most endogenous variable of the system, being affected by both domestic and foreign structural shocks. Finally, by including the foreign variables as exogenous, we assume that there is no feedback effect of domestic variables on

the world economy[18]. At the same time, the contemporaneous impact of exogenous variables on the endogenous ones is allowed.

In the augmented specifications, private consumption and private investment are ordered before the output, which can be justified on the grounds that innovations in these national income components have immediate effects on the output. The trade balance is ordered before the real effective exchange rate since it takes time for demand for exports and imports to change in response to a movement in currency. The nominal wage is placed after the inflation rate in the ordering, which reflects that nominal wages may be a mark-up on inflation. Nominal wages can be important as they indicate inflationary pressures that the central bank may want to respond when setting the interest rate. Because of the possible existence of labor market rigidities, the unemployment rate is assumed not to be very sensitive to changes in the other variables of the system within the same quarter. For the baseline model of unconventional monetary policy, equation (3.4) can be expressed as follows:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ a_{cpip} & 1 & 0 & 0 & 0 & 0 \\ a_{raip} & a_{racpi} & 1 & 0 & 0 & 0 \\ a_{lrip} & a_{lrcpi} & a_{lrra} & 1 & 0 & 0 \\ a_{rerip} & a_{rercpi} & a_{rerra} & a_{rerlr} & 1 & 0 \\ a_{spip} & a_{spcpi} & a_{spra} & a_{splr} & a_{sprer} & 1 \end{bmatrix} \begin{bmatrix} u_t^{ip} \\ u_t^{cpi} \\ u_t^{ra} \\ u_t^{lr} \\ u_t^{rer} \\ u_t^{sp} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e_t^{ip} \\ e_t^{cpi} \\ e_t^{ra} \\ e_t^{lr} \\ e_t^{rer} \\ e_t^{sp} \end{bmatrix} \quad (3.5)$$

The baseline model includes the variables with the following ordering: the industrial production index, the consumer price index, the central bank's reserve assets, the long-term government bond yields, the real effective exchange rate and the stock price index. The particular ordering of the variables has the same motivations and implications as those for the case of conventional monetary policy. In the alternative specifications, private consumption, private investment and the unemployment rate are all ordered first in the system, whereas the nominal wage and the trade balance are ordered just after the consumer price index and the long-term government bond yields, respectively.

[18] While this assumption is plausible for a small open economy such as Switzerland, we acknowledge that it may be somewhat restrictive in some respects for the United Kingdom. In particular, the United Kingdom stock price index is calculated from the prices of common shares of companies traded on the London Stock Exchange and therefore exhibits a correlation with the euro area stock price index. Nevertheless, considering the euro area stock price index as endogenous would require additional restrictive assumptions on the contemporaneous relations between domestic variables and the euro area stock price index. For simplicity purposes and in order to be consistent with our approach of separating domestic and foreign variables into two different blocks, we consider the euro area stock price index as exogenous.

3.4 Data Description

For the examination of the transmission mechanisms of conventional monetary policy, we use quarterly seasonally adjusted data for Switzerland and the United Kingdom over the period 1990-2009. The appendix A.3.1 provides details on definitions and data sources for all variables used in this chapter. The components of national income are in real terms and were obtained by dividing them by the GDP deflator. They are expressed in their per capita terms. For Switzerland, all the series are taken from FRED, with the exception of the nominal wage series, which is obtained from the Organisation for Economic Co-operation and Development (OECD). For the United Kingdom, the series are obtained from four sources. The consumer confidence indicator, the output, the real effective exchange rate, the trade balance, the inflation rate, private consumption, the unemployment rate and the stock price index series come from FRED. The nominal wage series is obtained from the ONS. Private investment series is taken from the AMECO and the official bank policy rate series is drawn from the BoE database. The global oil price, the global commodity price index, and the euro area series, including the short-term interest rate, the consumer price index and the stock price index come all from FRED.

Due to the differences in availability of data for these two countries, we use different definitions for certain variables. Consumer confidence corresponds to the confidence composite indicator from consumer opinion surveys of the European Commission. The consumer confidence indicator is based on answers to questions on the expected change in the financial situation of households, general economic conditions, unemployment and savings, all over the next 12 months. It is expressed as the arithmetic average of the seasonally adjusted balances, which are constructed as the difference between the percentages of respondents giving positive and negative replies. A positive balance indicates an increase in the consumers' confidence with regards future economic conditions, while a negative balance indicates a pessimistic attitude. The output corresponds to the gross domestic product. Private investment is defined as gross fixed capital formation of the private sector[19]. Private consumption refers to private final consumption expenditure. The inflation rate refers to the growth rate same period previous year of the consumer price index

[19] For Switzerland, gross fixed capital formation of the private sector series is not available at the quarterly frequency. Instead, we use gross fixed capital formation series, which is available at this frequency, to avoid excessive loss of information due to the interpolation of the series.

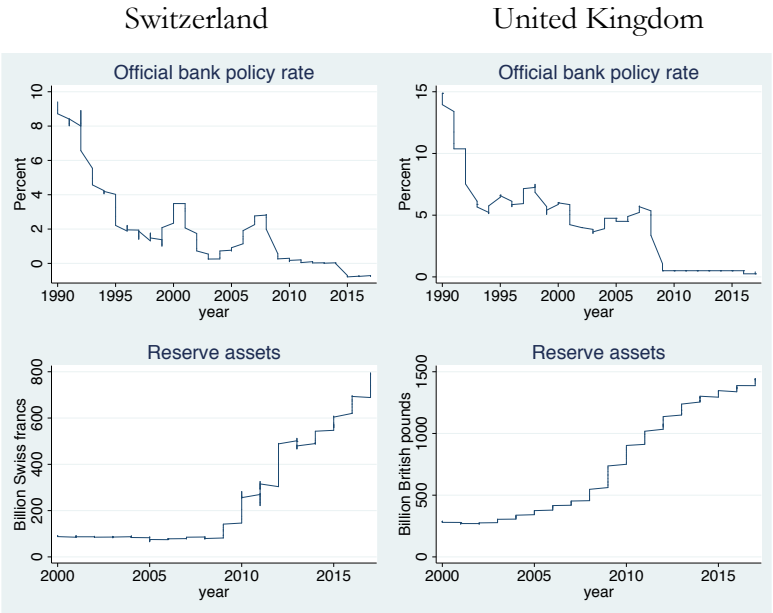
for all items. The official bank policy rate is defined as the three-month Swiss franc London Interbank Offered Rate (LIBOR) for Switzerland and the official bank rate for the United Kingdom. The trade balance corresponds to real net exports of goods and services as a percentage of GDP. The real effective exchange rate is the real narrow effective exchange rate, and an increase means real appreciation in the domestic currency against the rest of the world. Nominal wages are defined as wages and salaries. The unemployment rate is the ratio of registered unemployed under the labor force. Stock prices are defined as the total share price index for all shares. The euro area short-term interest rate is constructed by combining the German three-month interbank rates and the euro area three-month interbank rates. The euro area consumer prices refer to the consumer price index for all items for the euro area. The euro area stock prices correspond to the total share price index for all shares for the euro area. The global oil price refers to the global price of West Texas Intermediate crude and global commodity prices to the global price index of all commodities.

For the examination of unconventional monetary policy, we use monthly seasonally adjusted data over the period 2009-2017. The components of national income are in real terms and were obtained by dividing them by the consumer price index. The consumer price index, the real effective exchange rate, the stock price index, the central bank's reserve assets, the global oil price and euro area series are available at the monthly frequency and were taken from their respective sources. Private consumption, private investment, the trade balance and the nominal wage[20] series have been obtained converting data from quarterly to monthly frequency using the Denton method as implemented in EVIEWS version 10. Definitions and sources of the new series used for the case of unconventional monetary policy are the following. Reserve assets refer to the official total reserve assets for Switzerland and government stock (gilts) for the United Kingdom. They are obtained from the Swiss National Bank (SNB) and the ONS databases. Consumer prices refer to the consumer price index for all items. Industrial production corresponds to the production of total industry index. The long-term government bond yields are defined as the ten-year government bond yields. The euro area reserve assets correspond to the European Central Bank's assets. These series are all taken from FRED.

[20] For the United Kingdom, we use the log of hourly earnings in the manufacturing sector, which is available at the monthly frequency. For Switzerland, the model could not be estimated in Stata 13 using the log of nominal per capita wage because of collinearity issues. Thus, we use the growth rate of the nominal wage, defined as the log difference of wages and salaries.

Figure 3.1 shows the evolution of conventional and unconventional monetary policies over the periods 1990-2017 and 2000-2017[21], respectively. It can be seen that the official bank policy rates have approached the zero lower bound in early 2009, when central banks implemented the first conventional measures in response to the global financial crisis. There is a visible structural change in the reserve assets at the end of 2008 when central banks started to implement unconventional monetary policy measures[22]. For this reason, the estimation sample period for the case of unconventional monetary policy covers the post-2009 period. A common preliminary examination of the data properties is to check the order of integration of the series with unit root tests. However, as pointed out by Cochrane (1991), unit root tests have low power in small samples and can potentially lead to misleading conclusions. Since our analysis is based on sub-periods, we do not perform such an examination of the series. The descriptive statistics of the data are provided in tables A.3.3.1 and A.3.3.2.

Figure 3.1: Evolution of conventional and unconventional monetary policies



[21] The data for reserve assets are only available since 2000.

[22] We perform the Zivot and Andrews (1992) unit root test with a single structural break for the official bank policy rate and central bank's reserve assets. In this procedure, the date of the structural break in the series is determined endogenously. From the table A.3.4.1, it can be noted that structural breaks in central bank's reserve assets occurred in 2009m6 for Switzerland and 2008m10 for the United Kingdom. In addition, structural breaks in the official bank policy rate were identified in 1995q1 and 2008q4, respectively. For Switzerland, although the detected structural break does not coincide with the year 2009, interest rates reached unprecedent low levels at the end of 2008 and have turned negative since the beginning of 2015. For this reason, we can reasonably assume that another structural break occurred in 2009.

3.5 Empirical Analysis

This section presents the results from the empirical analysis. Before proceeding with the VAR estimation, we first have to check whether the baseline model and the alternative specifications are correctly specified. Different specification tests are performed, including residual autocorrelation and cointegration tests. We then present the results of the VAR estimation. We interpret the results from the orthogonalized impulse response functions and the variance decomposition analysis. The figures show the responses of the endogenous variables to a one standard deviation shock to conventional and unconventional monetary policy. The impulse response functions are reported for a horizon of five years for the case of conventional monetary policy and two years and a half for the case of unconventional monetary policy, with the 68 percent confidence interval[23]. The results of the variance decomposition analysis are reported for a horizon of two years. Subsection 3.5.1 presents the results of the specification tests and subsection 3.5.2 the results of the VAR estimation.

3.5.1 Specification Tests

We refer to the residual autocorrelation test conclusions to select the appropriate number of lags for the baseline VAR model and the alternative specifications. The results of the test are presented in tables A.3.5.1 and A.3.5.2. For the case of conventional monetary policy, the literature generally uses between one and four lags for the VAR model (e.g., Christiano et al., 1999; Bjørnland, 2008). Since our model specification requires the estimation of many parameters, we use a small number of lags to minimize the loss of degrees of freedom. The number of lags is set to two, three or four, depending on the model specification, when they provide serially uncorrelated residuals. Considering the short sample period for the case of unconventional monetary policy, we use two or three lags, following Gambacorta et al. (2014). The results from the Breusch-Godfrey Lagrange Multiplier test reveal that no serial correlation is detected in the different specifications of both model cases.

The series are then analysed to detect possible cointegration relations among them. Johansen procedure (Johansen, 1995) is performed within the VECM representation of the VAR model to check whether the series are cointegrated.

[23] The choice of using the 68% error bands is explained in footnote 11 at page 32.

The results of the Johansen cointegration test with constant and linear trend are presented in tables A.3.6.1 and A.3.6.2. They indicate that the series are cointegrated and that one or more cointegration relationships are present in the different model specifications. Therefore, the VAR models can be estimated in levels or in the corresponding VECM form. Since the cointegration structure is unknown, we prefer to use VAR models rather than VECMs. The VECM approach is also less appropriate when short time series are used, as it becomes more difficult to define cointegration relations among them. In addition, the use of VAR models facilitates comparison with the existing literature examining the relationships between monetary policy and economic variables.

3.5.2 Empirical Results

First of all, the empirical analysis is carried out for evaluating the effects of conventional monetary policy shocks in the baseline model and in the augmented specifications with quarterly data. We then proceed with the evaluation of the effects of unconventional monetary policy shocks in the baseline model and in the alternative specifications with monthly data. Our modelling approach shows that augmenting the VAR model with a forward-looking informational variable of near-term development in economic activity and several foreign exogenous variables is able of producing theory-consistent responses of macroeconomic aggregates to monetary policy shocks. The obtained results indicate that conventional and unconventional monetary policies were effective in providing temporary stimulus to the economies of Switzerland and the United Kingdom during the considered periods. The qualitative responses are generally similar in both model cases[24]. Figures 3.2 to 3.5 display the impulse response functions for the case of conventional monetary policy and figures 3.6 to 3.9 those for the case of unconventional monetary policy. Table 3.1 contains the results of the variance decomposition analysis. Tables A.3.7.1 and A.3.7.2 provide additional details on the results described in this section.

[24] In the analysis, the various specifications generally yield very similar results to those of the baseline model, with only small differences in the magnitude of the impulse responses. As a robustness check, we have estimated a variant of the presented models by including the effective federal funds rate and federal reserve assets, respectively, as exogenous variables to control for spillovers emanating from United States monetary policy innovations. Overall, the results remain similar to those of the chapter. In addition, we have found no evidence of the price puzzle when using inflation based on GDP deflator instead of the consumer price index.

3.5.2.1 The Dynamic Effects of Conventional Monetary Policy Shocks

In Switzerland, after an expansionary conventional monetary policy shock, the nominal interest rate decreases, and inflation rises during two quarters. The decline in interest rates causes an increase in the demand for money and thus in the liquidity in the market, implying a temporary rise in spending and prices. A positive innovation leads to an increase in output during one year. Kugler and Rich (2002) and Assenmacher-Wesche (2008) obtain similar findings as regards the response of output and inflation for Switzerland. After an expansionary shock, consumer confidence increases during approximately one year, indicating a positive perception of households with regards future economic conditions. Households interpret this as a signal of low monetary policy rates to come over a prolonged period and anticipate an increase in output and prices. As regards the national accounts, the rise in output is accompanied by a temporary increase in private consumption and private investment. The decline in interest rates makes borrowing more attractive with respect to saving, which stimulates private activity. In the financial market, stock prices increase sharply during one year. An expansionary monetary policy improves financing conditions, which fosters firms' investment activities and growth. This in turn has positive effects on the expected amount of future cash flows and increases the price of the firm's stock. Since changes in monetary policy rates affect financing conditions in the whole market, all firms experience a rise in their stock prices and consequently the key stock indexes go up. Turning on the labor market variables, unemployment declines slightly during four years and nominal wages increase after six quarters. The response of labor market variables can be rationalized on the grounds that expanded output leads firms to create new business activities and vacancy positions, thus implying an increase in labor demand. In relation to the open economy variables, the real effective exchange rate appreciates surprisingly on impact before its response turns insignificant, while net exports increase during three quarters. Evidence of an exchange rate puzzle for Switzerland is also observed in Assenmacher-Wesche (2008) but not in Natal (2002, 2004). This could be partly justified on the grounds that the latter studies include credit variables in their analysis. The credit channel can potentially amplify the response of national income components, which may in turn lead to increased demand for foreign currency and a subsequent real depreciation.

Figure 3.2: Impulse response functions to a conventional monetary policy shock (Baseline model, Switzerland)

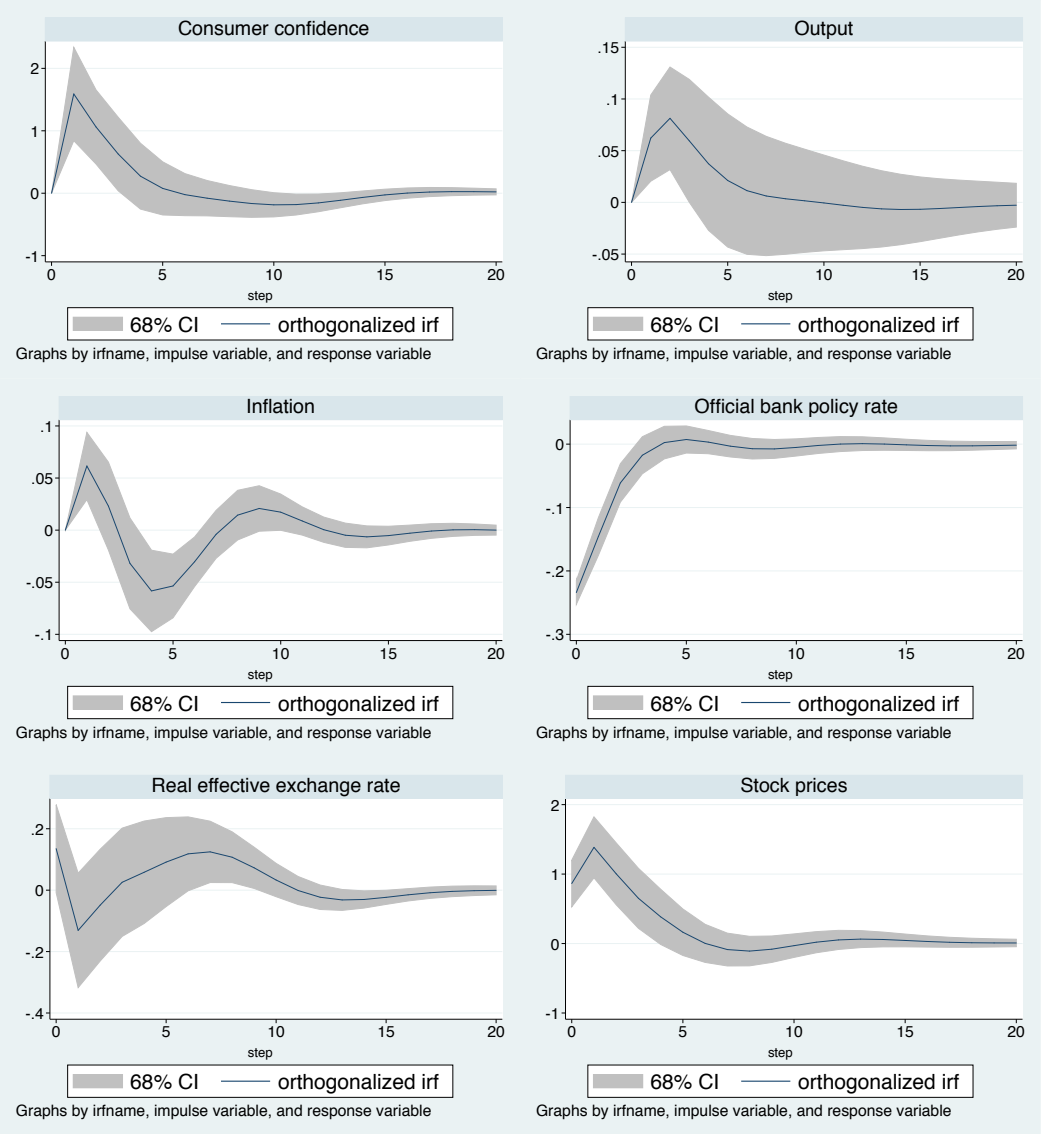


Figure 3.3: Impulse response functions to a conventional monetary policy shock (Augmented specifications, Switzerland)

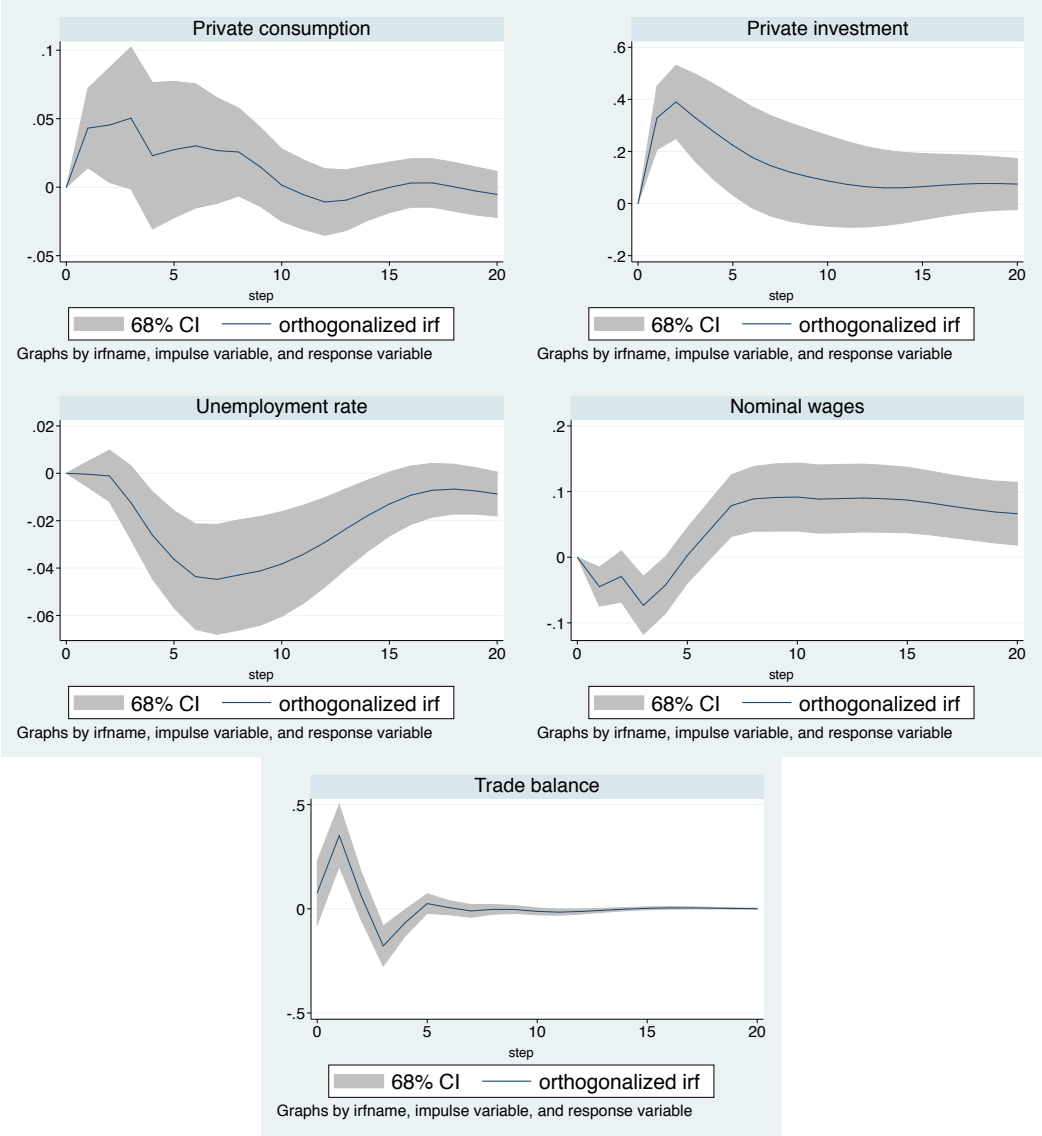


Figure 3.4: Impulse response functions to a conventional monetary policy shock (Baseline model, United Kingdom)

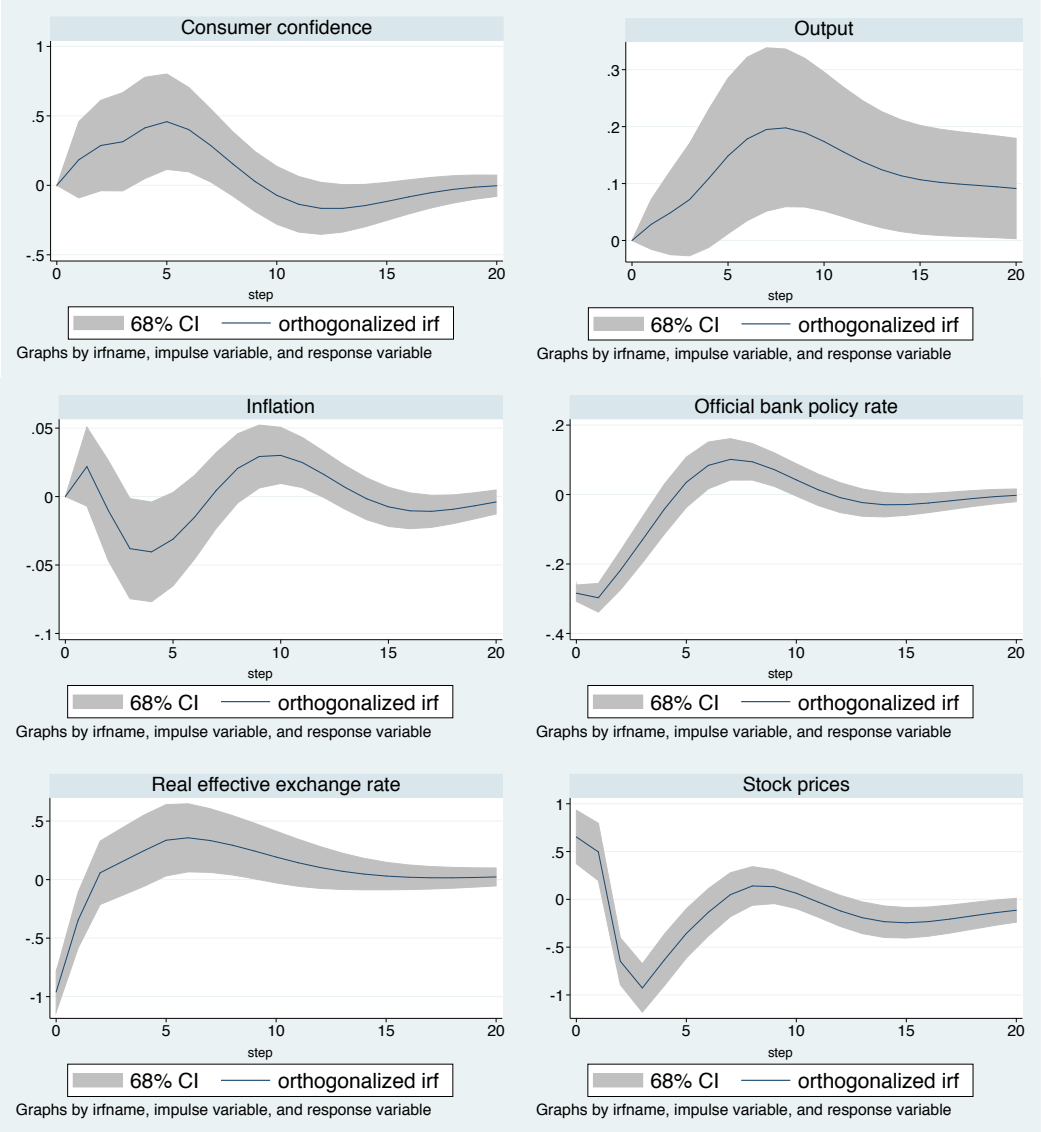
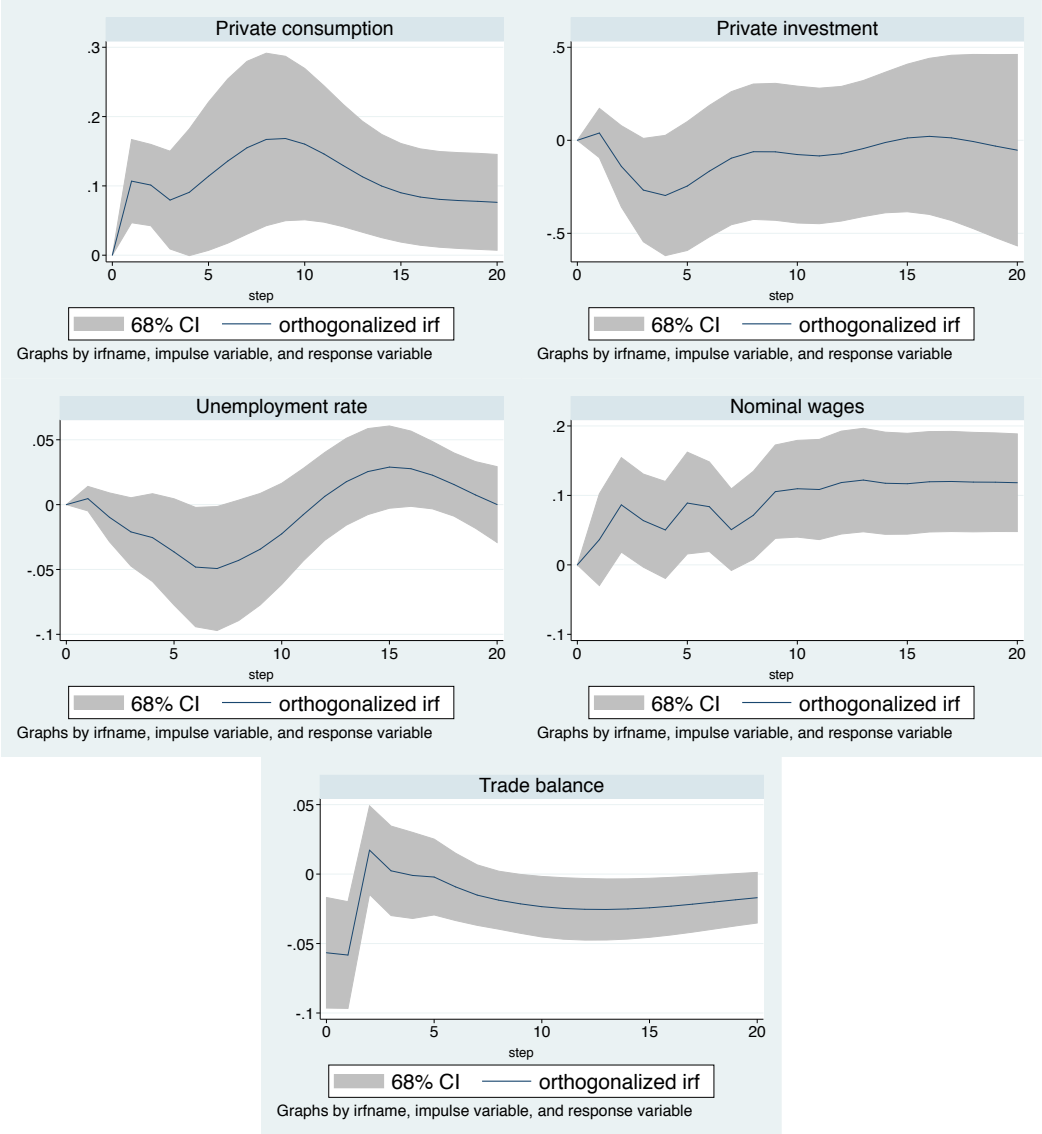


Figure 3.5: Impulse response functions to a conventional monetary policy shock (Augmented specifications, United Kingdom)



In the United Kingdom, after an expansionary shock, the nominal interest rate declines, while inflation increases after approximately seven quarters. Following a decrease in the central bank's policy rate, the output increases steadily and consumer confidence as regards the future economic development increases temporarily. To the best of our knowledge, no other previous study has investigated the impact of conventional monetary policy on consumer confidence in the United Kingdom. In the recent literature, Debes et al. (2014) find a similar response of consumer confidence for the United States. In relation to the national accounts, the rise in output is accompanied by a persistent increase in private consumption. In contrast, private investment does not react significantly after an expansionary shock. The positive response of output is consistent with Cloyne and Hürtgen (2016) for the United Kingdom. In the financial market, stock prices increase during two quarters before their response turns negative until the sixth quarter. In the labor market, unemployment declines insignificantly, while nominal wages increase slightly and persistently. Similar findings are obtained for Norway in Bjørnland (2008). The response of labor market variables can be explained by the output dynamics. The observed rise in nominal wages might reflect higher productivity and can be justified by the increase in labor demand, resulting from expanded output. In relation to the open economy variables, an expansionary conventional monetary policy shock implies a strong and immediate depreciation of the real effective exchange rate. The initial depreciation is followed by a gradual appreciation until the initial steady state level is reached, thereby providing support to the Dornbusch's (1976) exchange rate overshooting hypothesis. Finally, the trade balance deteriorates during two quarters before its response turns insignificant. This finding is not consistent with Kim (2001), which can be partly justified by the differences in the model specification and the covered sample period[25].

3.5.2.2 The Dynamic Effects of Unconventional Monetary Policy Shocks

The empirical analysis for the case of unconventional monetary policy reveals that the central bank's reserve asset purchases have slight and temporary positive effects on the Swiss economy. After an expansion of central bank's reserve assets, consumer prices increase slightly, while the long-term government bond yields decline temporarily and slightly. The rise in prices can

[25] Kim (2001) covers the period 1979-1996 and includes foreign variables as endogenous in the VAR model, meaning that the author allows feedback effect of the United Kingdom variables on the world economy.

be justified by the increase in liquidity in the market, which leads to inflationary pressures. The negative response of yields is consistent with Christensen and Krogstrup (2019). An expansionary policy has temporary positive effects on the real economy by increasing slightly industrial production, private consumption and private investment. However, it can be noted that the response of private consumptions turns slightly negative after approximately one year. The slight boost in economic activity can be justified by the temporary decline in long-term interest rates, which facilitates general financing conditions and stimulates aggregate demand. An expansion of central bank's reserve assets has temporary positive effects on the labor market by reducing unemployment and increasing nominal wages slightly. The response of labor market variables can be justified on the grounds that expanded output leads firms to create new business activities and vacancy positions, thus implying an increase in labor demand. In the financial market, an expansionary shock implies a sharp and temporary increase in stock prices. Turning on the open economy variables, the real effective exchange rate depreciates temporarily and net exports increase during ten months. These findings can be explained on the grounds that expansions of central bank's reserve assets cause a fall in the yields of assets denominated in domestic currency, which makes domestic bonds less attractive and leads to a real depreciation due to the decline in demand for domestic currency. The trade balance improvement can be attributed to the depreciation of the real effective exchange rate, which boosts exports and discourages imports.

Our findings indicate that the unconventional measures were effective in providing some stimulus to the United Kingdom economy at the zero lower bound. After an expansion of central bank's reserve assets, consumer prices increase steadily, while the long-term government bond yields decline after approximately eight months. The negative response of long-term government bond yields can be explained by the signaling and portfolio balance effects. First, it may reflect expectations of economic agents about lower monetary policy rates to come over a prolonged period (signaling effect). Second, as central bank's reserve asset purchases reduce the supply of long-term government bonds, private investors need to adjust their portfolios towards assets of similar characteristics (portfolio balance effect). As a result, the price of the purchased bonds rises, which in turn lowers their yields. The latter finding is in line with Joyce et al. (2011). The positive effect on economic activity is characterized by an increase in industrial production, private consumption and private investment. In the financial market, stock prices rise during one year.

Figure 3.6: Impulse response functions to an unconventional monetary policy shock (Baseline model, Switzerland)

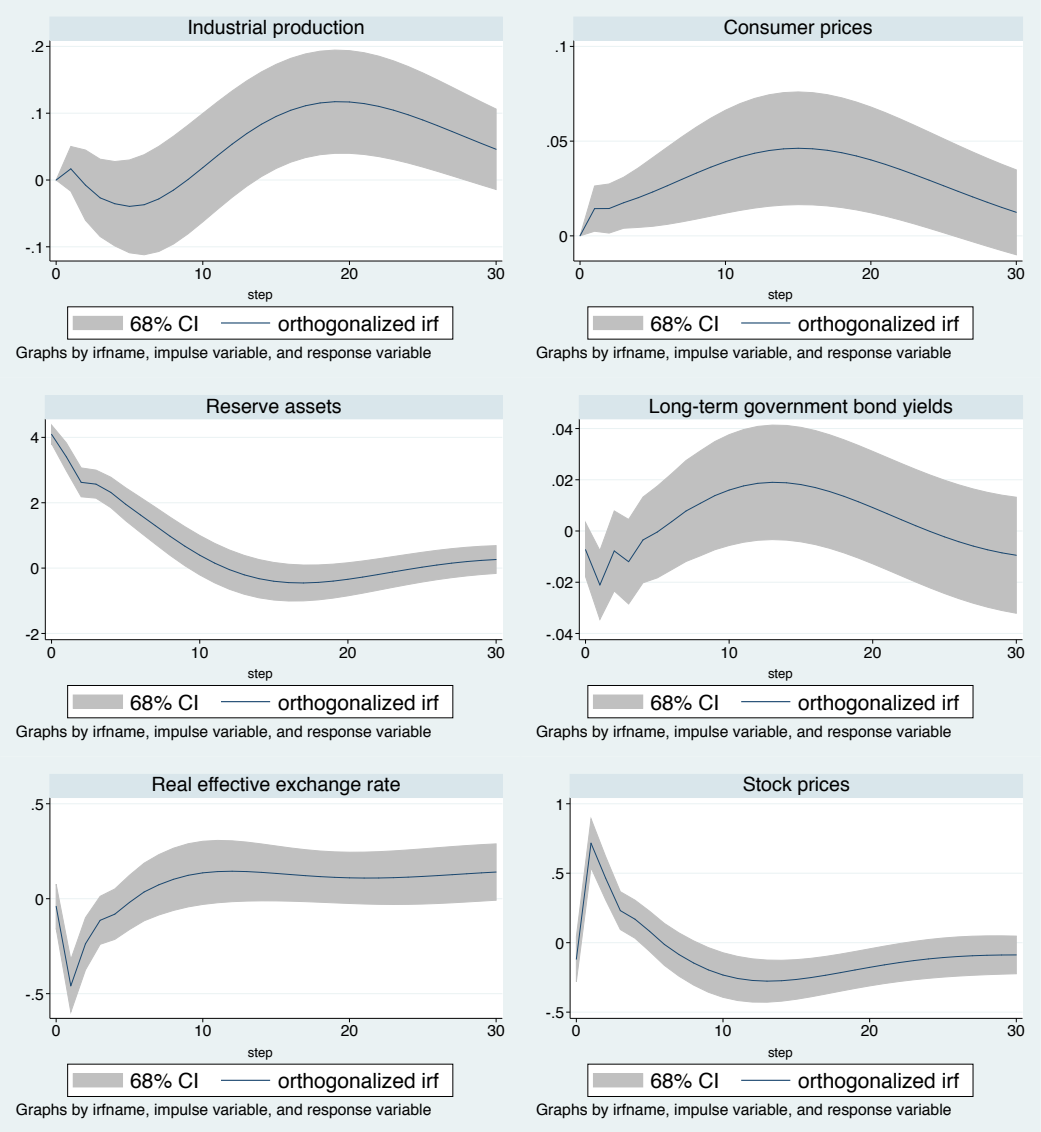


Figure 3.7: Impulse response functions to an unconventional monetary policy shock (Alternative specifications, Switzerland)

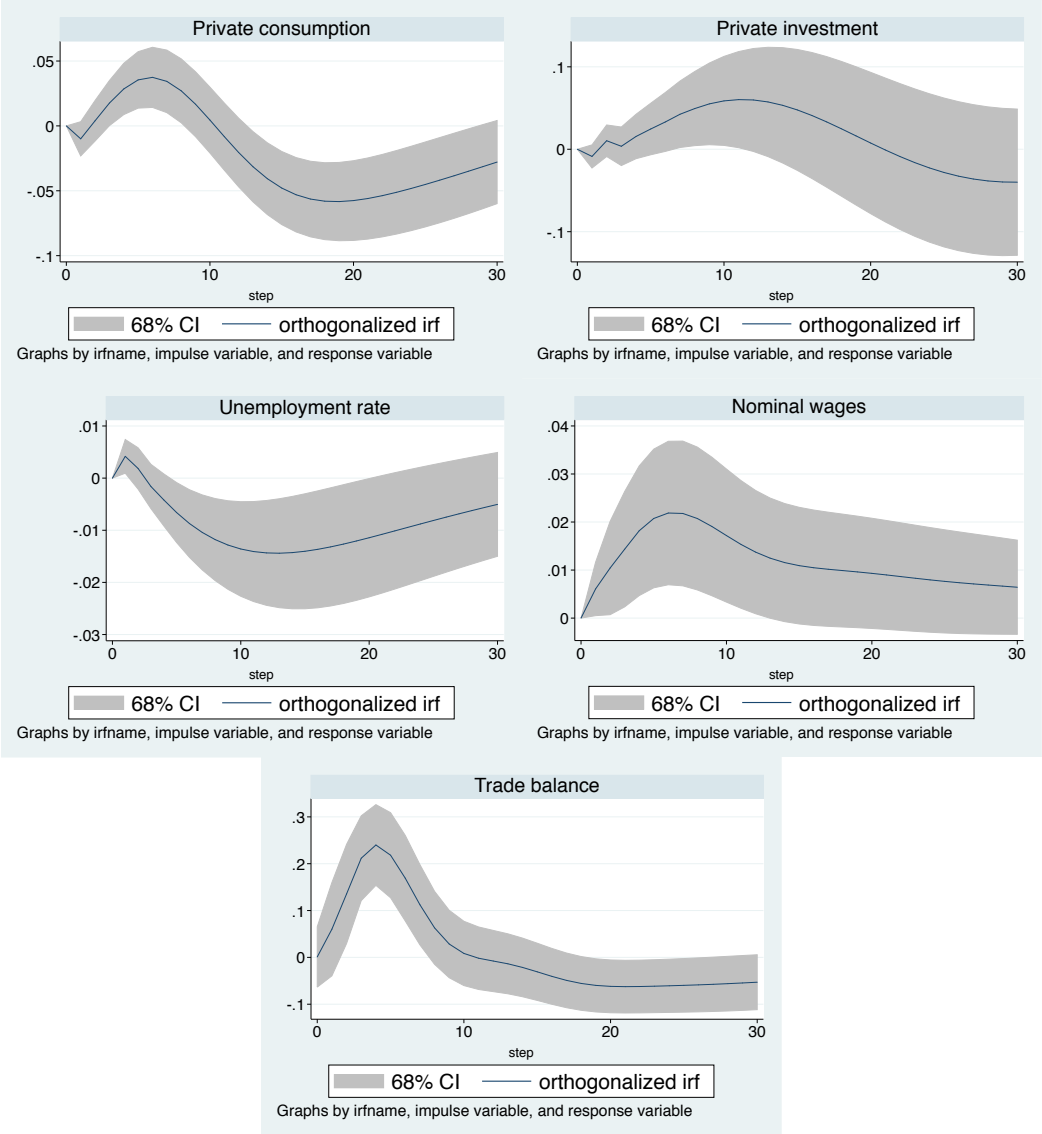


Figure 3.8: Impulse response functions to an unconventional monetary policy shock (Baseline model, United Kingdom)

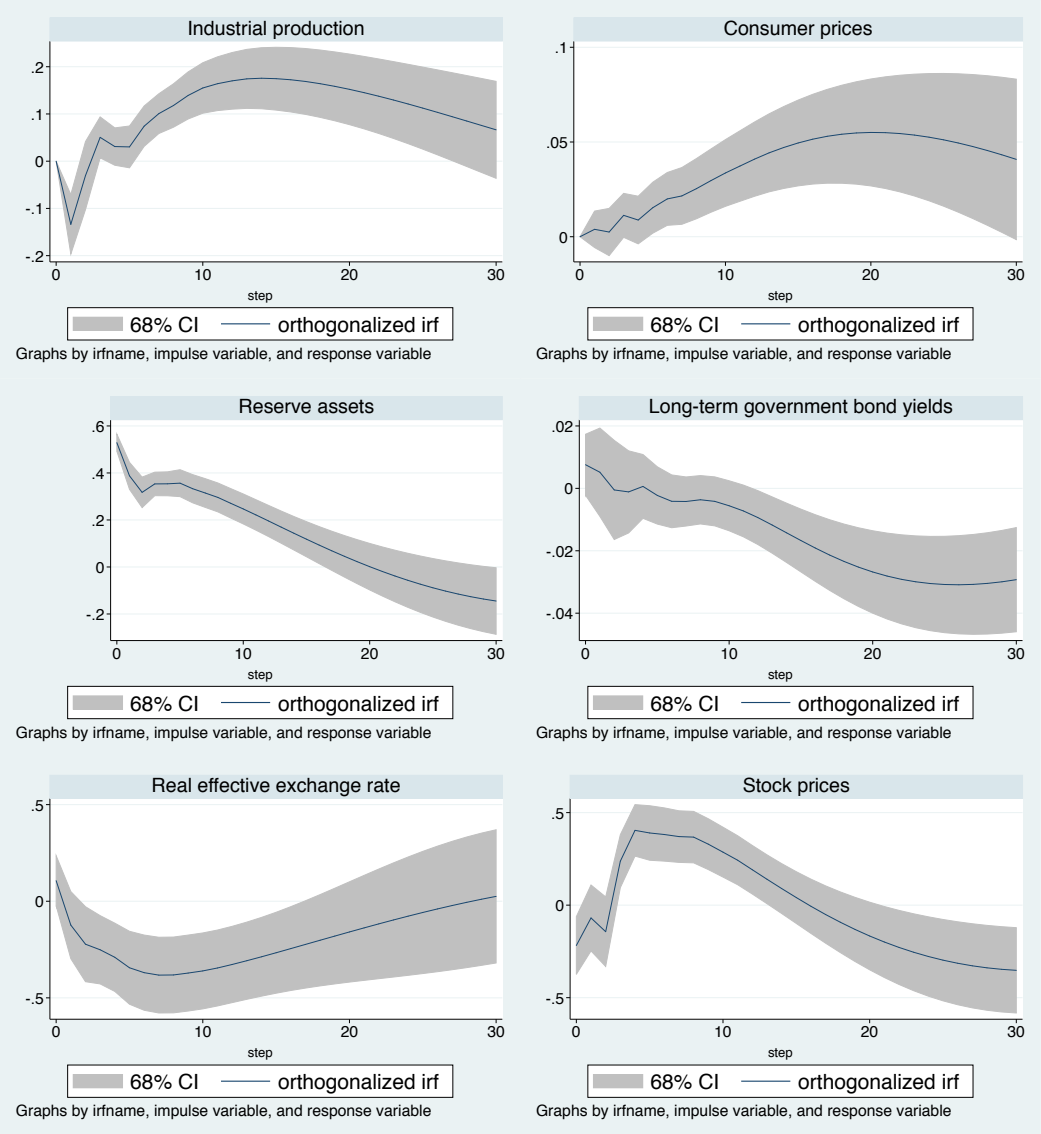
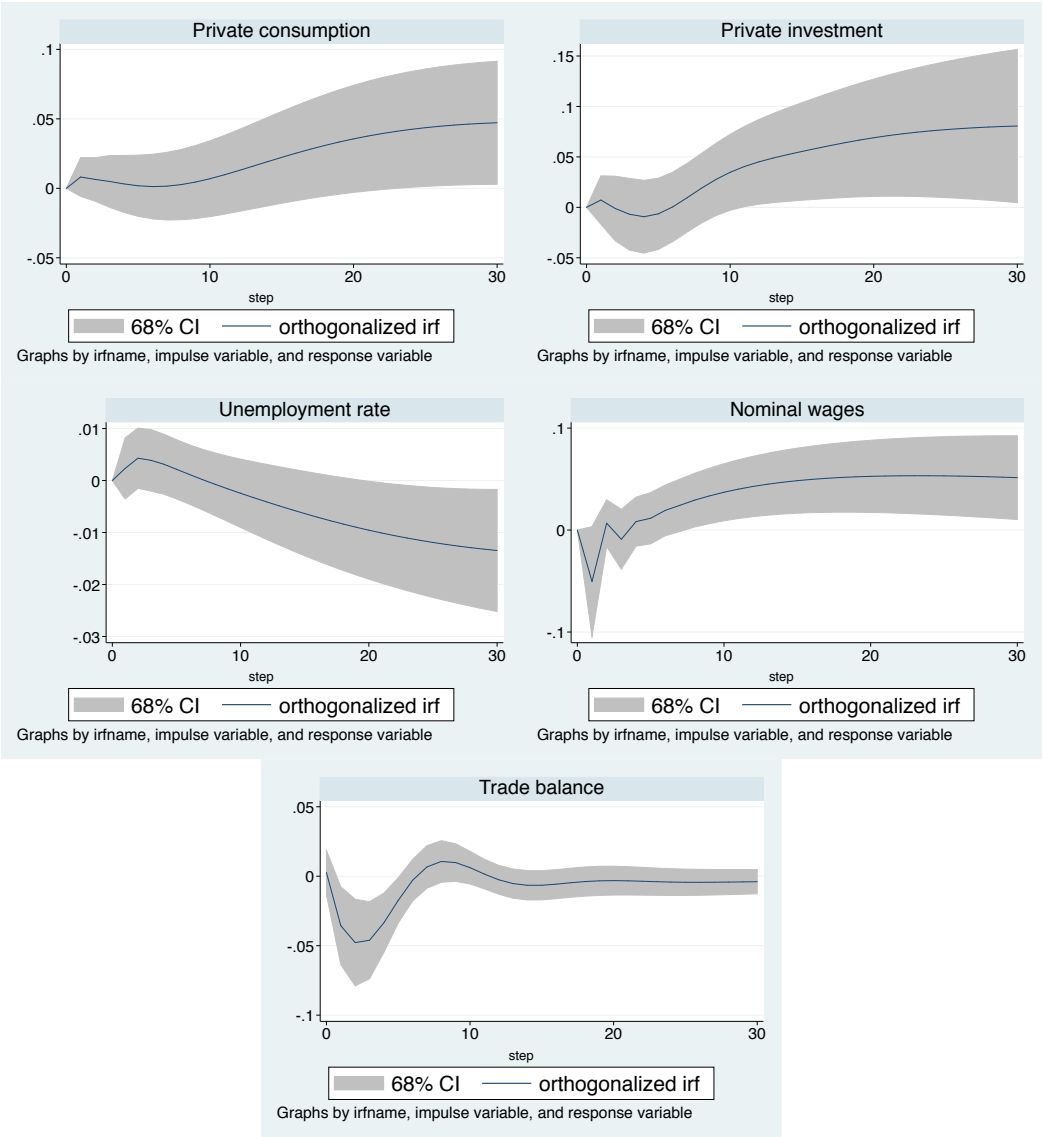


Figure 3.9: Impulse response functions to an unconventional monetary policy shock (Alternative specifications, United Kingdom)



Central bank's reserve asset purchases increase the liquidity injected in the markets and lower long-term interest rates, which in turn affects the stock market through two different mechanisms. First, lower borrowing costs for firms translate into higher profitability and a higher propensity to invest. Then, the low return offered in the bond market leads to a move of investors away from it and towards the stock market. These two mechanisms contribute to the rise in prices in the stock market. The increase in stock prices and the decrease in long-term interest rates transmit to the real economy through an increase in the wealth of shareholders and the reduction of costs of capital, thus implying a subsequent increase in spending and economic growth. Turning on the labor market variables, unemployment declines slightly and persistently, while nominal wages follow the opposite dynamics. Finally, the real effective exchange rate depreciates and net exports decline surprisingly during five months.

3.5.2.3 Variance Decomposition Analysis

In order to assess the relative importance of conventional and unconventional monetary policy shocks, the variance decomposition analysis is implemented. It provides informative conclusions about the effectiveness of the respective monetary policies. The results are presented for the first two years following the structural shocks in table 3.1.

We start with the description of the variance decomposition of Swiss macroeconomic aggregates with respect to conventional monetary policy shocks. Central bank's policy rate innovations explain a significant share of the variability in consumer confidence and stock prices. They account for 6.60 and 14.98 percent of their fluctuations after one year, respectively. National income and its components are generally little sensitive to unexpected changes in monetary policy rates at the first quarter horizons. The contribution to the variability of private investment and the trade balance reaches 6.83 and 5.25 percent after one year, respectively. On the other hand, the contribution to the variability of private consumption is relatively low at all horizons. Conventional monetary policy shocks explain a relatively small share of the variability of the real effective exchange rate and inflation. In relation to the labor market variables, the contribution of conventional monetary policy shocks to fluctuations in unemployment and nominal wages is also relatively modest.

The contribution of unconventional monetary policy shocks to the variability of the central bank's reserve assets is lower at all horizons than that

of conventional monetary policy shocks to the variability of the official bank policy rate. This means that unconventional monetary policy has been more systematic during the crisis, responding more to economic shocks than conventional monetary policy during the pre-crisis period. Exogenous increases in central bank's reserve assets have a greater contribution to the variability of the real effective exchange rate and consumer prices than innovations in the official bank policy rate. Unconventional monetary policy shocks explain 10.95 percent of fluctuations in stock prices after one year. The contribution to the variability of the real effective exchange rate, trade balance and consumer prices reaches 5.35, 8.12 and 10.61 percent after two years, respectively. In contrast, industrial production and long-term government bond yields are little sensitive to unexpected changes in central bank's reserve assets. Moreover, the contribution to the variability of national income components and labor market variables is quite modest at the first month horizons, although it increases progressively over time. The shares of the variance of private consumption, nominal wages and unemployment resulting from unconventional monetary policy shocks reach 10.10, 4.99 and 5.98 percent after two years, respectively.

In the United Kingdom, the contribution of conventional monetary policy shocks to the variability of national income and its components increases after a few lags, although it remains quite modest at all horizons. These findings are consistent with the assumption that economic activity reacts with a delay to monetary policy decisions. In addition, the share of the variability of the trade balance explained by central bank's policy rate innovations is relatively moderate at all horizons. The variance decomposition analysis reveals that conventional monetary policy shocks explain up to 5.11 percent of the variability in consumer confidence after two years. The contribution of conventional monetary policy shocks to fluctuations in the official bank policy rate is 90.49 percent at the first quarter horizon and declines considerably over time. The variability of the real effective exchange rate explained by conventional monetary policy shocks is substantial on impact with a value up to 30.68 percent, before declining progressively over time. This result is consistent with the Dornbusch's (1976) exchange rate overshooting prediction. Despite this, the contribution to the variability of inflation is modest at all horizons. Conventional monetary policy innovations explain about 6.46 percent of stock prices variability on impact and up to 18.63 percent of their variability after two years. On the other hand, the contribution of conventional monetary policy shocks to the variability of unemployment and nominal wages is up to 2.19 and 1.90 percent, respectively.

Table 3.1: Variance decomposition (Switzerland, United Kingdom)

			Switzerland		United Kingdom	
	Quarter	Month	CMP	UCMP	CMP	UCMP
Consumer confidence;	1	3	0.00	1.78	0.00	0.28
Long-term government	2	6	3.90	1.24	0.37	0.24
bond yields (CMP; UCMP)	4	12	6.60	1.70	1.60	0.53
	8	24	6.14	2.50	5.11	8.76
Output;	1	3	0.00	0.04	0.00	2.77
Industrial production	2	6	2.31	0.26	0.18	2.81
(CMP; UCMP)	4	12	3.37	0.39	0.70	9.30
	8	24	2.23	4.76	4.16	20.13
Inflation; Consumer prices	1	3	0.00	0.88	0.00	0.09
(CMP; UCMP)	2	6	1.15	1.82	0.40	0.97
	4	12	1.18	5.06	1.33	5.19
	8	24	2.28	10.61	2.52	16.38
Official bank policy rate;	1	3	95.93	85.19	90.49	91.30
Reserve assets	2	6	78.44	74.24	71.23	91.59
(CMP; UCMP)	4	12	64.16	52.72	49.70	87.27
	8	24	52.85	44.55	40.32	56.77
Real effective exchange	1	3	0.97	7.39	30.68	1.59
rate	2	6	0.94	5.03	17.50	3.78
	4	12	0.74	4.65	11.18	8.00
	8	24	1.51	5.35	11.05	10.86
Stock prices	1	3	7.84	14.34	6.46	1.60
	2	6	14.55	11.85	8.80	6.26
	4	12	14.98	10.95	18.35	11.28
	8	24	12.62	14.15	18.63	10.63
Private consumption	1	3	0.00	0.16	0.00	0.12
	2	6	0.80	2.02	2.84	0.06
	4	12	1.81	3.20	3.19	0.07
	8	24	2.09	10.10	4.07	1.65
Private investment	1	3	0.00	0.24	0.00	0.02
	2	6	4.92	0.52	0.04	0.04
	4	12	6.83	2.79	0.91	0.52
	8	24	5.69	1.83	1.33	3.69
Trade balance	1	3	0.08	1.21	2.61	2.41
	2	6	4.72	7.36	4.68	3.65
	4	12	5.25	7.90	4.15	3.51
	8	24	5.26	8.12	3.70	3.60
Nominal wages	1	3	0.00	0.50	0.00	0.61
	2	6	1.20	1.95	0.22	0.58
	4	12	2.64	4.58	1.27	1.51
	8	24	2.83	4.99	1.90	5.23
Unemployment rate	1	3	0.00	0.46	0.00	0.22
	2	6	0.00	0.88	0.08	0.30
	4	12	0.44	4.06	0.52	0.29
	8	24	6.21	5.98	2.19	2.20

The variance decomposition analysis reveals that conventional monetary policy has been more systematic than unconventional monetary policy in the United Kingdom, responding more to economic variables and less to unsystematic monetary policy shocks. Unconventional monetary policy shocks have a greater contribution to the variability of industrial production and consumer prices than conventional monetary policy shocks. They account for 20.13 and 16.38 percent of their variability after two years, respectively. In contrast, private consumption, private investment and net exports are little sensitive to unexpected changes in the central bank's reserve assets. The share of fluctuations in the long-term government bond yields explained by unconventional monetary policy shocks is small at the first month horizons and only increases after one year. The contribution to the real effective exchange rate variability is up to 10.86 percent, while the contribution to fluctuations in stock prices increases progressively over time and reaches a maximum of 11.28 percent after one year. Finally, the variance of labor market variables resulting from unconventional monetary policy shocks is modest at all month horizons.

The main findings of the variance decomposition analysis can be summarized as follows. First of all, conventional and unconventional monetary policy shocks have a significant contribution to stock prices variability. In addition, the results indicate that conventional monetary policy explains a meaningful part of the variability in consumer confidence. There are also some differences in the obtained results between the contribution of conventional and unconventional monetary policy shocks to the variability of economic variables. First, our findings reveal that unconventional monetary policy has been more systematic than conventional monetary policy in Switzerland, while the opposite holds true in the United Kingdom. Second, unconventional monetary policy shocks have a greater contribution to the variability of consumer prices than conventional monetary policy shocks. Finally, unconventional monetary policy shocks have a greater contribution to the variability of the real effective exchange rate than conventional monetary policy shocks in Switzerland, while the opposite holds true in the United Kingdom.

3.6 Conclusions

This chapter provides a detailed empirical examination on the transmission mechanisms of conventional and unconventional monetary policies on various macroeconomic aggregates in open economies. The study contributes to the literature by investigating the role of stock prices and consumer expectations in the transmission of monetary policy. The analysis is carried out for two non-EMU countries, Switzerland and the United Kingdom, over the period 1990-2017. The chapter proposes two distinct structural VAR models. The baseline model for the case of conventional monetary policy covers the pre-2009 period, while the baseline model for the case of unconventional monetary policy covers the post-2009 period. The study is based on sub-periods since the implementation of quantitative easing can be viewed as a new monetary policy regime. Using the recursive approach, we identify two monetary policy shocks: (i) the official bank policy rate (ii) the central bank's reserve assets. The modelling approach consists in augmenting the VAR model with a forward-looking informational variable of near-term development in economic activity and several foreign exogenous variables. For the case of conventional monetary policy, the consumer confidence indicator is used since it contains important information used by central banks about consumer expectations as regards future economic conditions. For the case of unconventional monetary policy, the long-term government bond yields are used to capture consumer expectations about future short-term interest rates.

The conducted analysis reveals that the inclusion of a forward-looking informational variable of near-term development in economic activity and a financial variable such as the stock prices are of key importance for the monetary policy assessment. We provide evidence for the existence of a consumer confidence channel in the transmission mechanism of conventional monetary policy. An expansionary policy enhances households' perception with regards future economic conditions, which may result in a tendency to consumer more and save less. Thus, changes in consumer confidence can potentially amplify the effects of monetary policy on the real economy. Moreover, the results indicate that the long-term government bond yields have an important role in the transmission mechanism of unconventional monetary policy. The increase in stock prices and the decrease in long-term interest rates transmit to the real economy through an increase in the wealth of shareholders and the reduction of costs of capital, thus implying an increase in spending and economic activity. Although the above results have limited policy implications, they reveal the importance of considering these specific transmission channels

and controlling for global supply and demand shocks in order to provide a comprehensive analysis of the effects of monetary policy.

Our findings indicate that conventional and unconventional monetary policies were effective in providing temporary stimulus to the economies of Switzerland and the United Kingdom during the considered periods. Conventional monetary policy shocks have temporary expansionary effects in both non-EMU countries by increasing national income components and consumer price inflation. Our findings reveal that expansionary shocks lead to a temporary increase in consumer confidence and stock prices. The boost in economic activity is also reflected by the fall in unemployment and the increase in nominal wages. However, the real effective exchange rate's reaction to conventional monetary policy shocks presents some contradictory patterns. In the United Kingdom, conventional monetary policy shocks imply a strong and immediate real depreciation, followed by a gradual appreciation until the initial steady state level is reached, thus providing support to the Dornbusch's (1976) exchange rate overshooting prediction. In contrast, the real effective exchange rate appreciates surprisingly on impact in Switzerland, providing evidence of an exchange rate puzzle. In addition, net exports increase temporarily in Switzerland, while they decline temporarily in the United Kingdom.

Unconventional monetary policy shocks have expansionary effects in both countries by temporarily increasing industrial production, private consumption and private investment. Nevertheless, the results indicate that the positive effects on the Swiss economy are relatively small and transitory. An expansion of central bank's reserve assets leads to an increase in consumer prices and a decline in the long-term government bond yields. These movements are associated with a substantial increase in stock prices. The labor market is characterized by a slight decline in unemployment and a slight rise in nominal wages. Unconventional monetary policy shocks imply a real depreciation in both countries, accompanied by an increase in Swiss net exports and a decline in the United Kingdom net exports. The variance decomposition analysis reveals that conventional and unconventional monetary policy shocks have a significant contribution to stock prices variability. The results also indicate that conventional monetary policy explains a meaningful part of the variability in consumer confidence. Finally, our findings suggest that unconventional monetary policy has been more systematic than conventional monetary policy in Switzerland, responding more to economic variables and less to unsystematic monetary policy shocks, while the opposite holds true in the United Kingdom.

Appendix 3

A.3.1 Data Sources and Variable Definitions

Switzerland

Output: Real Gross domestic product, Code: CLVMNACSAB1GQCH. Source: Federal Reserve Bank of St. Louis.

Industrial production: Production of total industry index, Code: CHEPROINDQISMEI. Source: Federal Reserve Bank of St. Louis.

Private consumption: Private final consumption expenditure, Code: CHEPFCEQDSMEI. Source: Federal Reserve Bank of St. Louis.

Private investment: Gross fixed capital formation (1990-2009), Code: CHEGFCFQDSMEI. Source: Federal Reserve Bank of St. Louis. Gross fixed capital formation: Private sector (2009-2017). Source: Annual macro-economic database of the European Commission.

Nominal wages: Wages and Salaries. Source: Organisation for Economic Co-operation and Development.

Inflation rate: Consumer price (all items) growth rate same period previous year, Code: CPALTT01CHQ659N. Source: Federal Reserve Bank of St. Louis.

Consumer prices: Consumer price (all items) index, Code: CHECPIALLMINMEI. Source: Federal Reserve Bank of St. Louis.

GDP deflator: GDP implicit price deflator, Code: CHEGDPDEFQISMEI. Source: Federal Reserve Bank of St. Louis.

Real effective exchange rate: Real narrow effective exchange rate, Code: RNCHBIS. Source: Federal Reserve Bank of St. Louis.

Official bank policy rate: Three-month Swiss franc London Interbank Offered Rate: LIBOR, Code: CHF3MTD156N. Source: Federal Reserve Bank of St. Louis.

Unemployment rate: Registered unemployment rate, Code: LMUNRRTTCHQ156S. Source: Federal Reserve Bank of St. Louis.

Reserve assets: Official total reserve assets. Source: Swiss National Bank.

Trade balance: Net exports of goods and services as a percentage of GDP, Exports of goods and services (Code: CHEEXPORTQDSMEI) minus imports of goods and services (Code: CHEIMPORTQDSMEI). Source: Federal Reserve Bank of St. Louis.

Population: Total population, Code: POPTOTCHA647NWDB. Source: Federal Reserve Bank of St. Louis.

Stock prices: Total share prices for all shares, Code: SPASTT01CHQ661N. Source: Federal Reserve Bank of St. Louis.

Consumer confidence: Consumer opinion surveys: Confidence indicators (composite indicators): European Commission and National Indicators, Code: CSCICP02CHQ460S. Source: Federal Reserve Bank of St. Louis.

Long-term government bond yields: Long-term government bond yields: 10-year, Code: IRLTLT01CHM156N. Source: Federal Reserve Bank of St. Louis.

Euro area interest rate: German three-month interbank rates (1990-1993), Code: IR3TIB01DEM156N. Three-month interbank rates for the euro area (1994-2009), Code: IR3TIB01EZQ156N. Source: Federal Reserve Bank of St. Louis.

Euro area stock prices: Total share prices for all shares for the euro area, Code: SPASTT01EZQ661N. Source: Federal Reserve Bank of St. Louis.

Euro area consumer prices: Consumer price (all items) index for the euro area, Code: EA19CPALTT01IXOBQ. Source: Federal Reserve Bank of St. Louis.

Euro area reserve assets: Central bank assets for the euro area, Code: ECBASSETS. Source: Federal Reserve Bank of St. Louis.

Global oil price: Global price of West Texas Intermediate crude, Code: POILWTIUSDM. Source: Federal Reserve Bank of St. Louis.

Global commodity prices: Global price index of all commodities, Code: PALLFNFINDEXQ. Source: Federal Reserve Bank of St. Louis.

United States official bank policy rate: Effective federal funds rate, Code: FEDFUNDS. Source: Federal Reserve Bank of St. Louis.

United States reserve assets: Total assets (less eliminations from consolidation), Code: WALCL. Source: Federal Reserve Bank of St. Louis.

United Kingdom

Output: Gross domestic product, Code: UKNGDP. Source: Federal Reserve Bank of St. Louis.

Industrial production: Production of total industry index, Code: GBRPROINDMISMEI. Source: Federal Reserve Bank of St. Louis.

Private consumption: Private final consumption expenditure, Code: GBRPFCEQDSMEI. Source: Federal Reserve Bank of St. Louis.

Private investment: Gross fixed capital formation: Private sector. Source: Annual macro-economic database of the European Commission.

Nominal wages: Wages and Salaries: Resources (1990-2009), Code: RPCG. Source: Office for National Statistics. Hourly earnings in the manufacturing sector (2009-2017), Code: LCEAMN01GBM661S. Source: Federal Reserve Bank of St. Louis.

Inflation rate: Consumer price (all items) growth rate same period previous year, Code: CPALTT01GBQ659N. Source: Federal Reserve Bank of St. Louis.

Consumer prices: Consumer price (all items) index, Code: GBRCPIALLMINMEI. Source: Federal Reserve Bank of St. Louis.

GDP deflator: GDP implicit price deflator, Code: GBRGDPDEFQISMEI. Source: Federal Reserve Bank of St. Louis.

Real effective exchange rate: Real narrow effective exchange rate, Code: RNGBBIS. Source: Federal Reserve Bank of St. Louis.

Official bank policy rate: Official bank rate, Code: IUQABEDR. Source: Bank of England.

Unemployment rate: Registered unemployment rate, Code: LMUNRRTTGBM156S. Source: Federal Reserve Bank of St. Louis.

Reserve assets: Government stock (gilts), Code: BKPM. Source: Office for National Statistics.

Trade balance: Net exports of goods and services as a percentage of GDP, Exports of goods and services (Code: GBREXPORTQDSMEI) minus imports of goods and services (Code: GBRIMPORTQDSMEI). Source: Federal Reserve Bank of St. Louis.

Population: Resident population: Mid-year estimates (quarterly data interpolated), Code: EBAQ. Source: Office for National Statistics.

Stock prices: Total share prices for all shares, Code: SPASTT01GBQ661N. Source: Federal Reserve Bank of St. Louis.

Consumer confidence: Consumer opinion surveys: Confidence indicators (composite indicators): European Commission and National Indicators, Code: CSCICP02GBM460S. Source: Federal Reserve Bank of St. Louis.

Long-term government bond yields: Long-term government bond yields: 10-year, Code: IRLTLT01GBM156N. Source: Federal Reserve Bank of St. Louis.

Euro area interest rate: German three-month interbank rates (1990-1993), Code: IR3TIB01DEM156N. Three-month interbank rates for the euro area (1994-2009), Code: IR3TIB01EZQ156N. Source: Federal Reserve Bank of St. Louis.

Euro area stock prices: Total share prices for all shares for the euro area, Code: SPASTT01EZQ661N. Source: Federal Reserve Bank of St. Louis.

Euro area consumer prices: Consumer price (all items) index for the euro area, Code: EA19CPALTT01IXOBQ. Source: Federal Reserve Bank of St. Louis.

Euro area reserve assets: Central bank assets for the euro area, Code: ECBASSETS. Source: Federal Reserve Bank of St. Louis.

Global oil price: Global price of West Texas Intermediate crude, Code: POILWTIUSDM. Source: Federal Reserve Bank of St. Louis.

Global commodity prices: Global price index of all commodities, Code: PALLFNFINDEXQ. Source: Federal Reserve Bank of St. Louis.

United States official bank policy rate: Effective federal funds rate, Code: FEDFUNDS. Source: Federal Reserve Bank of St. Louis.

United States reserve assets: Total assets (less eliminations from consolidation), Code: WALCL. Source: Federal Reserve Bank of St. Louis.

A.3.2 Model Specifications

Table A.3.2.1: Model specifications

Specification	Endogenous variables							Exogenous variables[a]			
Conventional monetary policy (CMP)											
A	ci	y	π	r	rer	sp		r*	cpi*	sp*	op*
B	ci	c	y	π	r	rer	sp	r*	cpi*	sp*	op*
C	ci	i	y	π	r	rer	sp	r*	cpi*	sp*	op*
D	ci	y	π	r	tb	rer	sp	r*	cpi*	sp*	op*
E	ci	u	y	π	r	rer	sp	r*	cpi*	sp*	op*
F	ci	y	π	w	r	rer	sp	r*	cpi*	sp*	op*
Unconventional monetary policy (UCMP)											
A	ip	cpi	ra	lr	rer	sp		ra*	cpi*	sp*	
B	c	cpi	ra	lr	rer	sp		ra*	cpi*	sp*	
C	i	cpi	ra	lr	rer	sp		ra*	cpi*	sp*	
D	cpi	ra	lr	tb	rer	sp		ra*	cpi*	sp*	
E	u	cpi	ra	lr	rer	sp		ra*	cpi*	sp*	
F	cpi	w	ra	lr	rer	sp		ra*	cpi*	sp*	

[a] For the United Kingdom, the global commodity price index (cp*) is used instead of the euro area consumer price index (cpi*).

Table A.3.2.2: Summary of variables

Variables	Notation	Variables	Notation
Consumer confidence	ci	Private investment	i
Output	y	Nominal wages	w
Inflation rate	π	Trade balance	tb
Official bank policy rate	r	Unemployment rate	u
Real effective exchange rate	rer	Euro area interest rate	r*
Stock prices	sp	Euro area consumer prices	cpi*
Industrial production	ip	Euro area reserve assets	ra*
Consumer prices	cpi	Euro area stock prices	sp*
Reserve assets	ra	Global oil price	op*
Long-term government bond yields	lr	Global commodity prices	cp*
Private consumption	c		

A.3.3 Descriptive Statistics

Table A.3.3.1: Descriptive statistics (Switzerland)

		1990-2009		2009-2017	
Variables	Unit	Mean	Std.dev	Mean	Std.dev
Consumer confidence	Net percent	-10.20	20.13	-	-
Output	Billion Swiss franc	125.94	13.26	-	-
Private consumption	Billion Swiss franc	70.79	6.01	84.37	3.62
Private investment[a]	Billion Swiss franc	34.40	3.23	130.96	8.30
Real effective exchange rate (index 2015=100)	Percent	82.24	3.67	93.12	5.10
Stock prices (index 2015=100)	Percent	56.61	25.62	83.86	14.64
Unemployment rate	Percent	3.19	1.27	3.21	0.31
Inflation rate	Percent	1.65	1.72	-	-
Consumer prices (index 2015=100)	Percent	-	-	100.95	0.85
Trade balance	Percent	5.71	3.12	10.56	2.31
Official bank policy rate	Percent	2.99	2.60	-	-
Nominal wages	Billion Swiss franc	54.83	8.43	78.46	4.03
Long-term government bond yields	Percent	-	-	0.79	0.85
Reserve assets	Billion Swiss franc	-	-	443.20	201.25
Industrial production (index 2015=100)	Percent	-	-	99.07	4.16

[a] For the period 1990-2009, the mean and the standard deviation refer to gross fixed capital formation (Unit: Billion Swiss franc).

Table A.3.3.2: Descriptive statistics (United Kingdom)

		1990-2009		2009-2017	
Variables	Unit	Mean	Std.dev	Mean	Std.dev
Consumer confidence	Net percent	-7.67	7.52	-	-
Output	Billion British pound	358.13	55.57	-	-
Private consumption	Billion British pound	233.97	38.85	301.55	14.13
Private investment	Billion British pound	226.92	23.32	247.91	24.20
Real effective exchange rate (index 2015=100)	Percent	100.51	7.73	91.82	5.91
Stock prices (index 2015=100)	Percent	67.98	20.68	92.76	12.65
Unemployment rate	Percent	5.02	2.42	3.77	1.06
Inflation rate	Percent	2.78	1.91	-	-
Consumer prices (index 2015=100)	Percent	-	-	96.67	4.98
Trade balance	Percent	-1.39	1.15	-1.58	0.49
Official bank policy rate	Percent	6.09	2.95	-	-
Nominal wages[a]	Billion British pound	114.30	32.62	96.48	5.10
Long-term government bond yields	Percent	-	-	2.41	0.92
Reserve assets	Billion British pound	-	-	1124.2	251.78
Industrial production (index 2015=100)	Percent	-	-	99.81	1.97

[a] For the period 2009-2017, the mean and the standard deviation refer to the hourly earnings in the manufacturing sector (Unit: Percent, index 2015=100).

A.3.4 Results from Unit Root tests

Table A.3.4.1: Zivot-Andrews unit root test with single structural break (Period 1990-2017)

		Zivot-Andrews unit root test with single structural break			
Variables	Deterministic terms	Level[a]	Break date	Difference	Break date
Switzerland					
r	Trend and intercept	-4.284	1995q1	-5.657***	2008q3
ra	Trend and intercept	-3.932	2009m6	-4.645	2009m3
United Kingdom					
r	Trend and intercept	-5.127**	2008q4	-	1997q4
ra	Trend and intercept	-5.505**	2008m10	-	2008m10

[a] The series has an unit root under the null hypothesis.

*** Indicates significance at the 1% level ** Indicates significance at the 5% level
* Indicates significance at the 10% level

A.3.5 VAR Model: Lag Length Selection and Specification tests

Table A.3.5.1: Residual autocorrelation test and lag length selection (CMP model specifications)

	Residual autocorrelation[a]				
Lags	1	2	3	4	No. lags selected[b]
Specification					
A					
Switzerland	0.00000	0.04919	0.47816	0.00620	2
United Kingdom	0.40678	0.03619	0.12776	0.08339	2
B					
Switzerland	0.00000	0.00455	0.25778	0.05058	4
United Kingdom	0.71234	0.30510	0.06459	0.12491	2
C					
Switzerland	0.00000	0.09908	0.74875	0.02762	2
United Kingdom	0.45297	0.03428	0.17118	0.04969	3
D					
Switzerland	0.00000	0.08911	0.74730	0.00245	2
United Kingdom	0.06991	0.08479	0.62111	0.39418	2
E					
Switzerland	0.00005	0.23543	0.23336	0.00558	3
United Kingdom	0.00635	0.01418	0.07455	0.01510	3
F					
Switzerland	0.00009	0.02976	0.84916	0.00832	3
United Kingdom	0.03086	0.00726	0.26424	0.09073	3

[a] Residual autocorrelation test (p-value) is based on the residuals from the reduced VAR form. Reported p-values are from the Breusch-Godfrey Lagrange Multiplier test. No serial correlation under the null hypothesis.

[b] We refer to the residual autocorrelation test conclusions to select the appropriate number of lags. The number of lags is set to two, three or four depending on the model specification when they provide serially uncorrelated residuals.

Table A.3.5.2: Residual autocorrelation test and lag length selection (UCMP model specifications)

	Residual autocorrelation[a]				
Lags	1	2	3	4	No. lags selected[b]
Specification					
A					
Switzerland	0.04652	0.37847	0.00008	0.78561	2
United Kingdom	0.00000	0.00315	0.45323	0.32158	3
B					
Switzerland	0.10319	0.82196	0.00706	0.45608	2
United Kingdom	0.00003	0.28592	0.22937	0.05720	2
C					
Switzerland	0.04684	0.41914	0.26086	0.77808	3
United Kingdom	0.00466	0.45356	0.05412	0.19227	2
D					
Switzerland	0.28875	0.41639	0.00226	0.84464	2
United Kingdom	0.00035	0.42707	0.02426	0.25406	2
E					
Switzerland	0.04417	0.57335	0.23175	0.08762	2
United Kingdom	0.00102	0.05502	0.52680	0.03755	2
F					
Switzerland	0.03218	0.24853	0.07107	0.33830	2
United Kingdom	0.00054	0.12321	0.37615	0.14492	2

[a] Residual autocorrelation test (p-value) is based on the residuals from the reduced VAR form. Reported p-values are from the Breusch-Godfrey Lagrange Multiplier test. No serial correlation under the null hypothesis.

[b] We refer to the residual autocorrelation test conclusions to select the appropriate number of lags. The number of lags is set to two or three depending on the model specification when they provide serially uncorrelated residuals.

A.3.6 Johansen Cointegration Maximum Eigenvalue Test

Table A.3.6.1: Johansen cointegration maximum eigenvalue test (CMP model specifications)

	Switzerland		United Kingdom	
	Hypothesized number of cointegrating vectors	Hypothesized number of cointegrating vectors	Hypothesized number of cointegrating vectors	Hypothesized number of cointegrating vectors
Specification	Constant	Trend	Constant	Trend
A	2	2	1	1
B	4	5	2	2
C	3	3	2	3
D	3	3	2	2
E	2	3	5	3
F	4	5	4	5

Table A.3.6.2: Johansen cointegration maximum eigenvalue test (UCMP model specifications)

	Switzerland		United Kingdom	
	Hypothesized number of cointegrating vectors	Hypothesized number of cointegrating vectors	Hypothesized number of cointegrating vectors	Hypothesized number of cointegrating vectors
Specification	Constant	Trend	Constant	Trend
A	2	2	3	4
B	1	1	2	2
C	1	1	2	2
D	2	2	3	3
E	2	1	2	2
F	2	1	2	2

A.3.7 Summary of the Results

Table A.3.7.1: Summary of the results (Switzerland)

Shock	Quarter	1	4	8	12	20
Conventional monetary policy shock						
ci		+	0	0	0	0
y		+	0	0	0	0
π		+	-	0	0	0
r		-	0	0	0	0
rer		0	0	0	0	0
sp		+	0	0	0	0
c		+	0	0	0	0
i		+	+	0	0	0
u		0	-	-	-	0
w		-	0	+	+	+
tb		+	0	0	0	0
Shock	**Month**	**3**	**12**	**24**	**30**	_
Unconventional monetary policy shock						
ip		0	0	+	0	_
cpi		+	+	+	0	_
ra		+	0	0	0	_
lr		0	0	0	0	_
rer		0	0	0	0	_
sp		+	-	0	0	_
c		+	0	-	0	_
i		0	0	0	0	_
u		0	-	0	0	_
w		+	0	0	0	_
tb		+	0	0	0	_

The sign shows the direction of the impact, and 0 means that the null hypothesis of no effect cannot be rejected at the 0.32 level of significance.

Table A.3.7.2: Summary of the results (United Kingdom)

Shock	**Quarter**	**1**	**4**	**8**	**12**	**20**
Conventional monetary policy shock						
ci		0	+	0	0	0
y		0	0	+	+	0
π		0	0	+	0	0
r		-	0	+	0	0
rer		-	0	0	0	0
sp		+	-	0	0	0
c		+	+	+	+	+
i		0	0	0	0	0
u		0	0	0	0	0
w		0	0	+	+	+
tb		-	0	0	0	0
Shock	**Month**	**3**	**12**	**24**	**30**	_
Unconventional monetary policy shock						
ip		0	+	+	0	_
cpi		0	+	+	0	_
ra		+	+	0	0	_
lr		0	0	-	-	_
rer		-	-	0	0	_
sp		+	+	0	-	_
c		0	0	0	+	_
i		0	+	+	+	_
u		0	0	-	-	_
w		0	+	+	+	_
tb		-	0	0	0	_

The sign shows the direction of the impact, and 0 means that the null hypothesis of no effect cannot be rejected at the 0.32 level of significance.

Chapter 4: Interactions among Macroeconomic Policies, the Energy Market and Environmental Quality[26]

4.1 Introduction

Economic activities affect the environment in several ways. Common effects like increased pollution and greenhouse gas emissions, depletion of natural resources and contribution to global climate change have been recognized as the greatest negative externalities of today's global economy. Many scientific studies have been argued that climate change may in turn negatively affect economic growth and output levels (e.g., Dell et al., 2009, 2012). Renewable and non-renewable energy resources are major inputs for production, meaning that their availability will directly affect future production capabilities and economic activities. The energy sector is a particularly interesting case study since it represents by far the largest source of anthropogenic greenhouse gas emissions (International Energy Agency, 2009). Despite improvements in some countries, the level of global emissions emanating from the energy sector has little changed over the past decades (International Energy Agency, 2017). The potential very serious detrimental effects of climate change have involved a large part of the literature to study the ways in which to mitigate these effects. Macroeconomic policies are usually used for the purpose of stabilizing economic activity and maintain price stability. In response to the global financial crisis, many governments have employed expansionary fiscal and monetary policies to support the recovery of their economy, subsequently affecting economic aggregates and global welfare. Nevertheless, the impact of such policies on the energy market and environmental quality is still relatively uncertain.

In this context, this chapter analyses the interactions among macroeconomic policies, the energy market and environmental quality. Theoretical modelling of the relationships between macroeconomic policies, economic growth and environmental quality is still underdeveloped. However, empirical analysis can help achieve a better understanding of the complex links between them and provide a solid basis for theoretical and empirical approaches. The VAR methodology has become one of the main econometric tools used to analyse the influence of macroeconomic policies on the environment. This

[26] The chapter has been published in *Environmental Economics and Policy Studies* as an online first article (https://doi.org/10.1007/s10018-021-00305-x).

methodology has the advantage of being suitable when the variables of interest are endogenous, which is typically the case with environmental variables. Research on the influence of fiscal and monetary policies on the energy market and environmental quality has been mainly conducted for the United States (e.g., Halkos and Paizanos, 2016; Ziaei, 2018). Nevertheless, very few studies have investigated the effects of macroeconomic policies in Europe. Lopez and Palacios (2014) contribute to this literature by evaluating the impact of fiscal policy on environmental quality in European countries. On the other hand, Matikainen et al. (2017) analyse the impact of the Bank of England's and European Central Bank's monetary policy on the environment.

The link between economic growth and environmental quality is one of the most controversial in the environmental economics literature (e.g., Dinda, 2004; Kijima et al., 2010; Shahbaz and Sinha, 2019). The environmental Kuznets curve hypothesis predicts that economic growth initially leads to a deterioration of environmental quality, followed by an improvement of environmental quality once the economy has reached a certain level. Depending on the relationship between macroeconomic policies and economic growth and according to the shape of the environmental Kuznets curve, expansionary fiscal and monetary policies may lead to greater use of natural resources and greenhouse gas emissions in some levels of the gross domestic product. Moreover, the potential impact of macroeconomic policies on the quality of the environment can generate interactions between macroeconomic and environmental policies. As a result, this implies the need to explore how fiscal and monetary policies can affect the quality of the environment along the business cycle and the specific role of energy markets as transmission channels.

A body of literature has examined the link between macroeconomic policies and the energy market (e.g., Anzuini et al., 2012; Hammoudeh et al., 2015; Ziaei, 2018). Monetary policy can affect the demand for energy through different channels including supply, demand, exchange rate, portfolio balance and signaling (Ziaei, 2018). For instance, an expansionary policy can lead to economic growth, which would increase the demand for goods and services in different markets, including the energy market (Ziaei, 2018). A question that arises when evaluating the effects of monetary policy in the energy market is the reaction of prices, which directly affects the demand for energy. There have been some studies dealing with the effects of conventional and unconventional monetary policy on energy prices, especially oil prices (e.g., Anzuini et al., 2012; Rosa, 2014) and other commodity prices (e.g., Anzuini et al., 2012; Hammoudeh

et al., 2015). Turning on the role of fiscal policy, government incentives can help generate revenue for environmental purpose, promote low-carbon activities and encourage green investment by pricing environmental externalities (Kosonen and Nicodème, 2009). However, to the best of our knowledge, the links between the energy market and government spending components, including government consumption and public investment, have not been explored yet. Economic theory predicts that if an expansionary fiscal policy is associated with an increase in output, the demand for energy and the price would increase. Nevertheless, we believe that the interactions between government spending components and the energy market need an empirical assessment.

Several studies have suggested that fiscal policy may be a determinant of environmental quality (e.g., Lopez et al., 2011; Halkos and Paizanos, 2013, 2016; Lopez and Palacios, 2014). Environmental quality is usually proxied by greenhouse gas or carbon dioxide emissions. The relationship between fiscal policy and environmental quality depends critically on the type of government spending. For instance, if spending is largely used for improvements in renewable energy, then increases in government consumption and public investment could be associated with lower emissions. In contrast, we would expect the opposite relationship if spending is targeted towards non-renewable energy. Fiscal policy measures have been predominantly implemented to moderate climate change issues (e.g., Kosonen and Nicodème, 2009). However, Matikainen et al. (2017) and Economides and Xepapadeas (2018) recently showed that monetary policy and central banks may also have to play an important role in the fight against climate change. Therefore, although environmental considerations are not the main concerns of macroeconomic policies, it is essential to consider their potential effect on environmental quality.

Fiscal instruments like spending and taxes have usually been considered sufficient to counteract the negative externalities generated by economic activity (Kosonen and Nicodème, 2009). It has been commonly admitted that since the central banks' main objectives of inflation and output stabilization are primarily short term, their influence on a long-term process such as climate change is relatively weak (Economides and Xepapadeas, 2018). However, the very probable impact of climate change on the financial market, economic growth and future output levels might require more involvement of monetary policy (Matikainen et al., 2017; Dafermos et al., 2018; Economides and Xepapadeas, 2018). Therefore, central banks may also be required to support climate change

policies, which would imply the need to address long-term and short-term issues. Moreover, the potential impact of climate change related fiscal policy measures on prices can generate interactions between fiscal and monetary policies (Economides and Xepapadeas, 2018). This implies the necessity of considering them together for the analysis of their influence on environmental quality. From a different perspective, Matikainen et al. (2017) suggest that the environmental impact of the central bank's unconventional monetary policy depends on government commitment to support low-carbon activities through direct spending. For instance, purchasing sovereign green bonds or corporate bonds from renewable energy issuers could support environmental sustainability. In contrast, if central bank's reserve asset purchases are skewed towards high-carbon sectors, then environmental quality could deteriorate. As a result, monetary policy may not be energy-neutral.

This chapter provides an empirical examination on the interactions among macroeconomic policies, the energy market and environmental quality. These interactions and channels among them are studied through structural VAR models. Due to the lack of data availability, we consider aggregate levels of government spending components and central bank's reserve asset purchases, being this a clear limitation of our analysis that, however, in our view does not invalidate the interest of this approach. The motivation to focus on the energy market is based on the importance of energy use for economic activities and its substantial contribution to greenhouse gas emissions. We use quarterly and monthly data from two non-EMU countries, Switzerland and the United Kingdom, over the period 1990-2016. This study sheds light on the implications of fiscal and monetary policies on the environmental sustainability for European countries that have adopted a flexible exchange rate regime. The analysis of these specific countries is relevant in the context of environmental issues. Switzerland, as an Alpine country, is particularly affected by global warming (Beniston, 2012). On the other hand, the United Kingdom is a coastal country and is seriously threatened by rising sea levels due to the global climate change (de la Vega-Leinert and Nicholls, 2008). Switzerland relies heavily on imports to cover its energy needs (Admin, 2019), while the United Kingdom was a large producer of oil and natural gas before becoming a net importer of energy in 2004 (U.S. Energy Information Administration, 2011). Moreover, these two countries represent unique case studies on the effects of unconventional monetary policy on the environment, as they were the only non-EMU countries to implement quantitative easing in response to the global financial crisis.

The study of Switzerland and the United Kingdom is particularly interesting given their pursuing important efforts to reduce their greenhouse gas emissions. These two countries embarked on an energy transition to lower their reliance on fossil fuels and stimulate the use of clean energy. Public sector support and specific incentives such as feed-in tariffs and a variety of subsidies have contributed to the development of their renewable energy markets (Admin, 2019; International Energy Agency, 2019). From 2005 to 2015, the share of renewable energy consumption over total final energy consumption has increased from 19.3 to 25.3 percent in Switzerland and from 1.4 to 8.7 percent in the United Kingdom (World Bank, 2019). Energy efficiency improvements and the spread of renewable energies reduced demand for oil and natural gas, which has contributed to the decline in their emissions (International Energy Agency, 2007, 2019). The main factor explaining their good environmental performance compared to other European countries is the access to a wide range of environmental technologies. They are among the most innovative countries with high spending on research and development (R&D) (Admin, 2019; Office for National Statistics, 2020). Switzerland was one of the first countries to adopt strong environmental laws, which in turn contributed to the development of environmental technologies much earlier than in other countries (International Energy Agency, 2007). The United Kingdom puts energy innovation at the center of its decarbonization policy (International Energy Agency, 2019).

This chapter examines for the first time how the implementation of macroeconomic policies, that aim to stimulate the economy, may also affect the quality of the environment along the business cycle and the specific role of energy markets as transmission channels. Our structural VAR models capture the supply and demand factors of energy markets, which enables us to examine the impact of fiscal and monetary policies on environmental quality that occurs through these two channels. In this analysis, we believe that it is essential to differentiate between the effects of fiscal and monetary policy on renewable and non-renewable energies since each of them has different economic and environmental implications. On the one hand, the chapter evaluates the implications of macroeconomic policies on the price of non-renewable energy and the use of both renewable and non-renewable energy. On the other hand, it assesses the influence of fiscal policy components, conventional and unconventional monetary policies on greenhouse gas emissions generated by the energy sector. We aim to provide some policy recommendations that can help support the achievement of environmental sustainability.

To the best of our knowledge, there is no theoretical model analysing the underpinnings of the relationship between macroeconomic policies, economic growth and environmental quality. This makes empirical modelling particularly challenging and interesting from the perspective of setting the ground for theoretical and empirical approaches to this issue. We propose two distinct structural VAR models based on a macroeconomic framework including the energy market. Using the recursive approach[27], we identify four policy shocks: (i) government consumption (ii) public investment (iii) the official bank policy rate (iv) the central bank's reserve assets. The baseline model for the cases of fiscal and conventional monetary policy is estimated using quarterly data on the government spending component, the output, the consumer price index, the non-renewable energy price index, the official bank policy rate, energy consumption and greenhouse gas emissions. For the case of conventional monetary policy, the empirical analysis is carried out for the pre-2009 period. The baseline model for the case of unconventional monetary policy covers the post-2009 period and is estimated using monthly data on the industrial production index, the consumer price index, the non-renewable energy price index, the central bank's reserve assets, energy consumption and greenhouse gas emissions. The government spending component rotates between government consumption and public investment. Energy consumption is decomposed into its renewable and non-renewable forms. The effects of policy shocks are assessed by the impulse response functions and the variance decomposition. The analysis reveals that fiscal and monetary policies have a significant influence on the energy market and environmental quality. Fiscal policy can contribute to achieving non-renewable energy conservation and enhancing environmental quality. Besides, the examination of monetary policy reveals that central banks should investigate the impact of their interventions on environmental quality through the renewable and non-renewable energy markets.

The rest of the chapter is organized as follows. Section 4.2 discusses the interactions and channels among macroeconomic policies, economic growth, the energy market and environmental quality. Section 4.3 presents the econometric methodology. Section 4.4 describes the data. Section 4.5 provides the results. Section 4.6 contains concluding remarks and policy implications.

[27] Since the identification of exogenous structural shocks using the sign-restrictions approach is generally based on theoretical models, we prefer to use the standard recursive identification approach as it only requires assumptions on the contemporaneous responses of the variables to innovations in the other variables of the system.

4.2 Interactions among Macroeconomic Policies, Economic Growth, the Energy Market and Environmental Quality

This section discusses the interactions among macroeconomic policies, economic growth, the energy market and environmental quality by reviewing the related literature. Subsection 4.2.1 describes the literature on the link between economic growth and environmental quality. Subsection 4.2.2 describes the literature on the relationship between macroeconomic policies and the energy market. In subsection 4.2.3, the literature on macroeconomic policies and environmental quality is discussed.

4.2.1 Economic Growth and Environmental Quality

The link between economic growth and environmental quality is one of the most controversial in the environmental economics literature (e.g., Dinda, 2004; Kijima et al., 2010; Shahbaz and Sinha, 2019). The environmental Kuznets curve hypothesis predicts that economic growth initially leads to a deterioration of environmental quality, followed by an improvement of environmental quality once the economy has reached a certain level. This means that environmental pressures increase faster than income in the early stage of development and slow down relative to the economic growth in higher income levels. Grossman (1995) suggested three potential channels through which economic growth affects environmental quality. First, an expansion of economic activity may lead to increased environmental degradation since higher output levels require that more inputs and more natural resources are used in the production process (scale effect). Higher levels of output imply increased wastes and emissions, which contributes to worsen environmental quality. Second, the structure of the economy tends to change as income grows, which can gradually increase the share of cleaner activities in the gross domestic product (income effect). Panayotou (1993) argues that environmental degradation tends to increase as the structure of the economy changes from rural to urban and from agricultural to industrial. However, it starts falling with the second structural change from energy-intensive heavy industry to services and technology-intensive industry. Finally, the expansion of economic growth is often accompanied by a technological progress since wealthier countries can afford to spend more on R&D (technique effect). This may lead to the substitution of dirty technologies with cleaner ones, thereby improving the quality of the environment.

4.2.2 Macroeconomic Policies and the Energy Market

In the past decades, the study of the energy market has received particular attention. Most of the recent work has been done on the relationship between energy consumption and economic factors (e.g., Apergis and Payne, 2010; Camarero et al., 2015). A body of literature has also investigated the link between macroeconomic policies and the energy market (e.g., Anzuini et al., 2012; Hammoudeh et al., 2015; Ziaei, 2018).

There have been some studies dealing with the effects of conventional and unconventional monetary policy on energy prices, especially oil prices (e.g., Anzuini et al., 2012; Rosa, 2014) and other commodity prices (e.g., Anzuini et al., 2012; Hammoudeh et al., 2015). These studies generally argue that an expansionary (contractionary) monetary policy has a positive (negative) effect on energy prices. In this literature, empirical research has been mainly conducted for the United States. Anzuini et al. (2012) find that an expansionary conventional monetary policy shock implies an increase in the commodity price index and all of its components. Hammoudeh et al. (2015) provide evidence that a contractionary shock causes persistent reductions in energy and metal prices. Moreover, Halkos and Paizanos (2016) find that energy prices, defined as the weighted average price of coal, natural gas and oil, rise after an expansionary shock. Using an event study with intraday data, Rosa (2014) reveals that conventional and unconventional monetary policy have a positive effect on oil prices. In contrast, Killian and Vega (2011) find no evidence of a confirmed relationship between monetary policy announcements and energy prices.

Little is known about the relationship between monetary policy and energy consumption. To the best of our knowledge, Ziaei (2018) is the first study to examine the effects of conventional monetary policy on energy consumption. Using the VAR methodology, the author finds that cuts in interest rate spreads lead to an increase in energy consumption in different sectors in the United States. In contrast, Ziaei (2018) finds that the effective federal funds rate had a weak impact on energy consumption before the implementation of quantitative easing policies. From a different perspective, Kosonen and Nicodème (2009) reveal that fiscal policy instruments such as tax instruments and subsidies are cost effective means to achieve energy savings. In another relevant work, Halkos and Paizanos (2016) use aggregate spending data and find that non-renewable energy prices increase temporarily after a government spending shock.

4.2.3 Macroeconomic Policies and Environmental Quality

A large part of the literature examines the scope to which different economic and non-economic factors influence environmental quality. Greenhouse gas emissions from fossil fuel combustion are influenced by a number of short-term and long-term factors, including population growth (Zhu and Peng, 2012), economic growth (Grossmann and Krueger, 1995), energy prices (Hang and Tu, 2007), international trade (Cole and Elliott, 2003) and consumer behavior (Baiocchi et al., 2010). Nevertheless, research on the impact of macroeconomic policies on environmental quality is relatively limited.

Several studies have suggested that fiscal policy may be a determinant of environmental quality (e.g., Lopez et al., 2011; Halkos and Paizanos, 2013, 2016; Lopez and Palacios, 2014). The mechanisms through which fiscal policy affects environmental pollution depends on the source of greenhouse gas emissions, namely whether they are generated by production or consumption activities (McAusland, 2008). Calbick and Gunton (2014) suggest that countries with an important fiscal sector are more likely to have undertaken redistributive payments that enhance income distribution, which may in turn lead to a greater demand for reduced environmental pollution. The literature recognizes four different mechanisms through which an increase in government spending may affect environmental quality (e.g., Lopez et al., 2011; Halkos and Paizanos, 2013, 2016; Lopez and Palacios, 2014). First, the potential expansion of output after an increase in government spending can enhance the demand for reduced environmental pollution (income effect). Second, government spending increases can encourage the development of activities that require human capital rather than physical capital, which would be less detrimental to the environment (composition effect). Third, greenhouse gas emissions can be reduced if the labor efficiency is associated with higher levels of spending on health and education sectors (technique effect). Fourth, depending on the relationship between fiscal policy and economic growth and according to the shape of the environmental Kuznets curve, an increase in government spending may lead to greater emissions in some levels of the gross domestic product (scale effect). In addition, Lopez et al. (2011) reveal that government spending can contribute to pollution reduction by altering the composition of consumption goods towards less pollution intensive goods. For instance, an increase in spending may foster investment on the use of public transportation that creates less pressure on the environment than private means of transportation (Islam and Lopez, 2015).

The literature provides some contradictory findings on the influence of fiscal policy on environmental quality. Lopez and Palacios (2014) evaluate the impact of fiscal policy on pollution levels in European countries over the period 1995-2008 and find that increasing the share of fiscal spending in the gross domestic product enhances environmental quality. Using a VAR model based on sign restrictions, Halkos and Paizanos (2016) examine the effects of fiscal policy on carbon dioxide emissions in the United States over the period 1973-2013. These authors find that government spending expansions significantly reduce carbon dioxide emissions from production and consumption activities. In contrast, Bernauer and Koubi (2013) find that an increase in government spending generates higher levels of pollution (proxied by sulfur dioxide concentrations) for 42 countries over the period 1971-1996. Several other studies like Lopez et al. (2011) and Islam and Lopez (2015) underline the importance of government spending composition as a determinant of environmental quality. In particular, these authors provide evidence that a larger share of social and public goods in total government spending enhances environmental quality.

From this same perspective, several studies have recently suggested that the very probable impact of climate change on economic growth might require more involvement of monetary policy (e.g., Matikainen et al., 2017; Dafermos et al., 2018; Economides and Xepapadeas, 2018). Using a new Keynesian DSGE model, Economides and Xepapadeas (2018) show that monetary policy can have an important role in tackling climate change. Halkos and Paizanos (2016) find that carbon dioxide emissions from production and consumption activities decline temporarily after an expansionary conventional monetary policy shock. Matikainen et al. (2017) suggest that the environmental impact of the central bank's unconventional monetary policy depends on government commitment to support low-carbon activities through direct spending. For instance, purchasing sovereign green bonds or corporate bonds from renewable energy issuers could support long-term sustainable growth. On the contrary, if the central bank's reserve asset purchases are skewed towards high-carbon sectors such as oil and natural gas, then environmental quality could deteriorate. The idea of a green quantitative easing is also supported by Dafermos et al. (2018). Using a stock-flow-fund ecological macroeconomic model, these authors analyse the financial and global warming implications of a green quantitative easing programme. They find that the implementation of such a programme can reduce climate-induced financial instability and restrict global warming.

4.3 Econometric Methodology

This section presents the structural vector autoregressive methodology used for the examination of the relationships among macroeconomic policies, the energy market and environmental quality. The structural shocks are recovered using the recursive approach, commonly adopted in the structural VAR literature, as in Sims (1980) and Christiano et al. (2005). The chapter considers one baseline model for the evaluation of the effects of fiscal and conventional monetary policy shocks and one baseline model for the evaluation of the effects of unconventional monetary policy shocks. Government consumption and public investment are used as fiscal policy instruments. The official bank policy rate and central bank's reserve assets are used as instruments for conventional and unconventional monetary policy. Subsection 4.3.1 presents the specification of the VAR models and subsection 4.3.2 describes the identification approach.

4.3.1 VAR Specification

The considered baseline VAR form model has the following reduced form:

$$Y_t = \mu_0 + A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + \beta X_t + u_t \qquad (4.1)$$

Where $Y_t = (y_{1t},\ldots,y_{kt})'$ is a k-dimensional vector of endogenous variables, X_t is the exogenous variable, A_i (i=1,…,p) are (k x k) matrices of coefficients and $u_t = (u_{1t},\ldots,u_{kt})'$ is a k-dimensional vector of reduced form shocks with $E(u_t) = 0$, $E(u_t u_t') = \Omega_u$ and $E(u_t u_s') = 0$ for $t \neq s$.

The shocks of the reduced form (4.1) do not generally have a meaningful economic interpretation since they are linear combinations of structural shocks. The underlying structural model is obtained by pre-multiplying the above equation by the matrix A of order k, which refers to the contemporaneous relations among variables in the vector Y_t. This enables us to obtain the following structural VAR (p) representation:

$$AY_t = V_0 + \Gamma_1 Y_{t-1} + \Gamma_2 Y_{t-2} + \cdots + \Gamma_p Y_{t-p} + bX_t + Be_t \qquad (4.2)$$

Where $\Gamma_i = AA_i$, $V_0 = A\mu_0$, $b = A\beta$ and $e_t = (e_{1t},\ldots,e_{kt})'$ is the k-dimensional vector of exogenous structural shocks with a standardized identity variance-

covariance matrix, that is, $E(e_t e_t') = \Omega_e = I_k$. These transformations of the innovations allow us to analyse the dynamics of the system in terms of a change to an element of e_t. The Cholesky decomposition is used to orthogonalize the disturbances and obtain structurally interpretable impulse response functions.

In the baseline model for the cases of fiscal and conventional monetary policy, the vector of endogenous variable Y_t contains the log of real per capita government spending component (g), the log of real per capita output (y), the log of the consumer price index (cpi), the log of the non-renewable energy price index (ep), the official bank policy rate (r), the log of energy consumption (ec) and the log of per capita greenhouse gas emissions (ghg). The government spending component (g) rotates between government consumption (gc) and public investment (pi). Energy consumption (ec) is decomposed into non-renewable energy consumption (nrec) and renewable energy consumption (rec). The global oil price (op*) is included as a critical exogenous variable.

We propose a structural VAR model that captures the interactions and channels among macroeconomic policies, economic growth, the energy market and environmental quality. This approach enables to address the endogeneity issue among the variables and to study them in a system. The model specification is based on a macroeconomic framework including the energy market. Since the primary objectives of a country's government and central bank are economic activity and inflation stabilization, the output and consumer prices are natural choices as endogenous variables. Energy consumption is included given the substantial contribution of the energy sector to economic activities and greenhouse gas emissions. Since renewable energy prices are not available for the entire sample period, we use the price of non-renewable energy instead. The non-renewable energy price index is included for multiple purposes. First, it enables to control for aggregate supply and demand shocks in the economy. Second, it represents one transmission channel through which fiscal and monetary policies may affect the demand for renewable and non-renewable energy. In the renewable energy analysis, its inclusion is important to account for potential substitution effects, emanating from changes in non-renewable energy prices. Third, it represents an asset price that central banks may want to respond, as higher non-renewable energy prices induce inflationary pressures. Since non-renewable energy prices at the national level are determined by the domestic market and global economic shocks, the global oil price is added as an exogenous variable to control for global supply and demand effects.

For the case of unconventional monetary policy, the baseline VAR model contains the log of the industrial production index (ip), the log of the consumer price index (cpi), the log of the non-renewable energy price index (ep), the log of the central bank's reserve assets (ra), the log of energy consumption (ec) and the log of per capita greenhouse gas emissions (ghg). Since the analysis is based on a shorter period, our estimation sample is not sufficiently long to include a fiscal variable in the model. Thus, we omit the government spending component.

4.3.2 Identification: The Recursive Approach

The chapter applies the recursive approach to identify the structural shocks. This identification scheme imposes a causal ordering from the top variables to the bottom variables based on the economic theory. For the model of fiscal and conventional monetary policy, the relationship between the vector of reduced form shocks and the vector of structural shocks is given by:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{yg} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{\mathrm{cpi}g} & a_{\mathrm{cpi}y} & 1 & 0 & 0 & 0 & 0 \\ a_{epg} & a_{epy} & a_{ep\mathrm{cpi}} & 1 & 0 & 0 & 0 \\ a_{rg} & a_{ry} & a_{r\mathrm{cpi}} & a_{rep} & 1 & 0 & 0 \\ a_{ecg} & a_{ecy} & a_{ec\mathrm{cpi}} & a_{ecep} & a_{ecr} & 1 & 0 \\ a_{ghgg} & a_{ghgy} & a_{ghgcpi} & a_{ghgep} & a_{ghgr} & a_{ghgec} & 1 \end{bmatrix} \begin{bmatrix} u_t^g \\ u_t^y \\ u_t^{\mathrm{cpi}} \\ u_t^{ep} \\ u_t^r \\ u_t^{ec} \\ u_t^{ghg} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e_t^g \\ e_t^y \\ e_t^{\mathrm{cpi}} \\ e_t^{ep} \\ e_t^r \\ e_t^{ec} \\ e_t^{ghg} \end{bmatrix} \quad (4.3)$$

The baseline model is specified with the particular order of: the government spending component, the output, the consumer price index, the non-renewable energy price index, the official bank policy rate, energy consumption and greenhouse gas emissions. We impose short-run restrictions, which prevent a structural shock from affecting an endogenous variable contemporaneously. The particular ordering of the variables has the following implications: (i) The government spending component is not affected contemporaneously by structural shocks to other variables in the system. (ii) The domestic macroeconomic aggregates such as the output and consumer prices do not react contemporaneously to the conventional monetary policy shock. (iii) The simultaneous reaction of monetary policy to the macroeconomic environment is allowed by placing the output and consumer prices above the official bank policy rate in the ordering. (iv) The simultaneous response of monetary policy to changes in non-renewable energy prices is allowed. (v) Monetary policy does not react within the same quarter to changes in energy consumption and

greenhouse gas emissions. Note that after the initial period, the variables in the system are allowed to interact freely. Finally, by including the global oil price as exogenous, we assume that there is no feedback effect of domestic variables on the world economy. At the same time, the contemporaneous impact of the global oil price on the domestic variables is allowed.

When using quarterly data, it is plausible to assume that public spending decisions cannot be revised and implemented within a quarter, and thus cannot react to current economic and environmental conditions. This implicitly means that the automatic stabilizers of government spending components are equal to zero. However, this ordering assumes that public spending decisions can affect contemporaneously all variables in the system. The macroeconomic aggregates such as the output and consumer prices do not react simultaneously to the conventional monetary policy shock. The fact that monetary policy affects domestic variables with a lag is in line with the transmission mechanism of monetary policy emphasized in the theoretical set-up in Svensson (1997). This can be rationalized on the grounds that the interest rate is the main tool of the central bank's monetary policy whose objective is to stabilize the output gap and maintain price stability. The non-renewable energy price index is ordered before the official bank policy rate since it indicates inflationary pressures that the central bank may want to respond when setting the interest rate. Since environmental issues are not the primary concerns of central banks, energy consumption and greenhouse gas emissions are ordered after the official bank policy rate. Energy consumption is ordered before greenhouse gas emissions since energy use has a direct contribution to emissions. For the model of unconventional monetary policy, equation (4.3) can be expressed as follows:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ a_{cpiip} & 1 & 0 & 0 & 0 & 0 \\ a_{epip} & a_{epcpi} & 1 & 0 & 0 & 0 \\ a_{raip} & a_{racpi} & a_{raep} & 1 & 0 & 0 \\ a_{ecip} & a_{eccpi} & a_{ecep} & a_{ecra} & 1 & 0 \\ a_{ghgip} & a_{ghgcpi} & a_{ghgep} & a_{ghgra} & a_{ghgec} & 1 \end{bmatrix} \begin{bmatrix} u_t^{ip} \\ u_t^{cpi} \\ u_t^{ep} \\ u_t^{ra} \\ u_t^{ec} \\ u_t^{ghg} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e_t^{ip} \\ e_t^{cpi} \\ e_t^{ep} \\ e_t^{ra} \\ e_t^{ec} \\ e_t^{ghg} \end{bmatrix} \quad (4.4)$$

The baseline model includes the variables with the following ordering: the industrial production index, the consumer price index, the non-renewable energy price index, the central bank's reserve assets, energy consumption and greenhouse gas emissions. This particular ordering of the variables has the same implications as those for the cases of fiscal and conventional monetary policy.

4.4 Data

4.4.1 Data Description

We use quarterly and monthly seasonally adjusted data for Switzerland and the United Kingdom over the period 1990-2016. The appendix A.4.1 provides details on definitions and data sources for all variables used in this chapter. The national income and fiscal series are in real terms and were obtained by dividing them by the GDP deflator. They are expressed in their per capita terms. For the cases of fiscal and conventional monetary policy, public investment, renewable energy consumption, non-renewable energy consumption and greenhouse gas emissions series have been obtained converting data from annual to quarterly frequency using the Denton method as implemented in EVIEWS version 10. The output, government consumption, consumer prices and the global oil price series are obtained from FRED. Public investment series are taken from AMECO. Non-renewable energy consumption series are constructed from the International Energy Agency (IEA). Renewable energy consumption series come from the World Bank (WB). Greenhouse gas emissions series are taken from the OECD. The following series have been obtained from different sources. For Switzerland, the official bank policy rate and the non-renewable energy price index series are taken from FRED and the SNB. For the United Kingdom, the official bank policy rate series is taken from the BoE and the non-renewable energy price index series is constructed from the ONS.

Our definitions of macroeconomic and environmental variables closely follow the existing literature. Due to the differences in availability of data for these two countries, we use different definitions for certain variables. Government consumption corresponds to the government final consumption expenditure for Switzerland and government consumption of goods and services for the United Kingdom. Public investment refers to gross fixed capital formation of the public sector. The output corresponds to the gross domestic product. Consumer prices refer to the consumer price index for all items. The official bank policy rate is defined as the three-month Swiss franc LIBOR for Switzerland and the official bank rate for the United Kingdom. Non-renewable energy consumption is defined as the sum of oil products, natural gas and coal consumption measured in kilotonne of oil equivalent. The non-renewable energy price index is defined as the weighted average of oil products, natural gas

and coal price indexes[28]. Since data on natural gas and coal prices are not available for Switzerland, the non-renewable energy price index refers to the oil products price index and non-renewable energy consumption to oil products consumption[29]. Renewable energy consumption is defined as the share of renewable energy in total final energy consumption. Greenhouse gas emissions refer to the per capita greenhouse gas emissions from energy use. The global oil price refers to global price of West Texas Intermediate crude.

For the case of unconventional monetary policy, we use monthly seasonally adjusted data over the period 2009-2016. The non-renewable energy price index, the central bank's reserve assets, the industrial production index and the consumer prices index series are available at the monthly frequency and were taken from their respective sources. Renewable energy consumption, non-renewable energy consumption and greenhouse gas emissions series have been obtained converting data from annual to monthly frequency using the Denton method. Reserve assets refer to the official total reserve assets for Switzerland and the government stock (gilts) for the United Kingdom. They are obtained from the SNB and ONS databases, respectively. Industrial production corresponds to the production of total industry index and is taken from FRED.

4.4.2 Data Properties

This subsection provides a preliminary examination of the data properties. The descriptive statistics of the data are provided in tables A.4.3.1 and A.4.3.2. Figure 4.1 shows the evolution of fiscal and monetary policy variables for Switzerland and the United Kingdom over the period 1990-2016[30]. It can be seen that the official bank policy rates have approached the zero lower bound in early 2009, when central banks implemented the first conventional measures in response to the global financial crisis. There is a visible structural change in the reserve assets at the end of 2008 when central banks started to implement

[28] The weights are meant to reflect the relative importance of the natural resources as measured by their share in total final energy consumption.
[29] We acknowledge that using a different definition of non-renewable energy prices and consumption makes the comparison of the results for these two countries less straightforward. Nevertheless, we believe that using a broader measure of non-renewable energy provides further insights as regards the impact of macroeconomic policies on the energy market. In subsection 4.5.3, we reproduce the same analysis using the price and consumption of oil products to enable comparison of the results.
[30] The data for reserve assets are only available since 2000.

unconventional measures. For this reason, the estimation sample period for the case of unconventional monetary policy covers the post-2009 period. We separate the pre-crisis and the post-crisis period since the implementation of quantitative easing can be viewed as a new monetary policy regime. This procedure is also followed by Gambacorta et al. (2014) and Ziaei (2018). As regards fiscal policy components, government consumption has a clear positive trend, while public investment fluctuates more during booms and recessions.

Figures 4.2 and 4.3 show the evolution of macroeconomic and environmental variables over the period considered. It can be noted that the output, consumer prices, non-renewable energy prices and renewable energy consumption have a positive trend. In contrast, non-renewable energy consumption and greenhouse gas emissions have a negative trend. The evolution of environmental variables shows the pursuing important efforts of these countries to lower their emissions by reducing their reliance on fossil fuels and increasing the deployment of renewable technologies. We then check the order of integration of the series with the augmented Dickey-Fuller test. The null hypothesis that the series has a unit root is tested against its stationarity. The test is carried out for the levels of the variables, as well as for their first differences. The results are reported with only an intercept and both an intercept and a trend in table A.4.4.1[31]. They indicate that most series are not stationary and that they are integrated of order one. However, it can be noted that government consumption and renewable energy consumption are not stationary in their first differences for the United Kingdom. This may suggest the presence of structural changes in these two series. Models that can incorporate structural changes, such as Markov Switching and Threshold VAR could be relevant for examining such patterns. For comparison purposes, we follow most of the literature using linear models to examine the relationships between economic and environmental variables.

[31] As pointed out by Cochrane (1991), unit root tests have low power in small samples and can potentially lead to misleading conclusions. Thus, the results are only reported for the period 1990-2016.

Figure 4.1: Evolution of fiscal and monetary policy variables

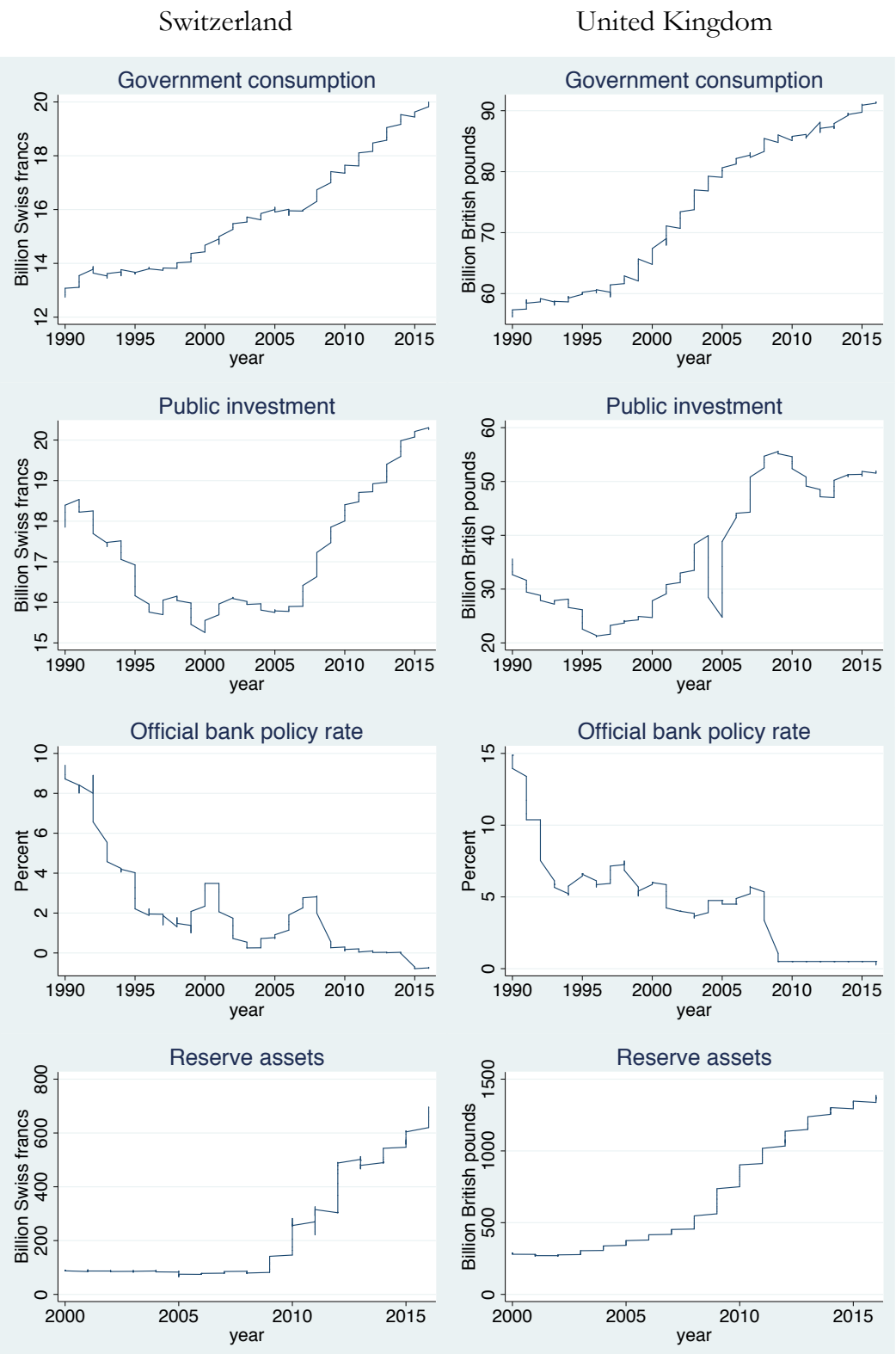


Figure 4.2: Evolution of macroeconomic aggregates and environmental variables (Switzerland)

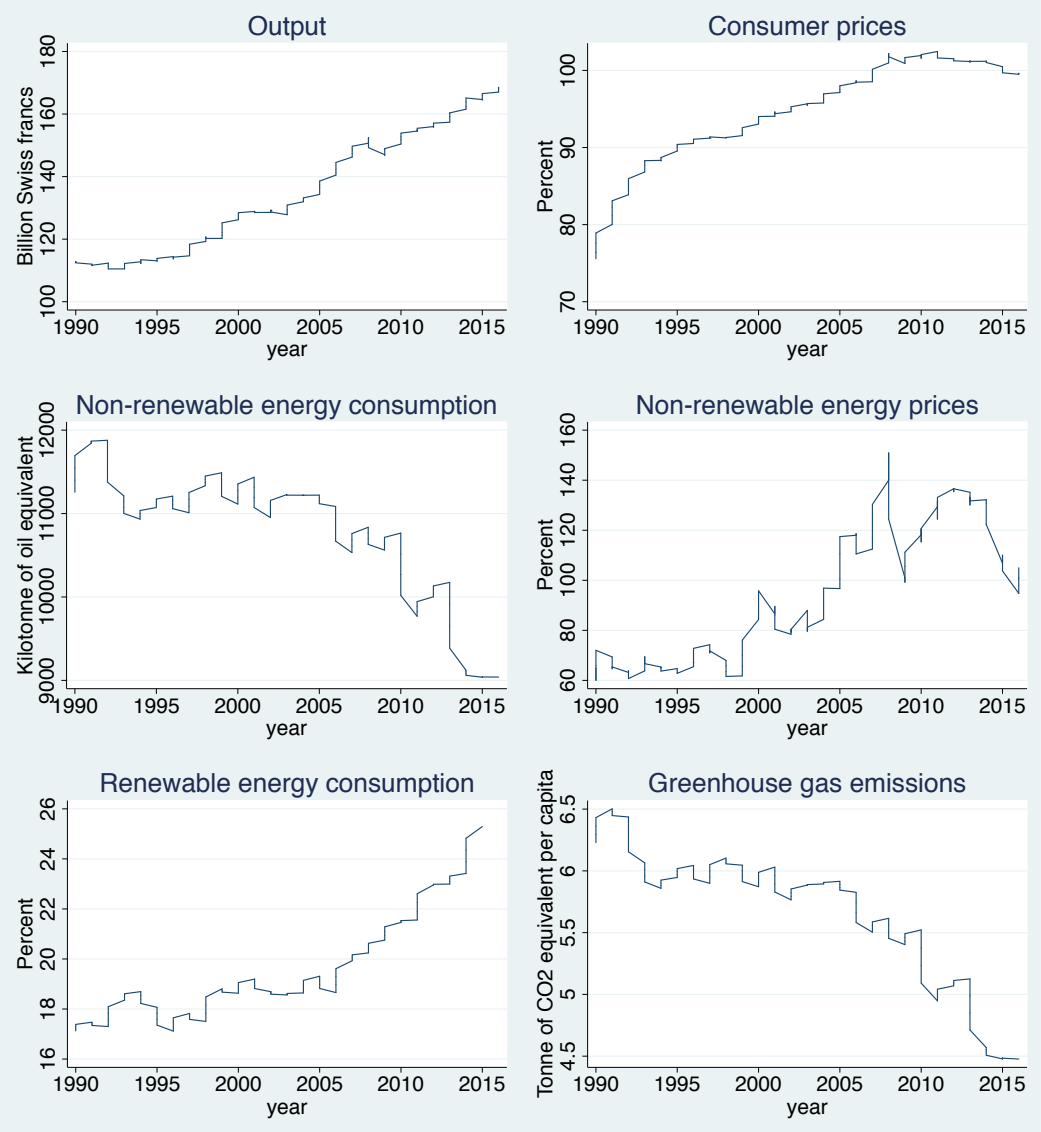
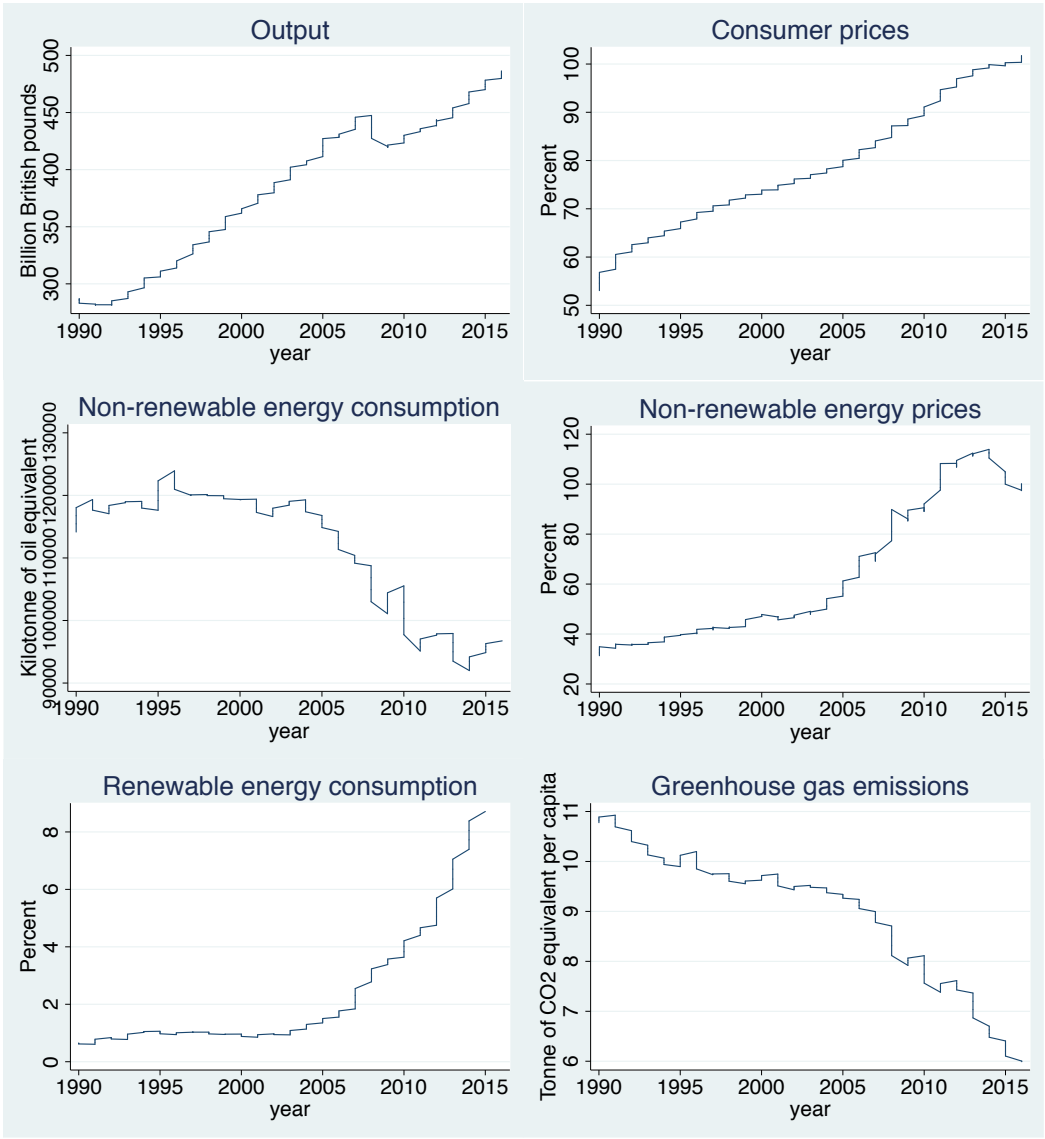


Figure 4.3: Evolution of macroeconomic aggregates and environmental variables (United Kingdom)



4.5 Empirical Analysis

This section presents the results from the empirical analysis. Before proceeding with the VAR estimation, we first have to check whether the different specifications in both model cases are correctly specified. We then present the results of the VAR estimation based on the effects of shocks to fiscal and monetary policy on the macroeconomic aggregates and environmental variables. The figures show the responses of the endogenous variables to a one standard deviation shock to government consumption, public investment, conventional and unconventional monetary policy. The orthogonalized impulse response functions are reported for a horizon of five years for the cases of fiscal and conventional monetary policy and two years and a half for the case of unconventional monetary policy, with the 68 percent confidence interval[32]. In addition, we interpret the results of the cumulative orthogonalized impulse response functions and the variance decomposition analysis. The tables report the results at horizon 1, 4, 8, 12 and 20 for the cases of fiscal and conventional monetary policy. For the case of unconventional monetary policy, the results are reported at horizon 3, 12, 24 and 30. Subsection 4.5.1 presents the results of the specification tests and subsection 4.5.2 the results of the VAR estimation. Finally, the results of the sensitivity analysis are discussed in subsection 4.5.3.

4.5.1 Specification Tests

The first step is to select the appropriate number of lags for the baseline VAR models. For this purpose, we consider two different criteria (HQIC and BIC) and refer to the residual autocorrelation test conclusions. Tables A.4.5.1 and A.4.5.2 present the results of the lag length selection and specification tests. The two criteria usually select one, two or eight lags. Since our specification requires the estimation of many parameters, we decided to use a small number of lags to minimize the loss of degrees of freedom. For the cases of fiscal and conventional monetary policy, the number of lags is set to two for each model specification since they provide serially uncorrelated residuals[33]. Considering the short sample period for the case of unconventional monetary policy, we use two lags, following Gambacorta et al. (2014). To ensure that there is no residual

[32] The use of the 68% error bands is explained in footnote 11 at page 32.

[33] With the exception of specification (A) for Switzerland, which does not provide serially uncorrelated residuals. However, the impulse responses generally yield very similar results in the different specifications and thereby do not seem affected by possible misspecification bias.

autocorrelation in the reduced VAR form, we performed the Breusch-Godfrey Lagrange Multiplier test. The results of the test reveal that no serial correlation is detected in the different specifications of both model cases.

The series are then analysed to detect possible cointegration relations among them. Johansen procedure (Johansen, 1995) is performed within the VECM representation of the VAR model to check whether the series are cointegrated. The results of the Johansen cointegration test with constant and linear trend are presented in table A.4.6.1. They all indicate that the series are cointegrated and that one or more cointegration relationships are present in the different model specifications. Therefore, the estimation of VAR models in levels provides consistent estimates (Sims et al., 1990; Lütkepohl and Reimers, 1992). The advantage of VAR models in levels over VECMs is that they can also be used when the cointegration structure is unknown. The VECM approach is also less appropriate when disaggregated and short time series are used, as it becomes more difficult to define cointegration relations among them.

4.5.2 Empirical Results

This chapter studies the dynamic interactions among the variables through orthogonalized impulse response functions. We present them as graphical representation of impact multipliers with corresponding standard errors. This might reflect the short-run and medium-run interactions of the variables. We also provide the cumulative orthogonalized impulse response functions, which can be regarded as long-run multipliers when they are considered over long period. The impact multipliers are accumulated up to twenty quarters for the cases of fiscal and conventional monetary policy and up to thirty months for the case of unconventional monetary policy. The empirical analysis is divided into five parts. First, we proceed with the evaluation of the effects of government consumption shocks in the baseline model with quarterly data over the period 1990-2016. Second, the model is estimated to evaluate the effects of public investment shocks over the same period. For the case of monetary policy, the analysis is explicitly made on sub-periods. We evaluate the effects of conventional monetary policy shocks in the baseline model over the period 1990-2009, while the effects of unconventional monetary policy shocks are assessed over the period 2009-2016. The variance decomposition analysis is also carried out to estimate the shares of the variance of the variables that result from the policy shocks. Figures 4.4 to 4.7 display the impulse response functions for

the case of fiscal policy and figures 4.8 to 4.11 those for the case of monetary policy. Tables 4.1 to 4.4 report the cumulative impulse response functions. Tables 4.5 and 4.6 contain the results of the variance decomposition analysis. Tables A.4.8.1 and A.4.8.2 provide a summary of the main results of the chapter.

4.5.2.1 The Dynamic Effects of Government Consumption Shocks

The empirical analysis reveals that an expansion of government consumption leads to a slight and temporary decline in the consumption of non-renewable energy and greenhouse gas emissions. In addition, the obtained results provide evidence that government policy can help promote the deployment of renewable energy. We also find that an unexpected increase in government consumption implies a decline in non-renewable energy prices.

In Switzerland, after a government consumption shock, the output increases slightly on impact before its responses turns negative and mostly insignificant. The nominal interest rate increases initially before falling after one year, while consumer prices do not react significantly. An unexpected increase in government consumption leads to a decline in non-renewable energy prices during three years. In addition, we find that non-renewable energy consumption and greenhouse gas emissions decline insignificantly after five quarters. On the other hand, an expansionary fiscal shock implies a steady increase in renewable energy consumption. The analysis of the cumulative impulse response functions reveals that a government consumption shock has no long-run impact on the output and nominal interest rate. A positive innovation induces to the decreases in non-renewable energy prices, non-renewable energy consumption and greenhouse gas emissions by accumulated 5.20, 0.65 and 0.84 percent after five years, respectively. However, only the long-run multiplier of government consumption on non-renewable energy prices is significant. Moreover, the total positive impact on renewable energy consumption is 7.81 percent.

In the United Kingdom, the output increases steadily after an expansion of government consumption. The nominal interest rate falls slightly during two years and consumer prices decline insignificantly. In the energy market, non-renewable energy prices fall steadily and non-renewable energy consumption declines slightly during one year. Moreover, a government consumption shock leads to a steady increase in renewable energy consumption. However, it can be noted that the confidence interval is quite wide, making the impulse response

mostly insignificant. These movements in the energy market are accompanied by a slight reduction in greenhouse gas emissions during one year. The long-run analysis reveals that a government consumption shock leads to the increase in output by accumulated 3.47 percent after five years, while it has no significant long-run impact on the nominal interest rate and consumer prices. In addition, a positive innovation induces to the decline in non-renewable energy prices by accumulated 7.27 percent. In contrast, the long-run multipliers of government consumption on the other environmental variables are not significant.

In a similar framework but for aggregate spending shocks, Halkos and Paizanos (2016) find that a shock to government spending leads to an increase in non-renewable energy prices and a decline in carbon dioxide emissions in the United States. However, we believe that the comparison between these studies is not straightforward since these authors use a government spending variable that includes government consumption and investment. The positive impact of fiscal policy on environmental quality is not in line with Bernauer and Koubi (2013). This could be justified on the grounds that these authors use a panel of countries and sulfur dioxide emissions as a proxy for environmental quality, which does not necessarily reflect the specific effect in each country and general levels of air pollution. The impact of fiscal policy on environmental quality depends on the composition of government consumption of goods and services (Lopez et al., 2011; Halkos and Paizanos, 2013, 2016; Lopez and Palacios, 2014). For instance, if the expansion of government consumption consists of goods and services that enhance the demand for clean energy technologies and reduced environmental pollution, it can reduce the use of fossil fuels and the associated greenhouse gas emissions (income effect). Then, government consumption increases can encourage the development of activities that require human capital rather than physical capital, which are less detrimental to the environment (composition effect). Finally, government consumption may reduce the ratio pollution-output by increasing capital and labor efficiency with higher levels of spending on the health and education sectors (technique effect).

However, it should be mentioned that the main objective of a government consumption expansion is the stimulation of economic activity rather than the improvement of environmental quality. This means that some components of government consumption may be neutral to the energy market and the environment. A government consumption expansion leads to a slight decline in non-renewable energy consumption and greenhouse gas emissions.

Figure 4.4: Impulse response functions to a government consumption shock (Baseline model, Switzerland)

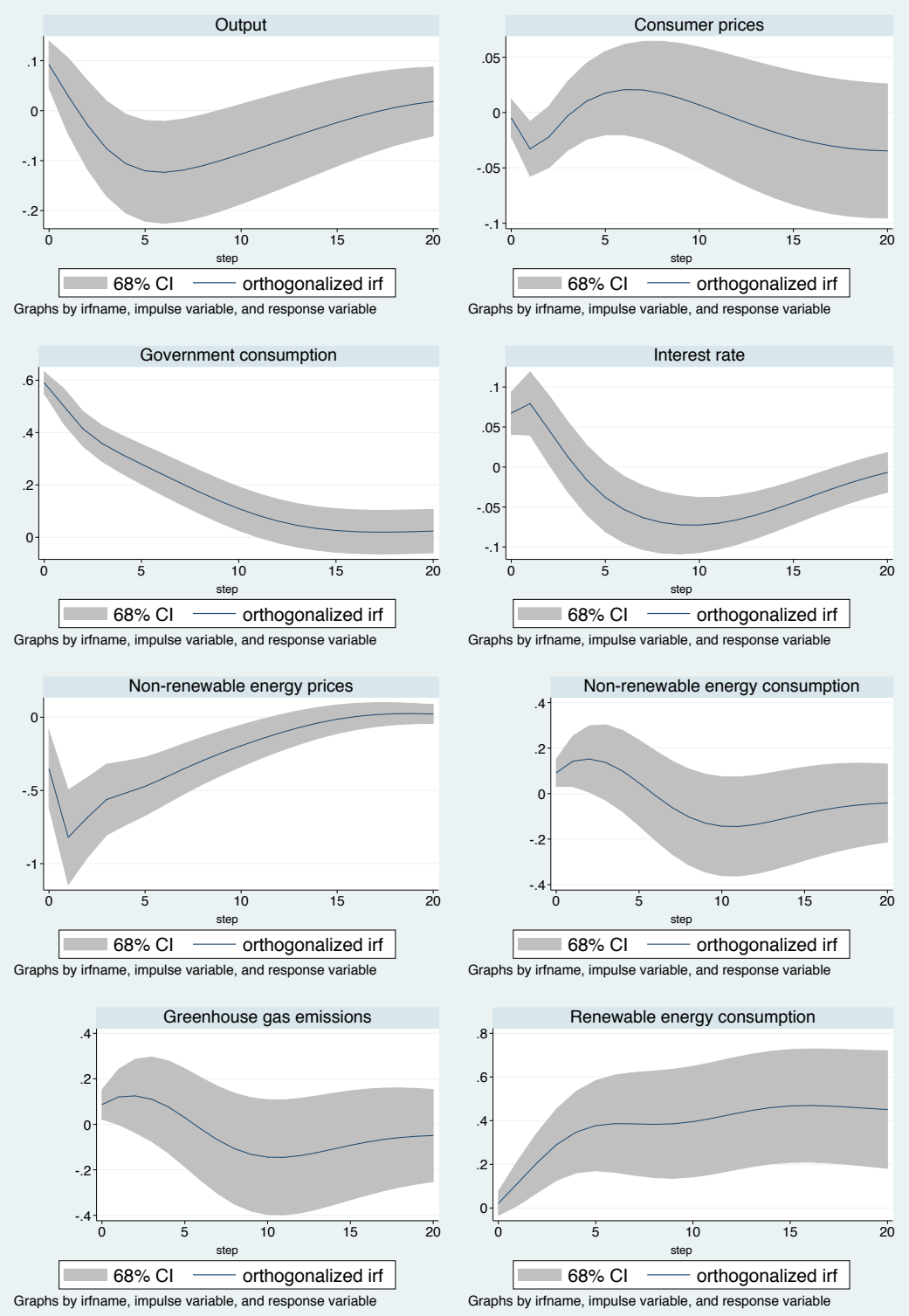


Figure 4.5: Impulse response functions to a government consumption shock (Baseline model, United Kingdom)

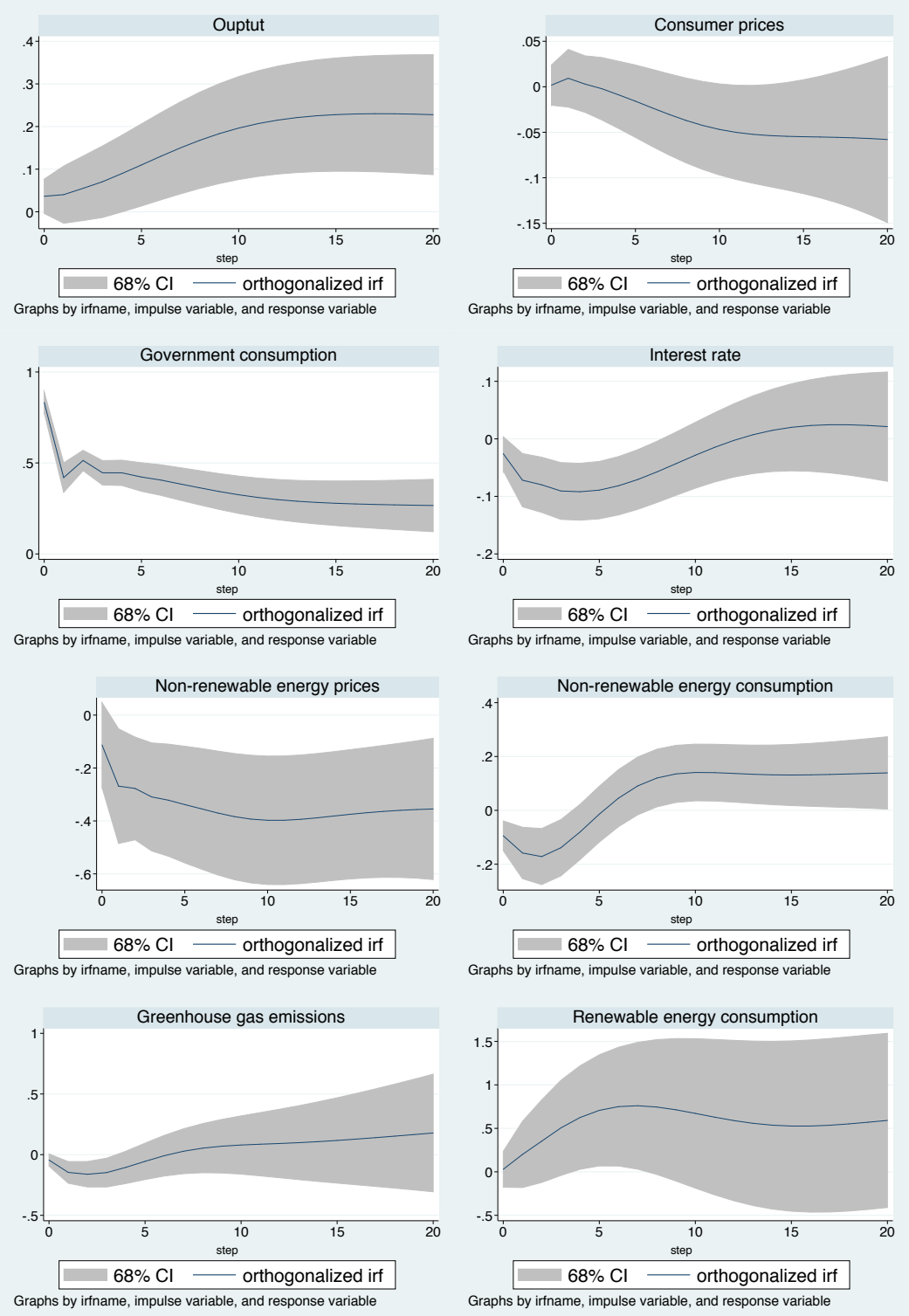


Table 4.1: Cumulative impulse response functions to government consumption and public investment shocks (Baseline model, Switzerland)

Shock	Quarter	1	4	8	12	20
Government consumption shock						
	r	0.147	0.190	-0.034	-0.315	-0.576
		(0.061)	(0.177)	(0.306)	(0.398)	(0.484)
	y	0.121	-0.090	-0.563	-0.885	-0.970
		(0.117)	(0.377)	(0.729)	(1.067)	(1.614)
	cpi	-0.037	-0.053	0.024	0.038	-0.174
		(0.039)	(0.123)	(0.275)	(0.470)	(0.905)
	ep	-1.175	-2.939	-4.476	-5.173	-5.203
		(0.511)	(1.004)	(1.460)	(1.798)	(2.071)
	nrec	0.234	0.623	0.497	-0.057	-0.645
		(0.165)	(0.626)	(1.309)	(2.038)	(3.382)
	ghg	0.208	0.519	0.350	-0.209	-0.839
		(0.181)	(0.700)	(1.516)	(2.395)	(4.010)
	rec	0.136	0.983	2.514	4.136	7.814
		(0.153)	(0.612)	(1.427)	(2.339)	(4.192)
Public investment shock						
	r	0.039	-0.007	-0.180	-0.334	-0.455
		(0.062)	(0.203)	(0.365)	(0.454)	(0.497)
	y	0.191	0.312	0.113	-0.092	-0.090
		(0.114)	(0.383)	(0.720)	(0.998)	(1.471)
	cpi	-0.017	-0.028	-0.095	-0.227	-0.716
		(0.038)	(0.127)	(0.285)	(0.470)	(0.830)
	ep	0.426	-0.251	-2.476	-3.609	-4.063
		(0.475)	(1.021)	(1.475)	(1.765)	(1.985)
	nrec	0.146	0.177	-0.813	-2.583	-5.706
		(0.160)	(0.637)	(1.286)	(1.808)	(2.706)
	ghg	0.116	-0.005	-1.359	-3.489	-7.133
		(0.172)	(0.694)	(1.449)	(2.105)	(3.269)
	rec	-0.099	0.017	1.239	3.085	6.369
		(0.147)	(0.623)	(1.485)	(2.402)	(3.984)

Standard errors are in parentheses.

Table 4.2: Cumulative impulse response functions to government consumption and public investment shocks (Baseline model, United Kingdom)

Shock	Quarter	1	4	8	12	20
Government consumption shock						
r		-0.098	-0.360	-0.659	-0.748	-0.590
		(0.072)	(0.204)	(0.369)	(0.566)	(1.145)
y		0.077	0.292	0.850	1.652	3.473
		(0.103)	(0.341)	(0.721)	(1.160)	(2.151)
cpi		0.011	0.003	-0.103	-0.295	-0.740
		(0.051)	(0.148)	(0.307)	(0.486)	(0.940)
ep		-0.382	-1.290	-2.737	-4.319	-7.268
		(0.353)	(0.913)	(1.720)	(2.552)	(4.243)
nrec		-0.253	-0.644	-0.402	0.151	1.225
		(0.146)	(0.430)	(0.738)	(1.062)	(1.843)
ghg		-0.191	-0.606	-0.589	-0.263	0.824
		(0.135)	(0.461)	(1.076)	(2.005)	(5.032)
rec		0.229	1.711	4.673	7.277	11.674
		(0.573)	(2.138)	(4.671)	(7.699)	(14.761)
Public investment shock						
r		-0.108	-0.440	-0.900	-1.053	-1.018
		(0.073)	(0.242)	(0.427)	(0.580)	(1.060)
y		0.118	0.110	-0.542	-1.194	-1.901
		(0.098)	(0.366)	(0.791)	(1.189)	(1.816)
cpi		-0.026	-0.044	0.098	0.319	0.758
		(0.049)	(0.171)	(0.364)	(0.532)	(0.919)
ep		-0.278	0.128	1.066	1.960	3.247
		(0.354)	(1.085)	(2.008)	(2.636)	(3.574)
nrec		-0.126	-0.819	-1.845	-2.129	-2.642
		(0.138)	(0.458)	(0.781)	(1.032)	(1.675)
ghg		-0.153	-0.948	-2.155	-2.633	-3.767
		(0.128)	(0.485)	(1.188)	(2.188)	(5.119)
rec		0.146	0.670	3.174	6.275	11.144
		(0.568)	(2.474)	(5.725)	(8.833)	(13.800)

Standard errors are in parentheses.

Nevertheless, these findings do not tell us which consumption categories to increase in order to achieve non-renewable energy conservation and optimize the abatement of emissions. Further investigation on the composition of government consumption would be needed to explore the ways in which spending decisions can affect the energy market and environmental quality.

4.5.2.2 The Dynamic Effects of Public Investment Shocks

The empirical analysis reveals that an expansion of public investment can achieve important non-renewable energy conservation and greenhouse gas emissions reduction. In addition, our findings provide evidence that public investment can have an important role in promoting the deployment of renewable energy. Nevertheless, we find no evidence of a confirmed relationship between public investment and non-renewable energy prices.

In Switzerland, after a public investment shock, the output increases during approximately one year. In the money market, consumer prices decline slightly and persistently, while the nominal interest rate does not move significantly from its trend. In the energy market, non-renewable energy prices fall during approximately three years and non-renewable energy consumption decreases steadily. The decline in non-renewable energy prices can be partly explained by the basic principle of aggregate supply and demand. As the demand for non-renewable energy decreases, an excess of supply is created, and the price of such resources goes down. On the other hand, we find that an expansion of public investment implies a persistent increase in renewable energy consumption and a persistent decrease in greenhouse gas emissions. The reduction of detrimental gases emissions can be rationalized by the increase in the share of renewable energy in total final energy consumption. The analysis of the cumulative impulse response functions reveals that a public investment shock has no significant long-run impact on the output, nominal interest rate and consumer prices. Turning on the environmental variables, a public investment shock induces to the decreases in non-renewable energy prices, non-renewable energy consumption and greenhouse gas emissions by accumulated 4.06, 5.71 and 7.13 percent after five years, respectively. Moreover, the total positive impact on renewable energy consumption is 6.37 percent.

We proceed with the description of the impulse response functions of the United Kingdom macroeconomic and environmental variables to public investment shocks. Following an expansionary shock, the output is crowded out

with a minimum of 0.2 percent after two years. The nominal interest rate declines during approximately ten quarters, while consumer prices rise slightly and mostly insignificantly. Turning on the environmental variables, the response of non-renewable energy prices is negative on impact before turning insignificant. A public investment shock leads to a decline in non-renewable energy consumption and greenhouse gas emissions during approximately two years. Moreover, we find that an expansion of public investment leads to an increase in renewable energy consumption, although the response appears insignificant across the entire impulse response horizon. The analysis of the cumulative impulse response functions reveals that the total negative impacts of a public investment shock on the output, non-renewable energy consumption and greenhouse gas emissions are 1.90, 2.64 and 3.77 percent, respectively. However, it can be noted that the long-run multipliers of public investment on the macroeconomic and environmental variables are not significant.

The positive impact of public investment on environmental quality is consistent with Lopez and Palacios (2014) and Halkos and Paizanos (2016). However, these authors pool all types of spending together, which makes the comparison between these studies not straightforward. The response of non-renewable energy prices for Switzerland is not in line with Halkos and Paizanos (2016). This could be justified on the grounds that our VAR model contains energy consumption, which enables us to capture the impact of fiscal policy on non-renewable energy prices that occurs through the supply and demand factors of energy markets. The positive influence of public investment on the energy market and environmental quality could be rationalized by the increase of certain categories of investment. For instance, an increase in public investment in R&D for non-renewable energies could lead to technological advancements that enhance capital and labor efficiency, thereby reducing the amount of energy resources required to produce the same amount of goods and services. The resultant improvement of energy efficiency may in turn explain the reduction in non-renewable energy consumption. On the other hand, an increase in public investment in R&D for renewable technologies such as solar and wind can support the deployment of clean energy resources. In terms of environmental measures, an increase in public investment in environmental infrastructure can enhance pollution control and resource utilization. Improving infrastructure could therefore help conserve non-renewable energy resources and reduce emissions. We believe that further investigation on the composition of public investment would be needed to explore the potential ways in which spending decisions can affect the energy market and environmental quality.

Figure 4.6: Impulse response functions to a public investment shock (Baseline model, Switzerland)

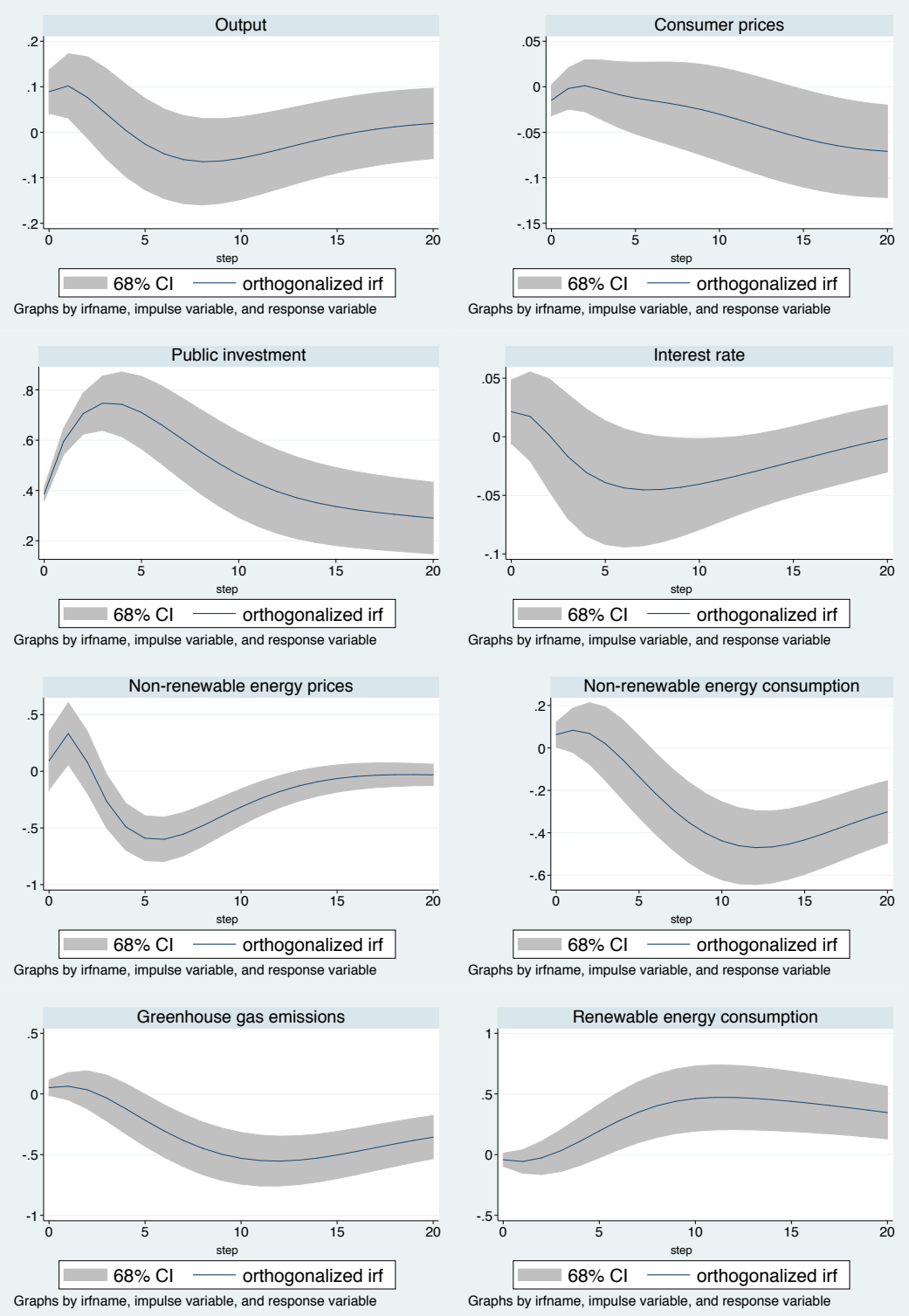
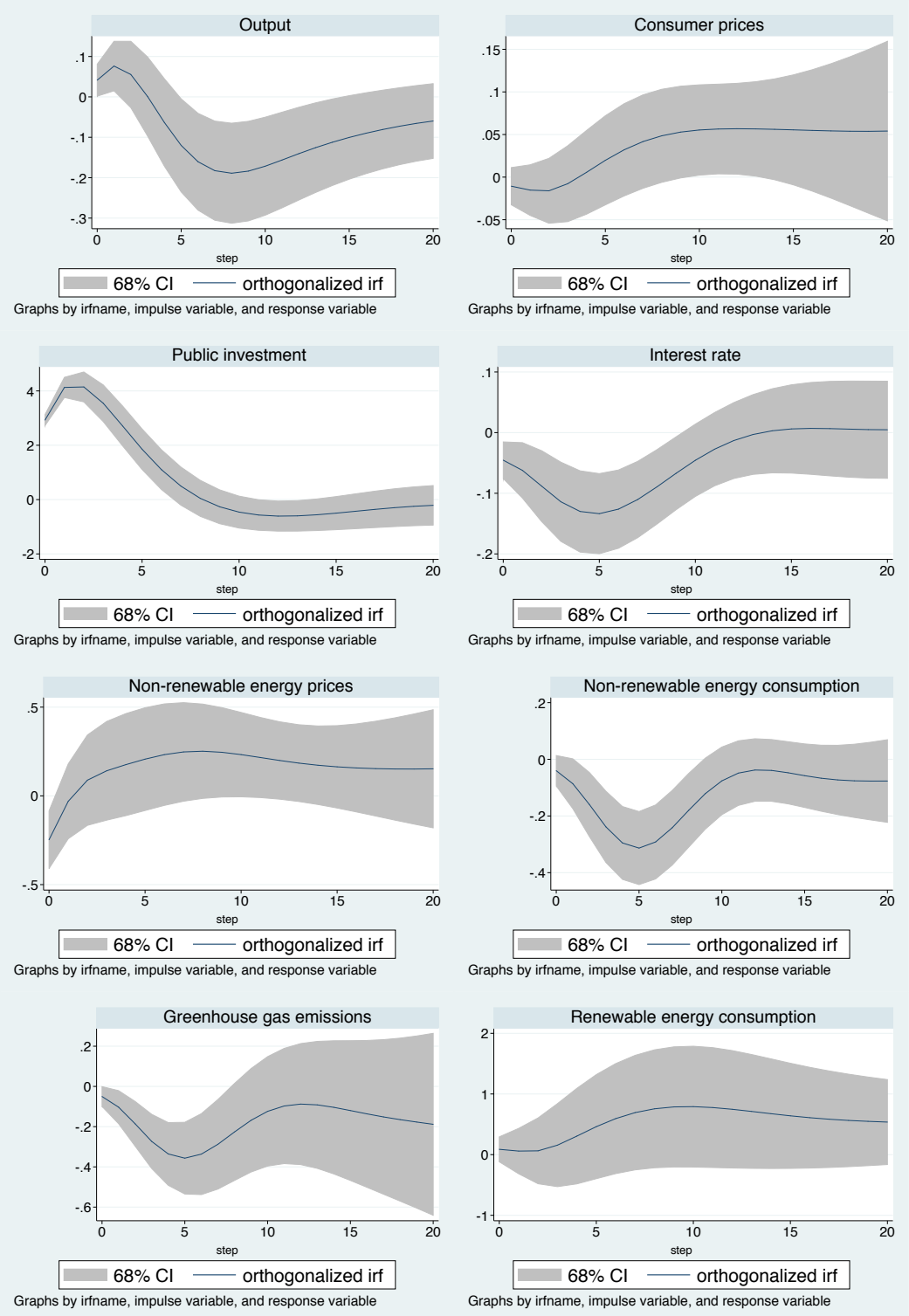


Figure 4.7: Impulse response functions to a public investment shock (Baseline model, United Kingdom)



4.5.2.3 The Dynamic Effects of Conventional Monetary Policy Shocks

The empirical analysis provides mixed evidence as regards the impact of conventional monetary policy on environmental quality. In the United Kingdom, an expansionary shock implies an improvement of environmental quality associated with an increase in renewable energy consumption, while the opposite holds true in Switzerland. In addition, we find that an expansionary policy leads to an increase in non-renewable energy prices and consumption.

In Switzerland, after an unexpected decrease in the official bank policy rate, the output increases during four years, while consumer prices initially rise insignificantly before falling during approximately six quarters. As regards fiscal policy variables, an expansionary shock implies a steady increase in government consumption. This finding suggests that conventional monetary policy and government consumption act as complements to each other for the achievement of macroeconomic goals. In contrast, public investment declines after a positive innovation, suggesting that conventional monetary policy and public investment act as substitutes to each other. In the energy market, a conventional monetary policy shock leads to a steady increase in non-renewable energy consumption. The decline in interest rates makes borrowing more attractive with respect to saving, which stimulates the demand for goods and services in different markets, including the energy market. Moreover, we find that an expansionary conventional monetary policy shock leads to a slight and temporary increase in non-renewable energy prices. On the other hand, a positive innovation implies a decline in renewable energy consumption during two years. These movements are accompanied by an increase in greenhouse gas emissions during approximately four years. Our findings suggest that the improvement of firms' financing conditions could affect more high-carbon sectors than low-carbon sectors, thus leading to a deterioration of environmental quality. The long-run analysis reveals that a conventional monetary policy shock induces to the decline in public investment by accumulated 2.71 percent, as well as the increases in output and government consumption by accumulated 3.17 and 3.29 percent, respectively. However, a positive innovation has no significant long-run impact on consumer prices, non-renewable energy prices and renewable energy consumption. Moreover, the obtained results indicate that a conventional monetary policy shock induces to the increases in non-renewable energy consumption and greenhouse gas emissions by accumulated 2.85 and 2.50 percent, respectively.

Figure 4.8: Impulse response functions to a conventional monetary policy shock (Baseline model, Switzerland)

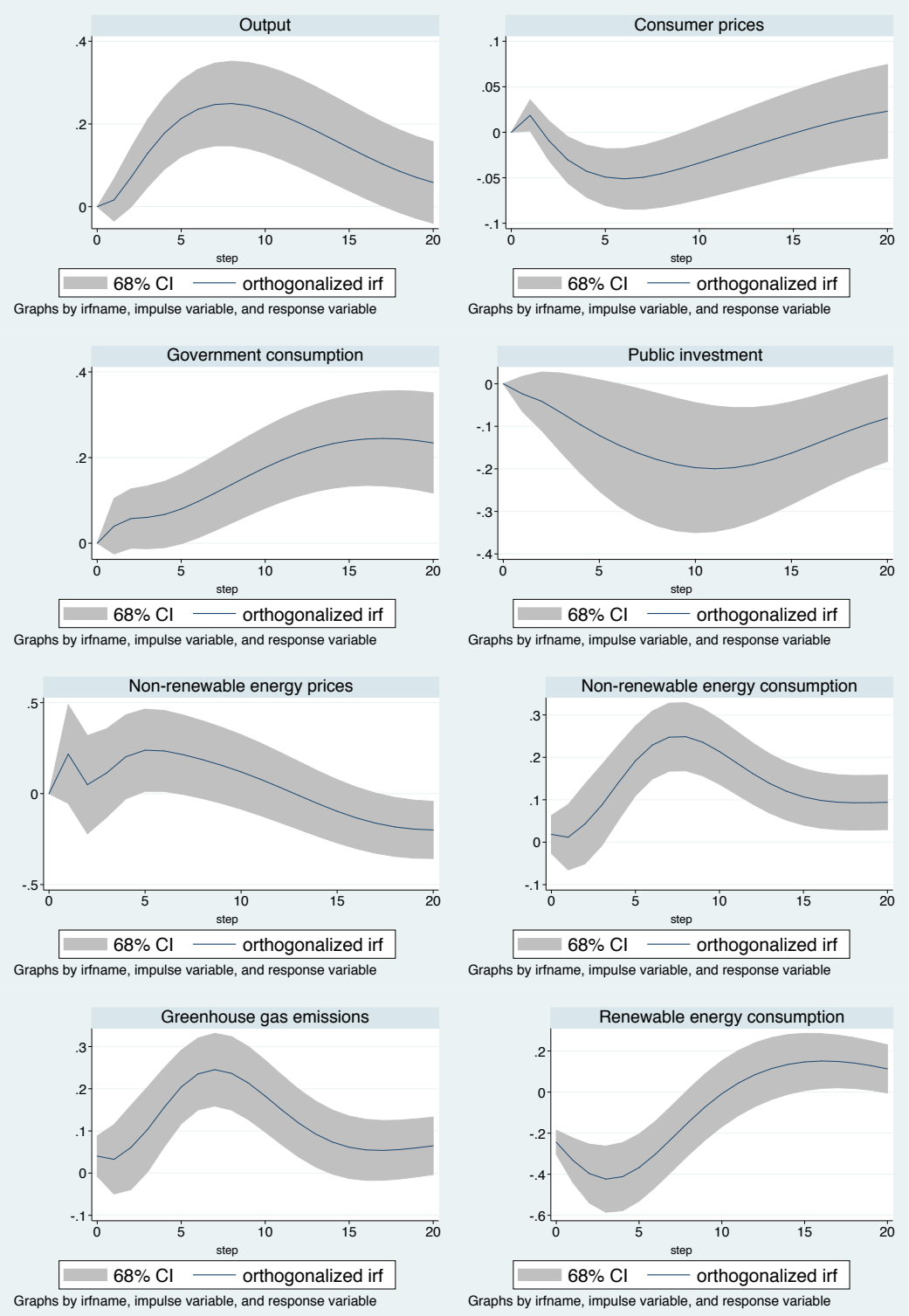


Figure 4.9: Impulse response functions to a conventional monetary policy shock (Baseline model, United Kingdom)

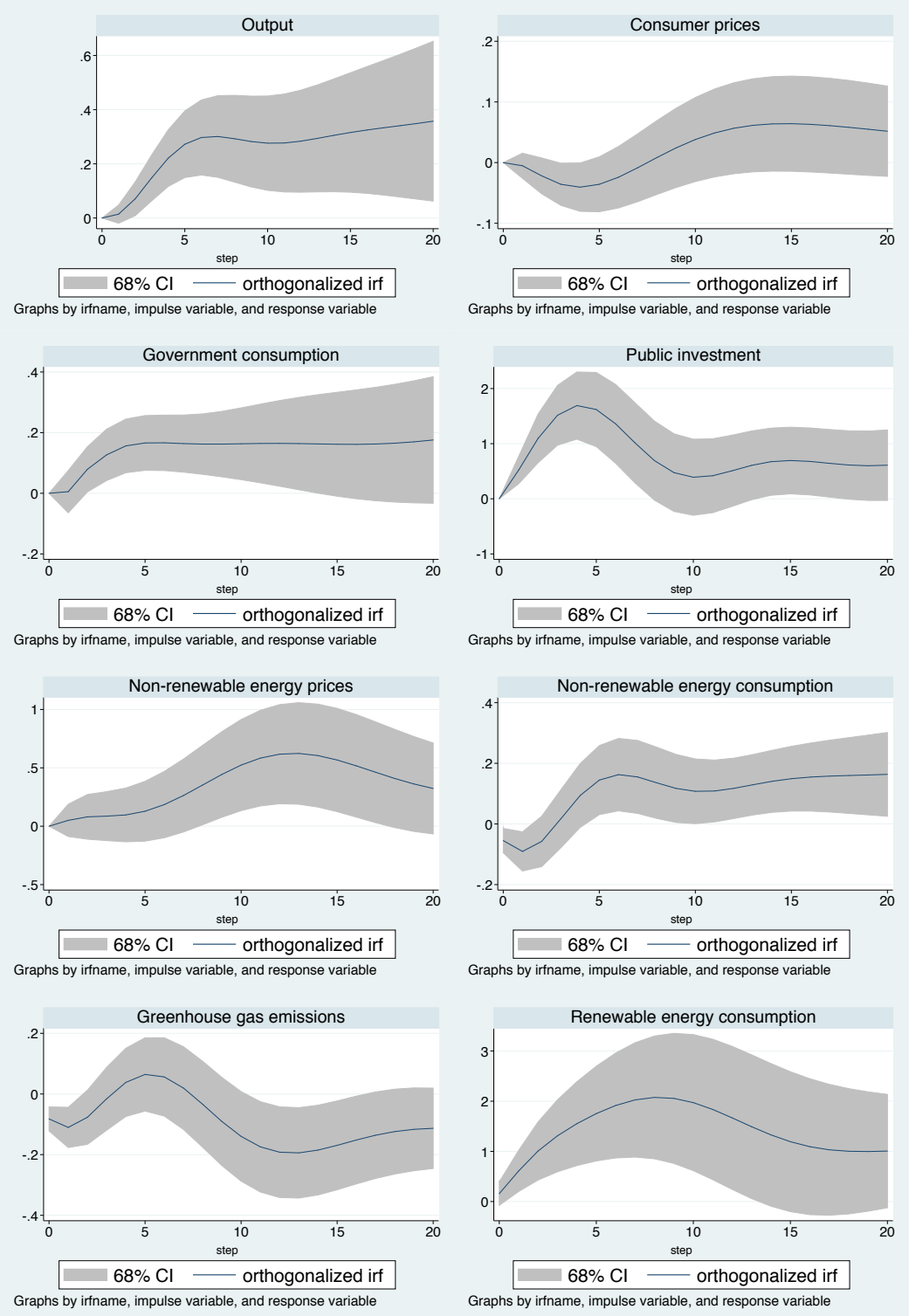


Table 4.3: Cumulative impulse response functions to conventional and unconventional monetary policy shocks (Baseline model, Switzerland)

Shock	Quarter	1	4	8	12	20
Conventional monetary policy shock						
gc		0.040	0.225	0.656	1.394	3.294
		(0.065)	(0.268)	(0.568)	(0.875)	(1.505)
pi		-0.024	-0.229	-0.835	-1.619	-2.710
		(0.042)	(0.305)	(0.830)	(1.333)	(1.891)
y		0.016	0.393	1.338	2.241	3.170
		(0.051)	(0.278)	(0.611)	(0.966)	(1.615)
cpi		0.019	-0.064	-0.259	-0.381	-0.330
		(0.017)	(0.087)	(0.209)	(0.353)	(0.693)
ep		0.217	0.582	1.455	1.844	0.808
		(0.272)	(0.855)	(1.481)	(2.019)	(2.745)
nrec		0.030	0.301	1.218	2.016	2.854
		(0.118)	(0.371)	(0.548)	(0.679)	(1.003)
rec		-0.576	-1.809	-2.848	-2.799	-1.719
		(0.162)	(0.604)	(1.093)	(1.486)	(2.039)
ghg		0.073	0.394	1.315	1.979	2.496
		(0.126)	(0.394)	(0.588)	(0.738)	(1.077)
Shock	**Month**	**3**	**12**	**24**	**30**	_
Unconventional monetary policy shock						
ip		0.428	1.941	3.512	4.175	_
		(0.161)	(0.701)	(1.340)	(1.583)	
cpi		0.042	-0.071	-0.226	-0.324	_
		(0.030)	(0.142)	(0.226)	(0.244)	
ep		1.405	3.720	4.428	4.374	_
		(0.370)	(1.464)	(2.252)	(2.265)	
nrec		-1.334	-1.270	-4.445	-5.957	_
		(0.197)	(1.324)	(2.528)	(2.727)	
rec		0.044	0.290	2.086	3.382	_
		(0.084)	(0.408)	(1.669)	(2.734)	
ghg		-0.153	-1.530	-5.312	-7.097	_
		(0.210)	(1.434)	(2.830)	(3.112)	

Standard errors are in parentheses.

Table 4.4: Cumulative impulse response functions to conventional and unconventional monetary policy shocks (Baseline model, United Kingdom)

Shock	Quarter	1	4	8	12	20
Conventional monetary policy shock						
gc		0.005	0.367	1.026	1.680	3.002
		(0.070)	(0.291)	(0.609)	(1.028)	(2.359)
pi		0.521	4.821	9.504	11.297	16.414
		(0.250)	(1.692)	(3.599)	(5.235)	(8.702)
y		0.014	0.454	1.617	2.736	5.356
		(0.034)	(0.273)	(0.780)	(1.419)	(3.277)
cpi		-0.005	-0.103	-0.163	0.004	0.482
		(0.021)	(0.118)	(0.308)	(0.557)	(1.085)
ep		0.050	0.314	1.243	3.410	7.279
		(0.139)	(0.706)	(1.690)	(3.033)	(5.929)
nrec		-0.145	-0.092	0.505	0.956	2.172
		(0.102)	(0.347)	(0.690)	(0.995)	(1.811)
rec		0.767	4.637	12.405	19.936	29.078
		(0.627)	(2.606)	(6.435)	(11.231)	(20.638)
ghg		-0.193	-0.247	-0.141	-0.738	-1.928
		(0.102)	(0.374)	(0.760)	(1.160)	(1.963)
Shock	**Month**	**3**	**12**	**24**	**30**	_
Unconventional monetary policy shock						
ip		-0.081	0.412	0.829	0.847	_
		(0.151)	(0.412)	(0.454)	(0.473)	
cpi		0.000	0.039	0.293	0.441	_
		(0.040)	(0.180)	(0.314)	(0.367)	
ep		-0.207	-1.023	-1.058	-0.831	_
		(0.283)	(0.637)	(0.899)	(0.960)	
nrec		0.171	0.211	-0.333	-0.376	_
		(0.183)	(0.839)	(0.655)	(0.557)	
rec		0.079	1.773	3.596	3.736	_
		(0.189)	(0.931)	(2.200)	(2.885)	
ghg		0.047	-0.444	-1.527	-1.857	_
		(0.158)	(0.743)	(1.008)	(1.338)	

Standard errors are in parentheses.

In the United Kingdom, after an expansionary shock, the output increases steadily and consumer prices increase slightly after approximately two years. As regards fiscal policy variables, government consumption and public investment increase after an expansionary shock, suggesting that fiscal and monetary policy act as complements to each other in the United Kingdom. In the energy market, a conventional monetary policy shock implies a rise in non-renewable energy prices after five quarters, as well as a slight and persistent increase in non-renewable energy consumption. The response of energy prices may be partly driven by the demand channel. As demand for non-renewable energy increases and exceeds the supply, the final price of such resources rises. The impact of conventional monetary policy shocks on non-renewable energy prices can also occur through the signaling channel. Economic agents can interpret this as a signal of low monetary policy rates to come over a prolonged period and can anticipate an increase in output and prices. On the other hand, an expansionary shock leads to a sharp increase in renewable energy consumption. These movements in the energy market are associated with a slight and persistent decline in greenhouse gas emissions. The positive impact of conventional monetary policy on environmental quality could be rationalized by the increase in the share of renewable energy consumption in total final energy consumption. The long-run analysis reveals that an expansionary conventional monetary policy shock induces to the increases in output, government consumption and public investment by accumulated 5.36, 3.00 and 16.41 percent, respectively. In contrast, the total positive impact on consumer prices is not significant. Moreover, a positive innovation induces to the increases in non-renewable energy prices, renewable energy consumption and non-renewable energy consumption by accumulated 7.28, 29.08 and 2.17 percent, respectively. Finally, the total reduction of greenhouse gas emissions is 1.93 percent, although it can be noted that the accumulated impact multipliers are not significant.

In a similar framework for the United States, Halkos and Paizanos (2016) find that an expansionary conventional monetary policy shock leads to an increase in non-renewable energy prices. Nevertheless, our findings as regards the response of greenhouse gas emissions for Switzerland are not consistent with Halkos and Paizanos (2016). These authors find that carbon dioxide emissions decline temporarily after an expansionary shock. One possible explanation could be that these authors do not include energy consumption in the model specification and therefore ignore the potential impact of monetary policy on greenhouse gas emissions that can occur through changes in energy

consumption. On the other hand, the positive response of non-renewable energy consumption to an expansionary conventional monetary policy is consistent with Ziaei (2018) for the United States. Overall, our findings reveal that central banks should investigate the impact of their interventions on environmental quality through the renewable and non-renewable energy markets. Although conventional monetary policy cannot yet be considered as a policy instrument for climate change and energy, central banks should incorporate environmental issues in their welfare maximization problem.

4.5.2.4 The Dynamic Effects of Unconventional Monetary Policy Shocks

The empirical analysis reveals that an expansionary unconventional monetary policy can improve environmental quality in the short run by reducing the consumption of non-renewable energy and increasing the deployment of renewable energy. On the other hand, the obtained results provide mixed evidence as regards the impact of the central bank's reserve assets purchases on non-renewable energy prices. In Switzerland, non-renewable energy prices increase after an expansionary shock, while they decline in the United Kingdom.

In Switzerland, an expansionary unconventional monetary policy shock has a positive effect on the economic activity by increasing industrial production. After an expansion of central bank's reserve assets, consumer prices increase slightly before their response turns negative and mostly insignificant after four months. Non-renewable energy prices increase sharply during approximately one year and a half, while the consumption of non-renewable energy declines steadily. On the other hand, a positive innovation implies a steady increase in renewable energy consumption. In addition, our findings reveal that an unconventional monetary policy shock leads to a steady decline in greenhouse gas emissions. The analysis of the cumulative impulse response functions reveals that an expansion of central bank's reserve assets induces to the increases in industrial production and non-renewable energy prices by accumulated 4.18 and 4.37 percent after two years and a half, respectively. The obtained results indicate that an unconventional monetary policy shock leads to the increase in renewable energy consumption by accumulated 3.38 percent, as well as the decreases in non-renewable energy consumption and greenhouse gas emissions by accumulated of 5.96 and 7.10 percent, respectively.

In the United Kingdom, after an expansion of central bank's reserve assets, industrial production initially declines before increasing slightly and persistently after two months. Moreover, a positive innovation leads to a slight and steady increase in consumer prices. The rise in prices can be justified by the increase in liquidity in the market, which leads to inflationary pressures. In relation to the energy market variables, non-renewable energy prices fall slightly during approximately one year and the consumption of non-renewable energy declines slightly after ten months. In addition, an expansion of central bank's reserve assets leads to an increase in renewable energy consumption and a reduction in greenhouse gas emissions during approximately two years. In the long run, an unconventional monetary policy shock implies the increases in industrial production, consumer prices and renewable energy consumption by accumulated 0.85, 0.44 and 3.74 percent, respectively. In contrast, the total negative impact on non-renewable energy prices is not significant. Moreover, a positive innovation leads to the decreases in non-renewable energy consumption and greenhouse gas emissions by accumulated 0.38 and 1.86 percent, respectively. However, it can be noted that only the long-run impact of unconventional monetary policy on greenhouse gas emissions is significant.

Using a stock-flow-fund ecological macroeconomic model, Dafermos et al. (2018) show that a green quantitative easing programme can restrict global warming. However, the lack of comparability of the methods used limits a proper comparison of the results. Matikainen et al. (2017) provide several explanations about the ways in which quantitative easing can affect the energy market and environmental quality. According to these authors, the environmental impact of the central bank's reserve asset purchases depends on government commitment to support low-carbon activities through direct spending. For instance, purchasing sovereign green bonds or corporate bonds from renewable energy issuers could support long-term sustainable growth. In contrast, if the central bank's reserve asset purchases are skewed towards high-carbon sectors such as oil and natural gas, then environmental quality could deteriorate. Our findings suggest that unconventional monetary policy can help reduce emissions by decreasing the consumption of non-renewable energy and increasing the deployment of renewable energy. However, the present analysis does not tell us how the interactions between monetary policy and the energy market occur. We believe that further research on the composition of the central banks' reserve asset purchases of these two countries would be needed to determine the channels through which unconventional monetary policy can affect the energy market and environmental quality.

Figure 4.10: Impulse response functions to an unconventional monetary policy shock (Baseline model, Switzerland)

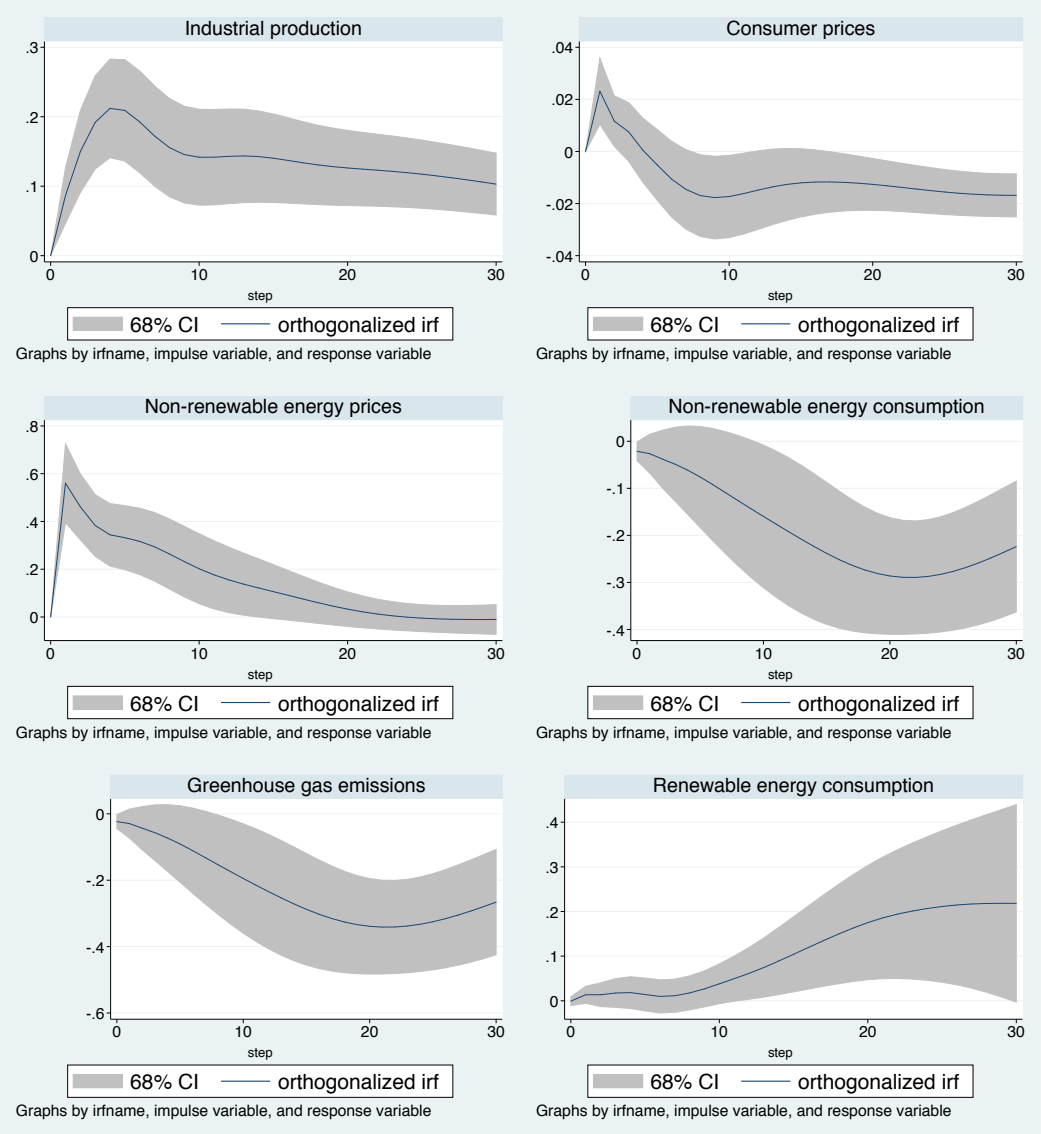
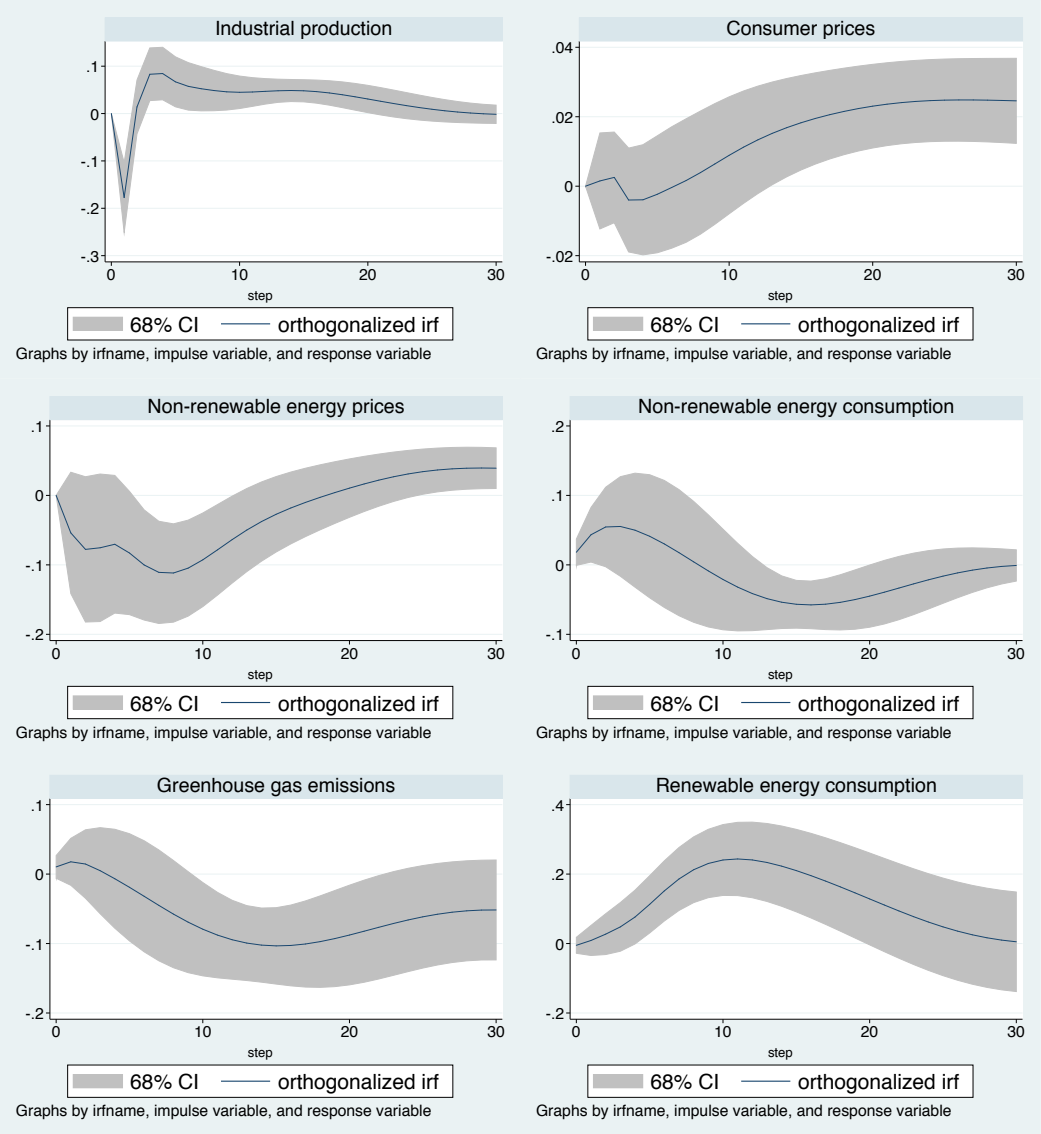


Figure 4.11: Impulse response functions to an unconventional monetary policy shock (Baseline model, United Kingdom)



4.5.2.5 Variance Decomposition Analysis

In order to assess the relative importance of fiscal and monetary policy shocks, the variance decomposition analysis is implemented. It provides informative conclusions about the effectiveness of the respective policies. The results are presented in tables 4.5 and 4.6 for the first five years following the structural shocks for the cases of fiscal and conventional monetary policy and two years and a half for the case of unconventional monetary policy.

The main findings of the variance decomposition analysis can be summarized as follows. First, public investment shocks have a greater contribution to the variability of non-renewable energy consumption and greenhouse gas emissions than government consumption shocks. Second, non-renewable energy prices are more sensitive to unexpected changes in government consumption than to those in public investment. Third, shocks to fiscal policy components have a greater contribution to the variability of renewable energy consumption in Switzerland than in the United Kingdom. Fourth, conventional and unconventional monetary policy shocks explain a meaningful part of the variability of renewable energy consumption, non-renewable energy consumption and greenhouse gas emissions in Switzerland. In the United Kingdom, both monetary policy shocks have a significant contribution to the variability of renewable energy consumption. However, the shares of the variance of non-renewable energy consumption and greenhouse gas emissions resulting from monetary policy shocks are moderate. Fifth, conventional monetary policy shocks generally have a greater contribution to the variability of renewable and non-renewable energy consumption than unconventional monetary policy shocks. Finally, unconventional monetary policy shocks have a significant contribution to fluctuations in non-renewable energy prices in Switzerland. In contrast, conventional monetary policy innovations explain a small share of their variability at all horizons. In the United Kingdom, non-renewable energy prices are little sensitive to unexpected changes in conventional and unconventional monetary policy.

Table 4.5: Variance decomposition (Baseline model, Switzerland)

Shock	Quarter	1	4	8	12	20
Government consumption shock						
	r	6.07	4.18	5.11	9.08	10.84
	y	3.62	1.18	3.18	3.92	3.61
	cpi	0.08	1.10	0.83	0.58	0.80
	ep	1.77	11.15	15.30	16.05	15.91
	nrec	2.25	1.87	1.11	1.40	1.56
	ghg	1.72	1.07	0.61	0.92	1.08
	rec	0.15	3.96	7.27	9.46	15.22
Public investment shock						
	r	0.60	0.29	1.53	2.79	3.21
	y	3.31	2.10	1.79	2.12	1.79
	cpi	0.74	0.17	0.34	0.86	3.92
	ep	0.13	1.65	10.41	13.52	13.66
	nrec	1.07	0.45	2.67	10.66	21.83
	ghg	0.65	0.22	4.00	13.03	23.59
	rec	0.60	0.21	3.16	8.92	15.49
Conventional monetary policy shock						
	gc	0.00	0.73	2.34	6.56	16.99
	pi	0.00	0.44	2.25	5.04	8.42
	y	0.00	1.63	9.54	15.96	19.66
	cpi	0.00	1.05	4.00	4.28	3.12
	ep	0.00	0.40	1.43	1.77	2.37
	nrec	0.20	0.85	11.36	19.93	23.30
	rec	19.24	16.56	18.41	15.91	16.73
	ghg	0.86	1.33	10.95	15.96	16.64
Shock	**Month**	**3**	**12**	**24**	**30**	_
Unconventional monetary policy shock						
	ip	3.54	17.03	21.63	22.56	_
	cpi	2.40	2.86	4.60	5.95	_
	ep	11.93	15.97	16.07	16.03	_
	nrec	0.65	2.63	11.35	13.66	_
	rec	0.12	0.93	9.12	11.52	_
	ghg	0.74	3.28	12.93	15.23	_

Table 4.6: Variance decomposition (Baseline model, United Kingdom)

Shock	Quarter	1	4	8	12	20
Government consumption shock						
	r	0.74	3.82	5.95	5.07	2.66
	y	0.78	0.82	2.50	5.48	11.45
	cpi	0.01	0.04	0.39	1.46	2.06
	ep	0.48	2.56	4.72	7.38	10.30
	nrec	2.77	3.52	2.83	4.04	5.20
	ghg	0.76	2.77	1.16	0.73	0.57
	rec	0.02	0.82	2.07	2.66	3.08
Public investment shock						
	r	2.16	4.96	11.84	10.19	5.11
	y	1.04	0.92	3.71	6.32	6.06
	cpi	0.23	0.27	0.79	2.27	2.03
	ep	2.20	0.88	1.87	2.87	2.36
	nrec	0.54	4.61	13.65	12.33	7.62
	ghg	0.99	5.53	8.09	4.69	1.87
	rec	0.18	0.08	0.99	2.21	3.16
Conventional monetary policy shock						
	gc	0.00	1.66	5.65	5.63	4.13
	pi	0.00	8.82	15.75	14.31	14.21
	y	0.00	2.23	10.46	12.82	14.84
	cpi	0.00	1.11	1.58	1.82	4.61
	ep	0.00	0.30	1.32	5.94	12.64
	nrec	1.99	1.19	4.72	6.71	10.91
	rec	0.54	6.32	12.91	17.14	17.76
	ghg	4.47	2.29	1.75	3.40	8.42
Shock	**Month**	**3**	**12**	**24**	**30**	_
Unconventional monetary policy shock						
	ip	4.54	5.29	5.77	5.58	_
	cpi	0.02	0.21	2.61	3.90	_
	ep	0.42	2.28	2.20	2.32	_
	nrec	1.60	0.74	1.75	1.75	_
	rec	0.25	11.36	9.78	7.38	_
	ghg	0.26	1.61	4.05	3.64	_

4.5.3 Sensitivity Analysis

This chapter implements several robustness checks for the estimation results. First, we try an alternative ordering for the contemporaneous relations among the variables. We check whether the results are robust when we order the non-renewable energy price index after the monetary policy instrument. All specifications yield very similar results to those of the baseline models. Besides, the results do not change significantly in all model specifications when the global commodity price index is used as a critical exogenous variable. The latter variable is added instead of the global oil price index to have a different measure of global economic shocks. We then reproduce the same empirical analysis for the United Kingdom by using oil prices and consumption instead of the broader measure of non-renewable energy to enable the comparison of the results. Figure A.4.7.1 displays the impulse response functions of oil prices and consumption to fiscal and monetary policy shocks. The results reveal that policies can have different effects on oil and non-renewable energy. In other words, they suggest that prices and demand for coal, natural gas and oil could react differently to policy shocks. The main findings can be summarized as follows. After a government consumption shock, oil prices decline temporarily, while oil consumption does not react significantly. A public investment shock implies a temporary decline in oil prices and consumption. Following a conventional monetary policy shock, oil prices decline temporarily after one year, while oil consumption increases steadily. Moreover, an expansionary unconventional monetary policy shock leads to a slight and temporary increase in oil prices, while oil consumption does not react significantly.

4.6 Conclusions and Policy Implications

This chapter provides an empirical examination on the interactions among macroeconomic policies, the energy market and environmental quality. These interactions and channels among them are studied through structural VAR models based on a macroeconomic framework including the energy market. The empirical analysis is conducted for two non-EMU countries, Switzerland and the United Kingdom, over the period 1990-2016. The chapter evaluates the effects of shocks to fiscal policy components, conventional and unconventional monetary policy on the energy market and environmental quality. For the case of monetary policy, the analysis is made on sub-periods. Using the recursive approach, we identify four policy shocks: (i) government consumption (ii) public investment (iii) the official bank policy rate (iv) the central bank's reserve assets.

The empirical analysis reveals that fiscal and monetary policies have a significant influence on the energy market and environmental quality. An expansion of government consumption leads to a slight and temporary decline in non-renewable energy consumption and greenhouse gas emissions. We also find that an unexpected increase in government consumption implies a decline in non-renewable energy prices. Public investment increases can achieve important non-renewable energy conservation and greenhouse gas emissions reduction in both countries. In contrast, the examination of the relationship between public investment and non-renewable energy prices has not provided clear empirical evidence. Moreover, our findings reveal that government policies can have an important role in promoting the deployment of renewable energy. The chapter provides mixed evidence as regards the impact of conventional monetary policy on environmental quality. In the United Kingdom, an expansionary shock implies an improvement of environmental quality associated with an increase in renewable energy consumption, while the opposite holds true in Switzerland. In addition, the empirical results indicate that an expansionary conventional monetary policy leads to an increase in non-renewable energy prices and consumption. An expansionary unconventional monetary policy can improve environmental quality in the short run by reducing the consumption of non-renewable energy and increasing the deployment of renewable energy. In contrast, the obtained results provide mixed evidence as regards the impact of the central bank's reserve assets purchases on non-renewable energy prices. In Switzerland, non-renewable energy prices increase after an expansionary shock, while they decline in the United Kingdom.

The results occurring from this chapter have several policy implications. Fiscal policy, besides its primary role in stabilizing economic activity, can contribute to the achievement of environmental sustainability. Our findings indicate that public investment is more efficient than government consumption in reducing non-renewable energy consumption and greenhouse gas emissions. The analysis of the composition of government spending seems crucial to establish how the different spending categories can complement the efforts to conserve natural resources, promote the use of clean energy and enhance environmental quality. On the other hand, the examination of monetary policy reveals that central banks should investigate the impact of their interventions on environmental quality through the renewable and non-renewable energy markets. In the United Kingdom, conventional monetary policy proves to be effective in promoting the deployment of renewable energies and reducing emissions. In Switzerland, central bank's efforts to stimulate the real economy through the decrease in interest rates should be accompanied by more strict environmental regulations in order to offset the rise in emissions. Moreover, the analysis reveals that unconventional monetary policy can lead to enhancements of environmental quality. However, as expected, quantitative easing is not by itself capable of substantially reducing emissions and other types of environmental policies need to be implemented jointly. Although monetary policy cannot yet be considered as a policy instrument for climate change and energy, central banks should incorporate environmental issues in their welfare maximization problem.

Nevertheless, there are several unique characteristics in Switzerland and in the United Kingdom that may limit the direct applicability of our findings to other countries realities. They are among the most advanced countries in the world with particularly high gross domestic product and household income per capita. Taking this into account, the effect of macroeconomic policies on the quality of the environment is more uncertain in developing countries, due to larger market failures and less developed banking sectors. For instance, the income and technique effects that follow an increase in government spending are more likely to exceed the scale effect in developed countries, and therefore contribute to a greater reduction in greenhouse gas emissions. On the other hand, the impact of monetary policy on environmental quality depends on country's energy mix and government commitment to support low-carbon activities. Therefore, it may be plausible to expect significant differences in the effects of monetary policy on environmental quality across countries.

Appendix 4

A.4.1 Data Sources and Variable Definitions

Switzerland

Output: Real Gross domestic product, Code: CLVMNACSAB1GQCH. Source: Federal Reserve Bank of St. Louis.

Government consumption: Government final consumption expenditure, Code: CHEGFCEQDSMEI. Source: Federal Reserve Bank of St. Louis.

Public investment: Gross fixed capital formation: Public sector. Source: Annual macro-economic database of the European Commission.

Consumer prices: Consumer price index (all items), Code: CHECPIALLMINMEI. Source: Federal Reserve Bank of St. Louis.

Official bank policy rate: Three-month Swiss franc London Interbank Offered Rate: LIBOR, Code: CHF3MTD156N. Source: Federal Reserve Bank of St. Louis.

Population: Total population, Code: POPTOTCHA647NWDB. Source: Federal Reserve Bank of St. Louis.

Non-renewable energy consumption: Oil products consumption. Source: International Energy Agency.

Non-renewable energy prices: Oil products price index. Source: Swiss National Bank.

Renewable energy consumption: Share of renewable energy consumption in total final energy consumption. Source: World Bank.

Greenhouse gas emissions: Greenhouse gas emissions generated by the energy sector. Source: Organisation for Economic Co-operation and Development.

Reserve assets: Official total reserve assets. Source: Swiss National Bank.

Industrial production: Production of total industry index, Code: CHEPROINDQISMEI. Source: Federal Reserve Bank of St. Louis.

GDP deflator: GDP implicit price deflator, Code: CHEGDPDEFQISMEI. Source: Federal Reserve Bank of St. Louis.

Global oil price: Global price of West Texas Intermediate crude, Code: POILWTIUSDM. Source: Federal Reserve Bank of St. Louis.

Global commodity prices: Global price index of all commodities, Code: PALLFNFINDEXQ. Source: Federal Reserve Bank of St. Louis.

United Kingdom

Output: Gross domestic product, Code: UKNGDP. Source: Federal Reserve Bank of St. Louis.

Government consumption: Real government consumption of goods and services, Code: RGCGASUKQ. Source: Federal Reserve Bank of St. Louis.

Public investment: Gross fixed capital formation: Public sector. Source: Annual macro-economic database of the European Commission.

Consumer prices: Consumer price index (all items), Code: GBRCPIALLMINMEI. Source: Federal Reserve Bank of St. Louis.

Official bank policy rate: Official bank rate, Code: IUQABEDR. Source: Bank of England.

Population: Resident population: Mid-year estimates (quarterly data interpolated), Code: EBAQ. Source: Office for National Statistics.

Non-renewable energy consumption: Oil products consumption plus natural gas consumption plus coal consumption. Source: International Energy Agency.

Non-renewable energy prices: Weighted average of retail price index of petrol and oil (Code: CHOL), retail price index of gas (Code: DOBY) and retail price index of coal and solid fuels (Code: DOBW). Source: Office for National Statistics.

Renewable energy consumption: Share of renewable energy consumption in total final energy consumption. Source: World Bank.

Greenhouse gas emissions: Greenhouse gas emissions generated by the energy sector. Source: Organisation for Economic Co-operation and Development.

Reserve assets: Government stock (gilts), Code: BKPM. Source: Office for National Statistics.

Industrial production: Production of total industry index, Code: GBRPROINDMISMEI. Source: Federal Reserve Bank of St. Louis.

GDP deflator: GDP implicit price deflator, Code: GBRGDPDEFQISMEI. Source: Federal Reserve Bank of St. Louis.

Global oil price: Global price of West Texas Intermediate crude, Code: POILWTIUSDM. Source: Federal Reserve Bank of St. Louis.

Global commodity prices: Global price index of all commodities, Code: PALLFNFINDEXQ. Source: Federal Reserve Bank of St. Louis.

A.4.2 Model Specifications

Table A.4.2.1: Model specifications

Specification[a]	Endogenous variables							Period
Government consumption								
A	gc	y	cpi	ep	r	nrec	ghg	1990-2016
B	gc	y	cpi	ep	r	rec	ghg	1990-2016
Public investment								
C	pi	y	cpi	ep	r	nrec	ghg	1990-2016
D	pi	y	cpi	ep	r	rec	ghg	1990-2016
Conventional monetary policy								
E	gc	y	cpi	ep	r	nrec	ghg	1990-2009
F	pi	y	cpi	ep	r	nrec	ghg	1990-2009
G	gc	y	cpi	ep	r	rec	ghg	1990-2009
H	pi	y	cpi	ep	r	rec	ghg	1990-2009
Unconventional monetary policy								
I	ip	cpi	ep	ra	nrec	ghg		2009-2016
J	ip	cpi	ep	ra	rec	ghg		2009-2016

[a] In all specifications, the global oil price (op*) is included as a critical exogenous variable.

Table A.4.2.2: Summary of variables

Variables	Notation
Government consumption	gc
Public investment	pi
Output	y
Consumer prices	cpi
Non-renewable energy prices	ep
Official bank policy rate	r
Non-renewable energy consumption	nrec
Renewable energy consumption	rec
Greenhouse gas emissions	ghg
Reserve assets	ra
Industrial production	ip
Global oil price	op*

A.4.3 Descriptive Statistics

Table A.4.3.1: Descriptive statistics (Switzerland)

Variables[a]	Unit	Mean	Std.dev	Min.	Max.
Government consumption	Billion Swiss franc	15.76	2.11	12.74	19.99
Public investment	Billion Swiss franc	17.25	1.50	15.26	22.31
Output	Billion Swiss franc	134.74	19.01	110.48	168.53
Consumer prices	Percent	94.64	6.59	75.57	102.45
Official bank policy rate	Percent	2.17	2.63	-0.79	9.41
Non-renewable energy prices	Percent	93.71	26.48	60.01	150.92
Non-renewable energy consumption	Kilotonne of oil equivalent	10808.24	737.16	9038	11879
Renewable energy consumption	Percent	19.51	2.02	17.12	25.29
Greenhouse gas emissions	Tonne of CO_2 equivalent	5.68	0.53	4.48	6.50
Industrial production	Percent	98.44	3.75	89.73	103.64
Reserve assets	Billion Swiss franc	404.56	178.65	81.74	696.27
Global oil price	Dollar per Barrel	46.64	30.37	12.97	120.20

Consumer prices (index 2015=100), Non-renewable energy prices (index 2015=100), Industrial production (index 2015=100).

[a] Descriptive statistics on industrial production and reserve assets are based on the period 2009-2016.

Table A.4.3.2: Descriptive statistics (United Kingdom)

Variables[a]	Unit	Mean	Std.dev	Min.	Max.
Government consumption	Billion British pound	73.64	12.13	56.13	91.44
Public investment	Billion British pound	37.39	11.66	21.13	55.59
Output	Billion British pound	382.77	64.25	281.25	486.45
Consumer prices	Percent	78.82	13.29	53.04	101.76
Official bank policy rate	Percent	4.63	3.54	0.25	14.88
Non-renewable energy prices	Percent	63.81	27.49	31.31	113.93
Non-renewable energy consumption	Kilotonne of oil equivalent	111809.9	9675.9	91991	123924
Renewable energy consumption	Percent	2.22	2.07	0.61	8.71
Greenhouse gas emissions	Tonne of CO_2 equivalent	9.00	1.31	5.99	10.93
Industrial production	Percent	99.44	1.72	95.10	103.27
Reserve assets	Billion British pound	1086.33	241.51	561.76	1388.1
Global oil price	Dollar per Barrel	46.64	30.37	12.97	120.20

Consumer prices (index 2015=100), Non-renewable energy prices (index 2015=100), Industrial production (index 2015=100).

[a] Descriptive statistics on industrial production and reserve assets are based on the period 2009-2016.

A.4.4 Results from Unit Root Tests

Table A.4.4.1: Augmented Dickey-Fuller test (Period 1990-2016)

		Augmented Dickey-Fuller test	
Variables	Deterministic terms	Level[a]	Difference
Switzerland			
gc	Intercept	-0.054	-3.424**
	Trend and intercept	-2.057	-3.845**
pi	Intercept	-2.860*	-
	Trend and intercept	-2.357	-4.199***
y	Intercept	-0.358	-3.378**
	Trend and intercept	-2.676	-3.278*
cpi	Intercept	-3.681***	-
	Trend and intercept	-2.898	-3.380*
r	Intercept	-2.506	-3.057**
	Trend and intercept	-2.771	-3.343*
ep	Intercept	-1.330	-3.662***
	Trend and intercept	-2.443	-3.712**
nrec	Intercept	2.861	-4.348***
	Trend and intercept	1.493	-5.007***
rec	Intercept	1.197	-2.828*
	Trend and intercept	-0.635	-3.839**
ghg	Intercept	1.106	-4.112***
	Trend and intercept	-0.396	-4.751***
United Kingdom			
gc	Intercept	-1.288	-2.483
	Trend and intercept	-0.203	-2.513
pi	Intercept	-0.867	-3.261**
	Trend and intercept	-2.317	-3.247*
y	Intercept	-1.634	-3.865***
	Trend and intercept	-1.506	-4.185***
cpi	Intercept	-1.050	-4.639***
	Trend and intercept	-2.782	-4.412***
r	Intercept	-2.594*	-
	Trend and intercept	-3.701**	-
ep	Intercept	-0.442	-3.656***
	Trend and intercept	-1.476	-3.638**
nrec	Intercept	-0.087	-2.622*
	Trend and intercept	-1.958	-2.639
rec	Intercept	1.116	-1.691
	Trend and intercept	-1.238	-2.340
ghg	Intercept	1.691	-2.270
	Trend and intercept	-0.060	-3.359*

[a] The series has an unit root under the null hypothesis.

*** Indicates significance at the 1% level ** Indicates significance at the 5% level * Indicates significance at the 10% level

A.4.5 VAR Model: Lag Length Selection and Specification tests

Table A.4.5.1: Residual autocorrelation test and lag length selection (Switzerland)

	Residual autocorrelation[a]				Lag length selection		
Lags	1	2	3	4	BIC	HQIC	No. lags selected[b]
Specification							
A	0.00455	0.01478	0.51525	0.00000	1	2	2
B	0.03746	0.43685	0.07407	0.00000	1	2	2
C	0.70117	0.73555	0.83828	0.00000	1	2	2
D	0.35749	0.79345	0.36110	0.00000	2	2	2
E	0.01583	0.68239	0.55563	0.00002	1	8	2
F	0.48494	0.88633	0.87016	0.00000	1	8	2
G	0.10881	0.64181	0.20980	0.00013	1	8	2
H	0.39999	0.88232	0.54433	0.00000	1	8	2
I	0.60044	0.04627	0.00022	0.96895	2	2	2
J	0.44522	0.01349	0.00006	0.96256	2	8	2

[a] Residual autocorrelation test (p-value) is based on the residuals from the reduced VAR form. Reported p-values are from the Breusch-Godfrey Lagrange Multiplier test. No serial correlation under the null hypothesis.

Table A.4.5.2: Residual autocorrelation test and lag length selection (United Kingdom)

	Residual autocorrelation[a]				Lag length selection		
Lags	1	2	3	4	BIC	HQIC	No. lags selected
Specification							
A	0.00780	0.51128	0.32489	0.00000	2	2	2
B	0.00176	0.26201	0.57430	0.00000	1	2	2
C	0.02947	0.90340	0.34489	0.00000	2	2	2
D	0.00215	0.50776	0.53907	0.00000	2	2	2
E	0.07497	0.90591	0.89417	0.00003	2	8	2
F	0.13699	0.97794	0.29881	0.00000	2	8	2
G	0.00900	0.52892	0.26911	0.00002	1	8	2
H	0.02359	0.54987	0.27143	0.00000	1	8	2
I	0.47443	0.38626	0.74398	0.96011	2	2	2
J	0.32439	0.52506	0.92855	0.33314	2	8	2

[a] Residual autocorrelation test (p-value) is based on the residuals from the reduced VAR form. Reported p-values are from the Breusch-Godfrey Lagrange Multiplier test. No serial correlation under the null hypothesis.

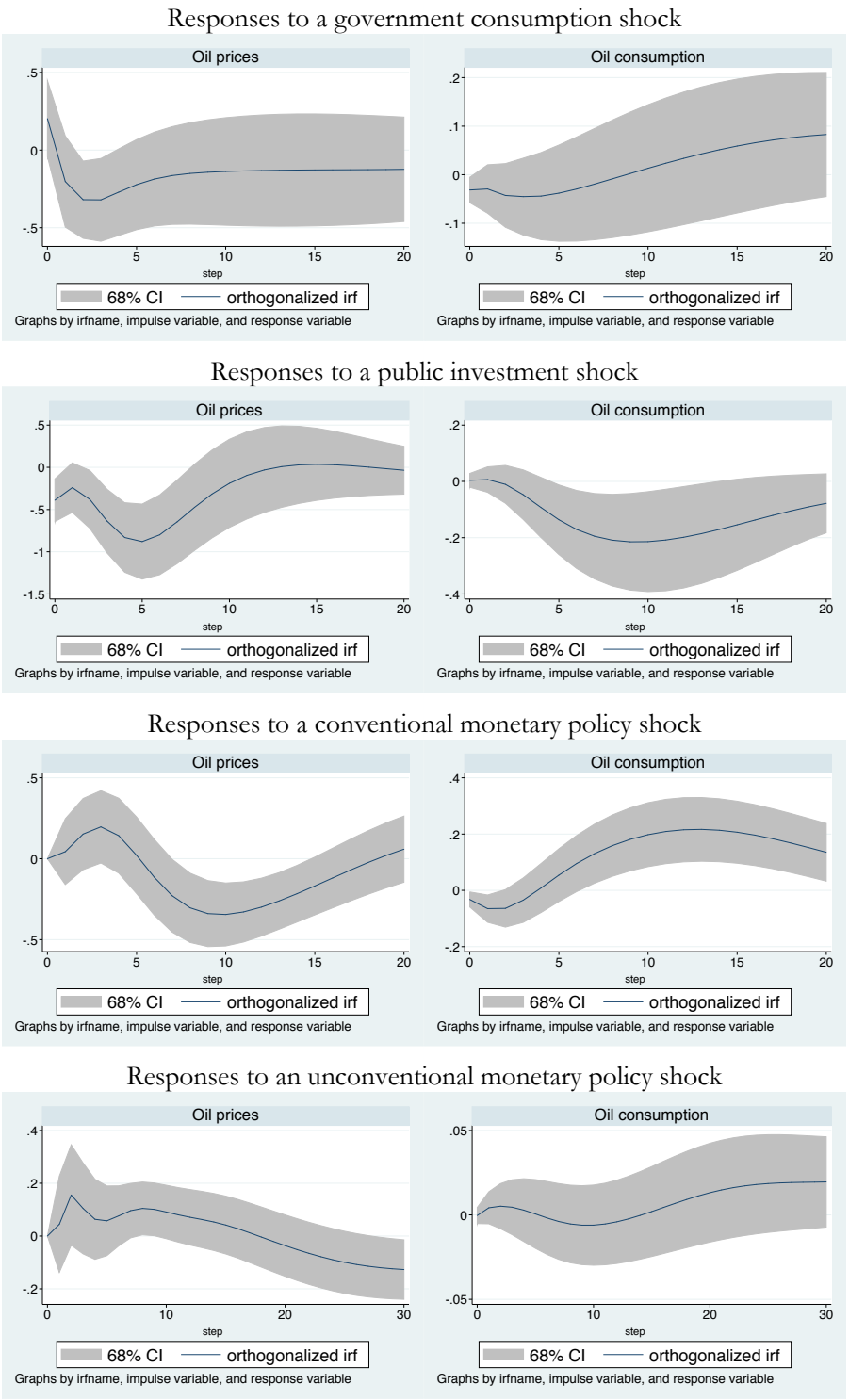
A.4.6 Johansen Cointegration Maximum Eigenvalue Test

Table A.4.6.1: Johansen cointegration maximum eigenvalue test

	Switzerland		United Kingdom	
	Hypothesized number of cointegrating vectors	**Hypothesized number of cointegrating vectors**	**Hypothesized number of cointegrating vectors**	**Hypothesized number of cointegrating vectors**
Specification	**Constant**	**Trend**	**Constant**	**Trend**
A	1	2	3	4
B	2	2	3	4
C	1	1	4	4
D	2	2	3	3
E	2	3	4	4
F	2	3	5	3
G	2	4	5	5
H	3	3	5	4
I	2	2	3	2
J	3	3	5	4

A.4.7 Impulse Response Functions: Figures

Figure A.4.7.1: Responses of oil prices and consumption (Baseline model, United Kingdom)



A.4.8 Summary of the Results

Table A.4.8.1: Summary of the results (Switzerland)

Shock	Quarter	1	4	8	12	20
Government consumption shock						
r		+	0	-	-	0
y		0	-	0	0	0
cpi		-	0	0	0	0
ep		-	-	-	0	0
nrec		+	0	0	0	0
ghg		0	0	0	0	0
rec		+	+	+	+	+
Public investment shock						
r		0	0	0	0	0
y		+	0	0	0	0
cpi		0	0	0	0	-
ep		+	-	-	0	0
nrec		0	0	-	-	-
ghg		0	0	-	-	-
rec		0	0	+	+	+
Conventional monetary policy shock						
gc		0	0	+	+	+
pi		0	0	-	-	0
y		0	+	+	+	0
cpi		0	-	0	0	0
ep		0	0	0	0	-
nrec		0	+	+	+	+
rec		-	-	0	0	0
ghg		0	+	+	+	0
Shock	**Month**	**3**	**12**	**24**	**30**	_
Unconventional monetary policy shock						
ip		+	+	+	+	_
cpi		+	0	-	-	_
ep		+	+	0	0	_
nrec		0	-	-	-	_
rec		0	0	+	0	_
ghg		0	-	-	-	_

The sign shows the direction of the impact, and 0 means that the null hypothesis of no effect cannot be rejected at the 0.32 level of significance.

Table A.4.8.2: Summary of the results (United Kingdom)

Shock	Quarter	1	4	8	12	20
Government consumption shock						
	r	-	-	0	0	0
	y	0	0	+	+	+
	cpi	0	0	0	0	0
	ep	-	-	-	-	-
	nrec	-	0	0	+	0
	ghg	-	0	0	0	0
	rec	0	+	0	0	0
Public investment shock						
	r	-	-	-	0	0
	y	+	0	-	-	0
	cpi	0	0	0	0	0
	ep	0	0	0	0	0
	nrec	0	-	0	0	0
	ghg	0	-	0	0	0
	rec	0	0	0	0	0
Conventional monetary policy shock						
	gc	0	+	+	+	0
	pi	+	+	0	0	0
	y	0	+	+	+	+
	cpi	0	0	0	0	0
	ep	0	0	+	+	0
	nrec	-	0	+	+	+
	rec	+	+	+	+	0
	ghg	-	0	0	-	0
Shock	**Month**	**3**	**12**	**24**	**30**	_
Unconventional monetary policy shock						
	ip	+	+	0	0	_
	cpi	0	0	+	+	_
	ep	0	0	0	0	_
	nrec	0	0	-	0	_
	rec	0	+	0	0	_
	ghg	0	-	0	0	_

The sign shows the direction of the impact, and 0 means that the null hypothesis of no effect cannot be rejected at the 0.32 level of significance.

Chapter 5: Concluding Remarks and Future Research

In line with its general objective, the doctoral thesis has explored the effects of macroeconomic policies on the economy and the environment. First, it has examined the composition of fiscal policy and its transmissions mechanisms on various macroeconomic aggregates in open economies. Next, the transmission mechanisms of conventional and unconventional monetary policies on the macroeconomic aggregates in open economies have been explored. Finally, the interactions between macroeconomic policies, the energy market and environmental quality have been analysed. This final chapter summarizes all the obtained findings of the thesis and contains future lines of research.

5.1 Concluding Remarks

Chapter 2 has examined the composition of fiscal policy and its transmission mechanisms for two Anglo-Saxon countries, the United States and the United Kingdom, over the period 1964-2017. The review of the literature made it clear how the quantitative and qualitative response of key economic variables are difficult to reconcile, due to the differences in the specification and the lack of comparability of fiscal policy experiments (Caldara and Kamps, 2008). This chapter has evaluated the effects of disaggregated fiscal policy shocks on the macroeconomic aggregates. Building on the existing literature on disaggregated fiscal policy analysis in open economies (e.g., Lane and Perotti, 1998; Bénétrix and Lane, 2009), it has explored the role of the exchange rate and the trade balance in the transmission of shocks to tax revenue and government spending components. The empirical analysis was conducted through structural VAR models. The effects of shocks to government non-wage consumption, government wage consumption, public investment and tax revenue were evaluated by the impulse response functions and the variance decomposition.

The conducted analysis revealed that the disaggregation of fiscal policy matters since each fiscal instrument implies different transmission channels and effects on the real economy. The results indicated that the components of government spending generally have different effects on the macroeconomic aggregates than aggregate fiscal policy. It therefore seems essential to disaggregate government spending into its main components to uncover significant and different patterns that an aggregated analysis cannot reveal. However, as expected, the effects of government spending components on

certain economic variables are weak and insignificant. The analysis showed that the components of government spending generally have smaller effects on the economic variables than aggregate fiscal policy. In addition, our findings suggested that fiscal policy can be operative, besides the interest rate channel, via an exchange rate and trade balance channels. Considering an open economy framework is therefore essential since a part of the fiscal stimulus propagates abroad through external channels. There are also generally some differences in the obtained results for the United States and the United Kingdom. This could be explained by the differences between the United Kingdom and the Anglo-American economic models. The United Kingdom has comparatively higher levels of taxation and spending on the welfare state and thus shares some common features with European continental economic models (Davtyan, 2016).

Our findings revealed that government non-wage consumption shocks can have contractionary effects in both countries by crowding out private consumption and private investment. Government wage consumption shocks seem to have little effect on the output, but lead to spillovers on private sector wages, that could induce a negative labor demand effect and decrease employment as a result. Public investment shocks have clear and strong expansionary short-run effects on the United States economy by increasing private consumption, private wages and employment. Nevertheless, private investment is crowded out. The results suggested that after the initial expansion of economic activity, the crowding out effect in the private sector predominates, thus leading to a slight decline in economic growth. In the United Kingdom, the economic slowdown is accompanied by contractionary effects on private activity. In addition, the obtained results indicated that the expansion of all government spending components increases inflation in the United Kingdom, while they reduce all inflation in the United States. Tax revenue increases lead to a decline in output and its components in the United States, while they have little distortionary effects on the United Kingdom economy.

The obtained impulse response functions have provided mixed evidence as regards the impact of government spending components on the open economy variables. Government non-wage consumption shocks have a relatively weak impact on the real effective exchange rate and lead to a slight increase in net exports. Government wage consumption shocks imply a real appreciation in the United States and a real depreciation in the United Kingdom. These movements are accompanied by a decline in net exports in the United Kingdom, while they do not react significantly in the United States. Public investment shocks lead to

a real depreciation, associated with an increase in the United States net exports and a decline in the United Kingdom net exports. Finally, tax revenue increases imply a real appreciation in both countries, accompanied by an increase in the United States net exports and a decline in the United Kingdom net exports. The responses of economic variables to shocks to tax revenue and government spending components were generally difficult to reconcile with most macroeconomic theories, an aspect that certainly deserves further investigation.

In any case, the results occurring from Chapter 2 revealed several interesting policy implications for the countries and the period considered in our analysis. First, government non-wage consumption increases could have contractionary effects on the real economy. Our findings also indicated that, as expected, public wage policies have a greater impact on the labor market than changes in the other components of government spending, while they have a relatively small effect on the output. Moreover, government efforts to stimulate the real economy through the increase in public investment should be accompanied by other types of macroeconomic policy instruments in order to offset the crowding out effect on private activity. The analysis of the composition of government spending seems essential to establish how different spending categories can influence macroeconomic aggregates. However, as expected, changes in the components of government spending are not by themselves capable of sufficiently improving economic conditions and other supportive policies need to be implemented jointly. Moreover, the examination of tax revenue revealed different policy implications. In the United States, tax revenue cuts can stimulate economic activity and increase prices in the short run. In contrast, tax revenue cuts do not seem to be effective in stimulating the United Kingdom economy.

Chapter 3 has examined the transmission mechanisms of conventional and unconventional monetary policies on the macroeconomic aggregates in open economies. While research on monetary policy has been substantial, less attention was given to the study of the role of consumer expectations and stock prices in the transmission of monetary policy (e.g., Brissimis and Magginas, 2006; Debes et al., 2014; Gambacorta et al., 2014). In addition, very few studies have analysed the effects of monetary policy in open economies outside the euro area. Taking this into account, the analysis was carried out for two non-EMU countries, Switzerland and the United Kingdom, over the period 1990-2017. We have examined the potential role of consumer expectations and stock prices in the transmission of monetary policy in an open economy framework. The

chapter proposed two distinct structural VAR models. The baseline model for the case of conventional monetary policy covered the pre-2009 period and was estimated using quarterly data, while the baseline model for the case of unconventional monetary policy covered the post-2009 period and was estimated using monthly data. The official bank policy rate and central bank's reserve assets were used as instruments for conventional and unconventional monetary policy. The modelling approach consisted in augmenting the VAR model with a forward-looking informational variable of near-term development in economic activity and several foreign exogenous variables. For the case of conventional monetary policy, the consumer confidence indicator was used since it contains important information used by central banks about consumer expectations as regards future economic conditions. For the case of unconventional monetary policy, the long-term government bond yields were used to capture consumer expectations about future short-term interest rates. The effects of policy shocks were assessed by the impulse response functions and the variance decomposition.

The conducted analysis revealed that the inclusion of a forward-looking informational variable of near-term development in economic activity and a financial variable such as the stock prices are of key importance for the monetary policy assessment. We provided evidence for the existence of a consumer confidence channel in the transmission mechanism of conventional monetary policy. An expansionary policy enhances households' perception with regards future economic conditions, which may result in a tendency to consumer more and save less. Thus, changes in consumer confidence can potentially amplify the effects of monetary policy on the real economy. Moreover, the results indicated that the long-term government bond yields have an important role in the transmission mechanism of unconventional monetary policy. The increase in stock prices and the decrease in long-term interest rates transmit to the real economy through an increase in the wealth of shareholders and the reduction of costs of capital, thus implying an increase in spending and economic activity. Although these results have limited policy implications, they revealed the importance of considering these specific transmission channels and controlling for global supply and demand shocks in order to provide a comprehensive analysis of the effects of monetary policy.

Our findings indicated that conventional and unconventional monetary policies were effective in providing temporary stimulus to the economies of Switzerland and the United Kingdom during the considered periods. The obtained results showed that conventional monetary policy shocks have

temporary expansionary effects in both countries by increasing national income components and inflation. Moreover, the results revealed that an expansionary policy leads to a temporary increase in consumer confidence and stock prices. The boost in economic activity is also reflected by the fall in unemployment and the increase in nominal wages. However, the real effective exchange rate's reaction to conventional monetary policy shocks presents some contradictory patterns. In the United Kingdom, conventional monetary policy shocks imply a strong and immediate real depreciation, followed by a gradual appreciation until the initial steady state level is reached, thus providing support to the Dornbusch's (1976) exchange rate overshooting prediction. In contrast, the real effective exchange rate appreciates surprisingly on impact in Switzerland, providing evidence of an exchange rate puzzle. In addition, net exports increase temporarily in Switzerland, while they decline temporarily in the United Kingdom.

Unconventional monetary policy shocks have expansionary effects in both countries by temporarily increasing industrial production, private consumption and private investment. Nevertheless, the results indicated that the positive effects on the Swiss economy are relatively small and transitory. An expansion of central bank's reserve assets leads to an increase in consumer prices and a decline in the long-term government bond yields. These movements are associated with a substantial increase in stock prices. The labor market is characterized by a slight decline in unemployment and a slight increase in nominal wages. Unconventional monetary policy shocks imply a real depreciation, accompanied by an increase in Swiss net exports and a decline in the United Kingdom net exports. The variance decomposition analysis revealed that conventional and unconventional monetary policy shocks have a significant contribution to stock prices variability. Moreover, the obtained results indicated that conventional monetary policy explains a meaningful part of the variability in consumer confidence. Finally, our findings revealed that unconventional monetary policy has been more systematic than conventional monetary policy in Switzerland, responding more to economic variables and less to unsystematic monetary policy shocks, while the opposite holds true in the United Kingdom.

Chapter 4 has examined the interactions among macroeconomic policies, the energy market and environmental quality. These interactions and channels among them were studied through structural VAR models based on a macroeconomic framework including the energy market. This chapter has built on the growing literature analysing the links between macroeconomic policies and environmental variables (e.g., Halkos and Paizanos, 2016; Ziaei, 2018). It

has examined how the implementation of macroeconomic policies can affect the quality of the environment along the business cycle and the specific role of energy markets as transmission channels. The empirical analysis was conducted for Switzerland and the United Kingdom over the period 1990-2016. The geographical and physical characteristics of these two countries make them particularly vulnerable to global warming. The chapter has evaluated the effects of shocks to fiscal policy components, conventional and unconventional monetary policy on the energy market and environmental quality. For the case of monetary policy, the analysis was explicitly made on sub-periods since the implementation of quantitative easing could be viewed as a new monetary policy regime. The impulse response functions and the variance decomposition were used as empirical tools to assess the effects of policy shocks.

The conducted analysis revealed that fiscal and monetary policies have a significant influence on the energy market and environmental quality. An expansion of government consumption leads to a slight and temporary decline in non-renewable energy consumption and greenhouse gas emissions. Our findings also indicated that an unexpected increase in government consumption implies a decline in non-renewable energy prices. Public investment increases can achieve important non-renewable energy conservation and greenhouse gas emissions reduction. In contrast, the examination of the relationship between public investment and non-renewable energy prices has not provided clear empirical evidence. Moreover, the results indicated that government policies can have an important role in promoting the deployment of renewable energy.

The obtained impulse response functions have provided mixed evidence as regards the impact of conventional monetary policy on environmental quality. In the United Kingdom, an expansionary shock implies an improvement of environmental quality associated with an increase in renewable energy consumption, while the opposite holds true in Switzerland. In addition, the empirical results indicated that an expansionary conventional monetary policy leads to an increase in non-renewable energy prices and consumption. The conducted analysis also revealed that an expansionary unconventional monetary policy can improve environmental quality in the short run by reducing the consumption of non-renewable energy and increasing the deployment of renewable energy. In contrast, the obtained results have provided mixed evidence as regards the impact of the central bank's reserve assets purchases on non-renewable energy prices. In Switzerland, non-renewable energy prices increase after an expansionary shock, while they decline in the United Kingdom.

The results occurring from Chapter 4 revealed several policy implications. Fiscal policy, besides its primary role in stabilizing economic activity, can contribute to the achievement of environmental sustainability. Our findings indicated that public investment is more efficient than government consumption in reducing non-renewable energy consumption and greenhouse gas emissions. The analysis of the composition of government spending seems crucial to establish how the different spending categories can complement the efforts to conserve natural resources, promote the use of clean energy and enhance environmental quality. On the other hand, the examination of monetary policy revealed that central banks should investigate the impact of their interventions on environmental quality through the renewable and non-renewable energy markets. In the United Kingdom, conventional monetary policy proved to be effective in promoting the deployment of renewable energies and reducing emissions. In Switzerland, central bank's efforts to stimulate the real economy through the decrease in interest rates should be accompanied by more strict environmental regulations in order to offset the rise in emissions. Moreover, the conducted analysis revealed that unconventional monetary policy can lead to enhancements of environmental quality. However, as expected, quantitative easing is not by itself capable of substantially reducing emissions and other types of environmental policies need to be implemented jointly. Although monetary policy cannot yet be considered as a policy instrument for climate change and energy, central banks should incorporate environmental issues in their welfare maximization problem.

5.2 Future Lines of Research

The analysis in **Chapter 2** opens the door for future empirical research on the transmission mechanisms of disaggregated fiscal policy shocks in open economies. Subject to data availability, a first extension of the chapter could be to augment the VAR model with a real-time forecast variable for government spending or public debt to control for expectations. In the presence of fiscal foresight, the use of standard VAR techniques may be problematic because of the difficulty in differentiating between expected and unexpected fiscal policy shocks. With the recursive identification approach, the forecast variable will be ordered first as it is predetermined and the government spending component variable will be regressed on the current and lag values of the forecast variable. In this way, spending shocks would better capture the unanticipated changes in the components of government spending. Another extension could be to use the VECM representation of the corresponding VAR model to identify fiscal

policy shocks. Such a methodology requires knowledge on the cointegration structure but is more relevant for the long-run analysis of fiscal policy, as it enables to separate the short-run and the long-run dynamics. Finally, a third extension of the chapter could be to use empirical models that can incorporate regime changes and nonlinearities, such as Markov Switching and Threshold VAR. These alternative methods can be meaningful for examining the effects of shocks to fiscal policy components in the presence of asymmetric and nonlinear relationships between fiscal and economic variables.

The analysis in **Chapter 3** leaves the floor for future research on empirical open economy macroeconomics and monetary policy. A first extension of the chapter could be to examine the interaction between fiscal and monetary policies as central banks might want to respond to changes in government spending and taxation. Since our analysis is based on sub-periods, our estimation sample is not sufficiently long to include fiscal variables in the VAR models. However, we believe that including them would enable a better identification of exogenous structural monetary policy shocks. Another extension could be to include a credit variable in the VAR model as it would provide a better understanding of the response of output and demand components to monetary policy shocks. The inclusion of the credit channel can potentially amplify the response of demand components, which in turn could lead to a greater impact of innovations in monetary policy on the real economy. In addition, alternative methods can be used for the identification of conventional and unconventional monetary policy shocks. For instance, it will be meaningful to identify monetary policy shocks using sign restrictions and compare the results with those in this chapter.

Based on the results of **Chapter 4**, new research lines arise on the relationship between macroeconomic policies and the environment. Subject to data availability, a first extension of the chapter could be to further disaggregate government spending components and central bank's reserve assets to explore the ways in which policy decisions affect the energy market and environmental quality. This would provide more informative conclusions on how these policies can help achieve environmental sustainability. Besides, the analysis could be extended into an open economy framework by including the exchange rate and the trade balance. The exchange rate represents an important transmission channel through which fiscal and monetary policies affect the macroeconomic aggregates and international trade. Trade in turn generates an increase in global consumption and production, which results in an overall environmental impact, including pollution and depletion of natural resources. Further research should

be done to see whether our conclusions remain valid with the use of more disaggregated data and the inclusion of open economy variables.

The research conducted as part of this doctoral thesis has also led to some reflections on the COVID-19 outbreak and the role of macroeconomic policies. Since December 2019, the disease has spread worldwide, leading to a global pandemic, which has caused a health and economic crisis unprecedent in recent history. In fact, besides its impact on public health, the deliberate shutdown of the economy triggered by the pandemic has produced a severe global recession. A common consensus is that the virus will create a negative supply shock to the global economy, forcing firms to shut down and disrupting global supply chains (Fornaro and Wolf, 2020; Organisation for Economic Co-operation and Development, 2020). The economic impact of COVID-19 also stems from the labor market, through the negative shocks to labor supply and demand (Brinca et al., 2020). Consequently, the decline in labor supply and demand will most likely result in a downward adjustment of hours worked (Brinca et al., 2020). This situation has led to massive and immediate responses from the economic authorities in order to cushion the negative impact of the pandemic on the economy. In view of the pandemic, the main role of macroeconomic policies is to support employment, income of workers and firms, as well as to minimize the long-term damage on the economy (European Central Bank, 2020).

The nature of the pandemic affects the transmission of fiscal and monetary policies (European Central Bank, 2020). When interest rates are very low and private demand is constrained, as is the case today with the global recession, the transmission of monetary policy from the easing of financing conditions to private activity might be attenuated (European Central Bank, 2020). In addition, when firms and households face high levels of uncertainty, they tend to save more as a precautionary measure and spend less (European Central Bank, 2020). While monetary policy can stimulate overall economic activity, it cannot support the specific sectors that would enhance welfare the most (European Central Bank, 2020). In these exceptional circumstances, fiscal policy may have the greatest impact on economic activity and respond in a more targeted manner to the specific sectors and parts of the economy affected by health restrictions (European Central Bank, 2020). Given the scale of the current crisis, several studies have analysed the policy responses to the pandemic (e.g., Aguilar et al. 2020; Faria-e-Castro, 2021). In the coming years, the examination of the transmission channels and the effects of macroeconomic policies on the economy during the global pandemic will certainly receive particular attention.

References

Admin (2019). Energy. Retrieved from https://www.eda.admin.ch/aboutswitzerland/en/home/wirtschaft/energie.html

Afonso, A. and Aubyn, M.S. (2018). Economic growth, public, and private investment returns in 17 OECD economies. *Portuguese Economic Journal*, *18*(1), 47-65.

Aguilar, P., Arce, Ó., Hurtado, S., Martínez-Martín, J., Nuño, G. and Thomas, C. (2020). The ECB monetary policy response to the COVID-19 crisis. Occasional Paper No. 2026, Banco de España.

Anzuini, A., Lombardi, M.J. and Pagano, P. (2012). The impact of monetary policy shocks on commodity prices. European Central Bank Working Paper No. 1232. Available at SSRN.

Apergis, N. and Payne, J.E. (2010). Renewable energy consumption and growth in Eurasia. *Energy Economics*, *32*(6), 1392-1397.

Assenmacher-Wesche, K. (2008). Modeling Monetary Transmission in Switzerland with a Structural Cointegrated VAR Model. *Swiss Journal of Economic and Statistics*, *144*(2), 197-246.

Baiocchi, G., Minx, J. and Hubacek, K. (2010). The Impact of Social Factors and Consumer Behavior on Carbon Dioxide Emissions in the United Kingdom. *Journal of Industrial Ecology*, *14*(1), 50-72.

Barran, F., Coudert, V. and Mojon, B. (1996). The transmission of monetary policy in European countries, CEPII Working Paper No. 96-03, Centre d'études prospectives et d'informations internationales.

Barsky, R.B. and Sims, E.R. (2012). Information, Animal Spirits, and the Meaning of Innovations in Consumer Confidence. *American Economic Review, 102*(4), 1343-1377.

Bauer, M.D. and Rudebusch, G.D. (2014). The Signaling Channel for Federal Reserve Bond Purchases. *International Journal of Central Banking*, *10*(3), 233-289.

Baumeister, C. and Benati, L. (2013). Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound. *International Journal of Central Banking*, *9*(2), 165-212.

Beetsma, R. and Giuliodori, M. (2011). The Effects of Government Purchases Shocks: Review and Estimates for the EU. *The Economic Journal*, *121*(550), F4-F32.

Bénétrix, A.S. and Lane, P.R. (2009). The Impact of Fiscal Shocks on the Irish Economy. *The Economic and Social Review*, *40*(4), 407-434.

Beniston, M. (2012). Impacts of climatic change on water and associated economic activities in the Swiss Alps. *Journal of Hydrology*, *412-413*, 291-296.

Bermperoglou, D., Pappa, E. and Vella, E. (2017). The government wage bill and private activity. *Journal of Economic Dynamics and Control*, *79*, 21-47.

Bernanke, B.S. and Gertler, M. (1995). Inside the Black Box: The Credit Channel of Monetary Policy Transmission. *Journal of Economic Perspectives*, *9*(4), 27-48.

Bernauer, T. and Koubi, V. (2013). Are bigger governments better providers of public goods? Evidence from air pollution. *Public Choice*, *156*(3), 593-609.

Bjørnland, H.C. (2008). Monetary Policy and Exchange Rate Interactions in a Small Open Economy. *The Scandinavian Journal of Economics*, *100*(1), 197-221.

Bjørnland, H.C. and Leitemo, K. (2009). Identifying the interdependence between US monetary policy and the stock market. *Journal of Monetary Economics*, *56*(2), 275-282.

Blanchard, O. and Perotti, R. (2002). An empirical characterization of the dynamic effects of changes in government spending and taxes on output. *Quarterly Journal of Economics*, *117*(4), 1329-1368.

Brinca, P., Duarte, J.B. and Faria-e-Castro, M. (2020). Measuring Sectoral Supply and Demand Shocks During COVID-19. Federal Reserve Bank of St. Louis Working Paper No. 2020-011. Available at SSRN.

Brissimis, S.N. and Magginas, N.S. (2006). Forward-looking information in VAR models and the price puzzle. *Journal of Monetary Economics*, *53*(6), 1225-1234.

Brückner, M. and Pappa, E. (2012). Fiscal Expansions, Unemployment, and Labor Force Participation: Theory and Evidence. *International Economic Review*, *53*(4), 1205-1228.

Burnside, C., Eichenbaum, M. and Fisher, J.D.M. (2004). Fiscal shocks and their consequences. *Journal of Economic Theory*, *115*(1), 89-117.

Burriel, P., De Castro, F., Garrote, D., Gordo, E., Paredes, J. and Pérez, J.J. (2010). Fiscal Policy Shocks in the Euro Area and the US: An Empirical Assessment. *Fiscal Studies*, *31*(2), 251-285.

Calbick, K.S. and Gunton, T. (2014). Differences among OECD countries' GHG emissions: Causes and policy implications. *Energy Policy*, *67*, 895-902.

Caldara, D. and Kamps, C. (2008). What are the Effects of Fiscal Policy Shocks? A VAR-based Comparative Analysis, European Central Bank Working Paper No. 877, 1-45.

Caldara, D. and Kamps, C. (2017). The Analytics of SVARs: A Unified Framework to Measure Fiscal Multipliers. *The* R*eview of Economic Studies*, *84*(3), 1015-1040.

Camarero, M., Forte, A., Garcia-Donato, G., Mendoza, Y. and Ordonez, J. (2015). Variable selection in the analysis of energy consumption-growth nexus. *Energy Economics*, *52*, 207-216.

Christensen, J.H.E. and Krogstrup, S. (2019). Transmission of Quantitative Easing: The Role of Central Bank Reserves. *The Economic Journal*, *129*(617), 249-272.

Christiano, L.J., Eichenbaum, M. and Evans, C.L. (2005). Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of Political Economy*, *113*(1), 1-45.

Chung, H., Laforte, J., Reifschneider, D. and Williams, J.C. (2012). Have We Underestimated the Likelihood and Severity of Zero Lower Bound Events?. *Journal of Money, Credit and Banking*, *44*(s1), 47-82.

Clarida, R., Galí, J. and Gertler, M. (2001). Optimal Monetary Policy in Open versus Closed Economies: An Integrated Approach. *American Economic Review*, *91*(2), 248-252.

Cloyne, J. and Hürtgen, P. (2016). The Macroeconomic Effects of Monetary Policy: A New Measure for the United Kingdom. *American Economic Journal: Macroeconomics*, *8*(4), 75-102.

Cochrane, J.H. (1991). A critique of the application of unit root tests. *Journal of Economic Dynamics and Control*, *15*(2), 275-284.

Cole, M.A. and Elliott, R.J.R. (2003). Determining the trade-environment composition effect: The role of capital, labor and environmental regulations. *Journal of Environmental Economics and Management*, *46*(3), 363-383.

Cushman, D.O. and Zha, T. (1997). Identifying monetary policy in a small open economy under flexible exchange rates. *Journal of Monetary Economics*, *39*(3), 433-448.

Dafermos, Y., Nikolaidi, M. and Galanis, G. (2018). Climate Change, Financial Stability and Monetary Policy. *Ecological Economics*, *152*, 219-234.

Davtyan, K. (2016). Interrelation among Economic Growth, Income Inequality, and Fiscal Performance: Evidence from Anglo-Saxon Countries. *Review of Public Economics*, *217*(2), 37-66.

Debes, S., Gareis, J., Mayer, E. and Rüth, S. (2014). Towards a consumer sentiment channel of monetary policy. Würzburg Economic Papers No. 91.

de la Vega-Leinert, A.C. and Nicholls, R.J. (2008). Potential Implications of Sea-Level Rise for Great Britain. *Journal of Coastal Research*, *24*(2), 342-357.

Dell, M., Jones, B.F. and Olken, B.A. (2009). Temperature and Income: Reconciling New Cross-Sectional and Panel Estimates. *American Economic Review*, *99*(2), 198-204.

Dell, M., Jones, B.F. and Olken, B.A. (2012). Temperature Shocks and Economic Growth: Evidence from the Last Half Century. *American Economic Journal: Macroeconomics*, *4*(3), 66-95.

Dinda, S. (2004). Environmental Kuznets Curve Hypothesis: A Survey. *Ecological Economics*, *49*(4), 431-455

Dornbusch, R. (1976). Expectations and Exchange Rate Dynamics. *Journal of Political Economy, 84*(6), 1161-1176.

Economides, G. and Xepapadeas, A. (2018). Monetary Policy Under Climate Change. CESifo Working Paper Series No. 7021. Available at SSRN.

Eichenbaum, M. and Evans, C.L. (1995). Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates. *Quarterly Journal of Economics*, *110*(4), 975-1009.

Eichenbaum, M. and Fisher, J.D.M. (2005). Fiscal Policy in the Aftermath of 9/11. *Journal of Money, Credit and Banking*, *37*(1), 1-22.

European Central Bank (2020). Monetary policy in a pandemic emergency. Keynote speech by Christine Lagarde, 11 November 2020, ECB Forum on Central Banking. Retrieved from https://www.ecb.europa.eu/press/key/date/2020/html/ecb.sp201111~d01e03eb9c.en.html

Faria-e-Castro, M. (2021). Fiscal policy during a pandemic. *Journal of Economic Dynamics and Control, 125*.

Fatas, A. and Mihov, I. (2001). The Effects of Fiscal Policy on Consumption and Employment: Theory and Evidence. CEPR Discussion Papers No. 2760, Centre for Economic Policy Research. Available at SSRN.

Fornaro, L. and Wolf, M. (2020). Covid-19 Coronavirus and Macroeconomic Policy. CEPR Discussion Paper No. DP14529, Centre for Economic Policy Research. Available at SSRN.

Gagnon, J., Raskin, M., Remache, J. and Sack, B.P. (2010). Large-Scale Asset Purchases by the Federal Reserve: Did They Work?. Federal Reserve Bank of New York Staff Report No. 441.

Gagnon, J., Raskin, M., Remache, J. and Sack, B.P. (2011). The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases. *International Journal of Central Banking*, *7(*1), 3-43.

Galí, J., López-Salido, J.D. and Vallés, J. (2007). Understanding the Effects of Government Spending on Consumption. *Journal of the European Economic Association*, *5*(1), 227-270.

Gambacorta, L., Hofmann, B. and Peersman, G. (2014). The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A Cross-Country Analysis. *Journal of Money, Credit and Banking*, *46*(4), 615-642.

Giordani, P. (2004). An alternative explanation of the price puzzle. *Journal of Monetary Economics*, *51*(6), 1271-1296.

Giordano, R., Momigliano, S., Neri, S. and Perotti, R. (2007). The effects of fiscal policy in Italy: Evidence from a VAR Model. *European Journal of Political Economy, 23*(3), 707-733.

Grossman, G.M. (1995). Pollution and Growth: What Do We Know?. In Goldin, I. and Winters, L.A. (Eds.). *The Economics of Sustainable Development*, Cambridge University Press, Cambridge, 19-47.

Grossman, G.M. and Krueger, A.B. (1995). Economic Growth and the Environment. *Quarterly Journal of Economics*, *110*(2), 353-377.

Halkos, G.E. and Paizanos, E.A. (2013). The effect of government expenditure on the environment: An empirical investigation. *Ecological Economics*, *91*, 48-56.

Halkos, G.E. and Paizanos, E.A. (2016). The effects of fiscal policy on CO_2 emissions: Evidence from the U.S.A. *Energy Policy*, *88*, 317-328.

Hamilton, J.D. and Wu, J.C. (2012). The Effectiveness of Alternative Monetary Policy Tools in a Zero Lower Bound Environment. *Journal of Money, Credit and Banking*, *44*(s1), 3-46.

Hammoudeh, S., Nguyen, D.K. and Sousa, R.M. (2015). US monetary policy and sectoral commodity prices. *Journal of International Money and Finance*, *57*, 61-85.

Hang, L. and Tu, M. (2007). The impacts of energy prices on energy intensity: Evidence from China. *Energy Policy*, *35*(5), 2978-2988.

International Energy Agency (2007). Energy Policies of IEA Countries: Switzerland 2007. Energy Polices of IEA Countries, OECD Publishing, Paris. Retrieved from https://doi.org/10.1787/9789264030701-en

International Energy Agency (2009). CO_2 Emissions from Fuel Combustion 2009. OECD Publishing, Paris. Retrieved from https://doi.org/10.1787/co2_fuel-2009-en-fr

International Energy Agency (2017). CO_2 Emissions from Fuel Combustion 2017. OECD Publishing, Paris. Retrieved from https://doi.org/10.1787/co2_fuel-2017-en

International Energy Agency (2019). Energy Policies of IEA Countries: United Kingdom 2019. Energy Polices of IEA Countries, OECD Publishing, Paris. Retrieved from https://doi.org/10.1787/50cf737f-en

International Monetary Fund (2020). Historical Public Debt Database [Data file]. Retrieved from https://data.imf.org/?sk=806ED027-520D-497F-9052-63EC199F5E63

Islam, A. and Lopez, R. (2015). Government spending and air pollution in the US. *International Review of Environmental and Resource Economics*, *8*(2), 139-189.

Johansen, S. (1995). Likelihood-based Inference in Cointegrated Vector Autoregressive Models. Oxford University Press, Oxford.

Joyce, M.A.S, Lasaosa, A., Stevens, I. and Tong, M. (2011). The Financial Market Impact of Quantitative Easing in the United Kingdom. *International Journal of Central Banking*, *7*(3), 113-161.

Kholodilin, K., Montagnoli, A., Napolitano, O. and Siliverstovs, B. (2009). Assessing the impact of the ECB's monetary policy on the stock markets: A sectoral view. *Economics Letters*, *105*(3), 211-213.

Kijima, M., Nishide, K. and Ohyama, A. (2010). Economic models for the environmental Kuznets curve: A survey. *Journal of Economic Dynamics and Control*, *34*(7), 1187-1201

Killian, L. and Vega, C. (2011). Do Energy Prices Respond to U.S. Macroeconomic News? A Test of the Hypothesis of Predetermined Energy Prices. *Review of Economics and Statistics*, *93*(2), 660-671.

Kim, S. (2001). Effects of monetary policy shocks on the trade balance in small open European countries. *Economic Letters*, *71*(2), 197-203.

Kim, S. and Roubini, N. (2008). Twin deficit or twin divergence? Fiscal policy, current account, and real exchange rate in the U.S. *Journal of International Economics*, *74*(2), 362-383.

Kosonen, K. and Nicodème, G. (2009). The Role of Fiscal Instruments in Environmental Policy. CESifo Working Paper Series No. 2719. Available at SSRN.

Kugler, P. and Jordan, T.J. (2004). Structural Vector Autoregressions and the Analysis of Monetary Policy Interventions: The Swiss Case. *Swiss Journal of Economics and Statistics*, *140*(I), 67-87.

Kugler, P. and Rich, G. (2002). Monetary Policy Under Low Interest Rates: The Experience of Switzerland in the late 1970s. *Swiss Journal of Economics and Statistics, 138*(3), 241-269.

Lane, P.R. and Perotti, R. (1998). The trade balance and fiscal policy in the OECD. *European Economic Review*, *42*(3-5), 887-895.

Lane, P.R. and Perotti, R. (2003). The importance of composition of fiscal policy: Evidence from different exchange rate regimes. *Journal of Public Economics*, *87*(9-10), 2253-2279.

Leeper, E.M., Sims, C.A., Zha, T., Hall, R.E. and Bernanke, B.S. (1996). What Does Monetary Policy Do?. *Brookings Papers on Economic Activity, 1996*(2), 1-78.

Lenza, M., Pill, H. and Reichlin, L. (2010). Monetary policy in exceptional times. *Economic Policy*, *25*(62), 295-339.

Lopez, R., Galinato, G.I. and Islam, A. (2011). Fiscal spending and the environment: Theory and empirics. *Journal of Environmental Economics and Management, 62*(2), 180-198.

Lopez, R. and Palacios, A. (2014). Why has Europe Become Environmentally Cleaner? Decomposing the Roles of Fiscal, Trade, and Environmental Policies. *Environmental and Resource Economics*, *58*(1), 91-108.

Ludvigson, S.C. (2004). Consumer Confidence and Consumer Spending. *Journal of Economic Perspectives, 18*(2), 29-50.

Lütkepohl, H. (2005). New Introduction to Multiple Time Series Analysis. Springer, Berlin.

Lütkepohl, H. (2011). Vector Autoregressive Models. Economics Working Papers ECO 2011/30, European University Institute.

Lütkepohl, H. and Netsunajev, A. (2018). The Relation between Monetary Policy and the Stock Market in Europe. *Econometrics*, *6*(3), 1-14.

Lütkepohl, H. and Reimers, H.E. (1992). Granger-causality in cointegrated VAR processes: The case of the term structure. *Economics Letters*, *40*(3), 263-268.

Matikainen, S., Campiglio, E. and Zenghelis, D. (2017). The climate impact of quantitative easing. Policy Paper, Grantham Research Institute on Climate Change and the Environment. London School of Economics and Political Science.

McAusland, C. (2008). Trade, politics, and the environment: Tailpipe vs. smokestack. *Journal of Environmental Economics and Management*, *55*(1), 52-71.

Meinusch, A. and Tillmann, P. (2016). The macroeconomic impact of unconventional monetary policy shocks. *Journal of Macroeconomics*, *47*(A), 58-67.

Mishkin, F.S. (1995). Symposium on the Monetary Transmission Mechanism. *Journal of Economic Perspectives*, *9*(4), 3-10.

Moffett, M.H. (1989). The J-curve revisited: An empirical examination for the United States. *Journal of International Money and Finance*, *8*(3), 425-444.

Mojon, B. and Peersman, G. (2001). A VAR Description of the Effects of Monetary Policy in the Individual Countries of the Euro Area. European Central Bank Working Paper Series No. 92. Available at SSRN.

Monacelli, T. and Perotti, R. (2010). Fiscal Policy, the Real Exchange Rate and Traded Goods. *The Economic Journal, 120*(544), 437-461.

Mountford, A. and Uhlig, H. (2009). What are the effects of fiscal policy shocks?. *Journal of Applied Econometrics*, *24*(6), 960-992.

Natal, J. (2002). Analyse Empirique de la Politique Monétaire à l'Aide de Modèles (B)(S) VAR: Le Cas de la Suisse. Institut Universitaire de Hautes Etudes Internationales, Université de Genève.

Natal, J. (2004). The Credit Channel in a Small Open Economy: A VAR-based Empirical Evidence for Switzerland. Swiss National Bank.

Office for National Statistics (2020). Research and development expenditure by the UK government: 2018. Retrieved from https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/ukgovernmentexpenditureonscienceengineeringandtechnology/2018

Organisation for Economic Co-operation and Development (2020). OECD Economic Outlook, Interim Report March 2020. OECD Publishing, Paris. Retrieved from https://doi.org/10.1787/7969896b-en

Panayotou, T. (1993). Empirical tests and policy analysis of environmental degradation at different stages of economic development. Working Paper WP238, Technology and Employment Programme, International Labour Office, Geneva.

Pappa, E. (2009). The effects of fiscal shocks on employment and the real wage. *International Economic Review*, *50*(1), 217-244.

Peersman, G. (2011). Macroeconomic Effects of Unconventional Monetary Policy in the Euro Area. European Central Bank Working Paper Series No. 1397. Available at SSRN.

Peersman, G. and Smets, F. (2001). The Monetary Transmission Mechanism in the Euro Area: More Evidence from VAR Analysis. European Central Bank Working Paper Series No. 91. Available at SSRN.

Perotti, R. (2005). Estimating the Effects of Fiscal Policy in OECD Countries. CEPR Discussion Papers No. 4842, Centre for Economic Policy Research. Available at SSRN.

Perotti, R. (2008). In Search of the Transmission Mechanism of Fiscal Policy. In Acemoglu, D., Rogoff, K. and Woodford, M. (Eds.). *NBER Macroeconomics Annual 2007, 22*, University of Chicago Press, 169-226.

Perotti, R. (2014). Defense Government Spending Is Contractionary, Civilian Government Spending Is Expansionary. NBER Working Paper No. 20179, National Bureau of Economic Research.

Ramaswamy, R. and Sløk, T. (1998). The Real Effects of Monetary Policy in the European Union: What Are the Differences?. *International Monetary Fund Staff Papers*, *45*(2), 374-396.

Ramey, V.A. and Shapiro, M.D. (1998). Costly capital reallocation and the effects of government spending. *Carnegie-Rochester Conference Series on Public Policy*, *48*, 145-194.

Ramos, X. and Roca-Sagales, O. (2008). Long-Term Effects of Fiscal Policy on the Size and Distribution of the Pie in the UK. *Fiscal Studies*, *29*(3), 387-411.

Ravn, M.O., Schmitt-Grohé, S. and Uribe, M. (2006). Deep Habits. *The Review of Economic Studies*, *73*(1), 195-218.

Ravn, M.O., Schmitt-Grohé, S. and Uribe, M. (2012). Consumption, government spending, and the real exchange rate. *Journal of Monetary Economics*, *59*(3), 215-234.

Romer, C.D. and Romer, D.H. (2010). The Macroeconomic Effects of Tax Changes: Estimates Based on a New Measure of Fiscal Shocks. *American Economic Review*, *100*(3), 763-801.

Rosa, C. (2014). The high-frequency response of energy prices to U.S. monetary policy: Understanding the empirical evidence. *Energy Economics*, *45*, 295-303.

Schenkelberg, H. and Watzka, S. (2013). Real effects of quantitative easing at the zero lower bound: Structural VAR-based evidence from Japan. *Journal of International Money and Finance*, *33*, 327-357.

Shahbaz, M. and Sinha, A. (2019). Environmental Kuznets curve for CO_2 emissions: a literature survey. *Journal of Economic Studies*, *46*(1), 106-168.

Sims, C.A. (1980). Macroeconomics and Reality. *Econometrica*, *48*(1), 1-48.

Sims, C.A. (1992). Interpreting the macroeconomic time series facts: The effects of monetary policy. *European Economic Review*, *36*(5), 975-1000.

Sims, C.A., Stock, J.H. and Watson, M.W. (1990). Inference in Linear Time Series Models with some Unit Roots. *Econometrica*, *58*(1), 113-144.

Sims, C.A. and Zha, T. (1999). Error Bands for Impulse Responses. *Econometrica*, *67*(5), 1113-1155.

Svensson, L.E.O. (1997). Inflation forecast targeting: Implementing and monitoring inflation targets. *European Economic Review, 41*(6), 1111-1146.

Svensson, L.E.O. (2000). Open-economy inflation targeting. *Journal of International Economics*, *50*(1), 155-183.

Tenhofen, J., Wolff, G.B. and Heppke-Falk, K.H. (2010). The Macroeconomic Effects of Exogenous Fiscal Policy Shocks in Germany: A Disaggregated SVAR Analysis. *Journal of Economics and Statistics, 230*(3), 328-355.

Uhlig, H. (2005). What are the effects of monetary policy on output? Results from an agnostic identification procedure. *Journal of Monetary Economics*, *52*(2), 381-419.

U.S. Energy Information Administration (2011). Today in Energy. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=3170

World Bank (2019). Renewable energy consumption [Data file]. Retrieved from https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS

World Bank (2020). Net lending (+)/net borrowing (-) (% of GDP) [Data file]. Retrieved from https://data.worldbank.org/indicator/GC.NLD.TOTL.GD.ZS

Zhu, Q. and Peng, X. (2012). The impacts of population change on carbon emissions in China during 1978-2008. *Environmental Impact Assessment Review*, *36*, 1-8.

Ziaei, S.M. (2018). US interest rate spread and energy consumption by sector (Evidence of pre and post implementation of the Fed's LSAPs policy). *Energy Reports*, *4*, 288-302.

Zivot, E. and Andrews, D.W.K. (1992). Further Evidence on the Great Crash, the Oil-Price Shock, and the Unit-Root Hypothesis. *Journal of Business & Economic Statistics, 10*(3), 251-270.