FISCAL POLICY IN A SMALL OPEN ECONOMY

by

Zohra Jamasi

Bachelor of Business Administration, University of Toronto, 2007

Master of Arts, Economics, York University, 2010

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Fiscal policy in a small open economy

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Zohra Jamasi

Economics, Ryerson University

Abstract

The great recession of 2008-2009 has brought fiscal policy modelling and analysis to the forefront, motivating a deeper understanding of fiscal issues. This thesis develops various strands of fiscal policy literature focusing on the identification of fiscal shocks, the modelling fiscal rules and the welfare implications of fiscal policy. The first few chapters are dedicated to building a rich fiscal model with debt rules for Canada and the last chapter explores the welfare implications of these fiscal rules. In the second chapter, we explore the role of temporary government spending shocks on macroeconomic fluctuations, primarily focusing on the response of private consumption. We estimate a four variable structural Vector Auto-Regression (VAR) model. We find across various identification approaches, a positive unanticipated temporary government spending shock generates a negative response in private consumption and a positive response in output. In the third chapter, we build a Dynamic Stochastic General Equilibrium (DSGE) model to account for these empirical findings. We use Bayesian estimation techniques to estimate five debt rules that correspond to various policy instruments and report the elasticities of these instruments to the cycle and the stock of federal government debt in Canada. We find an elasticity in response to debt of 0.26 for government spending and 0.16 for transfer payments. We find insignificant elasticities for the response of average effective tax rates to debt. Our findings support the presence of strong automatic stabilizers in Canada, with an elasticity of 0.41 and 1.73 for the response of average labour and capital tax rates to the cycle. In chapter four, we extend the homogenous framework in chapter three to a heterogeneous agent setting by introducing liquidity constrained agents and analyze the welfare effects of balanced budget rules and debt rules. Our results show that debt rules improve aggregate welfare in the economy compared to a balanced budget rule. This result is driven by the welfare gains of a large share of Ricardian households. The remaining liquidity-constrained households experience a welfare loss under debt rules, indicating that a balanced budget rule is preferable for agents who cannot engage in inter-temporal consumption smoothing.

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Dedication

I dedicate this dissertation to my loving my parents, Zahida and Ahmad Jamasi who have believed in me and given me the strength to take risks and be successful. I would like to thank my father for giving me opportunities and holding my hand throughout all these years. Thank you to my mother, who has stood by me and given me endless encouragement and love, without her this work would not have been possible.

Table of Contents

List of Tables

List of Figures

List of Appendices

Appendix A.2

Appendix A.3

1. INTRODUCTION

Among the many great lessons that the financial crisis of 2008-2009 bestowed upon the economics profession, the need to revisit the merits of activist fiscal policy has been an important one. In the last few decades, the macroeconomics discipline has almost entirely focused on monetary policy as the primary instrument for stabilizing economic activity, while sidelining fiscal policy. This policy paradigm became the status quo in many advanced countries and reflects an active monetary policy stance and a passive fiscal policy stance. Fiscal policy was seen as inferior to monetary policy due to risks associated with political influence, debt sustainability and time lags in the decision making process leading to delayed effects on the economy. It was deemed useful only to the extent that automatic stabilizers responded to the cycle and in the event that interest rates hit a floor leading monetary policy to become ineffective – a situation referred to as the liquidity trap. In this case, the fiscal policy stance becomes temporarily active and discretionary fiscal spending is used as a tool to achieve economic recovery, after which it becomes passive again. The use of fiscal policy in this manner became known as “Keynesian stop/go” measures.

In the aftermath of this crisis, policy makers belonging to the Group of twenty (G-20) and leading economic institutions such as the International Monetary Fund (IMF), the World Bank and the Organization for Economic Development and Co-operation (OECD) called for world leaders to shift their focus to activist fiscal policy, to combat the deflationary pressures on the global economy. This call for active fiscal policy was embodied at the G-20 summit meeting in November 2008 where leaders met to define a global policy response, and was echoed by the

IMF heeding as many countries as possible to implement stimulus measures[1]. The IMF World Economic Outlook in 2008 highlighted the need for reform of existing policy frameworks that have excessively relied on monetary policy:

"The deteriorating performance of the global economy has raised concerns about the choice of macroeconomic policy frameworks and the appropriateness of policies affecting financial and commodity markets"

This re-assessment of fiscal policy on a grand scale led by the Great Recession, created a dialogue about fiscal policy that ranges from questions about the effectiveness of government spending, to the fiscal policy mix governments should use and the impacts of deficit spending on debt stability. The focus among macroeconomists has finally shifted to exploring the stabilizing potential of fiscal policy, after decades of relying on monetary policy to smooth business cycles. This historic shift has impacted macroeconomic policymaking and research around the world. While most of the initial conversation (Auberbach and Gale (2009), Taylor (2009), Fatàs and Mihov (2012), Coenen, Straub and Trabandt (2012)) about fiscal policy tools focused on its discretionary component, more recently a large part of the discourse (Forni, Monteforte and Sessa (2009), Égert (2010), Leeper, Plante and Traum (2010), and Bi and Kumhof (2011)) has begun to highlight the importance of the systematic (automatic) component.

Systematic fiscal policy is rules based and moves with macroeconomic or fiscal aggregates to reduce deficits and debt. A prominent example is the Stability and Growth Pact (SGP) in the

[1] International Monetary Fund. World Economic Outlook October 2008. Financial Stress, Downturns and Recoveries. Washington, D.C, 2008.

European Union, which encourages member countries to maintain fiscal responsibility through targets. Examples of fiscal targets in the SGP include deficits not exceeding three per cent of gross domestic product (GDP) and a debt to GDP ratio below sixty per cent. Until recently, this area of research remained largely underexplored (Kumhof and Laxton (2013), Kliem and Kriwolouzky (2014), Leeper, Plante and Traum (2010), and Reicher (2014)) as the discipline remained focused on the interest rate rule in monetary policy.

The revival of activist fiscal policy has reenergized research on systematic fiscal policy and lead to important developments in the theoretical and empirical literature exploring the efficacy of numerical fiscal rules. Most of the research is motivated by governments' search for more sustainable fiscal frameworks in the post-recession environment that emphasize systematic fiscal policies (Budina, Kinda, Schaechter and Weber (2012), Corsetti, Meier, and Müller (2012), and Reicher (2014)). As public sector financial positions in many countries have deteriorated significantly, policymakers in these countries have been left with the challenge of dealing with growing deficits and national debts. For instance in 2010, debt to GDP in Canada, United States, Italy, Greece and Japan were 89.5, 94.6, 131.1, 157.3 and 193.3 percent respectively, these ratios have since grown to 93.6, 108.5, 147.4, 188.2, 232.5 percent in 2015[2]. Many governments[3] have responded by adopting rules to move towards restoring fiscal responsibility and debt sustainability while others have strengthened existing or past rules.[4] Germany presents a case in

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[2] Ratios obtained from OECD database.
[3] Australia (expenditure rule; 2009), Bulgaria (balanced budget rule and expenditure rule; 2009, 2012), Columbia (balanced budget rule; 2011), Denmark (expenditure rule and balanced budget rule; 2014), France (revenue rule and balanced budget rule; 2011), United States (expenditure rule; 2011).
[4] Budina, Kinda, Schaechter and Weber (2012) provides a comprehensive fiscal database tracking fiscal rules in place around the world. Defining an explicit fiscal rule as "imposing a long-lasting constraint on fiscal policy through numerical limits on budgetary aggregates", they report a sharp increase in the use of fiscal rules since the Great Recession.

point, with government borrowing being limited by the constitution since 1949, but adopting a new debt rule in 2009. Budina, Kinda, Schaechter and Weber (2012) and Wyplosz (2012) provide a historical account of fiscal rules in developed and developing countries and discuss the types of rules that have been used in the past and that are in use currently. Both works find that fiscal rules must be accompanied with institutions that support and enforce the rules in order to be effective. Bova, Kinda, Muthoora and Toscani (2015) documents an increased use of numerical fiscal rules as a key response to the late financial crisis. The literature shows rules based policies work to strengthen fiscal frameworks through two main channels. Fiscal rules serve as a medium term anchor by setting a budgetary target and signal a long-term commitment to fiscal discipline. The International Monetary Fund (IMF) Fiscal Affairs Department has taken great interest in documenting the instance of fiscal rules and more recently, analyzing their scope.[5]

The need to understand the potential of systematic rules based fiscal policy with respect to stabilizing business cycle volatility and the stock of debt has emerged as an overarching goal in the academy and policy institutions. Given this objective, an evaluation of the design of simple fiscal rules and its impact on key macroeconomic variables has become a growing strand of literature. As with any area of research, there are admittedly challenges such as data limitations and modelling restrictions that give rise to debates in the existing body of work. The debates in fiscal policy circles have led to motivating research questions and have greatly shaped the research agenda for this thesis. We focus our contribution to providing evidence for small open

[5] Please see Kotia and Lledo (2016), Bova, Medad and Poghosyan (2016), Budina, Kinda, Schaechter and Weber (2012), Kopits (2013).

economies, as most analysis in the fiscal policy literature has traditionally emphasized closed economies with an application to the United States.[6] It is a case in point that the results for closed economies may not be generalizable to open economies. We chose to extend our theoretical work to the Canadian economy as it represents a near perfect quintessential small open economy. Canada presents an interesting case as it has a diverse history (please see Tapp (2010)) of using fiscal rules and in recent times has seen the adoption of a balanced budget rule. This thesis has three overarching goals: to shed light on the empirical debate on the effects of changes in government purchases on aggregate consumption, to use richer models of fiscal policy in order to investigate the scope of countercyclical fiscal rules and its effects in small open economies and to explore their welfare implications in a heterogeneous agent framework.

While there were many new research directions we could have embarked on, we felt it necessary to first re-assess the state of existing debates in the literature. These debates are mainly around strands of literature where results are often mixed or contradict other results. This complicates our understanding of fiscal policy has becomes unclear how government spending and tax shocks affect key macroeconomic variables. Moving the literature forward by further developing the strand on systematic fiscal rules means that we first must confront the challenges that the fiscal policy literature faces at large. The theoretical literature (see for example, Aiyagari, Christiano and Eichenbaum (1992), Christiano and Eichenbaum (1992), Baxter and King (1993), Fatàs and Mihov (2001), Galí, López-Salido, and Vallés (2007), Monacelli and Perotti (2008), Ravn, Schmitt-Grohé and Uribe (2006), Forni, Monteforte and Sessa (2009)) and empirical

[6] Bohn (2005), Taylor (2000), Leeper, Plante and Traum (2010).

literature (see for example, Blanchard and Perotti (2002), Ramey and Shapiro (1998), Perotti (2005, 2007), Ramey (2011), Mountford and Uhlig (2009), Romer and Romer (20010), Caldera and Kamps (2012), Ravn and Mertens (2014)) is large but disjointed, mostly characterized by mixed results. In fact, mixed results exist for many elementary yet fundamental issues around fiscal policy. Most importantly, a big challenge lies around the lack of consensus on the effects of unanticipated fiscal policy shocks on macroeconomic variables of interest in both closed and open economies.

Specifically, the debate on the effects of unanticipated government spending shocks on private consumption and the real wage has polarized the literature. In the theoretical literature, we are confronted with opposing predictions from neoclassical and New Keynesian models. The main discrepancy between these competing theories is with respect to whether private consumption and the real wages rise or fall in response to a positive temporary government spending shock. Baxter and King (1993), Aiyagari, Christiano and Eichenbaum (1992) and Linneman and Schabert (2003), find that the response of these variables is negative in neoclassical models, whereas, the opposite arises in models with New-Keynesian features such as the liquidity constrained households of Galí, López-Salido, and Vallés (2007) , Greenwood, Hercowitz and Huffman (1988) style preferences, sticky prices of Monacelli and Perotti (2008) and the inclusion of deep habits as in Schmitt-Grohé and Uribe (2006) and Zubairy (2010). In neoclassical models, the propagation mechanism through which consumption and real wage decline is the negative wealth effect. Since forward-looking economic agents have expectations of tax increases in the future, they save more by reducing their consumption and increasing their labour supply. An increase in the supply of labour causes a downward shift in the labour supply curve and leads to a fall in the real wage. As a result, a temporary increase in government spending leads to a fall in consumption (crowding-out effect) and the real wage. On the other hand, models with New-Keynesian features predict the complete opposite effect on consumption and the real wage. In these models, the behaviour of consumption and the real wage are driven by an increase in labour demand. The presence of nominal rigidities or sticky prices and real rigidities represented by half of the population not being able to save means that instead of decreasing leisure and increasing labour supply, agents chose to decrease their labour supply. The labour demand curve shifts outward as firms demand more labour and the real wage increases. Clearly, the predicted effects of fiscal policy are dramatically different depending on whether we consult the neoclassical or New-Keynesian model. Given these opposing predictions, the natural resolution would be to reconcile these differences by consulting empirical evidence. However, the empirical literature on the effects of a temporary government purchases shock is also characterized by mixed results and offers little direction to help discriminate between the two premises. We make our first priority the reconciliation of the implied effects of temporary government purchases shocks in the empirical literature.

Empirical evidence on the effects on macroeconomic variables of fiscal policy shocks are commonly analyzed using Vector Auto-regression (VAR) models. Although the VAR model is unanimously a mainstay in conducting empirical research, there is a controversy about the approach used to identify structural shocks in this framework. There are several approaches to identifying an exogenous government spending shock from a systematic (automatic) response of fiscal policy; the main approaches come from the seminal work of Blanchard and Perotti (2002), and, Ramey and Shapiro (1998). Depending on the approach used to identify government spending shocks in a VAR, one can find support for the predictions of either the neoclassical or New Keynesian class of models. The use of various identification techniques is partly responsible for the mixed results in the literature. The Blanchard and Perotti (2002) method identifies government spending shocks by using information on the tax and transfer system. It assumes that government spending does not respond contemporaneously to other variables in the model. As a result, government spending enters first in the VAR model, followed by all other variables. This approach generally finds an increase in consumption and the real wage to a temporary positive government spending shock when applied to data samples for various advanced countries that include Canada and the United States.[7]

The Ramey and Shapiro (1998) (or narrative) approach identifies government-spending shocks as episodes of military spending build-ups that are unrelated to the state of the economy. This methodology only focuses on the specific episodes identified. These episodes are identified using various news sources to determine the exact time period in history where an increase in defense spending was forecasted. Dates corresponding to a wartime increase in defense spending are identified as wartime episodes and are represented as dummy variables in the estimation of defense spending shocks on key macroeconomic indicators. The narrative approach finds a decline in consumption and the real wage to an unexpected increase in defense spending for the United States for various periods of data.[8] Although both methodologies use a VAR framework, the main difference arises with the definition of the government spending shock and its timing.

We resolve this debate for Canada as it is important for both the theoretical and empirical literature. First, resolving the empirical debate will help us to resolve the theoretical controversy.

[7] Blanchard and Perotti (2002), Fatàs and Mihov (2001), Mountford and Uhlig (2002), Perotti (2005), Gali, López-Salido, and Vallés (2007).
[8] Edelburg, Eichenbaum and Fisher (1999), Burnside, Eichenbaum and Fisher (2004), Romer and Romer (2010), Ramey (2011), Ramey, Owyang and Zubairy (2013), Ramey and Zubairy (2015).

Second, it will provide guidance on the choice of a macroeconomic model that correctly predicts the effects of fiscal policy. Both of these achievements are important building blocks to pursuing our research goals as they help us define the economic framework of this thesis. Capturing the behaviour of private consumption in Canada is crucial for understanding how Canadian output and hours respond to fiscal shocks**.** These variables represent endogenous variables in all of our models. Often times, increased public spending can come in the form of stimulus packages, as was the case in the United States, Canada and several European countries after 2008-2009. It is important for policy makers to correctly characterize the response of private consumption so they can understand the extent to which fiscal policy can stabilize the economy when developing a strategic response. Lastly, identifying the processes through which fiscal policy affects the economy in simple models and deconstructing how they work is essential before we can investigate more complex models with a richer fiscal sector.

In the second chapter of this thesis, we explore the evidence on the implied effects of changes in government purchases on consumption using a VAR model. We use both the SVAR approach in Blanchard and Perotti (2002) and the narrative approach in Ramey and Shapiro (1998) to determine whether the behaviour of private consumption aligns to the neoclassical or the New Keynesian paradigm. This is an important first step in our research agenda as it sets the groundwork for the remaining chapters where we make our main contribution. As previously discussed, the VAR framework has become a hallmark of empirical research in the field of fiscal policy. These models are the most commonly used tool for economic multivariate time series analysis and offer great flexibility for forecasting and policy research.

To address the debate about the effects of unanticipated government purchases, we employ a VAR model to perform structural analysis of the following four variables: the log of real GDP, the log of real private consumption, the log of real government expenditures, and the log of real net tax revenues. This allows us to analyze the casual impacts of unanticipated shocks to government purchases on the other endogenous variables in the system. Performing impulse response analysis, forecast error variance decompositions and historical decompositions of the time series facilitate structural analysis in these models. We mainly rely on impulse response analysis to inform our understanding of the dynamic effects of temporary unexpected government purchases shocks on the Canadian economy.

While some quantitative research findings exist for Canada[9], as in the case with most small open economies, such empirical analysis is often limited to panel studies[10] due to short data samples. In the case of Canada, non-interpolated quarterly macroeconomic time series data is available only after 1981q1. This creates a challenge in conducting empirical time series analysis with a starting point prior to 1981q1 without interpolation. However, understanding the past behaviour of fiscal policy requires examination of historical data. In the second chapter, we avoid interpolation as is done in the literature (see Blanchard and Perotti (2002) and Perotti (2005)) by estimating our VAR model for various times periods ranging from 1961q1 to 2015q4. This allows us to assess over fifty years of fiscal data for Canada without compromising our results due to interpolation.

In the second chapter, the main finding arising from our VAR analysis supports a positive response of private consumption to a temporary unanticipated government shock in Canadian

[9] Mendoza (1991), Letendre (2007), Ramey and Zubairy (2015).
[10] Lane (2003), Perotti (2005), Perotti (2007), Égert (2010), Fatàs and Mihov (2012) Reicher (2014).

data. A finding most consistent with the neoclassical model predictions. In the third chapter, we propose a DGSE model with fiscal rules that can account for this evidence. We recognize that because of the global resurgence of fiscal rules the theoretical literature has been motivated to follow closely in the footsteps of the literature on rules based monetary policy. Specifically, the seminal contribution of Taylor (1993) in the form of the monetary policy rule (the Taylor Rule) has started an active search for a fiscal counterpart. As researchers and policymakers look to the simple interest rate rule and how it has proved to be a practical tool for central banks, this has led to a growing area of research with the objective of finding a fiscal equivalent. An important factor being that the fiscal equivalent to the Taylor rules should extend the same level of usefulness to the fiscal authority as the monetary rule does to central banks. While many specifications for a conceptual fiscal rule have been proposed, the literature has not yet converged to a common rule framework. Some **(**Leeper, Plante and Traum (2010), Kumhof and Laxton (2013), Kliem and Kriwoluzky (2014)) have conducted empirical research on the scope of rules based fiscal policies in developing and developed countries to inform the discipline of the various specifications.

In the third chapter of this thesis, we extend this strand of literature by estimating countercyclical fiscal rules for Canada. Specifically, we focus on capturing the extent to which the fiscal aggregates have behaved in an automatic manner. We hone in on the relationship between fiscal rules, consolidation policy and stabilization policy. Canada’s history with fiscal rules dates back to the 1990s, when it first adopted a legislated spending rule at the federal level of government.

The Spending Control Act was in effect from 1991 to 1995 and placed a spending limit[11] on the growth of program spending.[12] Since then, Canada's fiscal authorities have implemented many non-legislated fiscal targets that have continued to function as implied fiscal rules. Tapp (2010) identifies a reduction in Canada's federal debt to GDP ratio from 68.4 % to 29% over the period 1996 to 2008 during which a spending rule (1991), budget balance targets (1994-1997) and debt targets[13] (1998-2008) were in place. After more than a decade of consecutive fiscal surpluses, significant federal government fiscal deficits totaling $55.6 billion returned in 2008-2009 (Tapp, 2010). The Canadian federal government responded to this deterioration of the fiscal balance by making political commitments expressed as fiscal targets and proposing a legislated fiscal rule. In 2013, a target federal debt to GDP ratio of 25% was set in place to be achieved by 2021. The federal debt to GDP ratio today is 30.5% and it is expected to grow in the coming years. The Conservative government enacted The Balanced Budget Act (2015), as the second legislated national fiscal rule, legally requiring a balanced budget at the end of each fiscal year. This Balanced Budget rule is currently being repealed by the government in office (Liberal Party that came into power in October 2016) to allow for temporary deficits. The Liberal government has tabled investment spending plans totalling $125 billion to be financed by budgetary deficits. This fiscal policy will undoubtedly increase public debt levels in Canada and raise the debt to GDP

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[11] For 1991-92: $97,200,000,000, 1992-93: $100,900,000,000, 1994-95: $107,400,000, 1995-96: $111,250,000,000.

[12] Program spending referred to all expenditures in a fiscal year with exception to the following: (1) interest on public debt, (2) expenditures associated with the Employment Insurance Act (not including contributions by the government as employer's premium), (3) expenditures made under the Farm Income Protection Act, and expenditures associated with emergencies for court judgments against the government.

[13] A deficit target of 3 percent of GDP by 1996-97 announced in the federal Budget 1994, and the Debt Repayment Plan announced in Budget 1999 consisting of balanced budgets in 1998-2000, including a contingency reserve in the budget plan in the amount of $3 billion each year to be used to towards paying down debt.

ratio in the years to come. It is unclear if the act will be re-enacted or if fiscal policy in the future will be guided by an entirely different type of fiscal rule, however systematic adjustment of budgetary aggregates will have to occur to ensure the public debt is at a sustainable level. What we can say with certainty is that the pre-recession and post-recession economic environment in Canada has relied heavily on fiscal rules to achieve debt sustainability. Analyzing the dynamics of past systematic responses informs us about the fiscal instruments that have historically played an important role in the adjustment process.

Although Canada has a rich history of using rules based fiscal policy during times of budgetary pressure, little empirical research has been devoted to its study and impacts on the Canadian economy. In the third chapter, we explore the quantitative importance of counter-cyclical rules in stabilizing the business cycle and improving the fiscal position (reduction in the debt to GDP ratio) in Canada by estimating fiscal rules. We design numerical rules based on recognizing how fiscal consolidations were achieved in the past, and the set of budgetary instruments most frequently used during these periods. Using the Canadian fiscal experience that has emphasized deficit and debt reduction as a main priority, we propose debt rules as in Leeper, Plante and Traum (2010) along with government purchases and lump sum transfers as policy instruments. These simple rules are specified such that each instrument responds to an output gap in order to stabilize the business cycle in the short run and to a debt gap[14] to ensure debt sustainability in the long run. Additionally, we explore the relative effectiveness of a broader set of fiscal instruments by including capital, labour and consumption tax rates and estimating their elasticities with

[14] The output and debt gap refer to the deviation of the variable from its steady state level.

respect to movements in the cycle and the public debt level. We extend the closed economy business cycle model of Leeper, Plante and Traum (2010), to an open economy framework and use Bayesian techniques to estimate five debt rules embedded within a DSGE model for Canada.

The vast body of empirical research (Coenan and Straub (2005), Perotti (2005), Galí, López-Salido, and Vallés (2007), Kamps (2007)**)** on models of fiscal policy have a very simple fiscal structure that ignores distortionary taxation, deficit financing, fiscal rules and debt dynamics. Although there is some research that highlights this shortcoming in the literature (see for example, Baxter and King (1993), Sims (1998), Leeper and Chung (2008), and Leeper, Plante and Traum (2010)) and shows that ignoring these fiscal aspects can lead to misleading results, there remains more work to be done in this area. We choose to pursue our research objectives using a DSGE model, as it is the main quantitative tool used in the theoretical macroeconomics literature. DSGE models are rooted in general equilibrium theory and widely used in modern macroeconomic research to guide our understanding of economic forces. These models consist of various agents such as households, firms, a monetary authority, and a fiscal authority some of which make decisions with the aim to maximize their utility. The defining feature of these models is their stochastic nature, achieved through the inclusion of various shocks (technology, preferences, fiscal) that affect the agents in the economy as well as macroeconomic aggregates. The analysis comes from studying the decisions of the various agents with respect to the endogenous variables over time.

Our work features two DSGE models that are similar along many dimensions and differ mainly with respect to the type of agents in the model and the method used to test the model's predictions. In chapter 3, we put forward a DSGE model where all agents in the economy behave in the traditional Ricardian fashion, consistent with the ability to smooth consumption between periods. The main objective of this chapter is to report on the scope of systematic debt rules in Canada by estimating the elasticities of fiscal aggregates in response to the business cycle and public debt. For this reason, we abstract from the issue of heterogeneity between agents but later extend the model in the fourth chapter to account for presence of non-Ricardian agents. To present evidence on the responsiveness of fiscal aggregates, we cannot simply assume that parameter values are fixed quantities as in calibration exercise or maximum likelihood estimation. Instead, we need to treat the structural parameters of the model as unknown quantities and investigate their true values probabilistically. The Bayesian estimation methodology is a quantitatively rigorous approach that allows us to numerically express the systematic behaviour of fiscal aggregates. Estimating the parameters of the fiscal rules (and all other structural parameters) allows us to fit the model to the data. In chapter 4, our focus is on the welfare effects of these estimated rules on non-Ricardian agents who face a liquidity constraint preventing them to smooth consumption, unlike the Ricardian agents in chapter 3 who can engage in intertemporal consumption smoothing. Since we obtained the empirical estimates for the coefficients of these rules in our Bayesian analysis, we do not re-estimate the model parameters and instead calibrate the heterogeneous version of our small open economy model.

The application of Bayesian estimation to DSGE macroeconomic models has led to the development of a new field of research representing the intersection of macroeconomics and econometrics. Led by computational advancements in recent years, this empirical methodology has become a commonly used tool for policy analysis and offers several advantages over classical forms of estimation. Firstly, medium and large-scale DSGE models have many parameters while data is limited, leading to a low ratio of data observations to parameters. We find the small samples properties of this technique to be beneficial to our analysis as our DSGE model consists of 44 parameters and our empirical data set consists of 206 observations. Additionally, Bayesian estimation recognizes the importance of beliefs about structural parameters and treats these beliefs as pre-sample information. The use of priors is especially important when working with a smaller sample size. This allows the optimization algorithm used to maximize the likelihood function to be more stable. Secondly, the likelihood of DSGE models can be very complicated and are characterized with numerous maxima, minima and many flat surfaces. Maximization of such complex likelihoods are very challenging for many optimization algorithms used in the Maximum Likelihood approach to estimation (see Hong and Chernozhukov (2003) for a discussion on the difficulties associated with likelihoods). Estimation is generally carried out using the Markov Chain Monte Carlo (MCMC) algorithm, which is a simulation technique that generates a sample from a target distribution. This algorithm is simple yet powerful and is able to efficiently manage the likelihoods of DSGE models.[15] Lastly, classical approaches to estimation give rise to a host of misspecification and identification problems. Bayesian estimation deals with model misspecification by using the marginal likelihood to determine the predictive performance of competing models.

Our Bayesian estimation methodology uses nine macroeconomic time series from 1961q1 to 2012q2. The baseline model, considers a smaller set of fiscal instruments; namely government purchases and lump sum transfer rules. We then extend the rules to include capital, labour and consumption tax rate rules. We estimate both versions of the model and find that the estimation

[15] The idea behind the MCMC algorithm is "to specify a transition kernel for a Markov chain such that starting from some initial value and iterating a few times, we produce a limiting distribution that is the target distribution from which to sample from" Canova (2007).

results lend greater support for the baseline specification suggesting that rules based fiscal policy in Canada favours expenditure rules over taxation rules. Our empirical investigation yields two key results. Among all budgetary aggregates considered, government spending and transfer expenditure instruments have showed the most responsiveness (large debt coefficients) to movements in debt. This suggests that these instruments have played a key role in stabilizing debt relative to tax rates. On the other hand, we find that tax rates, specifically capital and labour rates, have adjusted historically to stabilize the business cycle. These results reveal that expenditure tools have been valuable to achieve long run debt stability goals, and tax rates have been central to stabilizing business cycle fluctuations. Alesina and Ardagna (2013) link fiscal actions of spending restraint to successful episodes of fiscal adjustments in Canada to demonstrate the effectiveness of expenditure instruments in reducing the deficit to GDP ratio.

Our results make an important contribution to the literature on the estimation of numerical fiscal policy rules in small open economies. We provide rigorous technical analysis using Bayesian estimation techniques to find robust estimates for the structural parameters in the Canadian economy. To our knowledge, this represents the first attempt to report empirical estimates on a wide set of fiscal policy rules for Canada. Providing empirical evidence for the use of debt rules in Canada adds empirical strength to the result in the literature of a greater reliance on spending cuts during fiscal consolidations across OECD countries[16]. Additionally, we use the estimates of a rich set of structural shocks to determine the contribution of various shocks to aggregate output and public debt in Canada. We find evidence for the importance of supply shocks (technology

[16] See Tapp (2010) for federal and provincial budgets analysis in Canada.

and labour supply shock) in explaining the forecast error variance of aggregate output and public debt.

In the final chapter of this thesis, we focus on the growing empirical literature that highlights the evidence on the existence of heterogeneity among households. Many studies show 50-60% of the total population in several European and developing countries being identified as “liquidity constrained households”. Building richer models of fiscal policy and connecting theoretical and empirical literatures also requires incorporating features that reflect economic realities. One such reality is that households lie in different places on income distribution and some may not have access to financial markets, so accounting for heterogeneity among households is important. In fact, recognizing the presence of heterogeneous household groups in macroeconomic models of fiscal policy has led to several important contributions. Many studies find a significant stabilizing role for fiscal policy when a large subset of the population face liquidity constraints.[17]

A central consideration in the research around fiscal rules is to improve our understanding of the effects of rules based policies on economic households and macroeconomic aggregates. Although macroeconomic models have traditionally focused on Ricardian households who make economic decisions around what quantities to consume, save and invest, and how much labour to supply, models of fiscal policy have now begun to increasingly recognize non-Ricardian households. The characteristic of non-Ricardian households that distinguishes them from traditional Ricardian households is their inability to save and invest preventing them from

[17] See Campbell and Mankiw (1989), Mankiw (2000),), Gali, López-Salido, and Vallés (2007), Forni, Monteforte and Sessa (2009) and references therein.

smoothing consumption inter-temporally and creating a market imperfection. These non-Ricardian households popularized by Mankiw (2000) and Galí, López-Salido, and Vallés (2007) are given many names in the literature that include “rule of thumb agents”, “hand to mouth consumers”, “spenders”, and “liquidity constrained households”. I will hereafter refer to non-Ricardian households as “liquidity constrained households”.

Since most of the research on the intersection between liquidity-constrained households and systematic rules based fiscal policy has mainly focused on developing Latin American countries such as Chile or the European area, an important goal of this strand of research has been to analyze welfare effects arising from different rule specifications. Bi and Kumhof (2011) and Kumhof and Laxton (2013) find that the design of fiscal rules leads to important welfare dynamics that differ between household types. Exploring the continuum of fiscal rule specifications and their welfare effects on different households and the aggregate economy for a developed small open economy such as Canada represents our contribution**.** Chapter four of this dissertation will examine the broader challenge of moving towards a widely accepted fiscal rule specification similar in spirit to the monetary policy Taylor rule. This chapter proposes and analyzes the welfare effects of a suite of fiscal rules on both Ricardian and liquidity constrained (non-Ricardian) agents. We use the findings in previous chapter as well as evidence in the literature as building blocks. The rules we focus on in this chapter include a balanced budget rule and the two debt rules (a government purchases rule and a lump sum transfers rule) that have displayed the most significant adjustment to Canadian public debt levels. Recall that our estimation findings in chapter 3 reveal that the debt coefficients for government spending and lump sum transfers were sizeable relative to debt coefficients corresponding to tax rates. We therefore do not analyze debt rules using tax rate instruments. We also use the finding in

Bartolomeo, Rossi and Tancioni (2011) that estimate the share of liquidity-constrained agents in Canada at 30%.[18] We extend the small open economy framework in the previous chapter to include both Ricardian and non-Ricardian behaving agents and we calibrate the model using microeconomic data and our estimation results from chapter 3. We analyze this model by performing impulse response analysis and an in-depth welfare analysis. The specific objectives of our welfare analysis include exploring whether welfare gains (losses) are higher under a balanced budget rule or under countercyclical debt rules in the aggregate, and for each type of agent in the economy. We are interested in understanding how welfare effects under alternative fiscal rules differ for households that face a liquidity constraint relative to households that have access to financial markets and can save and borrow to smooth their consumption. Lastly, we examine scenarios in which the government follows debt stabilization policies by varying expenditure instruments, and compute what the associated welfare impacts are on Ricardian and non-Ricardian households.

Our analysis of systematic rules based policy in the presence of liquidity-constrained households reveals that debt rules compared to a balanced budget rule improve aggregate welfare in the economy. This improvement in aggregate welfare is driven by the welfare gains of the large share (70%) of Ricardian households in the population. The liquidity-constrained households experience a welfare loss when the fiscal authority follows debt rules, but this loss in not reflected in the aggregate. We find debt rules are unable to increase the welfare of liquidity-

[18] Having added liquidity-constrained agents in the model, we do not re-estimate the parameters, as the model remains largely the same with the exception of this new feature. Incorporating heterogeneous households will not have a significant effect on parameter values.

constrained agents because the ability of governments to use deficit financing does not in any way alleviate the market imperfection that arises due to these agents' inability to smooth consumption between periods. Nevertheless, if the fiscal authority's main objective is to choose a policy rule that delivers the highest aggregate welfare, then debt rules are the preferred tool. These findings suggest that in practice having a uniform fiscal rule will create challenges given the heterogeneity among agents. The search for a widely used fiscal rule specification must take into account the differing welfare implications of a given population and the trade-offs that the fiscal authority will have to make in selecting and implementing a policy rule.

The plan for the remaining chapters is as follows. Chapter 2 provides an empirical evaluation of unexpected temporary government spending shocks using a VAR model for Canada. Chapter 3 introduces our small open economy DSGE model featuring only Ricardian agents and a full suite of fiscal rules and their estimation results. Chapter 4 builds on the small open economy model to include liquidity-constrained households and investigates the welfare implications of a balanced budget rules compared to debt rules for government spending and lump sum transfers. Lastly, Chapter 5 discusses the conclusions of this thesis and future directions of our work.

2. A VAR analysis of Canadian fiscal policy

2.1 Introduction

Do positive government spending shocks stimulate or crowd out private consumption? In recent years, a renewed interest in the role of fiscal policy has led to a revival in efforts to answer this very simple question.[19] The interpretation of the existing empirical fiscal policy literature currently is that depending on the strand of the literature consulted there is evidence of both a rise and fall in private consumption following a temporary rise in government purchases. There are disparities both within the theoretical and empirical literature as well as between them with respect to the sign of private consumption and real wages in response to a positive government spending shock. Neoclassical models predict a negative sign; whereas new Keynesian models predict the opposite.

Within the empirical literature, there are two main approaches to measuring the stance of government spending shocks that have led to conflicting answers to this question. The first method often referred to the SVAR approach proposed in Blanchard and Perotti (2002) assumes that government-spending shocks are not affected by any other innovation within a period. This means that government spending is pre-determined within the period and is ordered as the first variable in the VAR model. This way of identifying a government spending shock characterizes a strand of empirical literature that most often find private consumption and the real wage to rise

[19] Leeper, Plante and Traum (2010), Ramey (2011), Zubairy (2014), Fatàs and Mihov (2012), Monacelli and Perotti (2010), Afonso and Sousa (2012), Auberbach and Gorodnichenko (2012), Davig and Leeper (2011), Coenan, Straub and Trabandt (2012), Mertens and Ravn (2014), Égert (2014).

after a temporary rise in government purchases. The other method of identifying fiscal shocks follow a narrative approach as in Ramey and Shapiro (1998), where episodes of military spending are considered to be exogenous temporary government spending shocks. These military spending episodes are often referred to as the Ramey-Shapiro war dates (the Korean War (1950q3), the Vietnam War (1965q1) and the Carter-Reagan Build up (1980q1)) and are incorporated in the VAR model as dummy variables. The branch of literature that adopts this approach within a VAR framework, generally find that in response to positive military spending shocks, private consumption and the real wage fall. In this chapter, we synthesize these contradicting findings in the literature by investigating the effects of temporary government spending shocks on the Canadian economy using both these approaches. We are particularly interested in the response of private consumption and output in Canadian data and in the ability of small open economy neoclassical and New Keynesian models to match these empirical facts. The class of models that is able to best reproduce the dynamic responses of Canadian macroeconomic variables to fiscal shocks informs the framework in which we pursue our research questions in the following chapters.

Using Canadian data, we find that following the Blanchard and Perotti (2002) approach, private consumption and output fall when there is a positive temporary government spending shock for the period 1961q1 to 2001q1 but rise for the period 2001q2 to 2015q4. Perotti (2005) also finds opposite results for the direction of private consumption for different subsamples of data using the SVAR approach that assumes government spending is predetermined within the quarter. Using the narrative approach of Ramey and Shapiro (1998) for the period 1947q1 to 1997q4, we find that both output and private consumption fall in response to a temporary government spending shock. These findings represent a new contribution to the literature as the Ramey and

Shapiro approach has not been applied to Canadian data to analyze the response of private consumption to temporary government spending shocks. However, this line of research has been extensively investigated for the United States, and the body of literature that applies the Ramey and Shapiro (1998) method to VAR models supports the finding that positive government spending shocks increase aggregate output and decrease private consumption. We find that the neoclassical model predictions are best able to account for our empirical VAR results for the effects of fiscal (government spending) shocks on the Canadian economy, specifically matching well the response of private consumption in the data.

The assumptions and techniques employed by the Blanchard and Perotti (2002) and the Ramey and Shapiro (1998) approaches have been the subject of a heated exchange in the empirical fiscal policy literature, for quite some time now, and have led to a growing body of work on the subject. As we have mentioned in the introduction, these works represent the original contribution of these two different empirical identification approaches and have led to contradictory results. Both sides have made further additions to the literature that highlight the shortcomings of the opposing literature and attempt to reconcile the mixed results to strengthen the original findings in their work. Perotti (2007) criticizes the Ramey Shapiro (1998) approach of treating all defense spending episodes or war dates equally. He argues this to be a restrictive assumption, claiming that assigning the dummy variable corresponding to each episode a value of one implies each episode has the same intensity. This assumption results in all variables having the exact same response in terms of the shape and size of the variables, in each episode. When a positive government spending shock hits the economy the VAR generates a fall in consumption and the real wage for every war episode. Perotti (2007) argues that these episodes are in fact different and have different dynamics that could have resulted from “the different patterns of behaviour of taxation and of defense spending vs. civilian government spending in each episode".

He further states, "the method assumes that the abnormal fiscal events are entirely responsible for all the deviations from normal of all variables for several quarters following the episode". Perotti (2007) argues that this is problematic as the intensity of the rise in military spending differs across the various episodes, affecting the size of responses, and that different fiscal policies during these episodes (for example tax increases during the Korean War and tax cuts during the Vietnam War) would affect the shape of the responses to each episode. He modifies the Ramey and Shapiro (1998) approach to allow the responses of all variables in the VAR to have a different shape and intensity and then isolates the "abnormal" (military spending episodes) and estimates the "normal" response of the variables in the system to these events. Using the modified version of the Ramey and Shapiro (1998) dummy variable approach, Perotti (2007) estimates a seven variable VAR model[20] that finds a rise in private consumption and the real wage following a military spending episode. Perotti (2007) also extends the original contribution made in Blanchard and Perotti (2002) by applying the identification methodology inherent in that work to the United Kingdom, Australia and Canada.

The re-examination of the Ramey and Shapiro (1998) approach in Perotti (2007) is followed by a re-evaluation of the Blanchard and Perotti (2002) assumptions in Ramey (2011). This work contests that the structural VAR approach timing restrictions used in Blanchard and Perotti

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[20] The VAR consists of government spending on goods and services, the average marginal income tax rate, real GDP, private consumption on non-durables and services, private gross fixed capital formation, the log of hours in the non-farm business sector, and the log of real product hourly compensation in the non-farm business sector.

(2002), Perotti (2005), Fatàs and Mihov (2001), Caldera and Kamps (2008) and Galí, López-Salido, and Rabanal (2007) to identify government spending shocks might actually be identifying shocks that are anticipated by economic agents. Ramey (2011) purposes that large episodes of military as well as non-military spending are actually anticipated several quarters in advance, suggesting that these works fail to take into account the implementation lags associated with when a government spending decision is made and when spending is disbursed.[21] Since the Ramey and Shapiro (1998) military dates identify the onset of military spending episodes on the basis of historical news sources that foreshadow increased military spending, she argues that identifying fiscal shocks in this manner correctly capture timing effects. Ramey (2011) also argues that VAR analysis of government spending shocks should analyze shocks to defense (military) spending as opposed to non-defense (education, public order, transportation) spending, as is traditionally the practice in structural VAR models. This is based on the observation that a majority of the volatility in government spending comes from fluctuations in defense spending in U.S data. Additional concerns about the inclusion of the non-defense category of spending highlighted in Ramey (2011) include the largest component of non-defense spending (education) moves to a large extent by demographic changes and the possibility of government spending increases generates a positive wealth effect due to the efficiency inherent in public versus private spending. If the later holds true, then because in neoclassical models a rise in government spending creates a negative wealth effect comparing the New Keynesian and neoclassical model on the basis of shocks to non-defense spending that generate a positive wealth effect may not be

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[21] See Leeper, Walker and Yang (2009) on the effects of implementation delays for government investment in the U.S.

a good way to compare the models. Ramey (2011) shows that both the military build-up episodes and independently constructed professional forecasts Granger cause the government spending shocks used in structural VAR analysis. This evidence implies that the government spending shocks used in Blanchard and Perotti (2002) and works following this methodology are forecastable and occur a few quarters after the military spending episodes. Consequently, when the military episodes are delayed a few quarters the differences in empirical results between the Blanchard and Perotti (2002) and the Ramey and Shapiro (1998) collapse. Ramey (2011) shows that the military spending episodes are able to generate a positive response of private consumption and the real wage consistent with the predictions of new Keynesian models when anticipation effects are ignored.

Several other prominent attempts have been made at reconciling the differing empirical findings on the effect of fiscal policy shocks using alternative identification approaches. For example, Caldera and Kamps (2008) show that controlling for differences in specification of the reduced form model can bring the results on the effects of fiscal policy shocks across the two identification approaches closer together. Their empirical findings lend support to the results of SVAR studies with respect to government spending but are not able to find consistent results for the effect of tax shocks using common approaches in the literature. Mertens and Ravn (2014) aim to reconcile the divergent results arising from the empirical investigation of the effects of tax policy shocks on output. Using a new approach that embeds the narrative approach into an SVAR model (proxy SVAR) along with a higher output elasticity of tax revenues; they provide evidence of large tax multipliers for the U.S. Although many empirical studies aim to uncover the underlying differences between the SVAR and narrative approaches and bring consensus to the empirical literature on the effects of fiscal policy, the results remain mixed.

The impact of government spending and tax policy shocks on the Canadian economy remains largely underexplored. This literature[22] has predominantly focused on the effects of fiscal shocks in the U.S. As countries are heterogeneous in the conduct of fiscal policies, the empirical evidence for the U.S cannot be representative of the impact of fiscal policies on Canadian macroeconomic aggregates. There are only a handful of studies Perotti (2005), Corsetti and Müller (2006), Ravn, Schmitt-Grohé and Uribe (2007), Monacelli and Perotti (2010), Owyang Ramey and Zubairy (2013), Ramey and Zubairy (2015), and Belinga (2016)) that aim to explore the impact of fiscal policy in Canada. Empirical evidence for Canada is usually provided using panel VAR techniques as opposed to VAR analysis for each individual country.

Perotti (2005) considers a panel of OECD countries that include Canada to explore the effects of non-policy and fiscal policy shocks on output, consumption, and fiscal aggregates. In light of the debate on the response of consumption to an unanticipated government spending shock, his empirical findings on the response of Canadian consumption depends on the subsample used in the estimation. During the first subsample (1961q1 – 1979q4) output, private consumption and investment (to a lesser extent) increase after a positive temporary unanticipated government spending shock. In the second subsample (1980q1 – 2001q4) he finds opposite results for all variables. Given that empirical VAR analysis that investigates the effects of fiscal shocks for the Canadian economy are few at best, and the current limited empirical evidence in studies such as

[22] Rotemberg and Woodford (1992), Edelberg, Eichenbaum and Fisher (1999), Blanchard and Perotti (2002), Ramey and Shapiro (1998), Zubairy (2014), Mountford and Uhlig (2009), Rossi and Zubairy (2011), Gali, López-Salido and Rabanal (2007), Romer and Romer (2010), Canova and Pappa (2005).

Perotti (2005, 2007) are mixed, we focus on providing evidence on the effects of government spending shocks for Canada.

Since Perotti (2005), over a decade of Canadian data, rich in information on macroeconomic and fiscal aggregates have become available. Specifically, the sample period 2002 to 2015 consists of fluctuations in government spending and taxes that should provide more evidence on the effects of fiscal policy shocks in the Canadian context. Estimation using data from this sample period could also shed light on the opposing empirical findings in Perotti (2005) for Canada. We replicate the SVAR model in Perotti (2005) for the periods 1961q1 to 1979q4 and 1980q1 to 2001q4; and then extend this analysis to a new sub sample of data spanning 2002q1 to 2015q4. Our analysis reports mixed subsample results as in Perotti (2005). For the earlier data samples (1961q1-1979q4 and 1980q1- 2001q4) we find a negative response of private consumption to government spending shocks; this is consistent with the findings in Perotti (2005) for the latter period. However, to our surprise we find the VAR results for the recent sample of data for Canada report a positive response of private consumption following an unanticipated temporary positive government spending shock. Given that the majority of data samples estimated reveal a crowding out of consumption, we conclude that our structural vector auto regression analysis lends most support for predictions of the neoclassical model and set aside investigation of the underlying differences between the earlier and more recent data sample for future work.

One notable exception that contributes to the empirical fiscal policy literature for Canada is the work of Ramey and Zubairy (2015), who provide evidence of large multipliers during periods of economic slack for Canada. Ramey (2011) introduces a new and improved news variable for military spending in the U.S that captures the expected change in the present value of government spending. This news defense-spending variable can alternatively replace the military buildup episodes dummy variable in the VAR model and generate the traditional results as in Ramey and Shapiro (1998). Ramey and Zubairy (2015) build on the narrative methodology in Ramey (2011) to construct a similar news variable for Canadian data that spans from 1912 to 2011. The authors do not however explore the response of private consumption or real wages to a government spending shock using their defense news variable. Instead, they use the new spending variable to estimate government spending multipliers for Canada, finding evidence of large government spending multipliers in slack periods. Specifically, they report that over the entire sample (1912 -2011) the government multiplier is 0.5; during high unemployment states (recessions) they are in excess of one and during low unemployment states (booms) they are below 0.5.

In this chapter, we discuss how the news defense variable for Canada in Ramey and Zubairy (2015) can be used to estimate the effects of government spending shocks on macroeconomic variables within a VAR model. There has been no application of the Ramey and Shapiro (1998) dummy variable approach to Canadian data, so our results represent a new contribution to the literature. Our results are consistent with studies following the narrative approach (Ramey and Shapiro (1998), Ramey (2011), Edelberg, Eichenbaum and Fisher (1999) and Cavallo (2005)) in the empirical fiscal policy literature.

2.2 A VAR analysis of Canadian fiscal policy

After Sims (1980), VAR models have become the main tool used for data description, structural inference, and policy analysis in the applied macroeconomics discipline.[23] Vector-Error Correction Models (VECM) have also become a commonly used tool when dealing with time series that are co-integrated[24]. In our work, we exclusively focus on a VAR analysis that deals with stationarity by including a time trend following the fiscal VAR literature[25]. While we begin our discussion with SVAR models, in practice the reduced form version of the dynamic system of equations is estimated as the starting point for a VAR analysis. The structural form VAR is a system of simultaneous equations where each variable (equation) is expressed as a function of lagged values of itself and current and lagged values of the remaining variables. For simplicity let us assume the system contains two stationary variables, x_t , and, y_t , where, ρ , represents the number of lags. In this case the structural form is as follows:

$$x_t = \alpha_t^x y_t + \sum_{j=1}^{\rho} \beta_j^{xx} x_{t-j} + \sum_{j=1}^{\rho} \beta^{xy} y_{t-j} + u_t^x \tag{2.1}$$

$$y_t = \alpha^{yx} x_t + \sum_{j=1}^{\rho} \beta_j^{yy} y_{t-j} + \sum_{j=1}^{\rho} \beta_j^{yx} x_{t-j} + u_t^y \tag{2.2}$$

$$\Sigma_u = E\left(u_t u_t'\right) = \begin{bmatrix} \sigma_x^2 & \sigma_{x,y} \\ \sigma_{y,x} & \sigma_y^2 \end{bmatrix} \tag{2.3}$$

[23] Please see Stock and Watson (2001) for a full discussion on VAR models.
[24] Two time series or variables are cointegrated when each time series is a unit root process on its own but the liner combination is stationary.
[25] There is a consensus that estimating a VAR model in levels with sufficient lags is asymptotically the same as estimating a VECM model. We perform lag length tests and select 4 lags to include in our VAR model.

where, u_t^x **,** and, u_t^y **,** represent structural shocks, α and β , represent the structural parameters. The structural shocks are assumed to be mean zero and uncorrelated with one another. In other words, the structural shocks satisfy the following assumptions: $E\left(u_t^x\right) = E\left(u_t^y\right) = 0$ and $\mathrm{cov}\left(u_t^x, u_t^y\right)$.

The variance covariance matrix is given by, $\sum_u$, and is assumed to have a unit variance. This means that the variance covariance matrix of the structural shocks can be expressed as an identity matrix, $\sum_u = I$. All equations in the system are estimated using Ordinary Least Squares (OLS) regression methods. For instance OLS regression is to be used for equation (2.1) and (2.2) to obtain estimates of the structural parameters and the variance covariance matrix of structural shocks. There is however, a great challenge that presents itself; mainly we are unable to identify the structural parameters from the residuals of the equations because they are correlated with the variables in the system. In (2.1), y_t , will be correlated with, u_t^x , and in (2.2), x_t , will be correlated with, u_t^y. The correlation of these reduced form residuals with the regressors in their respective equations violates the OLS assumption of consistency. This problem is well known and is referred to as the “identification problem” in the VAR literature. [26]

There are various assumptions and methodologies that have been developed in the VAR literature to overcome this problem. The application of these methods to the SVAR framework has led to three classes of VAR models; namely reduced form VARs, recursive VARs and SVARs. Each of these classes of VAR models differs with respect to how the correlation

[26] Sims (1980), Ramey and Shapiro (1998), Blanchard and Perotti (2002), Mountford and Uhlig (2009), Fatàs and Mihov (2001),), Gali, López-Salido, and Vallés (2007), Mertens and Ravn (2012), Caldera and Kamps (2008).

problem is remedied. We now discuss each of these VAR models and their properties in turn, starting with the reduced form VAR model.

To convert the structural form VAR to a reduced form VAR we first express it in matrix form as follows:

$$\begin{bmatrix} 1 & -\alpha_0^x \\ -\alpha_0^y & 1 \end{bmatrix}\begin{bmatrix} x_t \\ y_t \end{bmatrix} = \begin{bmatrix} \beta_1^{xx} & \beta_1^{xy} \\ \beta_1^{yx} & \beta_1^{yy} \end{bmatrix}\begin{bmatrix} x_{t-1} \\ y_{t-1} \end{bmatrix} + \cdots + \begin{bmatrix} \beta_\rho^{xx} & \beta_\rho^{xy} \\ \beta_\rho^{yx} & \beta_\rho^{yy} \end{bmatrix}\begin{bmatrix} x_{t-\rho} \\ y_{t-\rho} \end{bmatrix} + \begin{bmatrix} u_t^x \\ u_t^y \end{bmatrix} \quad (2.4)$$

We can further simplify the above expression to obtain the reduced form VAR as follows:

$$A\begin{bmatrix} x_t \\ y_t \end{bmatrix} = B_1\begin{bmatrix} x_{t-1} \\ y_{t-1} \end{bmatrix} + \cdots + B_\rho\begin{bmatrix} x_{t-\rho} \\ y_{t-\rho} \end{bmatrix} + \begin{bmatrix} u_t^x \\ u_t^y \end{bmatrix} \quad (2.5)$$

where β , j=1,…., ρ is a (nxn) matrix. Pre-multiplying by A yields:

$$\begin{bmatrix} x_t \\ y_t \end{bmatrix} = A^{-1}B_1\begin{bmatrix} x_{t-1} \\ y_{t-1} \end{bmatrix} + \cdots + A^{-1}B_\rho\begin{bmatrix} x_{t-\rho} \\ y_{t-\rho} \end{bmatrix} + A^{-1}\begin{bmatrix} u_t^x \\ u_t^y \end{bmatrix} \quad (2.6)$$

for simplicity we can express the, ρ , lag VAR model as follows:

$$Z_t = \tilde{A}(L,q)Z_{t-1} + \varepsilon_t \quad (2.7)$$

where, $\varepsilon_t = \begin{bmatrix} \varepsilon_t^x \\ \varepsilon_t^y \end{bmatrix} \equiv A^{-1}\begin{bmatrix} u_t^x \\ u_t^y \end{bmatrix}$ **,** and represents the vector of innovations, Z_t , represents the n dimensional vector of endogenous variables, A(L,q) , is a nth order distributed lag polynomial, *L* , represents the number of lags , q , represents the number of quarterly dummy variables and, $\tilde{A}_j = A^{-1}B_j$, for $j = 1, \cdots\cdots, \rho$. The variance covariance matrix of the vector of innovations is given by, $\sum_\varepsilon = A^{-1}\sum_u A^{-1\prime}$.

The reduced form VAR in (2.7) still cannot be estimated using OLS since the innovations will be generally correlated with one another. In other words, the identification problem still persists. To solve the identification problem, restrictions must be placed on the contemporaneous relationships in the vector of endogenous variables. We must ensure that the system of equations is uniquely determined. A simple and intuitive way to ensure uniqueness is to recognize that the number of unknown elements must equate to the number of known elements. In the above reduced form VAR, there are n^2 unknown elements and, $\left(\frac{n+n^2}{n}\right)$, known elements making the system over-identified. There must be, $\left(\frac{n+n^2}{n}-n^2\right)$, restrictions placed on, A^{-1}, for the determination of a unique solution. Since the matrix, A^{-1}, informs how a given variable responds on impact to a given structural shock it is commonly referred to as the "impact matrix". Each category of VAR models (e.g. recursive or structural) proposes a methodology in choosing restrictions to be placed on the impact matrix. It is for this reason that when these methodologies are discussed in the literature they are referred to as approaches that "identify" structural shocks or simply "identification approaches". Some of these methodologies rely on economic theory and others on institutional information. The most commonly cited and used methodologies are the Blanchard and Perotti (2002) approach, the Ramey and Shapiro (1998) approach, and the sign restrictions approach pioneered by Mountford and Uhlig (2009).[27] In the next section we are

[27] The sign restrictions approach identifies government revenue and government spending shocks by placing sign restrictions on the impulse response functions of some variables. Please see Mountford and Uhlig (2009).

going to explore recursive and structural VARS and apply the Blanchard and Perotti (2002) and the Ramey and Shapiro (1998) approaches to conduct a VAR analysis of fiscal policy in Canada.

2.2.1 Recursive VAR

The recursive VAR specification expresses a system of equations as a recursive dynamic structural model in which the order that variables enter the system accounts for the contemporaneous correlation. Variables are ordered causally, such that each variable only depends on the variables above it in the vector containing all endogenous variables. For instance, the variable that enters first does not contemporaneously respond to all other shocks in the system, the variable ordered second only contemporaneously responds to the shocks of the first variable, and the variable ordered last responds to all shocks in the system. Recursive restrictions can simply be explained as restricting the response of some variables to certain shocks within a period, so that innovations are no longer correlated to regressors in the equation being estimated. This form of imposing restrictions is also described in the VAR literature as assuming that innovations are orthogonal to, Z_t. For example assuming, $\alpha^{xy} = 0$, imposes a zero restriction on the impact matrix. The restrictions implied by the recursive approach can be applied in practice by a Cholesky decomposition of the variance covariance matrix of innovations. A Cholesky decomposition imposes restrictions on the impact matrix, such that it becomes a lower triangular matrix of ones along the diagonal implying $\varepsilon_t = \begin{bmatrix} \varepsilon_t^x \\ \varepsilon_t^y \end{bmatrix} \equiv A^{-1} \begin{bmatrix} u_t^x \\ u_t^y \end{bmatrix}$. In practice, the VAR is estimated in its reduced form, followed by a Cholesky decomposition that yields the estimated, A^{-1} , and B_j , matrices for $j = 1, \cdots\cdots, \rho$ and the variance covariance matrix of structural shocks, $\sum_u$.

Now, that we have generally discussed the VAR framework let us proceed with our baseline fiscal VAR model. Consider a recursive VAR model with a four dimensional vector of endogenous variables represented by, $Z_t = [G_t, Y_t, T_t, C_t]$, (in log levels) and, (G_t) is real government expenditures on goods and services, (Y_t) is real GDP, (T_t) is real net tax revenues and, (C_t) is real private consumption. Let $\varepsilon_t = \left[\varepsilon_t^G, \varepsilon_t^y, \varepsilon_t^T, \varepsilon_t^C\right]$, represent the vector of reduced form residuals. As discussed above, the identification problem arises from the tendency of the reduced form disturbances to be correlated with each other. For instance, ε_t^G , and, ε_t^T , tend to be correlated with the other disturbances in, ε_t , creating a challenge in identifying the fiscal shock. It is difficult to determine whether the shock is an automatic fiscal response, a systematic discretionary response or a random discretionary response. To understand the effects of exogenous fiscal policy shocks on the economy we need to be able to identify the random discretionary response represented by structural shocks that are uncorrelated with other structural shocks in the system.

Following Fatàs and Mihov (2001), Galí, López-Salido, and Vallés (2007), Caldera and Kamps (2008), and Cayen and Desgagnés (2009), we order the endogenous variables of the VAR as follows: government expenditure is ordered first, followed by output, net tax revenues and lastly private consumption. Ordering the endogenous variables in this manner has important implications. By ordering government expenditure first, we assume that government expenditures do not respond contemporaneously to the shocks to any endogenous variable. The literature treats this as a plausible assumption mainly because there is no automatic stabilizer component to government expenditures net of transfer payments. For this reason, movements in government spending are deemed to be unrelated to movements in the business cycle, or its components. This restriction on the response of government spending holds only in the period in which the shock occurs, after which government spending can to respond to the shocks to any variable in the vector. The restriction on the timing of government spending can be deemed reasonable as it takes at the very least one quarter for the fiscal authority to react to a shock.

The ordering of GDP as second in the specification implies that the response of output is restricted to shocks in net tax revenues and private consumption in the first quarter. GDP does not respond contemporaneously to shocks in net tax revenues and private consumption. Given empirical evidence on the size and scope of the automatic stabilizers embedded in the tax structure, it is less plausible to assume that tax revenues do not display a contemporaneous reaction to movements in the cycle. Consequently, net taxes are ordered third implying that net taxes do not respond contemporaneously to shocks to private consumption but do respond to shocks to government spending and output. Lastly, private consumption responds contemporaneously to all shocks in the system. Again, these restrictions only apply to the initial period after which the structural shocks corresponding to any one variable can affect another variable.

The proposed causal ordering of endogenous variables in, Z_t , suggests the following relationship between the reduced form disturbances, ε_t , and the structural shocks u_t:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ -\alpha^{YG} & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\alpha^{CG} & -\alpha^{CY} & -\alpha^{CT} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_t^G \\ \varepsilon_t^Y \\ \varepsilon_t^T \\ \varepsilon_t^C \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_t^G \\ u_t^y \\ u_t^T \\ u_t^C \end{bmatrix} \qquad (2.8)$$

2.2.2 Blanchard and Perotti (2002) approach

SVARs use economic theory to impose identifying restrictions on the variance covariance matrix of innovations that in turn allow correlations to be interpreted causally. These restrictions can be short run restrictions such as the zero restrictions in the recursive approach discussed above or long run restrictions. Long run restrictions were popularized by Blanchard and Quah (1989) and correspond to structural shocks that have a long run impact on some endogenous variables. The Blanchard and Perotti (2002) approach has become the most celebrated methodology in the estimation of fiscal policy effects. It extends the recursive approach by using tax and transfer information to construct elasticities that capture the automatic response of government spending and taxes to the cycle. These elasticities replace some zero restrictions in the recursive approach with parameter values to achieve identification. We later use the Blanchard and Perotti (2002) methodology within the general recursive VAR framework to perform an analysis of fiscal policy in Canada. The VAR model using the Blanchard and Perotti (2002) approach has the specification as in (2.7). Including a lag polynomial term serves to let coefficients at each lag depend on the quarter indexing the variable to account for the seasonal patterns that may exist in the response of taxes to the cycle. To compare results for Canada with some of the results reported in Blanchard and Perotti (2002), we follow the latter and add a quadratic trend, the quarterly interaction dummies given by q, and four lags of the variables in each equation in (2.7). We can expand (2.8) to explicitly express the system of equations in the mapping between structural shocks and innovations and outline the identification approach when considering the application of the Blanchard and Perotti (2002) methodology:

$$\varepsilon_t^G = u_t^G \tag{2.9}$$

$$\varepsilon_t^Y = \alpha^{YG} \varepsilon_t^G + u_t^Y \tag{2.10}$$

$$\varepsilon_t^T = u_t^T \quad (2.11)$$

$$\varepsilon_t^C = \alpha^{CY}\varepsilon_t^Y + \alpha^{CG}\varepsilon_t^G + \alpha^{CT}\varepsilon_t^T + u_t^C \quad (2.12)$$

The structural shocks in (2.9) and (2.11) are a linear combination of an automatic response of government spending and taxes to movements in the cycle, the systematic discretionary response of policymakers to the cycle and lastly the random discretionary shocks. As discussed earlier, we cannot simply obtain parameters on the structural shocks using a standard OLS regression since reduced form residuals are correlated with the regressors. Identification using the Blanchard and Perotti (2002) approach is achieved by following several steps.

First and most importantly, this approach assumes that there is no systematic discretionary response in quarterly data. Therefore, the coefficients, α^{GY} , and, α^{TY} , only capture the automatic response of the fiscal variables to changes in output. Perotti (2005) estimates the output elasticity of government spending[28] $\left(\alpha^{GY} = 0\right)$ and the output elasticity of tax revenues, α^{TY} , for Canada to lie between 1.61 and 1.86. Similarly, Murchison and Robbins (2003) estimate the output elasticity for tax revenues to range between 1.65 and 2.03 for Canada. Once the output elasticities for government spending and taxes are obtained, the next step constructs the corresponding cyclically adjusted reduced form residuals.

$$\varepsilon_t^{T,CA} = \varepsilon_t^T - \alpha^{TY}\varepsilon_t^Y = \beta^{TG}u_t^G + u_t^T \quad (2.13)$$

$$\varepsilon_t^{G,CA} = \varepsilon_t^T - \alpha^{TY}\varepsilon_t^Y = \beta^{GT}u_t^T + u_t^G \quad (2.14)$$

[28] Perotti (2005) sets the output elasticity of government spending to zero citing a lack of empirical evidence of a government spending response to movements in the cycle within a quarter.

These cyclically adjusted reduced form residuals are then used to perform an instrumental variable (IV) regression of the output residual, ε_t^Y , on the government spending residual, ε_t^G , the tax revenue residual, ε_t^T , and the consumption residual, ε_t^C , to obtain estimates of, α^{YG} , and, α^{YT}. The last step of this identification methodology requires the calibration of, β^{TG} , and estimation of, β^{GT} , or vice versa to complete the identification process.[29] Following Perotti (2005), we calibrate, $\beta^{GT} = 0$, which implies that government spending is not contemporaneously affected by changes in government taxation revenues.[30] With the estimated coefficients in hand, some of the zero restrictions can now be replaced with parameter values that represent economic relationships between the endogenous variables. This gives us the relationship between the reduced form disturbances, ε_t , and the structural shocks, u_t , in the Blanchard and Perotti (2002) approach:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ -\alpha^{YG} & 1 & -\alpha^{YT} & -\alpha^{YC} \\ 0 & -\alpha^{TY} & 1 & 0 \\ -\alpha^{CG} & -\alpha^{CY} & -\alpha^{CT} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_t^G \\ \varepsilon_t^Y \\ \varepsilon_t^T \\ \varepsilon_t^C \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ \beta^{TG} & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_t^G \\ u_t^Y \\ u_t^T \\ u_t^C \end{bmatrix} \tag{2.15}$$

We estimate the recursive VAR model with the Blanchard and Perotti (2002) identifying restrictions and present the estimation results in section 2.4. We also discuss the Ramey and

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[29] The correlation between these two cyclically adjusted fiscal shocks is found to be low which is why their ordering does not seem to matter.

[30] Perotti (2005) and Cayen and Desgagnés (2009) find that setting $\beta_{GT} = 0$ does not significantly change the results and thus it does not matter which of these coefficients is calibrated and which is estimated.

Shapiro (1998) approach to identifying restrictions and present the estimation results of this methodology in section 2.4.

2.2.3 The Ramey and Shapiro (1998) 'war dates" approach

Ramey and Shapiro (1999) apply the narrative approach of Romer and Romer (1989) to fiscal policy and develop a methodology for identifying structural shocks using episodes of large defense spending build-ups. This methodology traces major movements in defense spending to a "war date", defined as a major political event unrelated to the state of the economy. It also argues that most of the volatility in government spending comes from changes in defense spending. Ramey (2011) strongly advises against the use of aggregate government expenditures in a VAR analysis of fiscal policy. She claims that including state, provincial or municipal expenditures as well as non-defense spending in the estimation of a VAR model is problematic, explaining that these categories of expenditures are driven by other variables that can have different effects on the economy. Proponents of the Ramey and Shapiro (1998) methodology find using an aggregate government expenditure variable as in the Blanchard and Perotti (2002) approach to be a questionable test of the New Keynesian model against the neoclassical model. For this reason, we consider both approaches in our analysis of the effects of government expenditure shocks of the Canadian economy. We then compare the estimation results and consult the corresponding impulse response functions across the approaches to guide the selection of an appropriate theoretical model for Canada.

Ramey and Shapiro (1998) and Ramey and Zubairy (2015) classify six exogenous and unanticipated episodes of defense spending in the U.S. These episodes often referred to as the Ramey-Shapiro "war dates" are: (1) 1898q1 Spanish-American War, (2) 1914q3 WWI, (3) 1939q3 WWII, (4) 1950q3 Korean War, (5) 1965q1 Vietnam War, (6) 1980q1 Soviet invasion of Afghanistan and (7) 2001q3 9/11 attacks in

New York City[31]. Given a short data sample for Canada we can only account for episodes (4) - (6) in our VAR analysis. Since Canada has been an important military ally of the U.S, movements in defense spending in Canada have followed closely those of the U.S even for wars in which Canada was not actively involved such as the Vietnam War. The narrative corresponding to war dates used in our analysis is as follows:

The Korean War:

"On June25, 1950 the North Korean army launched a surprise invasion of South Korea, and on June 30, 1950 the U.S Joint Chiefs of Staff unilaterally directed General MacArthur to commit ground, air and naval forces. The July, 1 1950 issue of Business Week immediately predicted more money for defense. By August 1950, Business Week was predicting that defense spending would more than triple by fiscal year 1952."

The Vietnam War:

"Despite the military coup that overthrew Diem on November 1, 1963, Business Week was still talking about defense cuts for the next year (November 2, 1963, p.38; July 11, 1961, p. 86). Even the Gulf of Tonkin incident in August 2, 1964 brought no forecasts of increases in defense spending. However, after February 7, 1965 attack on the U.S. Army barracks, Johnson ordered air strikes against military targets in North Vietnam. The February 13, 1965, Business Week said that this action was "a fateful point of no return" in the war in Vietnam. "

[31] Please see Ramey and Shapiro (1998), Ramey (2011), Owyang, Ramey and Zubairy (2013) and Zubairy and Ramey (2015).

The Soviet Invasion of Afghanistan:

"The Soviet invasion of Afghanistan on December 24, 1979 led to a significant turnaround in U.S. defense policy. The event was particularly worrisome believed it was a possible precursor to against the Persian Gulf oil countries. The January 21, 1980 Business Week (p. 78) printed an article entitled "A New Cold War Economy" in which it forecasted a significant and prolonged increase in defense spending. Reagan was elected by a landslide in November 1980 and in February 1981 he proposed to increase defense spending substantially over the next five years."

September 2001 Terror Attacks:

On September 11, 2001, terrorists struck the World Trade Center and the Pentagon. On October 1, 2001, Business Week forecasted that the balance between private and public sectors would shift, and that spending restraints were going "out the window". To recall the timing of key subsequent events, the U.S invaded Afghanistan soon after 9/11. It invaded Iraq on March 20, 2003."

Much of the movement in defense spending in the case of Canada is tied to its involvement to the North Atlantic Treaty Organization (NATO) and the United Nations (U.N) implying a later onset of defense build ups. The Korean War serves as an exception. On August 7th 1950, the Canadian Prime Minister, Louis St. Laurent announced the formation of the Canadian Army Special Forces to join UN and U.S efforts in Korea. We delay the Ramey and Shapiro war dates by two quarters in the case of Canada for episodes (5) and (6) and use the following war dates: 1951q1 Korean War, 1965q3 Vietnam War, 1980q4 Soviet invasion of Afghanistan.

FIGURE 2.1 displays the log of real per capita government spending and the six major defense spending episodes in Canada and the U.S for 1912q1 to 2011q1. It highlights the start of each war episode with vertical red dashed line showing a subsequent increase in government spending. The spikes in government spending following a defense-spending episode are especially apparent for the first three episodes. The largest increase in government spending occurs after the WWII (1939q3) episode, however the buildup in defense spending corresponding to the Spanish-American War (1898q1) and the Soviet invasion of Afghanistan (1980q1) were also sizeable. The remaining episodes are dwarfed by the WWII episode. The government spending series in Canada and the U.S. display an upward trend after 1950.

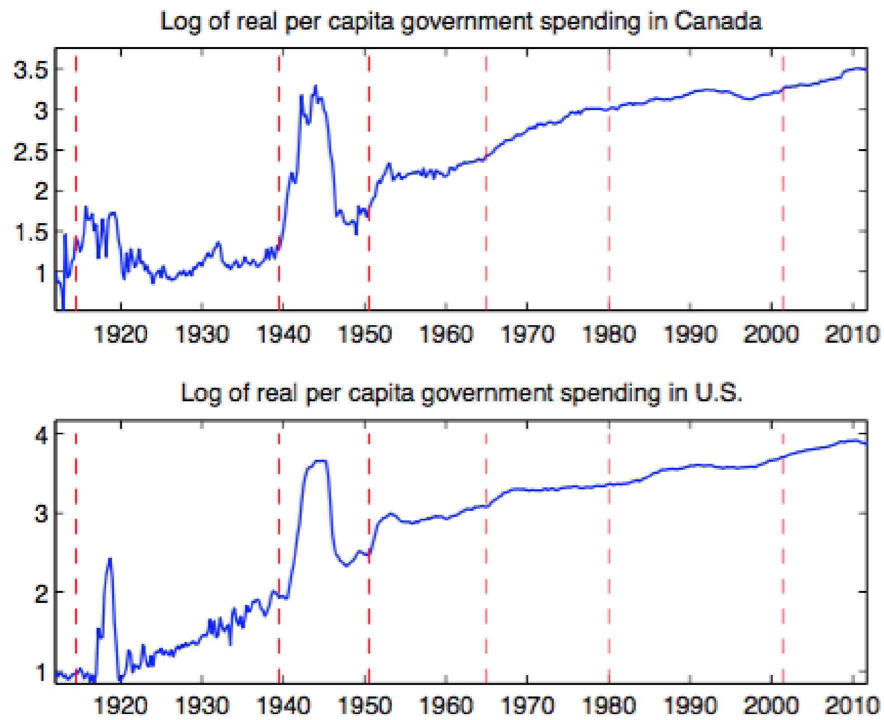

FIGURE 2.1 Government expenditure for Canada and the U.S. in Ramey and Zubairy (2015)

To estimate the structural VAR model using the Ramey and Shapiro (1998) identification approach the estimation methodology discussed in the preceding section is extended to include an additional variable, wd_t, that takes the value one for quarters identified as a war date and zero otherwise. The war dates variable is ordered first following Ramey (2011) followed by the remaining variables that have the same relative ordering as in section 2.2. To analyze the effects of fiscal policy, impulse response functions of the endogenous variables to a shock to, wd_t, is constructed to trace out the dynamics of the other macroeconomic variables using the estimation results.

2.3 Data

2.3.1 Blanchard and Perotti (2002) approach

In this section, we discuss the relevant data series and properties for the VAR analysis using the Blanchard and Perotti (2002) approach. The VAR specification in the Blanchard and Perotti (2002) approach includes the following variables at a quarterly frequency: the log of total real government expenditures on goods and services consisting of government expenditure and government investment from all levels of government (G_t)**,** the log of real net tax revenues defined as government revenues less government transfers (T_t), the log of real GDP (Y_t), and the log of real consumption (C_t). All variables are expressed in per capita terms. We chose the above variables for our analysis for several reasons. The two most important aspects of fiscal policy are captured by decisions about government expenditures and taxation. This makes government expenditures and tax revenues (for total government) the best indicators of fiscal policy. Since we are interested in the impact of these variables on macroeconomic aggregates we include GDP to capture economic activity. Our main objective in performing a VAR analysis is to find a suitable theoretical model for our research agenda that can match up well with the observed empirical Canadian data, and so we include private consumption to test the predictions of the neoclassical model against the New-Keynesian model.

The above series are from the National Income and Expenditures Accounts produced by Statistics Canada and are seasonally adjusted by the source. The real government expenditures measure is constructed as the sum of real government current expenditures on goods and services, real government gross fixed capital formation and real government investment in inventories for all levels of government. The real net tax revenues measure is constructed as the sum of total government taxes on income, contributions to social insurance plans, taxes on production and imports minus other transfers from persons less government sales, current transfers to persons and businesses deflated by the government expenditure deflator. Our tax revenues measure also encompasses all levels of government. These series are used to estimate a four variable VAR model for Canada for the following samples: 1961q1- 1979q4, 1980q1-2001q4 and 2002q1-2015q4. The start and end dates for the first two samples correspond to those in Perotti (2005) to allow a meaningful comparison of our estimation results to his. Perotti (2005) performed subsample analysis because data from several OECD countries, including Canada, suggested that there was a structural break in the macroeconomic series. This break was pinpointed to have occurred around 1980 and to be tied to a change in the transmission mechanism of monetary policy in these countries. The current vintage of macroeconomic data for Canada, containing the series needed for our analysis, only goes as far back as 1981q4. To conduct VAR analysis for the earlier sample we need to use another vintage beginning in 1961q1 and ending in 1980q4. Estimating the VAR model across three samples also allows us to avoid interpolating the time series. We plot each series, (C_t, Y_t, G_t, T_t) from both vintages of data in log levels below.

In FIGURE 2.2 - FIGURE 2.3 we display the log of real GDP (lrgdp) for the period 1961q1-1980q4 and 1981q1-2015q4. We observe a constant upward trend in real GDP during the first sample in FIGURE 2.2. In the second sample, we see a dip in the series corresponding to the deep recession in 1981-82, and the second dip corresponding to the recession in the early 1990s.

In the same figure, we observe a trough in 2008-2009 reflecting the recent financial crisis in the third sample.

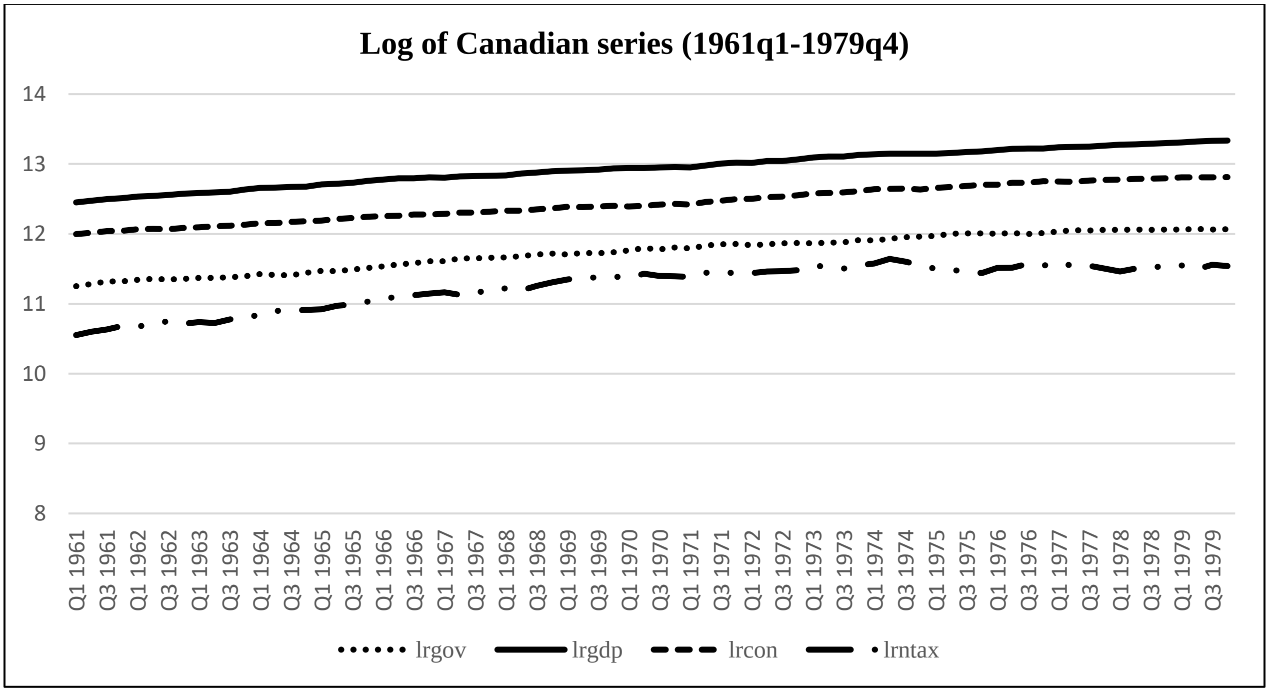

FIGURE 2.2 Log of real government spending, GDP, private consumption, and real net tax revenues (1961q1-1979q4)

In FIGURE 2.2 and FIGURE 2.3 the log of real consumption (lrcon) displays a similar trend to GDP with more muted dips during periods of recession. FIGURE 2.2 displays the log of real government spending (lrgov) increasing steadily during the first sample. In FIGURE 2.3 we observe the same upward trend for the series, it peaks in 1990 and then steadily declines for the rest of the 90s. This decline in the series can be explained by the introduction of the Spending and Control Act (the first legislated fiscal rule) by the federal government in 1991 to exercise spending restraint. The federal government brought into effect these restraint measures in order to reduce historically high deficit levels. The trough during the late 1990s reflects the significant impact of the deficit reduction strategy on the government spending series. After the drawdown of government spending during the late 1990s, the series began to rise steadily again. We observe a peak in government spending in 2010, as a result of federal spending stimulus (Economic Action Plan) implemented after the recession in 2008-2009.

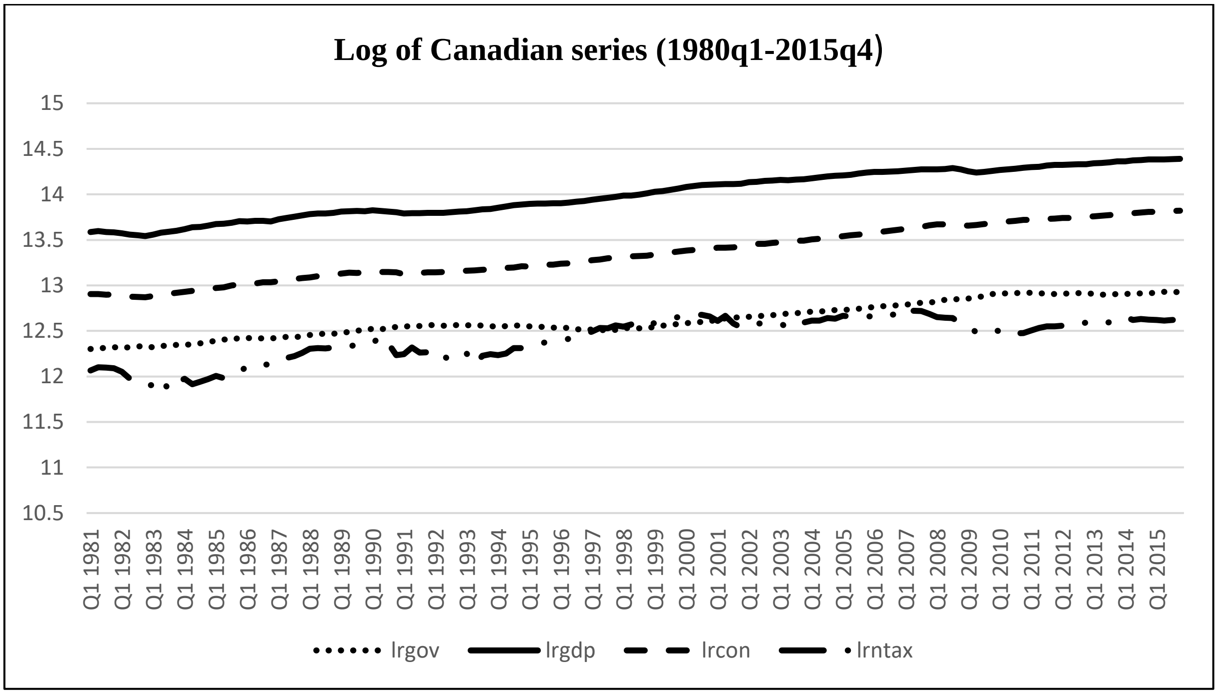

FIGURE 2.3 Log of real GDP, private consumption, government spending and real net tax revenues (1980q1-2015q4)

FIGURE 2.2 and FIGURE 2.3 also show the log of real net tax revenues. The net tax revenues series increased steadily during the first sample until 1974, where it declined and remained at a lower level for several years. FIGURE 2.3 reveals significant decreases in tax revenues during the two recessions in this period (mid 1980s and mid-1990s). This is not a surprise since taxes are closely tied to the cycle. We observe tax revenues declining again during the early 2000s due to a major restructuring of the personal income tax system that lead to a decrease in the income tax rates. During 2001-2004 the corporate tax rate was also greatly reduced.

2.3.2 The Ramey and Shapiro (1998) approach

In this section we present the data series for the VAR analysis using the Ramey and Shapiro (1998) approach. Most applications of the Ramey and Shapiro (1998) war dates approach within a VAR framework has been performed using four war dates in U.S data. However, in Canadian data we are limited in being able to account for at most three war dates. The longest length of time series data available pertaining to variables in our VAR model is for the period 1961q1 – 2012q4. Using this dataset allows us to capture the Vietnam War (1965q1), the Soviet invasion of Afghanistan (1980q4) and the 9/11 attacks (2001q3). However, using this data series means that we cannot include the Korean War (1950q3) episode because we cannot merge the two data sets. The VAR method requires the use of non-interpolated datasets for sufficiently long periods of time and cautions against using interpolation as it compromises reliability and leads to distortions.[32] However, the Korean War episode is the most important war date after the WWII episode in terms of the size of defense spending tied to the event and is important to include in the VAR analysis. Using Canadian quarterly time series data for the period 1947q1-1997q4 allows for the inclusion of the Korean War, the Vietnam War, and the Soviet Invasion of Afghanistan. Given that the importance of the Korean War episode relative to the 9/11 attacks episode we chose the latter data series for our analysis. We use the same set of endogenous variables when estimating the structural VAR model using the Ramey and Shapiro (1998) approach as in the Blanchard and Perotti (2002) approach, so that the impulse responses of the variables to a temporary unanticipated government spending shock can be compared.

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[32] Please see Blanchard and Perotti (2002), Blanchard and Perotti (20004), Giordano, Momigliano, Neri and Perotti (2007).

2.4 Empirical Results

In this section, we present the estimation results for Canada using the SVAR approach in which the structural shocks are identified using the Blanchard and Perotti (2002) and Ramey and Shapiro (1998) approaches. First we estimate a four- variable (private consumption, output, government spending and net tax revenues) VAR model using the Blanchard and Perotti (2002) approach for three sample periods, namely, 1961q1 to 1979q4, 1981q1 to 2001q4 and 2002q1 to 2015q4. We compare our estimation results to the empirical findings in Perotti (2005) for the earlier subsamples and provide a discussion of the estimates for the recent sample of data. The estimation results for 2002q1-2015q4 provide new evidence of the effects of fiscal and non-fiscal shocks on variables of interest in the Canadian economy.

The second set of results presents our findings for the estimated SVAR model identified using the Ramey and Shapiro (1998) war dates approach. We use Canadian data spanning 1947q1-1997q4 and estimate a five variable (war dates dummy, private consumption, output, government spending and net tax revenues) VAR model. We then present a comparative analysis of the effects of a fiscal and non-fiscal (output) shock on GDP, private consumption, government expenditures, and net tax revenues. We specifically focus our discussion of impulse responses on the effects of a temporary shock to government expenditures on private consumption in Canadian data. Overall, this analysis informs us about how fiscal policy in Canada has evolved and serves as an important backdrop when selecting a theoretical model to implement our research objectives in the remaining chapters.

We perform the analysis in this section using orthogonalized impulse responses as is common in the VAR literature. An orthogonalized impulse response measures the isolated effect from one shock in the system on the remaining variables in the system using a Cholesky decomposition. Recall that we causally ordered the variables in the VAR to decompose the vector of shocks into orthogonal or uncorrelated components that in turn implies a Cholesky decomposition. We also consult the cumulative orthogonalized impulse responses of variables to non-fiscal and fiscal shocks. This measure captures the cumulative effect of a shock on variables in the system at one and three years after the shock.

2.4.1 Blanchard and Perotti (2002) approach results

In this section we present the estimated VAR model identified using the Blanchard and Perotti (2002) methodology. We discuss the effects of an unanticipated temporary GDP shock (non-fiscal shock) and the effects of an unanticipated temporary government expenditures shock. Both shocks represent a one standard deviation increase. We find that the non-fiscal shock is followed by an increase in consumption and net tax revenues and a decrease in government expenditures. As output rises in response to a temporary GDP shock, a positive wealth effect operating through rising real wages incentivizes private consumption. During good economic times, tax revenues rise as higher spending levels in the economy lead to higher taxes being collected. Government spending falls during an expansionary period lending support to the counter-cyclical relationship found in many empirical studies.[33]

The fiscal shock (government expenditures shock) triggers a positive response in output and a mostly negative response in private consumption, and net tax revenues. As the government increases its spending, it absorbs resources from the economy and gives rise to a negative wealth effect that discourages private consumption. As consumption is crowded out, this leads to lower spending levels in the economy and the amount of taxes collected. Output rises despite the fall in private consumption since the negative wealth effect also leads labour supply to expand, as employment in the economy rises, aggregate output also increases. Our impulse response analysis of the Blanchard and Perotti (2002) identification approach is most consistent with the neoclassical model predictions and gives empirical support for the stabilizing potential of government stimulus.

2.4.1.1 Impulse responses to a non-fiscal shock

FIGURE 2.4 – FIGURE 2.7 display the response of consumption, GDP, government spending and net tax revenues to a positive non-fiscal shock in three sample periods. The non-fiscal shock refers to a one standard deviation increase in, ε_t^Y . The responses of consumption and government spending display different results across the sub samples whereas the response of net tax revenues only differs qualitatively. Following the non-fiscal shock, in the first sample

[33] See Alesina and Ardagna (2013) and Fatàs and Mihov (2012) for a review of empirical evidence supporting this finding.

private consumption first rises, then falls and then rises. In the second sample (1981q1-2001q4) it follows a similar pattern, and has a very small and negligible negative response initially in the most recent sample that becomes positive thereafter. When comparing the response of consumption across samples, the series displays a stronger response in the earlier subsamples compared to the later data samples. This can be partially explained by the growth in savings over this time period. In the earlier data samples, for example the early 1980s, private savings were low and at times even negative. Since the 1990s savings have grown tremendously and continued this path of sustained growth in more recent times. GDP reacts positively to the shock in all periods, declines in the first two time periods (1961q1-1979q4 and 1981q1-2001q4), and exhibits a hump shaped response in the last period (2002q1-2015q4).

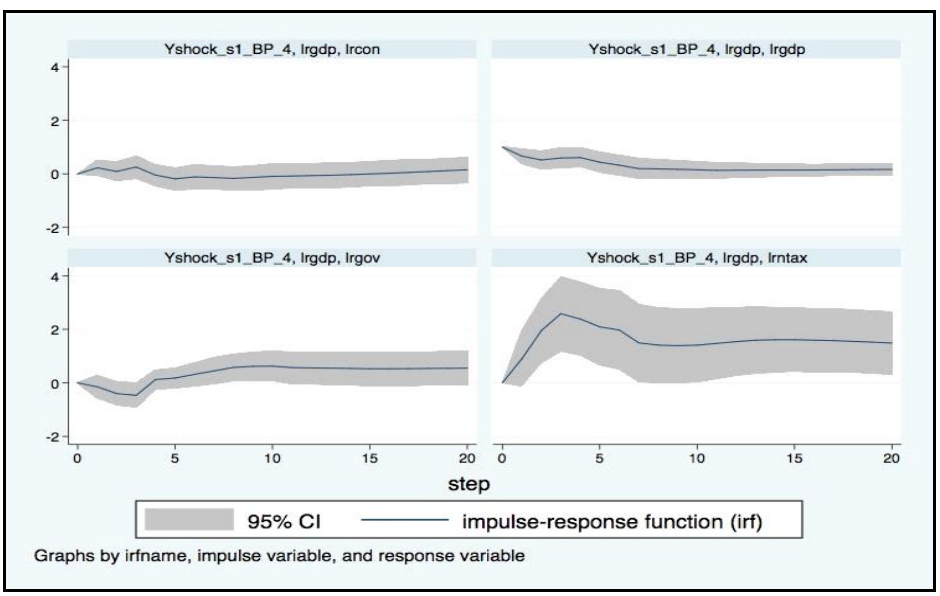

FIGURE 2.4 Orthogonalized impulse responses to a positive non-fiscal shock (1961q1-1980q4)

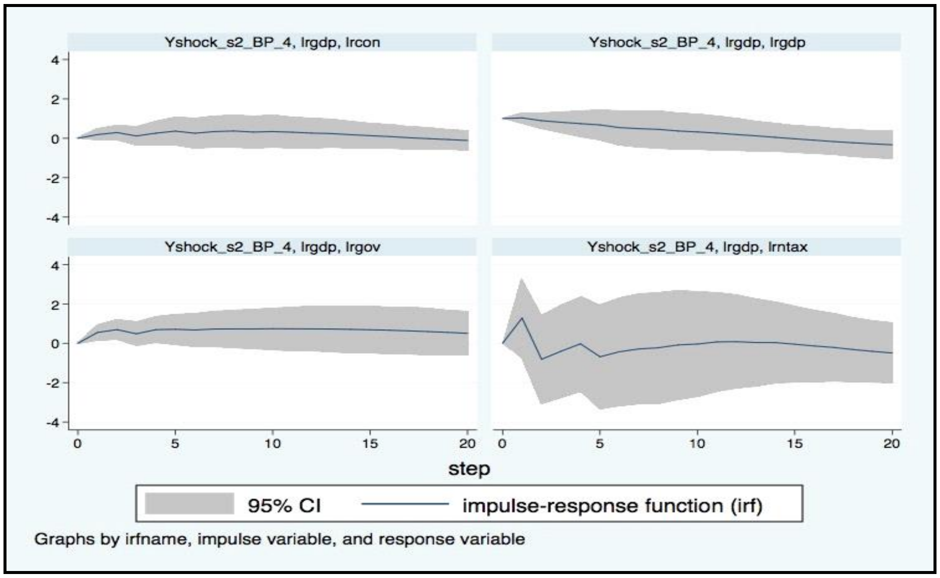

FIGURE 2.5 Orthogonalized impulse responses to a positive non-fiscal shock (1981q1-2001q4)

The response of government spending to the non-fiscal shock varies considerably across the samples. In the first sample, government spending declines for the first year after the shock and then becomes positive throughout its transition path. In the second sample (1981q1-2001q4) the series displays a modestly positive response. In the most recent sample of data (2002q1-2015q4), the response of government spending to the non-fiscal shock is moderately negative. The regression analysis of Fatàs and Mihov (2012) measuring the responsiveness of fiscal policy to business cycles in OECD countries also find that government spending policy in Canada post 1990 has become more countercyclical.

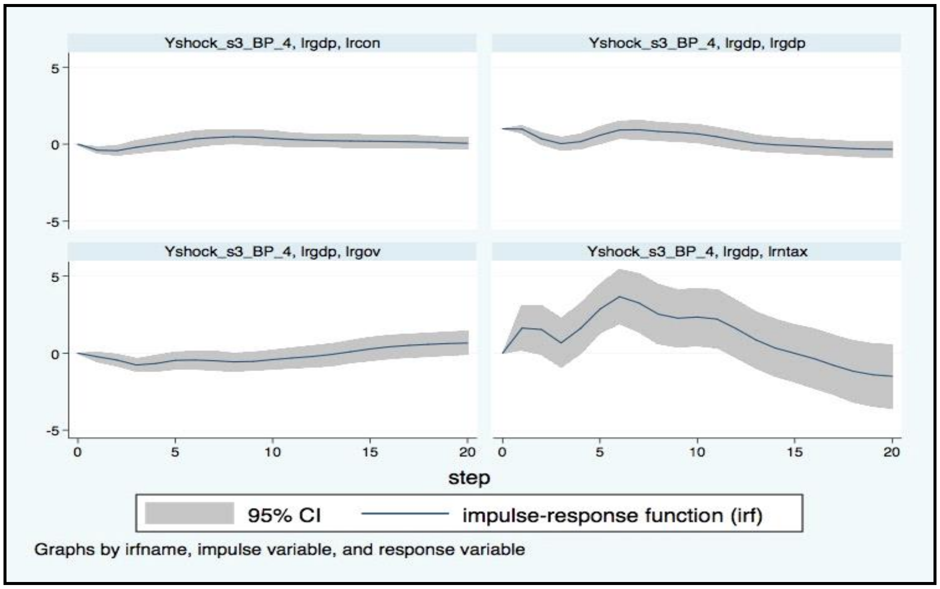

FIGURE 2.6 Orthogonalized impulse responses to a positive non-fiscal shock (2002q1-2015q4)

They find this change to be mainly driven by increased responsiveness of discretionary policies to the cycle. Counter cyclical fiscal policy most often refers to the conduct of fiscal policy that functions to stabilize business cycles, for instance higher taxes and lower government spending during good times. Evaluating the response of government spending across all samples to a temporary positive shock to output implies that the behaviour of government spending can be described as counter-cyclical or a-cyclical, meaning that government spending has responded negatively to the cycle during most periods in Canadian history. The behaviour of government expenditures from the VAR analysis is consistent with the empirical findings in Galí and Perotti (2003), Égert (2010), and Fatàs and Mihov (2012), all of which find evidence of government spending being a-cyclical, slightly countercyclical or countercyclical in OECD countries.

The response of net tax revenues to a temporary non-fiscal shock is qualitatively similar across the different sample periods used to estimate the VAR model. In all subsamples, we find evidence of tax revenues increasing in response to the non-fiscal shock. This result is not surprising as tax revenues are endogenous to the cycle to a great extent. In the first sample (1961q1-1979q4), net tax revenues display a hump shaped response, reaching a peak within a year after the shock and then remaining positive throughout its transition period. In the subsequent sample (1981q1-2001q4), net tax revenues also increase to a positive non-fiscal shock but the response is less persistent than the first sample. Again, when considering the most recent data sample (2002q1-2015q4) we observe an increase in the series, which displays a series of peaks throughout its transition path and falls below its steady state level three years after the shock.

Our results show that tax revenues in Canada have moved with business cycles, although how strongly they co-move depends on the time period being considered. Tax revenues have displayed the strongest response to movements in Canadian output in the recent decade (2002q1-2015q4) as shown in FIGURE 2.6.

Many other papers such as Lee and Sung (2007), Fatàs and Mihov (2012), and Reicher (2014) also find that tax revenues generally move with the cycle in Canada. In fact, Fatàs and Mihov (2012) find that the responsiveness automatic stabilizers in Canada have also increased post 1990, validating the findings from our estimated VAR. They also find tax revenues to be proportional to GDP and government spending to be stable in OECD countries. Together these factors contribute to a countercyclical government budget balance (tax revenues less government expenditures) that has the effect of stabilizing aggregate demand in these countries. The impulse response analysis of tax revenues to a temporary positive non-fiscal shock in this section can be partly explained by the presence of automatic stabilizers in the Canadian tax and transfer system. Automatic stabilizers refer to component of fiscal policy consisting of taxes and spending that change automatically due to the structure of the tax code or spending rules when output changes. Examples of automatic stabilizers include personal income tax deductions by employers that adjust with immediacy and employment insurance payments, which adjust with a bit of a lag.

To gain an understanding of the response of the non-cyclical component of tax revenues to the cycle, cyclically adjusted net tax revenues can replace the general net tax revenues variable in the VAR. However, an in depth analysis of tax revenues is outside the scope of this chapter and so we only provide evidence on a broad measure of net tax revenues. A recent strand of the fiscal policy literature (see for example Debrun and Kapoor (2010), Fatàs and Mihov (2012), Reicher (2014)) provides evidence for a cross section of OECD countries of large government size being correlated with lower volatility in GDP. This literature argues that government size is perhaps the best indicator of the strength of automatic stabilizers. As shown in Reicher (2014), the moderately large welfare state in Canada measured by a high rate of taxes and transfer payments (relative to the U.S, although smaller than European countries) is in line with the size of automatic stabilizers in the Canadian economy.

2.4.1.2 Impulse responses to a government spending shock

The response of output to a government spending shock on impact is negative in (1961q1-1979q4) and positive in the remaining samples. The impulse response analysis of the point estimates suggests that temporary increases in government spending have stimulated output in recent decades, both in the short run and in the medium run. Panel B of Table 2.1 summarizes the response of output in all subsamples at 4 and 12 quarters. The cumulative orthogonalized response of output is negative at 1 and 3 years after the shock only for the earlier sample (1961q1-1979q4). In the more recent decades, we find that the cumulative orthogonalized impulse response of output is moderately positive at 4 quarters, and significantly positive at 12 quarters.

TABLE 2.1 provides a breakdown of the orthogonalized impulse response and cumulative orthogonalized impulse response of private consumption, output, government spending, and net tax revenues to a temporary positive government spending shock at 4 and 12 quarters. A positive government spending shock is defined as a one standard deviation increase in, ε_t^G .

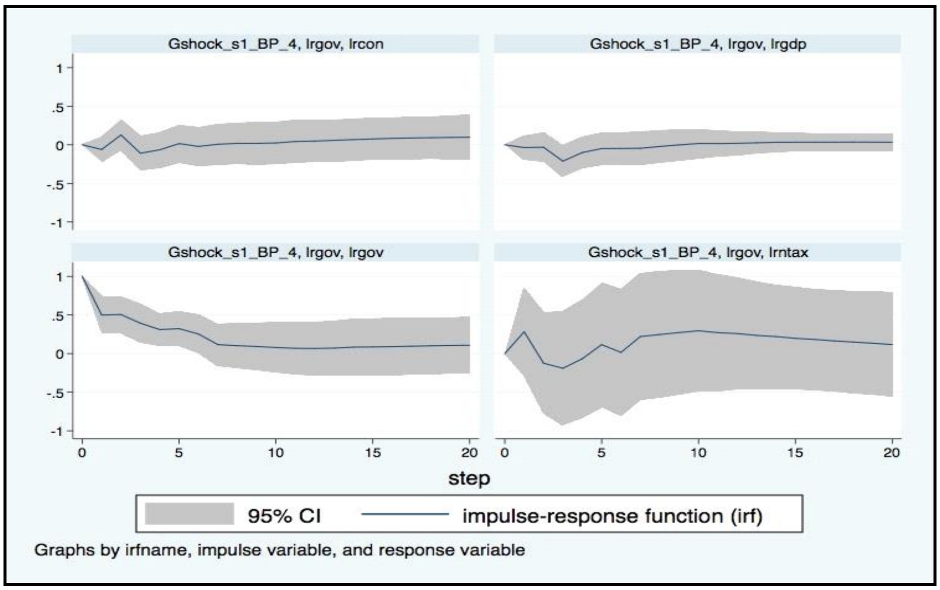

FIGURE 2.7 Orthogonalized impulse responses to a positive government spending shock (1961q1-1979q4)

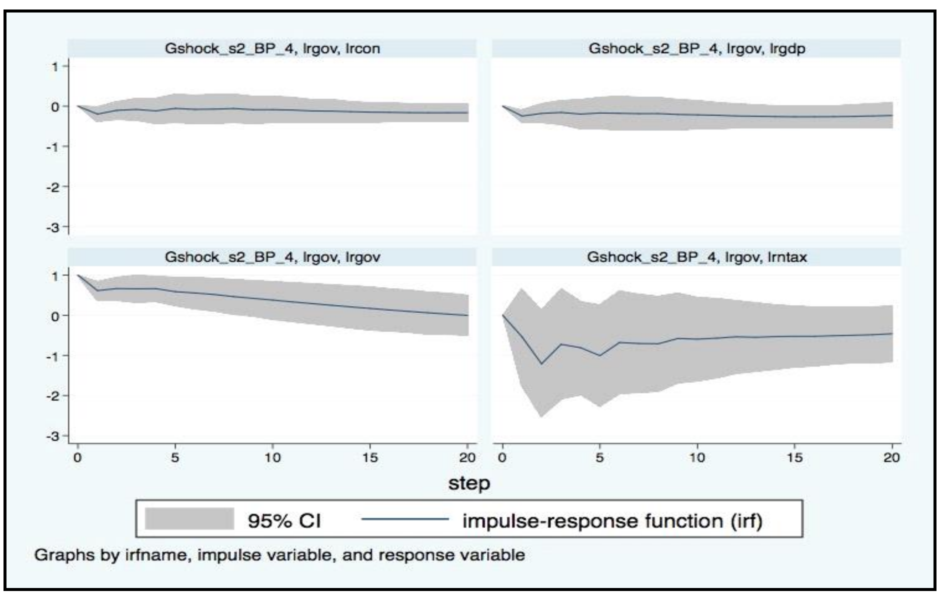

FIGURE 2.8 Orthogonalized impulse responses to a positive government spending shock (1980q1-2001q4)

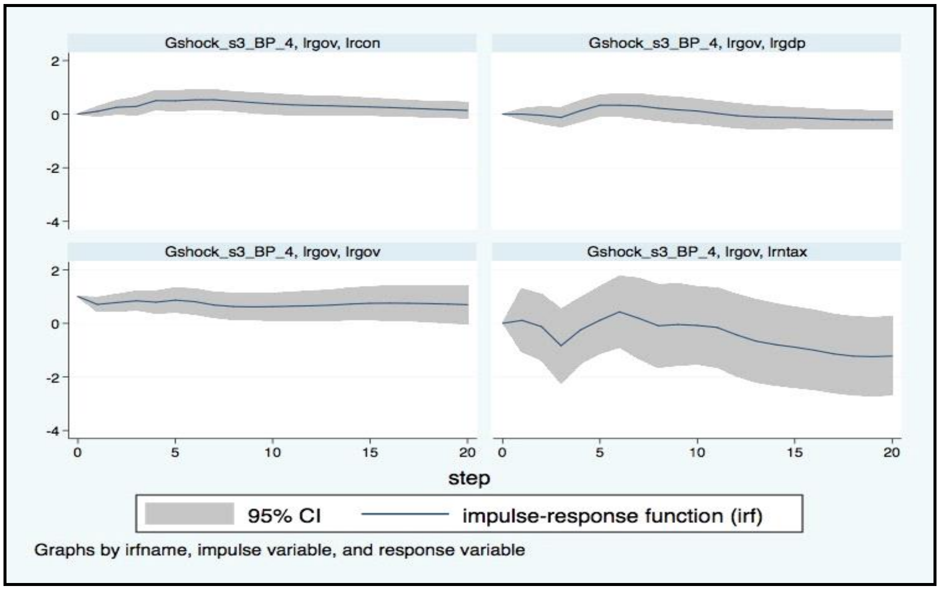

FIGURE 2.9 Orthogonalized impulse responses to a government spending shock (2002q1-2015q4)

We find that the response of private consumption to a temporary increase in government spending is negative in the earlier samples and positive in recent data based on the point estimates. When taking into account the wider confidence intervals on the impulse responses we still cannot reject a negative consumption response to a positive government spending shock. The impulse responses for private consumption show that the time path of this series differs qualitatively across the subsamples, but closely imitates the response of output, especially in later samples. In the (1961q1-1979q4) sample, private consumption declines upon impact of the government spending shock, then increases temporarily and displays a negative response thereafter. In the (1981q1-2001q4) sample, private consumption displays a negative response to the spending shock and declines throughout its transition path.

TABLE 2.1 shows that the cumulative orthogonalized impulse response of private consumption is negative at 4 and 12 quarters in the earlier two samples of data. It also shows that the negative response of private consumption is persistent over time during this period. We are able to find some support of the negative response of private consumption in our data sample consistent with the theoretical predictions of a crowding out effect driven by a negative wealth effect in neoclassical models when government expenditures increase unexpectedly.

An analysis of the effects of a positive government spending shock on private consumption from 1961q1 to 2001q4 would then suggest that neoclassical models do a good job in accounting for the observed empirical evidence for Canada. In the next chapter, we apply fiscal shocks to a medium scale neoclassical DSGE model and find that our model predicts a decrease in private consumption, when government spending rises unexpectedly and in a temporary manner. However, the impulse response for private consumption with respect to an increase in government spending in post 2001q4 data, suggests otherwise.

FIGURE 2.9 shows that the response of consumption to a government spending shock is positive during this period. The positive response of consumption lends supports to the predictions of New Keynesian models that predict a rise in private consumption in response to an increase in government spending. We use neoclassical models in the remaining chapters of this thesis.

The response of output to a government spending shock on impact is negative in (1961q1-1979q4) and positive in the remaining samples[34]. The impulse response analysis suggests that temporary increases in government spending have stimulated output in recent decades, both in the short run and in the medium run. Panel B of Table 2.1 summarizes the response of output in all subsamples at 4 and 12 quarters. The cumulative orthogonalized response of output is negative at 1 and 3 years after the shock only for the earlier sample (1961q1-1979q4). In the more recent decades, we find

[34] In the second sample the response of output is positive at 4 quarters but negative at 12 quarters.

that the cumulative orthogonalized impulse response of output is moderately positive at 4 quarters, and significantly positive at 12 quarters.

TABLE 2.1 Impulse responses to a government spending shock, Blanchard and Perotti (2002) approach.

	4 quarters	**12 quarters**
A. Private Consumption		
S1: OIRF	-0.29 (0.31)	-0.16 (0.20)
S1: COIRF	-0.58 (0.60)	-2.26 (2.27)
S2: OIRF	-0.057 (0.15)	0.00 (0.24)
S2: COIRF	-0.24 (0.48)	-0.35 (1.97)
S3: OIRF	0.26 (0.12)	0.22 (0.10)
S3: COIRF	0.77 (0.38)	2.76 (1.10)
B. Output		
S1:OIRF	-0.15 (0.23)	-0.04 (0.11)
S1: COIRF	-0.16 (0.25)	-1.09 (1.23)
S2: OIRF	0.01 (0.17)	-0.08 (0.25)
S2: COIRF	0.19 (0.51)	-0.25 (2.07)
S3: OIRF	0.11 (0.12)	0.10 (0.10)
S3: COIRF	0.14 (0.37)	1.39 (1.06)
C. Government Spending		
S1: OIRF	0.39 (0.11)	-0.15 (0.08)
S1: COIRF	2.70 (0.15)	3.17 (0.13)
S2: OIRF	0.71 (0.16)	0.31(0.26)
S2: COIRF	3.5 (0.52)	7.53(2.1)
S3: OIRF	0.28(0.10)	0.18(0.11)
S3: COIRF	1.72(0.32)	3.36(1.03)
D. Net Tax Revenues		
S1: OIRF	-0.06 (0.51)	0.26 (0.38)
S1: COIRF	1.07 (0.23)	1.43 (2.13)
S2: OIRF	-1.0 (0.48)	-0.74 (0.76)
S2: COIRF	-4.92(1.63)	-13.19 (5.91)
S3: OIRF	-0.31(0.33)	0.09(0.33)
S3: COIRF	-1.13(1.11)	-0.33(3.12)

Impulse response of consumption, output, government spending and net tax revenues to a positive one standard deviation government spending shock, at 4 and 12 quarters. Standard errors are in brackets.

TABLE 2.1 suggests that the stabilizing effect of government spending, measured as the extent to which increases in government spending increase GDP, has strengthened over time in Canadian history. In the following chapter, we apply a non-fiscal shock to our estimated theoretical small open economy model and similarly find a rise in aggregate output following a temporary government spending shock.

In the next section, we present the estimation of a VAR model identified using the Ramey and Shapiro (1998) approach. Our estimation findings using this alternative approach also yield a fall in private consumption following a temporary unanticipated government spending shock. These results imply that the negative response of private consumption following an unanticipated temporary positive government spending shock during most of Canadian history is a robust finding.

What then explains our opposing result found when applying the Blanchard and Perotti (2002) approach for recent Canadian data? One possible answer to why the Blanchard and Perotti (2002) approach finds a positive response of private consumption to a temporary positive government spending shock has been suggested in Ramey (2011). Ramey (2011) argues that the government spending shocks identified using the Blanchard and Perotti (2002) approach are anticipated a few quarters before they are assumed to occur in the VAR. For example, there are delays between when there is a decision made to increase government expenditures and when these expenditures actually occur. Ramey (2011) shows that the Ramey and Shapiro war dates Granger-cause the VAR shocks in the Blanchard and Perotti approach (2002) implying that the Blanchard and Perotti (2002) approach does not capture the timing of government expenditure shocks correctly. In fact, Ramey (2011) shows that estimating the VAR model when delaying the timing of each of the war dates by two quarters leads to a positive response of private consumption to a temporary positive increase in the government spending shock.

The opposite exercise in which the VAR is estimated using the Blanchard and Perotti (2002) methodology where future identified government spending shocks are taken into account is performed in Tenhofen and Wolff (2007). In this case a temporary positive government spending shock cause a decline in private consumption. This leads us to believe that the recent time period used in the VAR where we apply the Blanchard and Perotti (2002) approach may suffer from the theoretical argument in Ramey (2007). This criticism of the Blanchard and Perotti (2002) approach getting the timing of government spending shocks wrong can be a plausible explanation to why we find a rise in private consumption in response to a temporary positive government spending shock for one of three data samples.

The impulse responses of net tax revenues are markedly different in each subsample. In our first sample of data, tax revenues increase following a government spending shock, immediately reaching a peak and then declining for several quarters before rising again, but remaining positive throughout. In the second sample, tax revenues respond negatively. In recent data we find the response of tax revenues to be negative for several quarters after the shock and then positive for several quarters before returning to its steady state level. Panel D of Table 2.1.

The response of output to a government spending shock on impact is negative in (1961q1-1979q4) and positive in the remaining samples. The impulse response analysis suggests that temporary increases in government spending have stimulated output in recent decades, both in the short run and in the medium run. Panel B of Table 2.1 summarizes the response of output in all subsamples at 4 and 12 quarters. The cumulative orthogonalized response of output is negative at 1 and 3 years after the shock only for the earlier sample (1961q1-1979q4). In the more recent decades, we find that the cumulative orthogonalized impulse response of output is moderately positive at 4 quarters, and significantly positive at 12 quarters.

TABLE 2.1 highlights the differences in the response of net tax revenues across the three subsamples. The cumulative orthogonalized impulse response of net tax revenues is significantly positive at 1 and 3 years after the shock in (1961q1-1979q4), and significantly negative at both horizons during (1981q1-2001q4) and (2002q1-2015q4). These results suggest that the increase in government spending may have been financed via an increase in taxes during the 60s-70s but that increased taxes did not pay for higher government expenditures in recent Canadian history.

Additionally, a comparison of the cumulative orthogonalized impulse responses on net tax revenues in the later data reveals that tax revenues declined significantly more in response to a positive temporary government spending shock during (1981q1-2001q4), and that the cumulative negative response was strongest at 3 years after the shock. Tax revenues have generally declined during recent decades in Canada due to significant tax cuts implemented as part of tax reforms. During the first stage of the tax reforms (late 80s) personal income and corporate tax rates were reduced significantly. Further reductions in the personal income tax rate (2001 and 2006) and the corporate tax rate (2001-2004 and 2008-2013) were introduced as part of the second stage of the tax reform.

2.4.2 Ramey and Shapiro (1998) results

In this section we present the estimation results of the structural VAR model for Canada for the period 1947q1-1997q4 and use the Ramey and Shapiro (1998) war dates approach to identification. We then conduct impulse response analysis using the impulse responses to a non-fiscal and fiscal shock in the estimated VAR model. The fiscal shock in Ramey and Shapiro (1998) approach corresponds to an unanticipated positive war dates shock, used as a proxy for a government spending shock. Following the war dates shock the impulse responses of the endogenous variables are analyzed over their transition path. These responses are interpreted as the behaviour of the endogenous variables in response to temporary positive government spending shocks. Following Ramey (2011) we order the war dates variable first and allow the remaining variables to enter in the VAR in the same order as in the Blanchard and Perotti (2002) approach. All shocks are positive and correspond to one standard deviation in size. We find that the private consumption, government expenditures and net tax revenues all increase to an unanticipated temporary non-fiscal shock. With respect to the implied effects of an unanticipated temporary government spending shock, we find that the response of private consumption is negative, GDP has a small positive response and net tax revenues display a significantly positive response. These results validate the predictions of neoclassical models in terms of the effects of surprise temporary government spending shocks on macroeconomic variables of interest.

Impulse response to a non-fiscal shock FIGURE 2.10 shows the orthogonalized impulse responses of private consumption, GDP, government expenditures and net real tax revenues to a positive GDP shock. The positive non-fiscal shock is followed by a positive response of private consumption on impact. Private consumption displays considerable persistence in its response that can be explained by degree of persistence in the output shock itself. GDP also responds positively and in a non-persistent manner. Government expenditures do not react immediately after the shock, and instead take a few quarters before increasing in a hump shaped manner. Net tax revenues displays a hump shaped response and peaks one year after the shock. The impulse responses of the endogenous variables using the war dates approach are qualitatively similar to the impulse responses in the Blanchard and Perotti (2002) approach during the samples 1961q1-1979q4 and 1981q1-2001q4.

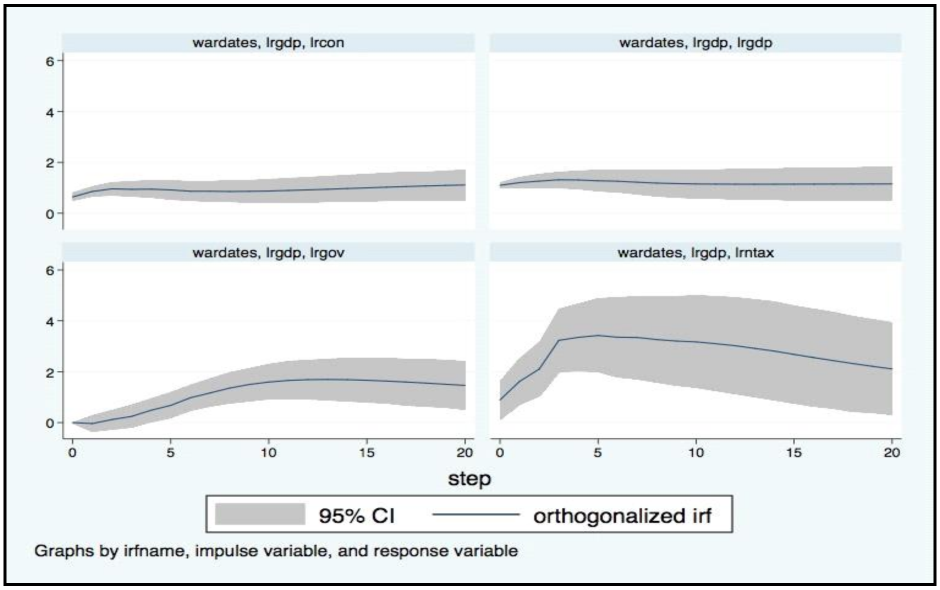

FIGURE 2.10 Impulse responses to a positive one standard deviation non-fiscal shock

Impulse response to a government spending shock FIGURE 2.11 displays the orthogonalized impulse responses of private consumption, GDP, government expenditures and net real tax revenues to a positive shock to the augmented Ramey and Shapiro (1998) war dates variable. TABLE 2.2 summarizes the corresponding orthogonalized and cumulative impulse responses of these variables at 4 and 12 quarters. FIGURE 2.11 suggests that government-spending shocks using the war dates identification approach decreases private consumption. Panel A of TABLE 2.2 shows that the cumulative response of private consumption at 4 quarters is -0.49 and that this response becomes more negative at 12 quarters (-0.77). The orthogonalized impulse of output suggests that government expenditure shocks do not substantially increase GDP but do lead to a significant positive response of net tax revenues. The negative response of private consumption is consistent with the findings for private consumption declining in response to government spending shocks for U.S data in Ramey and Shapiro (1998).

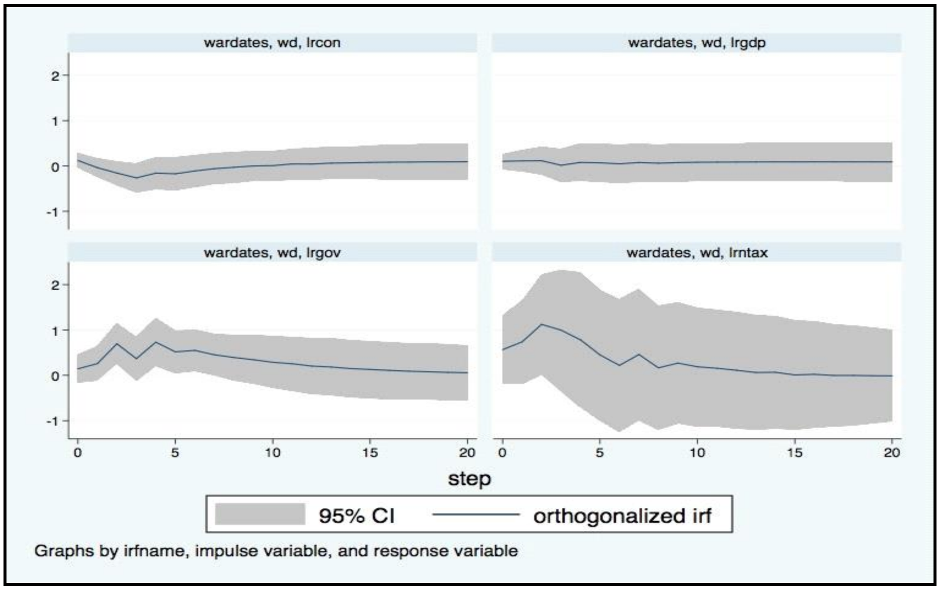

FIGURE 2.11 Impulse responses to a positive one standard deviation government spending shock

TABLE 2.2 Impulse responses to a government spending shock, Ramey and Shapiro (1998) approach.

	4 quarters	**12 quarters**
A. Private Consumption		
OIRF	-0.16 (0.18)	0.04 (0.17)
COIRF	-0.49 (0.57)	-0.77 (1.84)
B. Output		
OIRF	0.08 (0.20)	0.08 (0.21)
COIRF	0.42 (0.67)	1.00 (2.25)
C. Government Spending		
OIRF	0.73 (0.26)	0.20 (0.31)
COIRF	2.19 (0.89)	5.2 (2.57)
D. Net Tax Revenues		
OIRF	0.78 (0.75)	0.11(0.65)
COIRF	4.20 (2.3)	6.22 (7.15)

Impulse of consumption, output, government spending and net tax revenues to a positive one standard deviation government spending shock at 4 and 12 quarters. Standard errors are in brackets.

These set of results imply that real business cycle models correctly predict the effects of fiscal policy shocks and specifically generate the correct response of private consumption to a positive unanticipated government spending shock.

2.5 Discussion on the effects of government spending shocks in Canada

The impulse response analysis in the estimated VAR model identified using the Blanchard and Perotti (2002) and the Ramey and Shapiro (1998) methodologies convey several important insights. First, our subsample analysis shows that the effects of government spending shocks on the macro-economy have intensified over time. Given that both identification approaches support an increase of output following an unexpected positive temporary government spending shock, this implies that fiscal policy can be an effective tool in influencing aggregate output. Although we find a negative output response in (1961q1-1979q4), the more recent data sample supports a significantly positive output response in Canadian data. The different response of output between the earlier sample and the more recent samples can be explained by two factors. First, we find that the government spending process has become more persistent over time in Canada, but also the four period ahead forecast error variance of output has increased between (1961q1-1979q4) and (1981q1-2001q4). This represents an increase in the variance of output growth.

These results suggest that government stimulus makes sense in the context of a slow growth environment – one that Canada finds itself stuck in since the Great Recession in 2008. In fact, this empirical analysis lends some support to the current Liberal government's main policy response of investing $125 billion on infrastructure spending to boost economic growth in Canada. However, the proposed counter-cyclical government stimulus plans are deficit financed which means that they will lead to large deficits being incurred over the upcoming years. Even with the current low interest rate environment in Canada this raises concerns over the stock of federal debt and the pressure it will place on the debt to GDP ratio. In the next chapter we introduce a small open economy model that specifically focuses on numerical rules built around debt stability goals of a fiscal authority. Issues of budgetary balance and debt sustainability have been an important component of fiscal policy in Canada ever since debt to GDP ratios reached 67% during the mid-1990s[35].

Our analysis of the impulse responses for private consumption reveals that positive government-spending shocks decrease consumption when using both the Ramey and Shapiro (1998) war dates approach and the Blanchard and Perotti (2002) approach. The only exception being the recent sample (2002q1-2015q4) where application of the Blanchard and Perotti (2002) approach led to a rise of private consumption following a positive government spending shock. Perotti (2005) similarly found a negative response for private consumption in his analysis of Canadian data for the period 1980q1-2001q4. According to Perotti (2005) the relaxation of credit constraints in Canada over time make it more likely that a negative response of private consumption to government spending shocks is observed in more recent Canadian data. The Survey of Financial Security (SFS) reports that total debts among Canadians have increased from $586,095 million in 1995 to $1,337,001 million in 2012. The ratio of household debt to personal disposable income has also increased at a fast rate; recorded at 66% in 1980 it has now reached 165.4% in 2016. As a result of heated housing markets in Toronto and Vancouver, federal legislation has implemented tighter mortgage regulations that came into effect in February 2016, requiring a down payment ratio of at least 10% for homes above $500,000. These factors taken together suggest a pronounced relaxation in credit constraints for Canada in recent times and support the results from our VAR analysis for 1961q1-2001q4 that show a negative consumption

[35] Statistics Canada, CANSIM Table 378-0125.

response to positive government spending shocks. In chapter four of this dissertation we theoretically model credit constraints. The credit constraints are introduced through the fraction of households that do not have access to financial markets. A decrease in this fraction of households over time represents lower credit constraints. Using an estimate of 0.25 for the fraction of credit constrained households in the total Canadian population, which is considered to be small in the literature, we find that private consumption falls in response to temporary increases in government spending. Thus our theoretical model predictions validate the findings of our VAR analysis corresponding to a large sample (1961q1-2001q4) of Canadian data.

Understanding the effects of government spending shocks in Canadian data also plays an important role in helping macroeconomists distinguish between theoretical models. The analysis of fiscal and non-fiscal shocks using the two competing identification methodologies in the literature suggests that a neoclassical model is best suited for a fiscal analysis in Canada. Recall that in the standard neoclassical model, a temporary increase in government spending creates a negative wealth effect for the representative household. The utility maximizing household responds by increasing its labour supply and correspondingly decreasing its consumption. The increase in labour supply drives a positive response in aggregate output to the government spending shock. The impulse responses from our estimated VAR model also generate a positive output and negative private consumption response when both identification methodologies are applied to Canadian data.

We find mixed results with respect to the response of net tax revenues to positive government spending shocks depending on the identification approach. When the Blanchard and Perotti (2002) approach is used to identify the fiscal shocks in the VAR we find a positive net tax revenues response in (1961q1-1979q4) and a negative response in later samples (1981q1-

2015q4). Perotti (2005) also found a positive response for the effects of government spending shocks on net tax revenues in earlier Canadian data (1961q1-1979q4) and a negative response in later data (1980q1-2001q4). On the other hand, when using the Ramey and Shapiro (1998) approach net tax revenues increase when government spending increases unexpectedly. These differences are not easily discernible and require further empirical investigation that is beyond the scope of this chapter.

2.6 Conclusion

This chapter investigates the effects of temporary unanticipated output and government spending shocks on the Canadian economy, by exploring the debate between the Blanchard and Perotti (2002) and the Ramey and Shapiro (1998) approach to identifying government spending shocks. We estimate a structural VAR model using both approaches and focus our analysis on the effects of a positive unanticipated government spending shock on private consumption. These approaches have found dramatically different responses in consumption using U.S data, which in turn makes it difficult to choose a theoretical macroeconomic model that can explain these observed responses. We conduct this empirical investigation to determine if the behaviour of private consumption displays similar variability in Canadian data when different identification approaches are consulted. As the first step in our research agenda we document the empirical behaviour of macroeconomic variables to government spending shocks in Canada. We analyze the response of consumption (positive or negative) on impact to a positive government spending shock to help us distinguish between the neoclassical model and the new Keynesian model for our remaining research chapters.

Our analysis traces out the dynamic response of GDP and its components to a positive output shock and government spending shock across the Blanchard and Perotti (2002) and the Ramey and Shapiro (1998) approaches to yield several findings. Our findings are as follows: (1) a positive output shock (non-fiscal shock) causes a rise in consumption and net tax revenues in both approaches, whereas the response of government expenditures varied across the two identification approaches, (2) a positive government spending shock (fiscal shock) is followed by an increase in output, a decrease in private consumption, and the response of net tax revenues depends on the approach used to identify fiscal shocks, (3) conducting subsample analysis shows that the effects of government spending shocks have become stronger in Canadian data over time, (4) the opposing response of private consumption to a positive government spending shock is not an artefact of Canadian data – both the Blanchard and Perotti (2002) approach and the Ramey and Shapiro (1998) approach support a decline in consumption, (5) the crowding out effects of government spending shocks on private consumption can be accounted for by the predictions of the neoclassical model. With these results in hand, we can develop a theoretical DGSE model of the neoclassical flavour to evaluate the effects of systematic fiscal policy in the next chapter. The focus of the next chapter is to develop fiscal rules, in which various fiscal aggregates automatically adjust to changes in the output gap and the debt gap and to compare these rules to historical Canadian data. Given that these fiscal rules are typically nested in theoretical macroeconomic models and estimated to provide evidence on the behaviour of fiscal variables, it is important that the model is able to account for what is observed in the data.

3 Evidence of fiscal rules for Canada using a Bayesian Approach

3.1 Introduction

The financial crisis of 2008- 2009 has led to a global economic environment characterized by fiscal pressures that have led to the deterioration of public finances. According to OECD reports budgetary deficits reached a magnitude of 7.9% of GDP in the OECD group of countries during 2009. Prolonged deficits have led to rising public debt levels among G7 countries, with net debt to GDP ratios reaching unprecedented levels. In 2010, the net debt to GDP levels for the respective countries were as follows; Japan 121 %, Italy 99%, France 74 %, United Kingdom 69%, United States 66%, Germany 59% and Canada 32%. In the years to follow, net debt to GDP has unilaterally increased for all G7 countries and is currently higher than in 2008-2009 in all G7 countries with the exception of Germany. Although Canada appears to be in a better debt position relative to its G7 counterparts, the deterioration in public finances across all levels of government are sizable. A recent warning from the Parliamentary Budget Officer indicates that total subnational (provincial, territorial and municipal levels of government) net debt to GDP can reach levels in excess of 200 percent in the next 75 years unless fiscal adjustments take place (Frechette (2016)). The rising fiscal pressures can be partly attributed to an aging labour force creating a challenge for the government as net tax revenues fall and old age related government expenditures rise.

The IMF and the OECD[36] have strongly encouraged the use of fiscal rules as a first step in planning for a fiscal balance and sustainability in the medium and long term. The IMF fiscal database[37] maps the rise in fiscal rules internationally over the past two decades. Specifically, the database reports tremendous growth (from five in 1990 to 76 in 2012) in the use of fiscal rules during the entire period among advanced, emerging and low-income countries. Tapp (2010) draws on the Parliamentary Budget Office's Canadian fiscal rules database to show that over the last two decades' Canadian jurisdictions have also increasingly adopted fiscal targets and legally binding fiscal rules in their budgetary framework. Most of the fiscal rules at the federal and provincial levels came into effect during the mid-1990s. For example, at the federal level of government a legislated spending rule came into effect in 1991 followed by reoccurring balanced budget targets starting in 1994. Provincially, Alberta adopted a diverse set of rules that included a spending rule (1992), a balanced budget rule (1993), a revenue rule (1995) and a debt rule (1995)[38].

A key recommendation emerges in Tapp (2010) from the review of consolidation strategies across the G7, that call for the improvement of Canadian budget planning practices through measures that include well-designed fiscal rules or targets. The need for Canada to develop a credible fiscal plan was also echoed by international organizations such as the IMF and the OECD advocating for legislated fiscal targets to "provide clear yardsticks for accountability and transparency". The OECD Economic Review in 2010 states *"fiscal rules can be useful tools in*

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[36] OECD (2011), "Fiscal consolidation: targets, plans and measures", OECD Journal on Budgeting, Vol. 11/2. http://dx.doi.org/10.1787/budget-11-5kg869h4w5f6
[37] Bova, Kinda, Muthoora and Toscani (2015) and Budina, Kinda, Schaechter and Weber (2012).
[38] Tapp (2010).

achieving budgetary consolidation, but also as part of the general fiscal framework to limit deficit bias and counteract the tendency shown by some Canadian governments over the past two decades to run pro-cyclical fiscal policies". Along with a call for fiscal rules, the OECD also recommended fiscal targets (non-legislated budgetary commitments) that included spending growth limits, deficit and debt to GDP targets. An example of a fiscal target is the pre-recession federal debt to GDP target of 25%.

In 2015 the political leadership in Canada changed from a Conservative government to a Liberal government. A key part of the new fiscal authority's mandate includes implementing activist government policies in an environment of slow economic growth[39] and historically low interest rates. The government has taken an expansionary fiscal stance by budgeting $125 billion in infrastructure spending over the next ten years to support economic growth. While the decision to make significant increases in government investment arose due to the confluence of factors such as a low net debt to GDP ratio (relative to other G7 countries) and low public debt charges due to a low interest rate environment, the required fiscal adjustment may occur when economic factors are not so favourable. The increase in government expenditures will be mostly deficit financed and require a future budgetary adjustment in tax revenues or spending to stabilize the public debt. The 2016 federal budget projections show budget deficits as high as $29 billion (32.5 % of GDP) every year till 2020-21, the accumulation of which will lead to an increase in future public debt levels.

[39] In Canada growth in real GDP has not returned to its pre-recession level, with growth under 1 % in 2015. Global growth is also weak, with GDP growth in Europe at 1.5%, 6.9% in China (slowest in 25 years) and 2.4% in the U.S. Budget (2015).

Several economic factors in coming years will intensify the fiscal burden and make consolidation planning[40] even more difficult. These factors consist of weak global economic growth, an aging labour force and a future rise in interest rates. Demographic changes in the form of population aging will affect both government outlays and tax revenues in the next decade. The Parliamentary Budget Office predicts slower labour force growth at 0.1 % annually during the 2020's, which will hinder economic growth and depress tax revenues. On the spending side, a significantly larger proportion of the population aging will result in a spike in demand for age related expenditures such as health care and transfer payments such as old age benefits. Additionally with interest rates near zero, there is not much room to go lower,[41] and interest rates will rise as part of the normalization process with gains in economic growth. How will the necessary adjustments in budgetary aggregates take place in this context to stabilize the public debt?

As proposed by international organizations as well the PBO, a credible fiscal plan will include a fiscal rule that will serve to restrain budgetary aggregates to achieve set objectives. For instance, budgetary aggregates can include revenues, various government spending categories (program spending or defense spending) and specific tax rates. As an example, a spending fiscal rule places a limit on the growth of government spending as a percent of GDP to help the government achieve a target budget surplus. Equally important is the clear identification of policy tools and the quantification of required adjustments between spending and revenue tools to stabilize debt

[40] Consolidation planning refers to strategies designed to reduce government deficits and public debt accumulation.
[41] In January 2017 the Central Bank of Canada announced that it will maintain its overnight rate target at 0.5%. This decision marks twelve consecutive holds at this rate since 2015.

levels. The Canadian fiscal authority has to not only balance short-term policy objectives in their fiscal framework, but also prioritize longer-term goals to ensure debt sustainability. In this chapter we estimate simple numerical “debt rules” for Canada using Bayesian estimation techniques. These debt rules use federal budgetary aggregates (government spending, transfer payments, capital tax rate, labour tax rate and consumption tax rate) as policy instruments that automatically adjust to changes in the business cycle and to public debt levels. We use a dataset for the period 1961q1 to 2015q4 to analyze the systematic behaviour of expenditure and taxation tools in Canada and report on the elasticity of these policy instruments with respect to the cycle and the stock of federal public debt. Our findings reveal government spending and lump sum transfers have responded significantly more to changes in debt levels during this period compared to tax rates.

Tapp (2010) also shows that federal and provincial governments in Canada have almost entirely relied on spending restraint during fiscal consolidation episodes. This seems to suggest that Canada’s debt management strategy for the past several decades has highlighted the systematic adjustment of government expenditures in response to high public debt levels. Our estimated tax rate policy rules show that tax rates have shown considerable responsiveness to business cycle movements but have not adjusted meaningfully to stabilize debt levels. Our findings fill a void by modelling simple debt rules and providing empirical evidence on the systematic behaviour of government spending and transfer payments as tools to stabilize debt and achieve long term fiscal objectives. Our results make an additional contribution by providing estimates for the size of adjustments in these policy instruments.

The rest of this chapter is organized as follows; section 3.2 outlines the related literature on the estimation of fiscal rules in macroeconomic models, section 3.3 introduces our small open economy model, section 3.4 defines a competitive equilibrium, section 3.5 discusses the Bayesian estimation methodology, section 3.6 reports our estimation results and section 3.7 offers concluding remarks.

3.2 Survey of systematic fiscal policy literature

The movement towards discretionary fiscal tightening in the form of spending cuts and, in some cases, tax increases has led to a renewed interest in the literature[42] on fiscal adjustments. While the fiscal policy literature assigns many different definitions to the term "fiscal adjustment", two widely accepted definitions have emerged. The first definition of a fiscal adjustment is an improvement in the cyclically adjusted primary balance (CAPB)[43] to GDP ratio, whereas the second definition regards a fiscal adjustment to be an improvement in the central government's debt to GDP ratio[44]. While the body of academic literature focusing on fiscal adjustments is vast, two branches are relevant for the purpose of this thesis and require further discussion.

The first branch of literature focuses on the costs associated with large episodes of fiscal adjustments or consolidation across OECD countries (see for example, Devries, Guajardo, Leigh, and Pescatori (2011), Weo (2010), Favero and Giavazzi (2012), Alesina, Favero and Giavazzi (2015), Alesina and Ardagna (2013)). The key finding coming out of this literature is that spending focused fiscal adjustments are less contractionary and more effective at achieving debt

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[42] Alesina and Ardagna (2010), Blanchard and Cottarelli (2010), Leeper, Walker and Yang (2010), Favero and Giavazzi (2012), Alesina and Ardagna (2013), Yang, Fidmuc and Ghosh (2015), Alesina, Favero and Giavazzi (2015).

[43] The cyclically adjusted primary balance is defined as the primary balance (the difference between current and capital spending minus interest payments on government debt and total tax revenue) being adjusted for cyclical changes.

[44] See Alesina and Ardagna (2013) for a full discussion on the definitions and design of fiscal adjustments.

stability as opposed to tax-focused adjustments.[45] Additionally, Alesina and Perotti (1996), Guichard, Kennedy, Wurzel and André (2007), Alesina and Ardagna (2009), provide evidence of spending based fiscal adjustments leading to larger improvements in public finances and having expansionary effects on the economy in the short run.

This literature highlights the importance of the composition of fiscal adjustments, suggesting that some policy instruments are more successful than others at correcting budgetary imbalances. Spending adjustments have more favourable implications because they work well with accommodative monetary policy, whereas this is not necessarily the case for tax rate increases. In the case of spending restraint, lower interest rates reduce public debt charges and boost net exports through a lower dollar. On the other hand, increasing tax rates have a negative wealth effect and reduce private consumption and investment.

Tapp (2010) analyzes federal and provincial budget data from 1980 to 2010 to report on the composition of fiscal consolidations in Canada. He uses two methodologies to report on the behaviour of government spending compared to that of tax revenues during this period. In the first methodology, he identifies twelve[46] episodes of improvements in the national budget balance (1 federal and 11 provincial) with the criteria that they span two years and represent an improvement in the CAPB of at least 3 percentage points of potential GDP. His analysis shows that two thirds of these consolidation episodes were characterized by spending reductions, and

[45] Alesina and Ardagna (2010) identify 107 periods of successful fiscal adjustment defined as leading to higher growth, of which 70% are associated with spending cuts.

[46] Newfoundland (2004-05), Newfoundland (1994-96), Saskatchewan (1993-94), Nova Scotia (1993-96), Federal (1995-98), Prince Edward Island (2003-05), Alberta (1987-88), Ontario (1993-96), Alberta (1993-94), Manitoba (1986-88), Manitoba (1993-95), Quebec (1995-99).

half of them featured a fiscal rule. For example, in Saskatchewan a balanced budget rule and a debt rule was adopted in 1995, in Nova Scotia a spending rule was implemented in 1993, and three years later a debt rule, in Ontario a balanced budget rules emerged in 1999, Alberta used the widest selection of rules which included a spending rule in 1992, a balanced budget rule in 1993,a revenue and debt rule in 1999, in 1995 Manitoba adopted a balanced budget rule, a revenue rule and a debt rule, and Quebec phased in a balanced budget rule in 1996. Interestingly, Tapp (2010) found that contrary to Canadian experiences of fiscal consolidations; international consolidation efforts mainly relied on revenue increases. The second methodology identifies eight debt reduction episodes that represented a decline in the debt to GDP ratio of at least 10 percentage points. His investigation shows that fiscal rules (spending, revenue, balanced budget and debt) and targets were heavily implemented during six of these episodes but no evidence is provided on the composition of spending versus revenue adjustments.

The second branch of the fiscal adjustment literature focuses on estimating numerical fiscal rules using a historical perspective as opposed to analyzing specific periods of fiscal adjustments. This literature started with Auberbach (2002) and Taylor (2000), reporting empirical evidence that fiscal policy displays a contemporaneous reaction to the state of the economy. In fact, Taylor (2000) extended earlier work that featured a nominal interest rate-targeting rule in a monetary framework. Similar to the interest rate rule specification in which the short-term nominal interest rate responds to an output gap and inflation gap, Taylor (2000) proposed a fiscal rule where the fiscal budget surplus responds to the output gap. His finding relegates the use of fiscal rules to be limited in the presence of monetary rules and recommend that the role of fiscal policy be constrained to allow automatic stabilizers to function and provide economic stability. The analysis of the stabilizing role of fiscal policy in Taylor (2000) did however recognize that a fixed exchange rate system or an environment of near zero nominal interest rates creates a greater role for rules based fiscal policy.

These findings have led to a growing body of literature (see for example Forni, Monteforte and Sessa (2009), Leeper, Plante and Traum (2010), Traum and Yang (2011), Fatàs and Mihov (2012), Kumhof and Laxton (2013), Bouakez, Chihi and Normandin (2014), Kliem and Kriwoluzky (2014)) on the estimation of DSGE models with simple linear fiscal rules. The standard specification of fiscal rules in the literature allows fiscal variables (such as taxes, spending, primary balance, or the CAPB) to react to output and debt gaps. Most empirical work on the estimation of fiscal rules has primarily focused on determining estimates of the reaction coefficients on the fiscal rules and evaluating their impact for the United States and countries in Europe. Leeper, Plante and Traum (2010) find that increases in capital taxes have played an important role alongside reductions in government spending and transfer payments as fiscal adjustment tools for the U.S. These findings suggest that distortionary taxes such as capital and labour taxes are an important debt reduction policy tool. Forni, Monteforte and Sessa (2009) provide contrasting evidence for the Euro area, reporting insignificant estimates on feedback coefficients for taxes. The literature offers no empirical evidence on the use of numerical fiscal rules for Canada. Dorich, Mendes, Murchison and Zhang (2013) specify a fiscal rule for labor taxes to achieve a target debt to GDP ratio; however, the labour tax rule in their model is calibrated. The estimation of Canadian fiscal rules has been largely ignored in the literature. Thus, our findings contribute to the literature by providing robust estimates about the composition of fiscal adjustments in Canada.

3.3 The small open economy model

The small open economy model consists of three agents: a representative household, a perfectly competitive firm and a fiscal authority (government). Our model features numerous frictions such as external habit formation in consumption, capacity utilization costs, and investment adjustment costs; as well as nine transitory shocks. The rich structure of shocks is common in the literature on the estimation of DSGE models as they are important for the fluctuations in the endogenous macroeconomic variables, allowing for a better understanding of the dynamics in the data and a better understanding of the effects of fiscal policy.[47] The open economy setting permits access to international financial markets, as savers in the rest of the world can provide a supply of funds to the fiscal authority. This introduces external public debt to an otherwise standard closed economy real business cycle (RBC) framework. The interest rate in the small open economy is an increasing function of this level of external public debt. High levels of external debt translate into a higher country specific risk premium paid by the government. We do not consider productive government spending in the utility function or production function. Other studies have shown that when productive government spending is considered as a fiscal instrument it has the potential to provide the most built in stability relative to other instruments. This finding does not change our results in any way, in fact in reinforces one of our key findings.

[47] See for example, Smets and Wouters (2004, 2007), Christiano, Eichenbaum and Evans (2001), Leeper, Plante and Traum. (2010), King and Rebelo (2000).

3.3.1 Households

The representative household maximizes the following inter-temporal utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t u_t^b \left[\frac{\left(c_t - hC_{t-1}\right)^{1-\gamma}}{1-\gamma} - u_t^l \frac{l_t^{1+\kappa}}{1+\kappa} \right] \tag{3.1}$$

$$\gamma, \kappa \geq 0$$

The representative household's utility depends on consumption of a single good, c_t , relative to habit stock, given by, hC_{t-1} , where, $h \in (0,1)$, and is the habit parameter and labour is given by, l_t. We denote, E_0 , as the expectations operator at time zero, $\beta \in (0,1)$, is the subjective discount factor, γ , is the risk aversion parameter and, κ , is the inverse of the Frisch labour supply elasticity which measures the change in labour supply when the wage rate changes holding consumption constant, u_t^b , is a general preference shock, and, u_t^l , is a labour specific shock. In what follows in this chapter, X_t , denotes the aggregate level of any variable, x_t .

Following the estimation literature on medium scale DSGE models (see for example, Christiano, Eichenbaum and Evans (2005), Smets and Wouters (2004, 2007)) the model features external habit consumption, where the stock of habits depend on aggregate past consumption in the economy. Lettau and Uhlig (2000) provide evidence of the inclusion of habits in a closed economy setting being able to induce smoothness in the response of consumption to various policy shocks consistent with observed behaviour at business cycle frequencies. Letendre (2004) shows that the inclusion of habits in consumption improves the fit of a real business cycle small open economy model to Canadian data. Specifically, habit persistence brings the moments of consumption in the small open economy model closer to consumption moments in Canadian data by improving the properties of consumption and the current account.

The existing literature on the estimation of DSGE models (see for example, Smets and Wouters (2007), Justiniano, Primiceri, Tambalotti (2008), Schmitt-Grohé and Uribe (2008), Leeper, Plante and Traum (2010)) has shown the inclusion of a general preference shock to be a key mechanism in generating consumption fluctuations. The general preference shock affects the marginal utility of consumption as well as the marginal disutility of labour and has been found to help explain the co-movement of consumption and investment (Smets and Wouters (2007)). Both shocks are assumed to follow an AR (1) process:

$$\ln(u_t^b) = \rho^b \ln(u_{t-1}^b) + \varepsilon_t^b \quad \varepsilon_t^b \sim N\left(0,1\right) \tag{3.2}$$

$$\ln(u_t^l) = \rho^l \ln(u_{t-1}^l) + \varepsilon_t^l \quad \varepsilon_t^i \sim N\left(0,1\right) \tag{3.3}$$

where coefficients , $\left\{\rho^b, \rho^i\right\}$, capture persistence and the error terms are normally distributed with mean zero and variance of one.

Households face the following budget constraint:

$$(1+\tau_t^c)c_t + i_t + b_t^h = (1-\tau_t^l)w_t l_t + (1-\tau_t^k)R_t^k v_t k_{t-1} + R_{t-1}b_{t-1}^h + z_t \tag{3.4}$$

where , τ_t^c , is the consumption tax rate, i_t , is investment, b_t^h , is holdings of one period risk free home country government bonds, τ_t^l , is the labour tax rate, w_t , is the wage rate, τ_t^k , is the capital tax rate, R_t^k , is the return on capital, v_t , is capital intensity, k_t , is capital, R_{t-1} , is the return on domestic government bonds, and, z_t , is lump sum transfers payments to households by the fiscal authority. We assume that the representative household in the small open economy only has access to domestic markets and thus cannot buy bonds on world capital markets. This assumption is made to restrict attention on the effect of foreign capital markets on the dynamics of public debt. Since foreign assets/debt make up a small portion of household's portfolios, allowing the representative household to access foreign financial markets will not make much of a difference to our results. The household's total income consists of labour income, capital income, income from holding one period risk free government bonds and income from lump sum transfers by the government. Labour income is given by the after tax return on the amount of labour supplied by households in a given period, $\left(1-\tau_t^l\right) w_t l_t$. Capital income is given by the after tax return on the amount of capital services supplied to firms, $R_t^k v_t k_{t-1}$. The inclusion of capital utilization in closed economy models has been proven to reduce the variance of the innovation in technology shocks so that the volatility of output in RBC models match its empirical counterpart.[48] Additionally, Letendre (2004) shows that endogenous capital utilization improves the fit of a standard RBC model to Canadian data by increasing the volatility of output, investment and hours.

Interest on government bonds at the beginning of the period is given by, $R_{t-1} b_{t-1}^h$, where the interest rate, R_t , is given by the sum of the world interest rate, R^w , and, $p\left(B_t^f\right)$, a country specific interest rate premium where, B_t^f , is the level of foreign public debt.

$$R_t = R^w + p\left(B_t^f\right) \tag{3.5}$$

The premium over the world rate is given by, $p\left(B_t^f\right)$, and is assumed to be strictly increasing in

48 See for example Burnside, Eichenbaum and Rebelo (1993), King and Rebelo (1999) and Burnside and Eichenbaum (1996).

the level of external debt. The specification for the risk premium is adopted from Schmitt-Grohé and Uribe (2003) to circumvent the problem of a unit root in debt accumulation in the small open economy framework.[49]

The functional form used for the country specific interest rate premium is given by

$$p\left(B_t^f\right)=\psi_2\left(e^{B_t^f-\tilde{B}^f}-1\right) \tag{3.6}$$

where, ψ_2 , and, $\tilde{B}^f$, are constant parameters and, $\tilde{B}^f$, represents the steady state level of aggregate per capita foreign public debt.

The stock of capital evolves according to

$$k_t=\left[1-\delta(v_t)\right]k_{t-1}+\Gamma\left(u_t^i i_t, i_{t-1}\right) \tag{3.7}$$

where $\Gamma\left(u_t^i i_t, i_{t-1}\right)$, represents investment adjustment costs and is included in the model to avoid excessive investment volatility that persists when there are changes in the domestic-foreign interest rate differential.

The adjustment cost function is similar to that found in Christiano and Eichenbaum (2005), and is given by:

$$\Gamma\left(u_t^i, i_{t-1}\right)=\zeta\left\{\left(1-\frac{\chi}{2}\left(\frac{u_t^i i_t}{i_{t-1}}-1\right)^2\right)i_t\right\} \tag{3.8}$$

[49] Schmitt-Grohé and Uribe (2003) use a debt elastic interest rate or interest rate premium to determine the steady state net foreign asset position only in terms of the parameters of the model to eliminate the unit root in foreign debt.

where $\zeta = 1$, $\chi \geq 0$. Investment adjustment costs are often used in international macroeconomic models (see for example Wouters (2003) and Christiano, Eichenbaum and Evans, (2005)) and are assumed to satisfy the following conditions: $\Gamma(1) = \Gamma'(1) = 0$ and $\Gamma''(1) > 0$. These properties of the function ensure that investment adjustment costs are zero in the non-stochastic steady state. The adjustment cost is subject to an investment specific shock, u_t^i , included to capture exogenous variations in the level of productivity when investment is transformed into physical capital. Evidence from the RBC literature suggests that investment specific shocks are empirically important as it brings investment dynamics closer to the data.[50]

The investment specific shock is given by the AR (1) process:

$$\ln\left(u_t^i\right) = \rho^i \ln\left(u_{t-1}^i\right) + \varepsilon_t^i \quad \varepsilon_t^i \sim N\left(0,1\right) \tag{3.9}$$

where, ρ^i , captures the persistence of the shock to the error term of the investment process given by, ε_t^i .

Households have control over how intensively capital is used in the production process and they decide capital utilization, v_t . A higher capital intensity translates into a higher level of depreciation of the capital stock. As in Leeper, Plante and Traum (2010) and Schmitt-Grohé and Uribe (2008) the model includes an endogenous rate of depreciation given by the following quadratic function:

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[50] See Fisher (2003, 2006) and Letendr (2004).

$$\delta(v_t) = \delta_0 + \delta_1(v_t - 1) + \frac{\delta_2}{2}(v_t - 1)^2 \quad (3.10)$$

where, $\delta_0, \delta_1, \delta_2 > 0$. The parameter, δ_0 , represents the depreciation rate of the capital stock in steady state when the utilization rate takes the value of one. The parameter, δ_1 , governs the steady state level of the utilization rate and is set to a value that is consistent with the steady state of, v_t , at unity. Finally, the parameter, v_t , reflects the sensitivity of the capital utilization to changes in the rental rate of capital , r_t^k . An increase in the return to capital increases the intensity with which capital is used in the production process, δ_2 , captures the magnitude of this change. The representative household chooses the following processes, $\{c_t, l_t, k_{t+1}, b_t^h, v_t\}_{t=0}^{\infty}$, to maximize the utility function in (3.1) subject to (3.2) - (3.10).

3.3.2 Firms

The representative firm rents labour, l_t , and capital, k_{t-1} , from the representative household as inputs for production. The firm maximizes profits, which are given by:

$$\pi(k_t, l_t) = u_t^a (v_t k_{t-1})^{\alpha} l_t^{1-\alpha} - w_t l_t - R_t^k v_t k_{t-1} \quad (3.11)$$

where, $\alpha \in (0,1)$, and denotes capital's share of income, u_t^a , is a neutral technology shock following an AR (1) process:

$$\ln(u_t^a) = \rho^a \ln(u_{t-1}^a) + \varepsilon_t^a \qquad \varepsilon_t^a \sim N(0,1) \quad (3.12)$$

where, ρ^a , is the persistence parameter for the technology shock and, ε_t^a , is the error term of the technology process. Total output in period *t*, is given by a Cobb-Douglas production function, where capital, k_t , and labour, l_t , serve as inputs and, u_t^a , is the labour productivity shock.

$$y_t = u_t^a \left(v_t k_{t-1}\right)^{\alpha} l_t^{1-\alpha}$$

The first order condition of the firm's maximization problem yields the following rental rates for labour and capital services:

$$w_t = \frac{(1-\alpha)y_t}{l_t} \tag{3.13}$$

$$R_t^k v_t = \frac{\alpha y_t}{k_{t-1}} \tag{3.14}$$

3.3.3 Fiscal Authority

The fiscal authority faces the following budget constraint:

$$B_t + \tau_t^k R_t^k v_t K_{t-1} + \tau_t^l W_t L_t + \tau_t^c C_t = R_{t-1} B_{t-1} + G_t + Z_t \tag{3.15}$$

$$B_t = B_t^h + B_t^f \tag{3.16}$$

The fiscal authority has four sources of revenue: revenue from the sales of one period risk free government bonds to the domestic representative household, B_t^h , and one period risk free government bonds issued to the rest of the world, B_t^f , capital tax revenue, $\tau_t^k R_t^k v_t K_{t-1}$, labour tax revenue, $\tau_t^l W_t L_t$, and consumption tax revenue, $\tau_t^c C_t$. Total public debt, B_t , is the sum of outstanding bonds issued domestically and abroad. The government revenue is spread across interest payments on the stock of outstanding debt, $R_{t-1} B_{t-1}$, aggregate government expenditures,

G_t , and aggregate lump sum transfer payments, Z_t . Total debt, B_t , adjusts to balance the budget.

Fiscal policy is described by equations governing the specification of five debt rules: a government spending rule, a capital tax rule, a labour tax rule, a consumption tax rule and a lump sum transfers rule, that are taken as given by the fiscal authority. Our choice of a fiscal rule that depends on debt over other fiscal rule specifications reflects the evidence in the literature of the prevalence of debt rules in Canadian fiscal adjustment experiences.[51] These debt rules can be thought of as reaction functions for each of the government's fiscal instruments to output and debt deviating away from steady state levels. When output or debt rises above its steady state level, the fiscal authority can increase any tax instruments or decrease any expenditure instruments (or some combination of these instruments) to stabilize the growth in the level of debt. The fiscal authority adjusts each fiscal instrument in response to the current cyclical position of the economy (captured by the change in output from its steady state value in the current period) and the debt position of the economy (captured by the deviation of lagged aggregate public debt from its steady state). We allow for fiscal instruments to adjust for output deviations to capture adjustments in tax and transfer instruments that are not related to discretionary actions of the fiscal authority. In Canada, the main automatic stabilizers are capital and labour tax revenues that are built into the progressive tax structure and transfer schemes such as employment insurance. These fiscal instruments adjust automatically to provide income

[51] Tapp (2010) reports the use of fiscal rules in six out of eight debt to GDP reduction episodes for Canada and cites debt rules to be the most prevalent.

replacement when output falls below its steady state level and work to provide demand stabilization.

$$\hat{G}_t = -\varphi_g \hat{Y}_t - \gamma_g \hat{B}_{t-1} + \hat{u}_t^g \tag{3.17}$$

$$\hat{\tau}_t^k = \varphi_{tk} \hat{Y}_t + \gamma_{tk} \hat{B}_{t-1} + \phi_{kl} \hat{u}_t^l + \phi_{kc} \hat{u}_t^c + \hat{u}_t^k \tag{3.18}$$

$$\hat{\tau}_t^l = \varphi_{tl} \hat{Y}_t + \gamma_{tl} \hat{B}_{t-1} + \phi_{kl} \hat{u}_t^k + \phi_{lc} \hat{u}_t^c + \hat{u}_t^l \tag{3.19}$$

$$\hat{\tau}_t^c = \phi_{kc} \hat{u}_t^k + \phi_{lc} \hat{u}_t^l + \hat{u}_t^c \tag{3.20}$$

$$\hat{Z}_t = -\varphi_z \hat{Y}_t - \gamma_z \hat{B}_{t-1} + \hat{u}_t^z \tag{3.21}$$

where hats denote log deviations of the variables from the steady state and the, u_t^i , are assumed to have the following AR (1) processes:

$$\hat{u}_t^g = \rho_g \hat{u}_{t-1}^g + \varepsilon_t^g \tag{3.22}$$

$$\hat{u}_t^k = \rho_k \hat{u}_{t-1}^k + \varepsilon_t^k \tag{3.23}$$

$$\hat{u}_t^l = \rho_l \hat{u}_{t-1}^l + \varepsilon_t^l \tag{3.24}$$

$$\hat{u}_t^c = \rho_c \hat{u}_{t-1}^c + \varepsilon_t^c \tag{3.25}$$

$$\hat{u}_t^z = \rho_z \hat{u}_{t-1}^z + \varepsilon_t^z \tag{3.26}$$

where the error terms are distributed NIID (0, 1), and all parameters are positive, and, $\rho^i \in (0,1)$, for i = {g, k, l, c, z}.

The set of output gap coefficients; $(\varphi_g, \varphi_{tk}, \varphi_{tl}, \varphi_z)$, capture the strength of automatic stabilizers in the economy. Whereas the set of debt gap coefficients, $(\gamma_g, \gamma_{tk}, \gamma_{tl}, \gamma_z)$, capture the extent to which each instrument adjusts to the level of public debt in the economy. Expenditure debt rules require government spending and transfer payments to increase in response to output and/or debt falling below their steady state values and in response to positive innovations in the expenditure instrument. The increase in government expenditures and the decrease of tax rates characterize the behaviour of fiscal policy as consistent with stabilization objectives and stimulate the economy during bad times. Increases in government spending and transfers are debt financed causing the aggregate level of debt in the economy to rise. Once aggregate output exceeds its steady state level and the economy is in an upswing, the accumulation of debt triggers the reversal of fiscal policy. Good economic times, along with a high stock of public debt, require a combination of decreases in government spending and transfer payment initiatives and increases in tax rates.

Tax debt rules lower the average effective tax rates associated with capital, labour and consumption during downswings and increase them to stabilize debt levels. Additionally, tax instruments also react to exogenous policy changes with respect to itself and unexpected movements in other instruments. This specification recognizes that capital and labour tax rates are often changed jointly when there is an updating of the tax code. The set of coefficients corresponding to tax rates, $\left(\phi_{kl}, \phi_{kc}, \phi_{lc} > 0\right)$, capture the extent to which exogenous changes in one type of tax rate cause adjustments in the other. The consumption tax rate responds to unpredicted movements in capital and labour tax rates as well as exogenous shocks to consumption tax policy. We do not allow consumption tax rates to adjust to the cyclical position of the economy or debt. This mainly has to do with the fact that the consumption tax in our data set has a stable average share of output that is around two percent.

3.4 Competitive Equilibrium

A competitive equilibrium in the small open economy, is a set of allocations, $\left\{c_t, l_t, i_t, k_{t-1}, b_t^h, b_t^f, v_t, z_t, C_t, I_t, L_t, K_{t-1}, B_t^h, B_t^f, B_t, G_t, Z_t, \tau_t^k, \tau_t^l, \tau_t^c\right\}_{t=0}^{\infty}$ and prices $\left\{w_t, W_t, R_t^k, R_t\right\}_{t=0}^{\infty}$ for the representative firm and household, such that given prices, the allocation of the representative firm solves the firm's problem in (3.1) the allocation of the representative household satisfies (3.1) - (3.4) and (3.7) - (3.10) , the government budget constraint (3.15), the exogenous processes ((3.2), (3.3), (3.9), (3.12)), the domestic bonds market clearing (3.14-3.15) and fiscal rules (3.17)- (3.26) are satisfied. Lastly, markets clear as given in (3.27) subject to the transversality conditions for debt and capital accumulation.

The final goods market equilibrium condition is given as follows:

$$Y_t = C_t + I_t + G_t + R_{t-1}B_{t-1}^f - B_t^f \tag{3.27}$$

Aggregate production is spread across aggregate demand for consumption, investment, government expenditures and interest payments on external debt.

The first order conditions of the model are as follows:

$$\frac{u_t^b\left(c_t - hC_{t-1}\right)^{-\gamma}}{1+\tau_t^c} = \mathrm{E}_t \frac{\beta R_t u_{t+1}^b\left(c_{t+1} - hC_t\right)^{-\gamma}}{1+\tau_{t+1}^c} \tag{3.28}$$

$$u_t^l L_t^{1+\kappa}\left(1+\tau_t^c\right) = \left(c_t - hC_{t-1}\right)^{-\gamma}\left(1-\tau_t^l\right)\left(1-\alpha\right)Y_t \tag{3.29}$$

$$q_t = \beta \mathrm{E}_t \frac{u_{t+1}^b\left(c_{t+1} - hC_t\right)^{-\gamma}\left(1-\tau_t^c\right)}{u_t^b\left(c_t - hC_{t-1}\right)^{-\gamma}\left(1-\tau_{t+1}^c\right)}\left\{\left(1-\tau_{t+1}^k\right)\frac{\alpha Y_{t+1}}{K_t} + q_{t+1}\left[1-\delta(v_{t+1})\right]\right\} \tag{3.30}$$

$$\left(1-\tau_t^k\right)\frac{\alpha y_t}{v_t k_{t-1}} = q_t\left[\delta_1 + \delta_2(v_t - 1)\right] \tag{3.31}$$

$$1 = q_t\left\{\left[\left[1-\Gamma(\cdot)\right] - \Gamma'(\cdot)\frac{u_t^i i_t}{i_{t-1}}\right]\right\} + \beta E_t\left\{\frac{\lambda_{t+1}}{\lambda_t} q_{t+1}\Gamma'(\cdot)\left(\frac{u_{t+1}^i i_{t+1}}{i_t}\right)^2\right\} \tag{3.32}$$

The Euler equation for consumption is given by (3.28) it shows that the representative household that has maximized utility is indifferent between utility derived from the decision to consume one more unit today taxed at, τ_t^c , and the decision to save one unit today and consume it in the next period, where this future consumption is taxed at, τ_{t+1}^c. Equation (3.29) is the standard intra-temporal condition representing the labour-leisure choice of the representative households. It sets the wage rate equal to the ratio of marginal utilities of consumption and labour. Equation (3.30) shows that the shadow price of capital, q_t , is equal to the after tax return on saving one unit in the current period. Finally, equation (3.32) shows that the representative consumer is indifferent between the opportunity cost (in terms of the marginal utility of consumption) of investing today or investing in the next period, where, λ_t , represents the marginal utility of consumption at time t.

3.5 Bayesian Estimation Methodology

A Bayesian model mainly comprises of

1. The parameter set, Θ , from which we are interested in estimating a subset of parameters, Ψ . There exists prior information for some parameters either from economic intuition or through restrictions imposed by statistics, for example imposing a positive variance on a variable. This prior information is available *before* observing the data. The

Bayesian framework differs from classical treatment of parameters by considering them as random variables that have uncertainty attached to them. This uncertainty is expressed by a probability distribution. The Bayesian approach treats this type of a priori information as a prior density given by, $p(\Psi)$.

2. Observable data, given by $h^T = \{h_t\}_{t=}^{T}$. Given the data and the prior beliefs about parameter values, the likelihood function is $L(h^T \mid \Psi)$. This likelihood function communicates the probability of each data observation given the parameter values, implied by the model.
3. The Bayesian estimation methodology combines these two components together, expressing the joint distribution as, $p(h^T, \Psi) = L(h^T \mid \Psi)\, p(\Psi)$. Using Bayes theorem, (below) beliefs about the parameter values can be updated by combining the prior beliefs, $p(\Psi)$, with the likelihood function, $L(h^T \mid \Psi)$, containing information about the data to form new beliefs.

Bayes Theorem:

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

Bayes theorem states that one can find the conditional probability, $P(A|B)$, of an event A occurring given the occurrence of event B, if the reverse conditional probability, $P(B|A)$, is known. In other words, equipped with the likelihood function and the prior density over the parameters, an application of Bayes theorem can be used to update beliefs about the parameters to recover the posterior density, $p(\Psi \mid h^T)$, *after* observing the data.

Applying Bayes' theorem:

$$p\left(\Psi \mid h^T\right) = \frac{L\left(h^T \mid \Psi\right) p\left(\Psi\right)}{p\left(h^T\right)} \tag{3.33}$$

Since, the denominator of (3.33) is just a constant the expression can be simply expressed as follows to obtain the posterior distribution:

$$L\left(h_t \mid \Psi\right) p\left(\Psi\right) \quad \propto \quad \frac{L\left(h^T \mid \Psi\right) p\left(\Psi\right)}{p\left(h^T\right)} = p\left(\Psi \mid h^T\right) \tag{3.34}$$

To practically find the posterior densities for our parameters of interest we must use methods to evaluate and explore the likelihood function. Likelihood functions of DSGE models tend to be extremely complex, with several maxima and minima and often do not have an analytic solution. As is common in the Bayesian literature we use the Kalman filter[52] as a tool in the process of applying Bayes updating law to find the posterior distribution $p\left(\Psi \mid h^T\right)$. Next, we discuss each of the components of our Bayesian model. We also outline how we evaluate the likelihood function using the Kalman filter to identify the parameters of the fiscal rules in our model.

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[52] The Kalman filter can be described as an algorithm or process that estimates the state of a system from data and is used to evaluate the likelihood of the model through successive iterations. At each iteration it uses a previous estimate and a current measurement (observation of data) to predict the current state. In the next iteration it adds a correction to the estimate of the current states and updates again to recursively compute the distribution of a variable. To use the Kalman filter the model equations need to be linear and the observable data must be normally distributed.

3.5.1 State space representation of DSGE model

Taken jointly, the equilibrium conditions of the model (also listed in the appendix at the end of this chapter) represent a set of nonlinear functional equations that cannot be solved analytically. We use Dynare, a software program to find a unique solution for our model. Dynare uses a Taylor approximation up to a second order to characterize the equilibrium dynamics of DSGE models around a deterministic steady state. Using a first order Taylor approximation proves to be useful as it provides a linear solution of the model's policy functions and allows us to express the laws of motion of the endogenous variables in that state space form.

The state space of the model is given by:

1. The law of motion for the states followed by the first order Taylor series approximation:

$$\begin{aligned} S_t &= f\left(S_{t-1}, \varepsilon_t\right) \\ \varepsilon_t &= \left(\varepsilon_t^a, \varepsilon_t^b, \varepsilon_t^i, \varepsilon_t^l, \varepsilon_t^g, \varepsilon_t^k, \varepsilon_t^c, \varepsilon_t^z\right) \end{aligned} \tag{3.35}$$

where, the function $f\left(\cdot\right)$ relates, S_t, a vector describing the current state of the model at any given time to the previous state, S_{t-1} , and the exogenous shocks of the model, ε_t . From (3.35) we can compute $p\left(S_t \mid S_{t-1}\right)$.

2. The measurement equation given by:

$$H_t = g\left(f\left(S_{t-1}, V_t\right)\right) \tag{3.36}$$

where, H_t , represents observables and, V_t , is a vector of shocks applied to the observables.

From (3.36) we can compute $p\left(H_t \mid S_t\right)$. We can also compute $H_t = g\left(f\left(S_{t-1}, \varepsilon_t\right), V_t\right)$ from (3.35) and (3.36), which allows us to find, $p\left(H_t \mid S_{t-1}\right)$. These conditional densities are all part of the likelihood function.

3.5.2 *Evaluating the Likelihood function*

We can factorize the likelihood function as follows:

$$\begin{aligned} L\left(h^T \mid \Psi\right) &= p\left(h_1 \mid \Psi\right) \prod_{t=2}^{T} p\left(h_t \mid h^{t-1}\right) \\ &= \int p\left(h_1 \mid s_1\right) dS_1 \prod_{t=2}^{T} \int p\left(h_t \mid S_t\right) p\left(S_t \mid h^{t-1}\right) dS_t \end{aligned} \tag{3.37}$$

To evaluate the likelihood, we need to be able to find the initial distribution, $p\left(S_1\right)$, and the sequence, $\left\{p\left(S_t \mid h^{t-1}\right)\right\}_{t=1}^{T}$. We can find the sequence of conditional distributions of the states of our model given observations, $\left\{p\left(S_t \mid h^{t-1}\right)\right\}_{t=1}^{T}$, using the Kalman filter that can computationally solve the integrals in (3.37). The evaluation of these integrals over a highly dimensional parameter space are otherwise computationally infeasible and when feasible have large computational costs.

In order to use the Kalman filter to evaluate the likelihood the following assumption must hold true; the model can be expressed in linear state space representation, the structural shocks must be normally distributed and the sequence must consist of conditionally Guassian distributions (please see Villaverde, Quintana and Ramirez (2009)). Given that all these assumptions are satisfied the Kalman filter is used to obtain the likelihood function. The Kalman filter will generate a sequence of conditional distributions, given by, $p\left(s_t \mid H_{1:T}\right)$, and produces the sequence of densities $p\left(H_t \mid H_{1:T}, \Psi\right)$ (please see Schorfheide (2015)).

3.5.3 Posterior distribution

Once the likelihood function has been evaluated, the next step is to characterize the posterior distribution given by:

$$p(\Psi \mid H_{1:T}) \propto L(H_{1:T} \mid \Psi)\, p(\Psi) \tag{3.38}$$

Expressing the posterior distribution analytically is a difficult task as there is often no explicit way to describe it. The solution is to apply numerical techniques that generate random draws from the posterior. Specifically, the most common sampling tool used in Bayesian applications is Markov Chain Monte Carlo (MCMC) techniques[53]. The idea behind MCMC techniques is to use an algorithm that can efficiently navigate a highly dimensional parameter state space to construct a Markov Chain. A Markov Chain is a process with several states and where the probability of moving from one state to another does not depend on the previous states. However a Markov Chain that has a steady state distribution that is the posterior distribution, $p(\Psi \mid h^T)$ needs to be constructed. We use the Metropolis Hastings (MH) algorithm to simulate the posterior kernel, $L(h^T \mid \Psi)\, p(\Psi)$, and sample from the posterior distribution to approximate the true posterior density, $p(\Psi \mid h^T)$ using the posterior mode.

A series of steps are followed to obtain a resulting empirical posterior distribution**,** from which we can determine the mode and mean of the posterior, variances and the posteriors responses of variables to transitory shocks. The MH algorithm starts at the posterior mode then draws a

[53] Please see Gelfand and Smith (1990).

candidate value for the parameter from the jumping distribution[54], it calculates the acceptance ratio (value of the posterior kernel evaluated at the candidate value for the parameter) for this candidate and based on an acceptance rule decides to either accept or reject the candidate. The acceptance ratio is compared to the value of the posterior kernel, $L\left(h^{T} \mid \Psi\right) p\left(\Psi\right)$, at the mean of the jumping distribution. If the acceptance ratio is greater than one, the candidate is retained, and if not, the algorithm goes back to the candidate from the previous period. The objective of the acceptance ratio is to allow the algorithm to fully consider the domain of the posterior distribution. The mean of the jumping distribution is updated and the value of the retained parameter is recorded and the MH algorithm repeats these steps until the final draw. After scores of iterations the retained values create a smooth histogram that represents the posterior distribution.

Given the size of the model and the number of parameters being estimated a sample of 5,000,000[55] replications were performed in the simulations (each simulation starting from a different initial value) with two parallel Markov chains following Brooks and Gelman (1998)[56]. Brooks and Gelman found the optimum acceptance ratio for candidate values to be 0.234. The scale factor represents the variance of the jumping distribution and is usually set by the econometrician. A small-scale factor results in too large of a fraction of candidate parameters being accepted, decreasing the rate of convergence of the Markov chain distribution to the

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[54] A jumping distribution is a normal distribution with the mean set to the last value drawn from the distribution.

[55] The default number of replications in DYNARE is set to 20,000. Other papers estimating medium scale DSGE models such as Smets and Wouters (2007) and Leeper, Plante and Traum (2010) chose the number of replications at 1,000,000 and 2,000,000 respectively. We selected 5,000,000 because in the limit a very long length Markov chain will approximate the true posterior distribution very well.

[56] Brooks and Gelman (1998) is an influential paper in the Bayesian estimation literature.

posterior distribution. In this case the Markov chain may get stuck in some local maxima. On the other hand, a large scale factor implies that too small a fraction of candidate parameters will be selected and the Markov chain may get stuck in the tails of the distribution. Since the scale factor is important in the determination of the posterior distribution we set it to 0.3 for the estimation procedure to obtain an acceptance ratio close to 0.234 as in Brooks and Gelman (1998).

3.5.4 Observables

We use Canadian data with quarterly frequency from 1961q1 to 2012q2 to estimate the structural parameters of the small open economy DSGE model. We select nine macroeconomic aggregates: real consumption, real investment, hours worked, real government debt, real government spending, real capital tax revenues, real labour tax revenues, real consumption tax revenues, and real government transfers.[57] The nine time series are used as observable variables and are explained in terms of nine structural shocks. The data is broken down to construct time series for capital, labour and consumption average effective tax rates following Mendoza, Razin and Tesar (1994) and Leeper, Plante and Traum (2010). Appendix A.2 contains all relevant information pertaining to our dataset and data construction[58].

When conducting Bayesian estimation, you can select at most as many observable variables as structural shocks in the model, to avoid stochastic singularity. Stochastic singularity means that

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[57] We follow Leeper, Plante and Traum. (2010) by using data at the federal level of government. As suggested in their paper aggregating across different levels of government data might not be a sound approach given that some governments (provincial in the Canadian case) have fiscal rules in place while others do not. The time series are constructed as in Leeper, Plante and Traum (2010), where each series is logged and then de-trended to remove the deterministic trend. Appendix A.2 contains the data construction procedure.

[58] We also consider a diagnostic in which we compare the time paths of the detrended observables with their model simulate counterparts. These time plots show that the two series match up well for some variables and for the others we do not find that the series diverge.

the likelihood implied by the model would be infinity and thus we would not be able to perform likelihood-based estimation (please see Villaverde, Quintana and Ramirez (2009)). Since there are nine shocks in our DSGE model we also select nine observable variables to allow for as much information as possible to be supplied by the time series when performing the estimation. All observables are related to the model variables by converting them to per capita basis and taking their logarithms. We follow Leeper, Plante and Traum (2010) in de-trending each variable using a linear trend[59]. We estimate two versions of our model, one in which $\gamma_{tk} = \gamma_{tl} = 0$ so that only government spending and lump sum transfers react to deviations in the level of public debt, and a baseline model in which $\left(\gamma_g, \gamma_{tk}, \gamma_{tl}, \gamma_z\right)$ so that all fiscal instruments work to stabilize debt. The Bayesian approach allows us to compare the marginal likelihood of both models to determine which model better fits Canadian data.

3.5.5 Calibration and Priors

The likelihood function detailed in our discussion above and the priors over the parameters of interest are the two main building blocks of any Bayesian model. The econometrician is tasked with choosing prior densities for the model parameters based on economic theory, microeconomic evidence and intuition. Some model parameters are kept fixed during the estimation process for numerous reasons. First, estimating too many parameters with a limited data set can be uninformative in the sense that one may end up with posteriors with a large

[59] We also estimate the baseline small open economy model by de-trending the observables using a HP filter. The estimation results can be found in Appendix A.3.6.

spread. Secondly, some parameters are simply better identified with micro-data than macro-data thus calibrating them is a more sensible approach. In the estimation of the small open economy DSGE model, we keep fixed a small subset of the model parameters, and these serves as very strict priors. Although these parameters can be estimated from the means of the observable variables (most are related to the steady states of the state variables) they are difficult to pin down in our estimation due to the limitations inherent in the treatment of the data. The difficulty is apparent given that the observable variables are demeaned making it impossible to pin down steady state values.

TABLE 3.1 summarizes the values assigned to the calibrated parameters. The value for the discount factor is set at $\beta = 0.993$ which implies an annual steady state interest rate of 4.03%. This parameter value is adopted from Letendre (2007). The capital share parameter is set to $\alpha = 0.32$ corresponding to a steady state share of labour income of 70%. The depreciation rate, $\delta = 0.025$, is set as in Leeper, Plante and Traum (2010) and suggests an annual steady state depreciation rate of 10%. The parameter values for the ratios of government spending to output, debt to output and the steady state tax rates represent the respective average ratios in the sample.

The habit persistence parameter is calibrated at 0.6 to match estimates found for Canada in Justiniano and Preston (2010a) and Christensen, Mendicino and S-I. Nishiyama (2010).[60] As previously discussed, we must combine the likelihood function with a prior density for each structural parameter being estimated in order to get the resulting posterior distributions.

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[60] We tried to estimate the habit persistent parameter, choosing a Beta distribution that spans the range between 0 and 1. The mean value for the habit parameter is set to 0.7 and the standard deviation is set to 0.1. We found an estimate of 0.02, which is not significantly different from zero and diverges from estimates in the Canadian DSGE estimation literature

TABLE 3.1 Calibrated parameters

Parameter	Description	Value	Source
β	Discount factor	0.993	Letendre (2007)
δ_0	Depreciation rate	0.025	Leeper et al (2010)
α	Capital share of income	0.320	Letendre (2007)
$\bar{G}/\bar{Y}$	Ratio gov. spending to output	0.230	Average sample ratio
$\bar{B}/\bar{Y}$	Ratio of public debt to output	0.270	Average sample ratio
τ^k	Steady state capital tax rate	0.380	Average sample ratio
τ^l	Steady state labour tax rate	0.058	Average sample ratio
τ^c	Steady state consumption tax rate	0.099	Average sample ratio
R^w	World interest rate	1.010	Letendre (2007)
Ψ_2	Risk premium coefficient	0.001	Schmitt-Grohé and Uribe (2003)
h	Habit persistence	0.600	Justiniano and Preston (2010)

Next, we discuss the specification of prior densities for the 34 structural parameters that are estimated. Prior choices for the structural parameters (preference and fiscal parameters) and the prior choices for the parameters in the processes governing the structural shocks are summarized in TABLE 3.2.

The priors are chosen to be consistent with the Bayesian estimation literature, and mostly reflect the choice of priors in Leeper, Plante and Traum (2010). The Gamma distribution is selected for the preference parameters: risk aversion, γ , inverse of the Frisch elasticity, κ , investment adjustment cost, χ , and capital utilization cost, δ_2 . The Gamma distribution chosen allows for the exploration of a large range of values. I assign, γ , and, κ , mean values of 1.75 and 2 respectively with a standard deviation of 0.5. The relative risk aversion parameter and the inverse Frisch elasticity of labour supply are equally important in microeconomic and macroeconomic studies and have been difficult to pin down in the literature. There is a wide range of calibrations and estimations associated with these parameters.[61] Generally, micro-labour studies estimate a low value for the inverse Frisch elasticity parameter whereas macroeconomic DSGE studies estimate higher values. The assumed priors for the structural parameters are summarized in TABLE 3.2 and are similar to and cover the range of estimates found in the literature. The investment adjustment cost parameter, χ , follows a Gamma distribution with mean 5 and a standard deviation 0.25. This prior corresponds closely to the mean value of 4 chosen in Smets and Wouters (2003, 2007). The capital utilization cost parameter is associated with a Gamma distribution following Leeper, Plante and Traum (2010) and Schmitt-Grohé and Uribe (2008) with a mean value of 0.70 and a standard deviation of 0.5.[62]

For the policy parameters, wider priors are selected to allow the data to guide the estimation. The debt coefficients, γ_i , $i=\{tk,tl,g,z\}$, representing the fiscal response to government debt are all assumed to follow a Gamma distribution with a mean of 0.4 and a standard deviation of 0.2. The Gamma distribution is chosen since government spending and transfers should respond negatively (in the baseline model taxes should respond positively) to stabilize debt. The output coefficients, φ_i , $i=\{tk,tl,g,z\}$ representing the fiscal response to output are also assumed to follow a Gamma distribution. Given the progressivity of capital and labour taxes their respective coefficients are restricted to be positive. The priors for the output coefficients are as follows: the capital tax revenue coefficient is set to a mean value of 1 and a standard deviation of 0.3. The

[61] See for example, Smets and Wouters (2003, 2007) who chose a Normal distribution for the inverse Frisch elasticity parameter setting the mean value at 2 and the standard deviation at 0.75. Whereas, Fernandez-Villaverde (2014) and Justiniano and Preston (2010a) also chose a Normal distribution but set the mean value at 1 and the standard deviation at 0.25- 0.3.

[62] Smets and Wouters (2003, 2007) choose a Normal distribution with a mean value of 0.2 and a standard deviation of 0.075.

labour tax revenue coefficient is set to a mean of 0.5 and a standard deviation 0.25. The government spending coefficient and lump sum transfers coefficient is set to mean values of 0.07 and 0.2 and standard deviation values of 0.05 and 0.10. The parameters capturing the co-movement between the various tax rates are assigned the Normal distribution. These parameters have not been estimated for Canada to date. Since Leeper, Plante and Traum (2010) are the first to estimate these parameters for the United States; we use their choice of priors as a starting point in the estimation. The capital and consumption co-term ϕ_{kc} and the labour and consumption co-term ϕ_{lc} are given a mean value of 0.05 and a standard deviation of 0.10.

The autoregressive parameters, ρ^i , $i = \{a, b, l, i, g, tk, tl, tc, z\}$ are assigned a Beta distribution with a mean value of 0.7 and a standard deviation of 0.2. This assignment is close to the priors for the autoregressive processes in Smets and Wouters (2003, 2007).[63] We chose a loose prior to correspond to the standard deviations of the shock processes of the model. The density distribution assigned is the Inverse Gamma distribution following Smets and Wouters (2007) with the mean value set at 0.1 and the standard deviation set at 2.

3.6 Bayesian estimation results

We perform a Bayesian estimation of two different versions of the small open economy DSGE model presented above. First, we estimate the baseline model with all five fiscal rules responding

[63] In Smets and Wouters (2003) they chose to set the mean value of the AR (1) parameters at 0.85 and the standard deviation at 0.1 to have a clear separation between persistent and non-persistent shocks in their model. In Smets and Wouters (2007) the mean value of the persistence parameters were set at a mean value of 0.5 and a standard deviation of 0.2.

to debt and the state of the economy.[64] The estimation for the small open economy model used two MH chains, with acceptance rates of 36.67 percent and 36.45 percent, values that are consistent with the literature. The burn in period refers to the number of draws dropped at the beginning of a simulation**.** We select a burn in period of 0.25 by dropping the first quarter of the draws from the MH prior to the posterior simulations. The log data density for the estimation was -3102.94 and the Laplace approximation was -3119.60. Then we estimate a version of the model where tax instruments are not permitted to respond to debt and thus the corresponding tax-debt coefficients are set to zero[65]. Following the Bayesian literature, we compare the statistical strength of the competing models by comparing the log marginal densities and find that the alternative model outperforms the baseline model. In the remainder of the chapter we present the results of the alternative model, which has been found through the marginal likelihood tests to best fit Canadian data. The estimation results for the structural parameters of the alternative model are summarized in TABLE 3.2. Here we report three sets of results, the estimated posterior mode, the estimated posterior mean and the 5 and 95 percentile of the posterior distribution.

FIGURE 3.1- FIGURE 3.3 provides a visual representation, plotting the prior (grey line) and posterior (black line) distributions as well as the posterior mode (horizontal dashed green line). The estimation results indicate that all structural parameters of the model are significantly

[64] The results for the estimation of the baseline model can be found in Appendix A.3. Parameter estimates are presented in Appendix A.3.3, Table A.3.1 and posterior distributions are depicted in Figures A.3.1 – A.3.4. We also provide a discussion on model comparison of the baseline and alternative model in Appendix A.3.4.

[65] This estimation was conducted using two MH chains with an acceptance ratio of 30.51 % for the first chain and 30.45% for the second chain. The log data density was -3124.08 and the Laplace approximation was -3132.82.

different from zero. We also perform Monte Carlo Markov Chain diagnostics to check convergence diagnostics (results available in Appendix A.3.3). The convergence diagnostics checks the sensibility of convergence results by providing feedback on the extent to which the results within the two Markov chain simulations are similar and that the results between the two Markov chains are similar.

3.6.1 Preference Parameter estimates

The posterior distributions of risk aversion, the inverse Frisch elasticity of labour supply and habit persistence are significantly different than their respective prior distributions. The risk aversion parameter, γ , estimated at 4.82, is higher than estimates using Canadian data reported in the literature. For example, Gandelman and Hernandez–Murillo (2014) find an estimate for the risk aversion parameter of 0.83 using a Generalized Method of Moments approach and Justiniano and Preston (2010a) report an estimate of 0.70 using a Bayesian approach.[66]

The Frisch elasticity parameter reflects the elasticity of labour supply to the wage rate for a constant marginal utility of wealth. Macroeconomic studies estimate the elasticity of labour supply to gain an understanding about business cycle fluctuations. On the other hand, in the public finance literature it is important because the optimal tax rate depends inversely on the labour supply elasticity, making it useful for policy design (e.g. income support programs).

We find a posterior mean value of 0.52 for the inverse Frisch elasticity, implying a value of 1.92 for the Frisch elasticity of labour supply. This estimate is consistent with the range of estimates for DSGE models that find values between 1 and 2.[67] The estimation results for the investment adjustment cost parameter, χ , and capital utilization cost parameter, δ_2 , are very close to their assumed prior means.

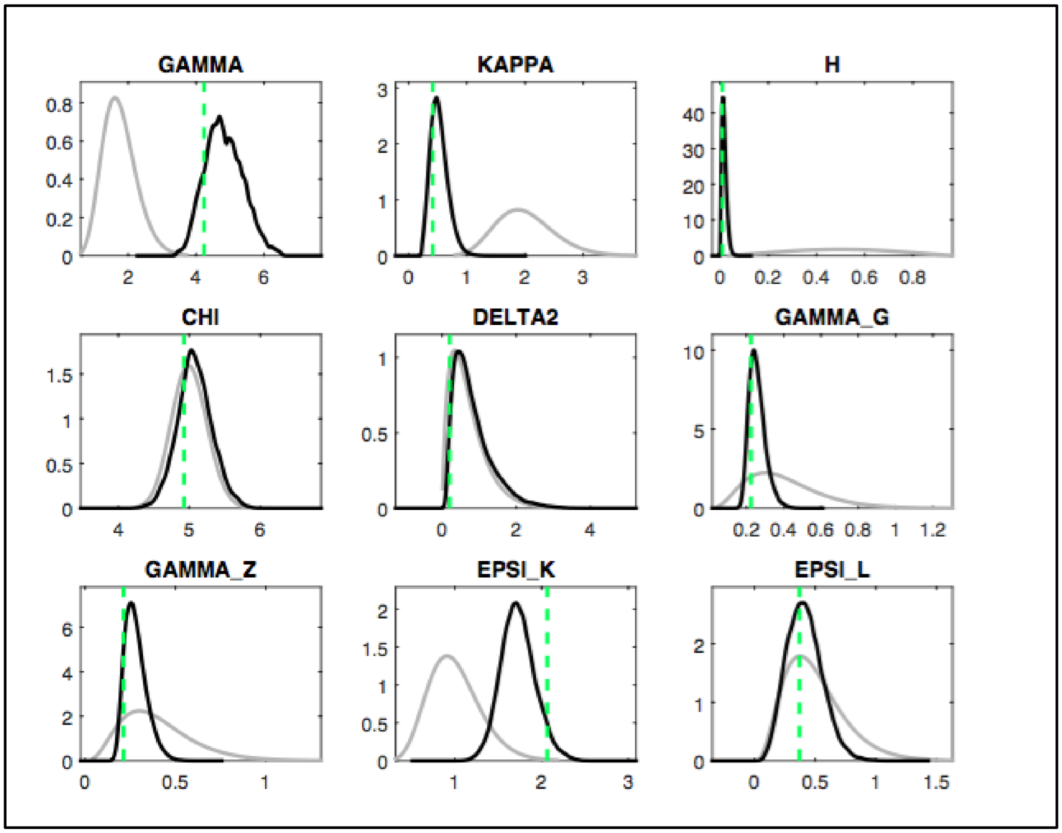

FIGURE 3.1 Small open economy model priors and posterior distributions

67 For Canada Christensen, Corrigan, Mendicino and Nishiyama (2009) report an estimate of 1.85 and Justiniano and Preston (2010) find an estimate of 1.3. Other works using Canadian data use a calibrated value of 2 (Mendoza (1991), Nason and Rogers (2003) and Letendre (2003, 2007).

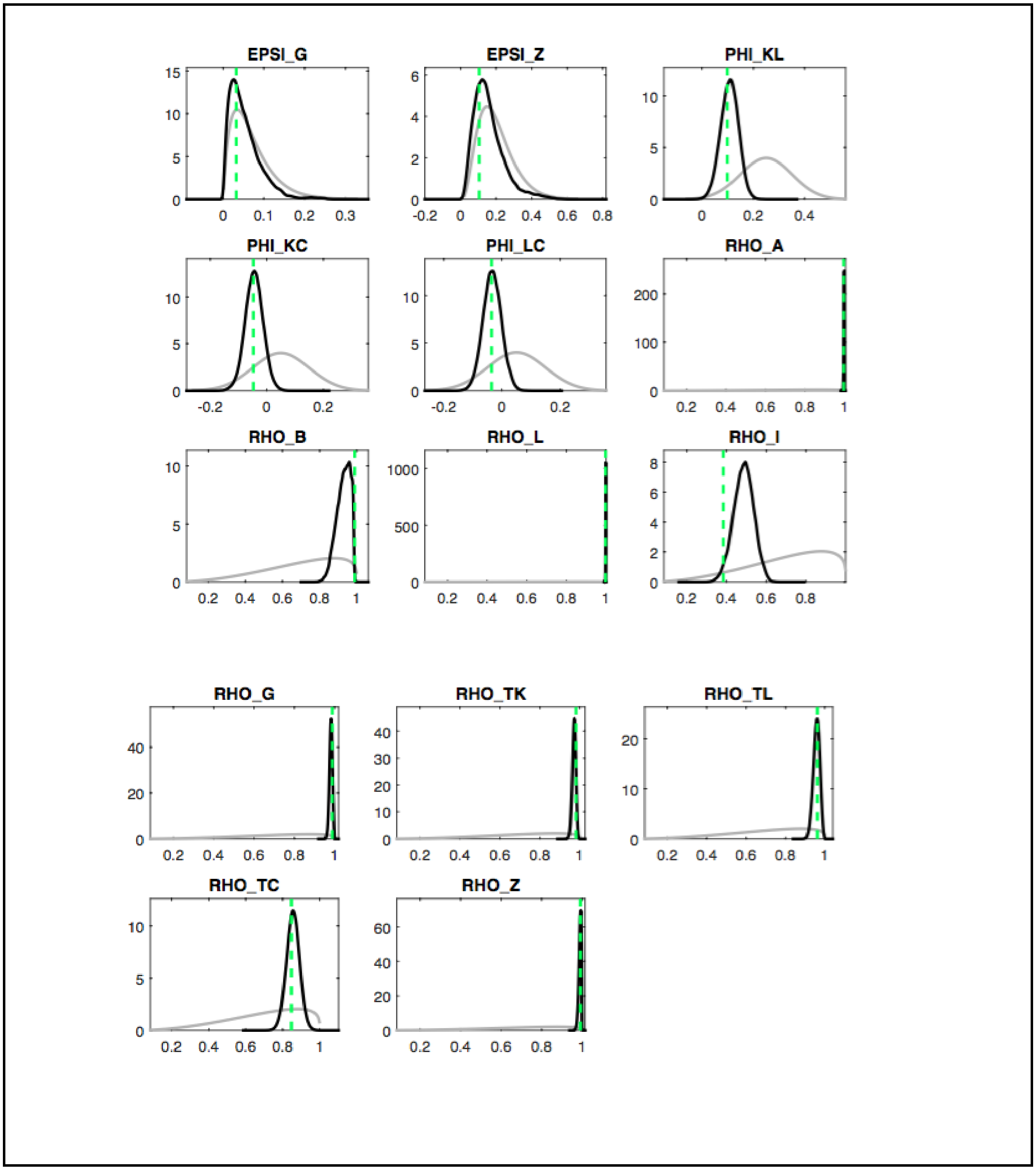

FIGURE 3.2 Small open economy model priors and posterior distributions

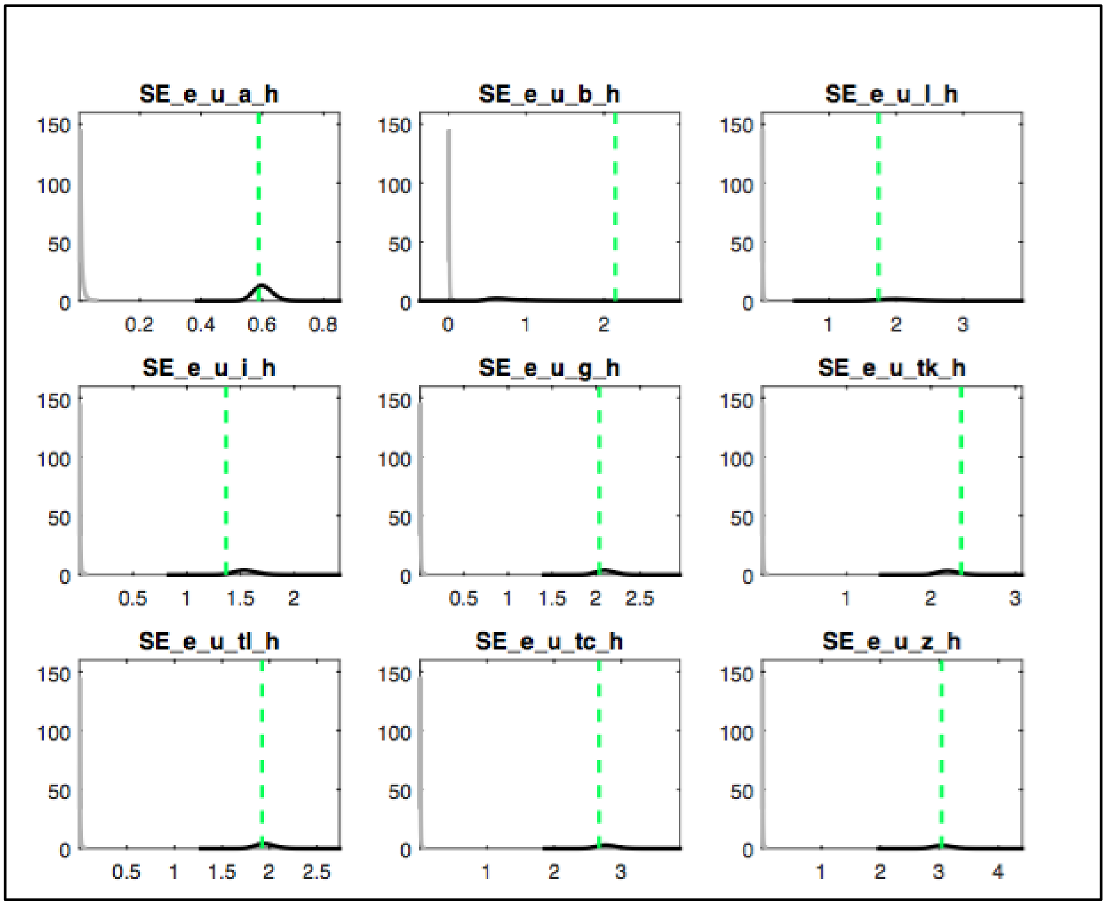

FIGURE 3.3 Small open economy model priors and posterior distribution

FIGURE 3.1 show that the distributions nearly overlap one another. This type of result is usually an indication of weak identification or simply suggests that prior assumptions reflect the information in the data very well. On the basis of identification tests[68] performed in DYNARE and the sensitivity plots we are able to infer that none of the parameters are likely to suffer from identification problems

[68] Identification tests in Bayesian inference are performed to determine how informative the prior is for each parameter and to determine which parameters are weakly identified by the data. Parameters that are weakly identified create a challenge for econometrician in obtaining a consistent posterior estimate as they are sensitive to the choice of prior.

TABLE 3.2 Prior and posterior distributions

Parameter		Prior	Posterior Distribution			
		Mean	Mode	Mean	5% C.I	95% C.I
γ	Risk Aversion	1.75	4.23	4.82	3.91	5.72
κ	Inv. Frisch	2.00	0.41	0.52	0.28	0.76
h	Habits	0.70	0.01	0.02	0.00	0.03
χ	Inv. Adj Cost	5.00	4.92	5.07	4.67	5.48
δ_2	Capital Util. Cost	0.70	0.20	0.82	0.13	1.57
γ_g	Gov. Spending B	0.40	0.22	0.26	0.19	0.32
γ_z	Transfer B coeff.	0.40	0.21	0.16	0.18	0.37
φ_{tk}	Cap. Tax Y coeff.	1.00	2.06	1.73	1.41	2.06
φ_{tl}	Labour Tax Y	0.50	0.37	0.41	0.05	0.16
φ_g	Gov. Spending Y	0.07	0.03	0.05	0.00	0.10
φ_z	Transfer Y coeff.	0.20	0.10	0.16	0.03	0.28
ϕ_{kl}	Cap. /Labour co-	0.25	0.10	0.11	0.05	0.16
ϕ_{kc}	Cap. /Cons co-	0.05	-0.05	-0.04	-0.10	0.01
ϕ_{lc}	Labour/Cons. co-	0.05	-0.03	-0.03	-0.08	0.02
ρ_a	Tech AR coeff.	0.70	0.99	0.99	0.99	0.99
ρ_b	Pref. AR coeff.	0.70	0.99	0.93	0.87	0.98
ρ_l	Labour AR coeff.	0.70	0.99	0.99	0.99	1.00
ρ_i	Inv. AR coeff.	0.70	0.38	0.48	0.43	0.57
ρ_g	Gov. Spend AR	0.70	0.99	0.98	0.97	0.99
ρ_{tk}	Cap. Tax AR	0.70	0.98	0.97	0.96	0.99
ρ_{tl}	Labour tax AR	0.70	0.96	0.96	0.93	0.98
ρ_{tc}	Cons. Tax AR	0.70	0.85	0.85	0.80	0.91
ρ_z	Transfer AR coeff.	0.70	0.99	0.99	0.98	1.00
σ_a	Tech. std.	0.01	0.59	0.60	0.55	0.65
σ_b	Pref. std.	0.01	2.14	0.80	0.41	1.23
σ_l	Labour std.	0.01	1.70	2.03	1.61	2.44
σ_i	Inv. std.	0.01	1.40	1.55	1.37	1.72
σ_g	Gov. Spend std.	0.01	2.04	2.11	1.93	2.28
σ_{tk}	Cap. Tax std.	0.01	2.36	2.20	2.00	2.40
σ_{tl}	Labour Tax std.	0.01	1.93	1.95	1.79	2.12
σ_{tc}	Cons. Tax std.	0.01	2.67	2.78	2.55	3.01
σ_z	Transfer std.	0.01	3.03	3.06	2.80	3.31

3.6.2 Fiscal Parameters Estimates: Coefficients on Debt

The parameters for the estimated fiscal rules corresponding to the main fiscal aggregates are also displayed in TABLE 3.2. These estimates suggest that numerical fiscal rules for Canada look as follows:

$$\hat{G}_t = -0.05\hat{Y}_t - 0.26\hat{B}_{t-1} + u_t^g \tag{3.39}$$

$$\hat{Z}_t = -0.16\hat{Y}_t - 0.16\hat{B}_{t-1} + u_t^z \tag{3.40}$$

Based on our results, it appears that the Canadian non-discretionary fiscal policy has negatively adjusted government spending and transfer payments in response to increases in the level of public debt. We do not find any evidence of tax rates responding to public debt. The responses of the individual fiscal instruments are captured by the estimated, γ_i , coefficients that reflect the percentage change in the individual instrument triggered by a one-percentage change of the lagged level of public debt from its steady state value. While we find that both government spending and transfer payments are important fiscal instruments as the fiscal policy has relied on these measures to stabilize the level of public debt, a higher estimated coefficient on government spending (0.26) suggest that reversals in government purchases have played a bigger role in debt stabilization.[69]

[69] The estimation results of the baseline model (Appendix A.2) provide a robustness check on the estimated values of these coefficients. The estimated values for the government-spending coefficient are very similar in the two models, however the coefficient on transfers is much larger for the baseline model.

In the case of both fiscal expenditure parameters, the estimated posterior means has moved away from the mean value set at 0.4 in the prior distribution. Our estimation results show that government spending debt coefficient mean value is 0.26 and the transfers' debt coefficient is 0.16. These results indicate that our data sample is rich with information, pushing us away from the priors and to a final distribution for each parameter being estimated. The results in TABLE 3.2 suggest that fiscal policy has relied on rules based fiscal policy by strongly adjusting government purchases to rising debt levels. This is supported by both Canadian data in recent decades and the fiscal consolidation literature that finds fiscal adjustments have occurred mostly on the spending side and have led to long lasting reductions of debt to GDP ratios.[70]

FIGURE 3.2 plots the percentage change in government spending and public debt at the federal level over the last three decades. The level of federal debt (solid black line) is shown to have reached a peak in 2008, however during the mid-1980s the debt to GDP ratio (not shown) reached a historically high level. The time series for government purchases (dotted black line) is shown to have plunged significantly between 1984 and 1986, as the fiscal authority implemented large spending cuts as part of their efforts to consolidate the debt. The consolidation efforts and continued spending restraint, consisting of a restriction on the growth of public service wages into the early 1990s helped to stabilize the level of public debt during the remainder of the decade. The federal fiscal balance began to deteriorate again after a recession in the early 1990s, which reduced government revenues.

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[70] Please see Tapp (2010) and Alesina and Ardagna (2012).

The figure shows a small rise in debt levels again during the early 1990's, and the data depicts a sharp decline in government purchases from 1991 to 1995. The large downward adjustment of government spending reflects the fiscal authority's decision to implement the first federal fiscal rule in 1991; the Spending Control Act.

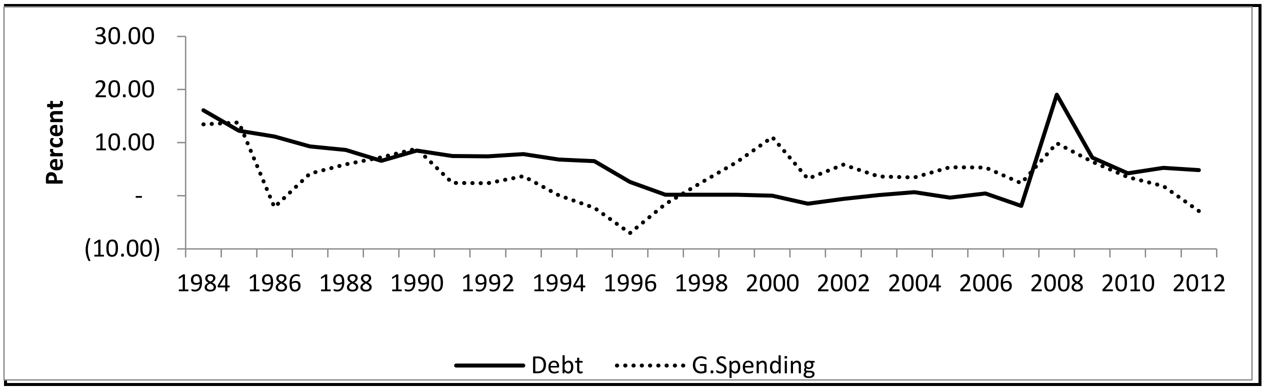


FIGURE 3.2 Percentage change in government spending and federal public debt in Canada

The fiscal authority further extended spending restraint by implementing The Program Review exercise during 1994 to 1997, which contributed to successfully reducing the ratio of program spending to GDP from 16.8 % to 12.7%. Alesina and Ardagna (2012) find empirical evidence for the period 1993 to 1997 in Canada being among the ten largest fiscal adjustments among OECD countries. Our findings on the estimated government-spending rule are in line with the findings in Alesina and Ardagna (2012), which find that debt stabilization in Canada during this period has been achieved through adjustments in government spending instruments as opposed to tax instruments and that adjustments on the spending side lead to more successful consolidation periods.

A similar result is found in Reicher (2014), where using a regression approach to estimate individual fiscal rules, government purchases are found to strongly stabilize the debt to GDP ratio in Canada. In contrast, her findings suggest that tax rates have displayed an even more meaningful and stronger adjustment than government purchases. The difference in findings between our estimation results and those in Reicher (2014) can be explained by differences in estimation methodology, length of data sample used and the large standard errors for estimated coefficients of individual countries (including Canada) in Reicher (2014). The finding in Reicher (2014) is also inconsistent with data on statutory tax rates, which shows that tax rates in Canada have largely declined from their levels in the 1960s and 70s.

FIGURE 3.3 displays the percentage change in the personal income tax rate and the corporate tax rate against the percentage change in the federal public debt for the period of 1982 to 2008. Tax rates do not display significant movements in response to movements in the public debt; namely we do not see a rise in tax rates during high debt periods in the mid-1980s and 90s. Instead we can observe two large periods of downward adjustments. A very large adjustment in both tax rates occurred in the late 1990s, as part of stage one of the tax reform motivated by tax reforms in the U.S and aimed at broadening the tax base. After this period, both rates have remained largely unchanged to declining debt levels until the year 2000, when the fiscal surplus resulting from significant improvements in the fiscal balance were used to cut corporate rates. The fiscal authority enforced subsequent cuts in the corporate tax rate in response to declines in the corporate tax rate in the U.S, as sharp increases in capital mobility threatened Canadian competitiveness. Our estimated coefficients on the capital and labour tax rate rules reinforce the observations in the data for statutory tax rates, suggesting that tax rates have not historically responded in a meaningful manner to movements in the federal public debt.

The estimated coefficient for transfer payments (0.16) implies that transfer payments have played an important stabilizing role during periods of rising public debt in Canada. FIGURE 3.4

depicts the percentage change in transfer payments alongside the percentage change in the level of federal debt for recent decades in Canada. Our results support the trends apparent in the data, which depict transfer payments declining during high debt periods and increasing during low debt periods.

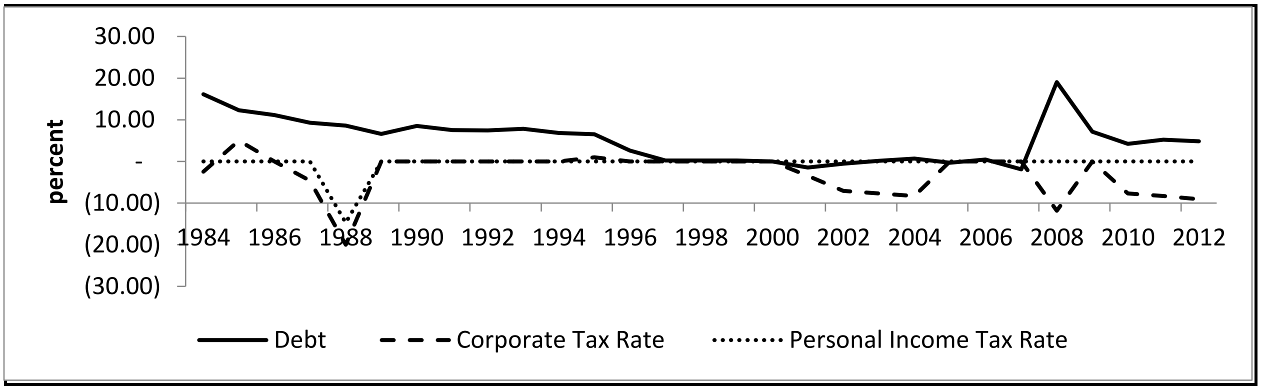


FIGURE 3.3 Percentage change in the personal and corporate tax rates and the federal public debt in Canada
SOURCE: GFS, 2015; OECD tax database table I and II, 2015.

This is an important contribution as the response of transfer payments to debt has been largely neglected in the fiscal policy literature. With the exception of Leeper, Plante and Traum (2010), Plödt and Reicher (2012) and Reicher (2014) the literature has mainly focused on the role government spending and tax rates for the conduct of countercyclical fiscal policy. Our findings underscore the important role of transfer payments for the design of DSGE models aimed at understanding the effects of fiscal policy on the macro economy. They further support a recent movement in the theoretical literature that has begun to explore the role of countercyclical transfer payments as a fiscal instrument.[71]

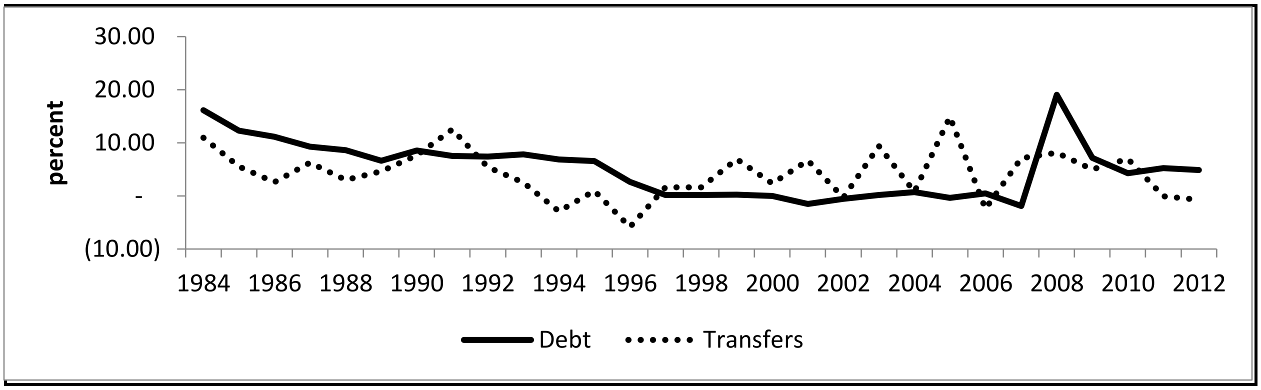


FIGURE 3.4 Percentage change in transfer payments and federal public debt
SOURCE GFS, 2015; Statistics Canada CANSIM table 380-0034.

3.6.3 Fiscal Parameter Estimates: Coefficients on Output

The extent to which individual fiscal instruments respond to the output gap (expressed as deviations from the steady state) are captured by the estimated, φ_i , coefficients and are listed in TABLE 3.2. Our results indicate that the average effective capital and labour tax rates have displayed a strong positive response to the output gap, transfer payments have responded negatively and government spending has not responded much to changes in the aggregate level of output. Capital tax rates exhibit a very pro-cyclical response to output, with a 1 percent deviation of output from the steady state causing a 1.97 percent change in capital taxes. Labour

71 Please see Bi and Kumhof (2011), Kumhof and Laxton (2013), Motta and Tirelli (2012), McKay and Reis (2013) and Reicher (2014).

tax rates rank second after capital tax rates in responsiveness, also reacting in a pro-cyclical manner. We find that a one percent deviation of output from steady state causes a movement of 0.54 percent in labour tax rates. Reicher (2014) also finds empirical evidence that average effective capital tax rates have responded more aggressively to output than average effective labour tax rates in Canada. These results indicate that the progressivity of the tax system is well reflected in the pro-cyclicality of average effective tax rates at the aggregate level. These findings are in line with the existing evidence on output coefficients in the literature suggesting that fiscal policy in developing countries is largely counter-cyclical. Égert (2010) and Fatàs and Mihov (2012) find that fiscal policy in Canada has been strongly countercyclical attributing the presence of strong automatic stabilizers to the large size of the government. They find that in OECD countries (including Canada) tax rates have responded strongly to the cycle, whereas government spending has been largely a-cyclical.

We also find that the elasticity of transfer payments to debt accumulation is 0.16, indicating an important role for transfer payments as a counter-cyclical policy instrument. The strong negative response of transfer payments to the output gap is in line with findings in the literature, which suggest that countries with a larger welfare state like Canada have displayed a strong counter cyclical adjustment to output. Taken together with the estimated coefficient on debt, we find that transfer payments are a very important fiscal policy instrument for stabilization and consolidation policy. This is an important contribution as the role of transfer payments as a fiscal policy tool has been underexplored in the literature.

3.6.4 Fiscal Parameter Estimates: Coefficients on Tax Co-terms and Shock Processes

TABLE 3.2 also reports the estimation results for the tax co-terms; captured by ϕ_i , these coefficients represent the extent to which tax rates move together. We find a value of 0.11 for the capital-labour tax coefficient suggesting that innovations in capital and labour tax rates effect the two rates simultaneously. Our estimates for the consumption tax co-terms are very small and imply that consumption tax rates have not moved together with capital and labour tax rates. This is an important contribution, as these fiscal tax parameters have not been estimated for Canada to date. The finding that capital and labour tax rates move jointly implies that changes in tax legislation by the fiscal authority changes both these rates. This result is consistent with OECD data on statutory tax rates, which shows that tax reforms in Canada have changed corporate tax rates, and personal tax rates together. Consider stage one of the federal tax reforms in 1987/88 that marked a historical change to the structure of the personal income tax and a significant reduction in the corporate tax rate. The personal income tax structure was changed to collapse ten income brackets to three, resulting in the top marginal rate being reduced from 34% to 29%. At the same time the tax reform called for a decrease in the corporate tax rate 36.05% to 28.84%. Another adjustment in these tax rates occurred between 2001 and 2006, when an extra tax bracket was added to the personal income tax structure reducing the lowest statutory tax rate from 17% to 15% and the corporate tax rate was reduced from 29.12% to 22.12%. This finding is also consistent with evidence of a strong correlation between capital and labour tax rates in the U.S. Leeper and Yang (2008) have estimated these parameters to be 0.26, while Leeper, Plante and Traum (2010) find an estimate of 0.19. This is not surprising given that tax reforms in Canada have largely mirrored changes in tax legislation in the U.S.

The estimated parameters governing the shock processes are also summarized in TABLE 3.2. We find that all shock parameters are estimated to be significantly different than zero. The autoregressive parameters are all estimated to be a larger value than their prior mean of 0.70, with exception of the autoregressive parameter for the investment specific shock. These results imply that all the shock processes are very persistent. The data pushes the posterior estimates away from the priors implying it is quite informative with respect to the standard errors of the shock processes. All standard errors are also estimated to be significantly larger than their assumed prior value. We find that standard errors corresponding to fiscal shocks are estimated at larger mean values relative to preference shocks implying higher volatility in fiscal instruments. The estimated autoregressive parameters and standard deviations for preference shocks are within the range of estimates found for Canada (see for example, Letendre (2004, 2007), Justiniano and Preston (2010a) and Dorich, Mendes, Murchison and Zhang (2013)).

3.6.5 The role of structural shocks on the Canadian economy

In this section we present the estimated impulse responses of several macroeconomic variables to an unanticipated temporary shock in technology, government spending and lump sum transfers. The impulse responses are depicted in FIGURE 3.5 – FIGURE 3.6 and correspond to a one standard deviation increase in the respective shocks. In the figures, the black solid lines are the mean impulse response and the grey shaded areas are the 5% and 95 % posterior intervals. The x-axis measures times in quarters and the y-axis represents percentage deviations from the steady state. FIGURE 3.5 depicts the impulse responses to a temporary increase in the technology shock. The increase in productivity is followed by a rise in output, consumption and investment on impact as predicted by canonical real business cycle models of Baxter and King (1993), Aiyagari, Christiano and Eichenbaum (1992). Labour supply responds negatively on impact of the shock; a result that is at odds with these simple theoretical models that predict an increase in labour supply in response to a positive technology shock. A positive technology shock leads to an increase in the marginal product of labour and generates an income effect and a substitution effect. The income effect arises from households earning more labour income after the shock with the same number of hours worked before the shock and the substitution effect arises from the incentive on behalf of households to supply more labour taking advantage of the temporarily higher real wage. As the shock is temporary, the model predicts that in the short run the substitution effect dominates. However, we find that the negative response of labour supply is a common result found in the literature for more sophisticated real business cycle models that feature rigidities, such as habit formation and investment adjustment costs. Some empirical works[72] have found a near zero unconditional correlation between productivity and employment in many advanced economies.

[72] Gali (1999) find evidence of a negative response of labour hours to a positive technology shock in an estimated VAR for Canada, Francis and Ramey (2005) and Gali and Rabanal (2004) find evidence for the U.S of the negative response of labour supply being consistent with estimated impulse responses of identified technology shocks.

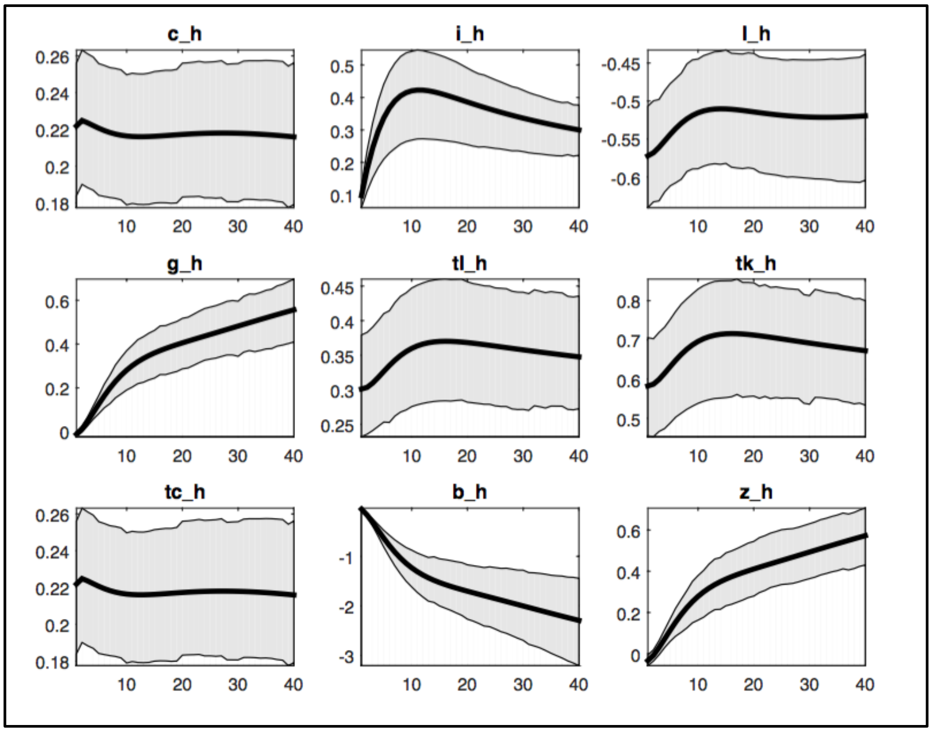


FIGURE 3.5 Impulse responses to a technology shock in the estimated model

The positive technology shock brings about a decrease in domestic debt, as tax revenues expand and are used to settle debt obligations. All tax instruments (except consumption taxes) increase in response to the increase in aggregate output. The estimated behaviour of the various tax tools is supported by the results of our VAR analysis in the second chapter that find taxes to rise in response to positive movements in aggregate output. The interest rate (not displayed) is invariant to productivity shocks in the open economy as it is constrained by a constant world interest rate.

We find that trade balance and the current account to output ratios (not depicted in the figure) display a pro-cyclical response to the positive technology shock, which is in contrast with the empirical evidence for most advanced countries. However, a well-known limitation of small open economy models is the difficulty they have with generating the counter-cyclical response of the trade balance and current account. This pro-cyclical response is explained in the open economy literature as the consumption smoothing desire dominating the effect of borrowing from foreign capital markets. Small open economies have a desire to borrow from foreign capital markets to finance a temporary investment boom that is driven by the temporarily high marginal productivity of labour. Letendre (2004, 2007) finds that a large value of the investment adjustment cost parameter weakens the incentive of borrowing from the rest of the world to increase investment at home. This in turn generates a pro-cyclical trade balance and current account. We attribute the pro-cyclical behaviour of the current account and trade balance ratios to a high value (5.07) for the adjustment cost parameter in the estimated model.

FIGURE 3.6 displays the impulse responses to a temporary one standard deviation increase in the government spending shock. As has been previously discussed, in a standard RBC model the main channel through which transitory government spending shocks affect the economy is the wealth effect and intertemporal substitution effects.

FIGURE 3.6 shows that consumption and investment fall in response to the government spending shock as the unexpected decrease in wealth causes the household to adjust their level of outlays to a lower level in the future periods. The negative wealth effect works to make the household feel insecure about their wealth, discouraging consumption and investment spending while encouraging the representative household to work harder. The increase in labour hours leads to the expansion of aggregate output on impact. The responses of output and private consumption are supported in the data for Canada as determined by the results of the estimated VAR models in chapter two.

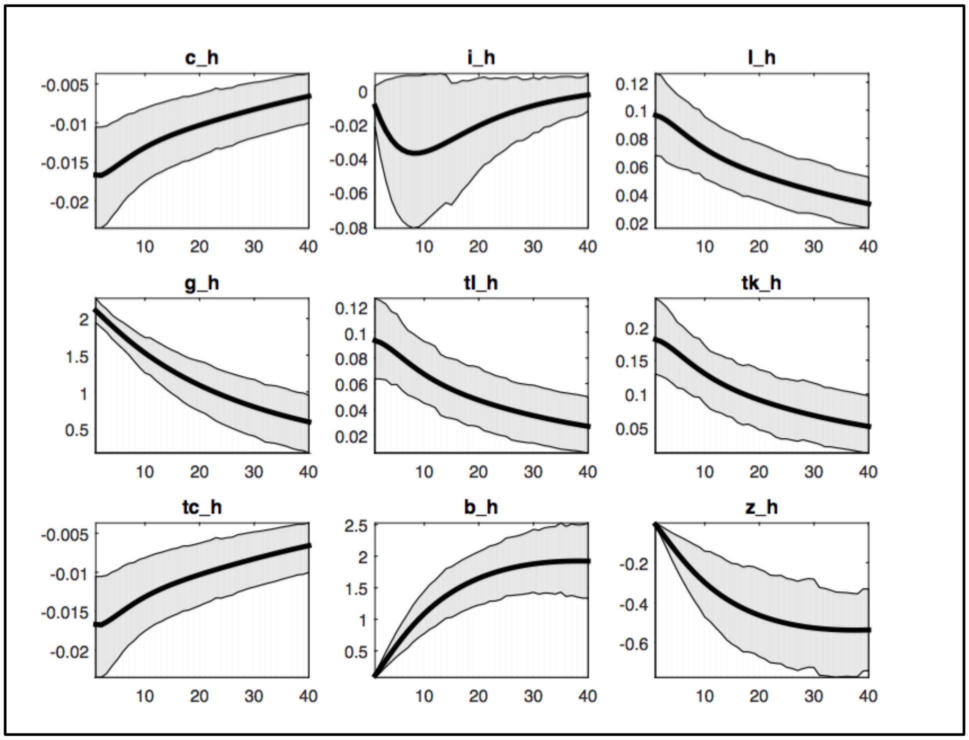


FIGURE 3.6 Impulse responses to a government spending shock in the estimated model

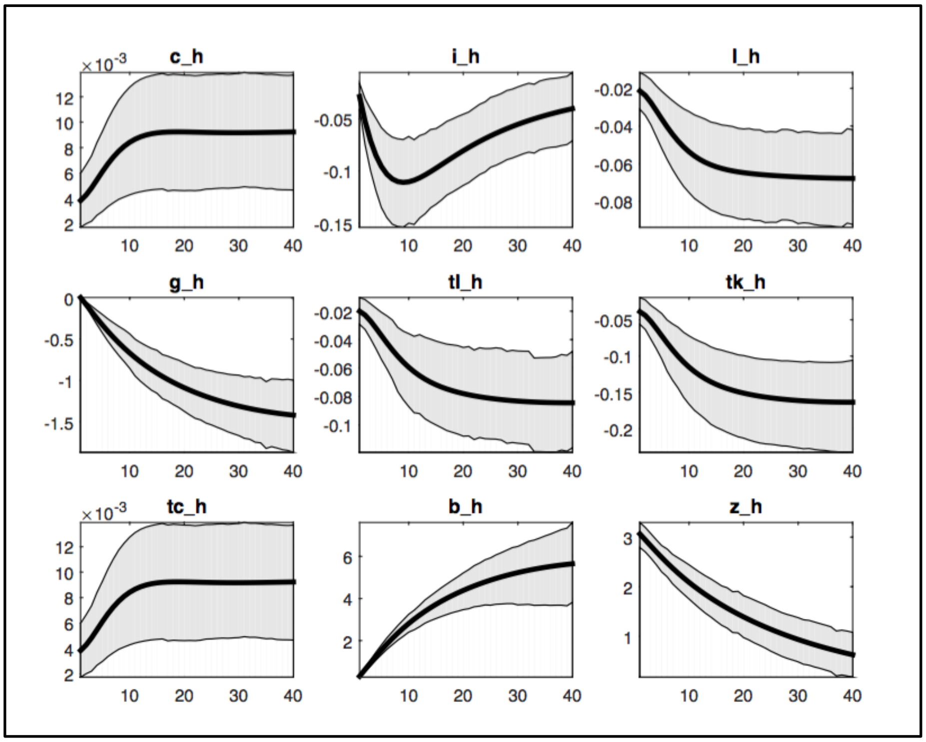
In chapter two we estimated various structural VAR models using different time periods in Canada and two leading identification methodologies to serve as a test for model selection. The results from that empirical exercise found a negative response of private consumption to an unexpected rise in government spending across all periods considered (except 2002q1-2015q4) and all identification techniques.

We also found that positive transitory government spending shocks lead to a non-persistent increase in output in Canada during 1980q1-2015q4, and a decrease in output during 1961q1-1979q4. We can find support for the implied effects of government spending shocks on output that come out of our VAR analysis and the estimated small open economy model above when considering the findings in Baxter and King (1993). They find positive transitory government spending shocks to have the weakest effect on output (lowest multipliers) when the government spending shock is temporary and when distortionary taxes rise to maintain a balanced budget following a temporary increase to government spending. In a model with distortionary taxation, Ricardian Equivalence no longer holds. In simpler models of fiscal policy that only feature lump sum taxes, Ricardian Equivalence implies that a forward looking household internalizes the budget constraint and it therefore does not matter whether increases in government spending are financed by current taxes or deficits, they do not distort the households' decisions. However, when models include distortionary taxes, as we do in our small open economy model the decisions of the represented households are impacted and findings from these models differ from those in the simple traditional models. Leeper, Plante and Traum (2010) and Forni, Monteforte and Sessa (2009) show that when the only fiscal instruments that respond to expansions in debt are capital and labour taxes, output falls in response to a positive temporary government spending shock. The impulse responses of aggregate variables in our model do not display such distortions in the presence of distortionary taxes. This is because estimation results from the baseline model do not lend support for taxes adjusting in Canadian data to support future expansions (contractions) in debt, and so we only allow expenditures to change in response to debt innovations. As a result, our estimated impulse responses have an interpretation that is similar to when Ricardian Equivalence holds.

FIGURE 3.6 shows that following a temporary increase in government spending that is deficit financed the aggregate level of debt in the economy expands. The fiscal rules kick in to stabilize debt levels, requiring an adjustment in fiscal instruments. We observe a decrease in transfer payments following the rise in debt levels aimed at reducing government outlays to stabilize debt. The observed increase in taxes is mainly due to taxes tracking output closely as opposed to rising to stabilize debt levels.

In the open economy model, the crowding out effect on consumption is smaller than on investment. Some empirical studies in the literature find a positive relationship between government debt and interest rates as evidence of crowding out. This is not the case in our analysis, as it would suggest that following a government spending increase the real interest rate rises while investment falls. However, in our small open economy model, the interest rate is invariant to the government spending shock. The difference in the path of investment can however be explained by the larger negative wealth effect that is generated following an increase in government spending in the open economy environment. The increase in the stock of foreign debt creates an increase in interest payments on this debt. As more resources are absorbed by the increase in government consumption, external debt and external debt repayment obligations, there are fewer resources left to invest by the private sector.

FIGURE 3.7 displays the impulse responses to a one standard deviation temporary increase in lump sum transfers shock. An increase in transfer payments creates a positive wealth effect, the wealthier representative agent increases consumption and decreases hours worked. The agent substitutes investment for consumption leading to a decrease in investment. The increase in transfer payments is debt financed, causing total debt in the economy to rise. The estimated government-spending rule implies that the representative household expects government spending to adjust (decline) to stabilize the rise in debt.



3.7 Impulse responses to a lump sum transfers shock in the estimated model

3.6.6 Variance Decomposition

In this section, we examine the forecast error variance decomposition (FEVD) at various time horizons in order to determine the driving forces of business cycles. Given that structural shocks contribute to cycles of main macroeconomic aggregates as well as their long run trends, we are interested in identifying the contribution of various shocks to fluctuations in aggregate output and debt over the business cycle. TABLE 3.3 reports the contribution of each structural shock to the forecast error variance of output and debt in our model.

Following Smets and Wouters (2003) we report FEVD on impact of the shock, one year after the shock (short run), two and a half years after the shock (medium run), and 25 years after the shock (long run). We consider the FEVD of aggregate output first. At every time horizon, a significant fraction of the forecast error variance of output is driven by the technology shock and the labour supply shock. The fraction of forecast error variance of output attributable to the technology shock is between 25 to 27 percent at all forecast horizons. Whereas the fraction of forecast error variance attributable to the labour shock is 56 percent on impact, 59 percent at four quarters, 60 percent at ten quarters and 63percent at 100 quarters. Jointly, these two shocks explain 81 percent of the fluctuations in output in the short run, 86 percent in the medium run and 91 percent in the long run. Among the fiscal shocks, spending shocks are more important to output variability than tax shocks. The government spending shock and the transfers shock jointly explain approximately 12 percent of the forecast error variance for output in the short run. TABLE 3.3 shows the transfers shock dominates in all periods when compared to the government spending shock, and consistently explains between 6.5 to 7.5 percent of the forecast error variance of output. These results are consistent with the RBC paradigms that find supply shocks to be the main source of aggregate fluctuations in the macro economy. Next, we consider which structural shocks drive fluctuations in aggregate debt over the business cycle. In the short run the lump sum transfers shock dominates by explaining 60 percent of the forecast error variance. Followed by the government spending shock, which accounts for 21 percent.

The two supply shocks jointly determine 14 percent of the forecast error variance for debt in the short run. In the medium run, innovations in transfers and government spending continue to be the main driving force in debt fluctuations, contributing approximately 80 percent of the forecast error variance, whereas supply shocks jointly account for 17 percent of the forecast error variance. In the long run, innovations in lump sum transfers predominantly explain the forecast error variance of debt. Supply shocks become more important at longer time horizons, jointly accounting for approximately 24 percent of fluctuations in debt.

TABLE 3.3 Forecast error variance decomposition

		Output (%)	Debt (%)
t = 0	Preference shock	2.48	0.32
	Labour shock	56.28	10.14
	Investment shock	4.15	0.24
	Technology shock	24.57	4.43
	Gov. spending shock	5.41	20.72
	Cap.tax rate shock	0.12	2.66
	Labour tax rate shock	0.30	1.86
	Cons. tax rate shock	0.02	1.59
	Transfers shock	6.67	58.04
t = 4	Preference shock	2.25	0.30
	Labour shock	58.50	9.71
	Investment shock	2.92	0.20
	Technology shock	25.53	4.24
	Gov. spending shock	3.98	20.27
	Cap.tax rate shock	0.07	2.43
	Labour tax rate shock	0.30	1.69
	Cons. tax rate shock	0.01	1.20
	Transfers shock	6.45	59.96
t = 10	Preference shock	1.78	0.33
	Labour shock	60.16	11.73
	Investment shock	1.92	0.13
	Technology shock	26.26	5.12
	Gov. spending shock	2.06	19.54
	Cap.tax rate shock	0.17	1.95
	Labour tax rate shock	0.25	1.30
	Cons. tax rate shock	0.00	0.63
	Transfers shock	7.40	59.27
t = 100	Preference shock	0.70	0.18
	Labour shock	63.29	16.40
	Investment shock	0.36	0.03
	Technology shock	27.63	7.16
	Gov. spending shock	0.57	12.87
	Cap.tax rate shock	0.35	0.69
	Labour tax rate shock	0.14	0.43
	Cons. tax rate shock	0.00	0.13
	Transfers shock	6.95	62.11

Government spending shocks become less important in the long run, accounting for only about 13 percent of the forecast error in debt. Overall, our results indicate that supply shocks play a key role in explaining the variance of aggregate output and fiscal shocks on the spending side play a key role in explaining the variance in debt. The labour supply shock appears to be more important than the technology shock by driving a larger fraction of fluctuations in both endogenous variables. The significant contribution of the government spending shock and the transfer shock to the forecast error variance of public debt is not surprising to some extent, given the estimated coefficients on the fiscal rules for the expenditure instruments. Our estimation results indicate that the largest adjustments occur in government spending and transfers payments when debt moves away from its steady state level.

3.7 How well does the estimated model match business cycle frequencies?

DSGE models are traditionally validated by a method of matching a model's first and second moments to empirical moments. In this section, we present a comparison of the estimated alternative model to Canadian real business cycle facts. TABLE 3.4 reports the historical moments for real output, consumption, investment (aggregating machinery, equipment and investment in structures), hours, trade balance to output ratio and the current account to output ratio. The historical moments for these macroeconomic time series are calculated using quarterly data for Canada, using a sample period ranging 1961q1 to 2012q2. We take the log of all series with the exception to the trade balance to output ratio and the current account to output ratio. The series are all de-trended using a Hodrick Prescott (HP) filter and using a smoothing parameter of 1600. TABLE 3.4 reports a set of statistical moments for the Canadian economy and the estimated open economy model to determine the fit of theoretically produced moments to actual data.

TABLE 3.4 Canadian business cycle facts

	Data				Open Economy			
Series	SD	Rel.SD	Corr	AR(1)	SD	Rel.SD	Corr	AR(1)
Output	1.14	1.00	1.00	0.74	1.16	1.00	1.00	0.76
Cons.	0.82	0.72	0.62	0.83	1.15	0.99	0.66	0.89
Investment	5.19	4.55	0.56	0.89	2.87	2.47	0.58	0.89
Hours	1.50	1.31	0.60	0.90	1.53	1.32	0.76	0.76
TB ratio	1.06	0.93	0.27	0.65	0.64	0.55	0.07	0.42
CA ratio	0.27	0.24	0.41	0.62	0.63	0.54	0.09	0.42

SOURCE: Data: 1960q1 to 2012q2. All data series are obtained from CANSIM and are in per capita. Except for the trade balance and current account output ratios all data are in logs. All data are de-trended using the HP filter with a smoothing parameter of 1600. AR(1) corresponds to the autocorrelation between variables.

We report volatilities, relative volatilities, correlation with output, and autocorrelation of order one for output, consumption, investment, hours, trade balance to output ratio and the current account to output ratio. These moments are presented for both the estimated model and Canadian data. The estimated model does very well in matching the volatilities for aggregate output and hours found in Canadian data. The standard deviation of output in the model is 1.16 and 1.14 in Canadian data. The standard deviation of hours in the model is 1.53 and 1.5 in the data. The model produces higher consumption and current account ratio volatility and lower investment and trade balance ratio volatility than found in Canadian data. Reproducing consumption and trade balance output ratio (current account output ratio) volatilities is a known challenge in the open economy real business cycle literature. Mendoza (1991) speaks to the challenges of producing a sufficiently countercyclical trade balance in open economies, and Correia, Neves and Rebelo (1995) show that it is difficult to correctly capture the volatilities of consumption and the trade balance (current account). The model does well at matching the first order autocorrelations for output, consumption and investment. The first order autocorrelation for output produced by the model is 0.76 and 0.74 in Canadian data. The consumption first order autocorrelation from the model is 0.89 and 0.83 in the data. The first order autocorrelation for labour is perfectly matched to its empirical counterpart at 0.89. The model does not match the first order autocorrelations for hours, the trade balance output ratio and the current account output ratio found in the data. This finding is common in the literature and has been attributed to a weak internal propagation mechanism in small open economy models.

Leeper, Plante and Traum (2010) did not report the second moment properties of their estimated closed economy model. In TABLE 3.5 we compare the theoretical moments from their closed economy model against the moments found in U.S quarterly data for the period 1960q1 to 2002q2. We also report the moments using the parameter values for the open economy.

The standard deviation, standard deviation relative to output, correlation with output and auto-correlation (order one) are reported for output, consumption, investment and hours. These moments reveal several inconsistencies between model generated moments and the moments in U.S data, suggesting that the closed economy model does not do a good job replicating basic business cycle facts for the U.S. The closed economy model produces consumption, investment and hours volatilities that are larger than their empirical U.S counterparts. However, when open economy parameter values are used the volatilities of output, investment and hours move closer to the observed volatilities in the data.

TABLE 3.5 U.S business cycle facts

	Data				Open Economy			
	SD	Rel.SD	Corr w/Y	AR(1)	SD	Rel.SD	Corr w/Y	AR(1)
Y	1.70	1.00	1.00	0.85	1.30 (1.60)	1.00(1.00)	1.00(1.00)	0.82(1.00)
C	0.90	0.53	0.76	0.79	1.88 (1.80)	1.45 (1.12)	-0.03(0.85)	0.86(1.00)
I	4.70	2.76	0.79	0.87	9.73 (3.60)	7.48 (4.67)	0.69(0.65)	0.87(1.00)
H	1.90	1.12	0.88	0.90	1.57 (2.00)	1.21 (0.75)	0.75(0.88)	0.78(1.00)

SOURCE: All data are obtained from the BEA. Data: 1948Q1-2010Q3. The data are in per capita and real terms. The data are HP filtered with a smoothing parameter of 1600. Moments calculated using open economy parameter estimates are reported in brackets.

The closed economy correlation of investment and hours with aggregate output is also lower than what is observed in the data. Again, using open economy parameter values allows us to perfectly match the correlation of labour hours and output in the data. A close inspection of TABLE 3.5 reveals the counterfactual results generated by the closed economy parameter values with respect to the relative rankings of output, consumption and hours volatilities. In the data output and hours are more volatile than consumption but the estimated parameter values in Leeper, Plante and Traum (2010) generate a consumption volatility that outrank the volatility in output and hours. We do not find evidence of open economy parameter values leading to a better matching of relative volatilities in the data.

We find the biggest shortfall of the estimated closed economy model in Leeper, Plante and Traum (2010) is that it produces a counterfactual negative correlation (-0.03) between consumption and output. We are able to reconcile this counter-intuitive finding when consulting open economy parameter values, which generate a correlation of 0.85 between consumption and output. The estimated small open economy model is able to correctly capture a positive correlation between consumption and output that is closer to the data (0.76). We find that the correlation between output and consumption stems from differences in the magnitude of the standard deviation for the preference and investment specific shocks. The standard deviation of the preference shock is estimated to be 1.4 in the open economy and 7 in the closed economy. Similarly, the standard deviation of the investment shock is estimated at 1.7 in the open economy and 6.4 in the closed economy. These demand shocks are significantly more volatile in the closed economy, and drive the negative co-movement between consumption and output. The estimation results of the open economy produce lower volatilities for these shocks and predict a positive co-movement between output and consumption, as seen in Canadian data. We are able to closely match the correlation between consumption and output (0.66) and investment and output (0.58) in our model to the respective correlations found in Canadian data (0.62 and 0.58). However, the model has difficulty in reproducing the correlation of the trade balance and current account ratios with output. The open economy model produces a pro-cyclical trade balance and current account output ratios, whereas this relationship is countercyclical in the data. This counterfactual result can be explained by a high estimated value for the investment adjustment cost parameter.

Matching first and second moments of estimated models to the data is a good test for checking model fit to empirical data. The Bayesian approach does not consider this form of classical testing to be a rigid out of sample test, as the parameters are estimated from the same dataset to which moments are being matched.[73] Instead, the literature on Bayesian estimation of DSGE models typically match the cross correlations coming from the estimated model against empirical

[73] Please see Smets and Wouters (2003).

cross correlations to perform model validation. The cross correlations for our estimated model measure up well with the cross correlations implied in Canadian data.

3.8 Welfare analysis

In this section we explore the welfare effects of each fiscal rule using the estimated parameter coefficients from TABLE 3.2. We conduct several policy experiments in which a 1 percent temporary negative (positive) shock to each spending (tax) instrument reduces steady state debt. We then compute the change in aggregate welfare to determine which adjustments in individual instruments have the highest welfare cost. We perform this welfare analysis using the estimated small open economy model to determine the effect of the following contractionary fiscal policy changes on macroeconomic aggregates: (1) a decrease in government spending, (2) an increase in the capital tax rate, (3) an increase in the labour tax rate, (4) an increase in the consumption tax rate and (5) a decrease in lump sum transfer payments. Each shock occurs while holding other shocks fixed.

Welfare measure

Following Lucas (1987) and Schmitt-Grohé and Uribe (2007) we define our welfare measure as lifetime utility in the deterministic steady state and measure welfare cost in terms of consumption equivalents. Consumption equivalents represent the percentage change in consumption required to equalize lifetime utility before and after each fiscal shock.

We define variables in the economy before a shock with an asterisk. As a first step we calculate the unconditional expected value of lifetime utility, $E\left[W^*\right]$, before the shock as follows:

$$E\left[W^*\right]=\sum_{t=0}^{T}\beta^t U\left(c^*,l^*\right) \tag{3.41}$$

Similarly, we then calculate the representative household's unconditional expected value of lifetime utility after the shock as follows (variables are denoted by a tilde after the shock):

$$E\left[\tilde{W}\right]=\sum_{t=0}^{T}\beta^t U\left(\tilde{c},\tilde{l}\right) \tag{3.42}$$

As a last step we determine the constant quantity of consumption (CE) required or the consumption equivalent that makes the representative agent as well off after the shock as he/she was before the shock. The consumption equivalent is then converted to a percentage.

$$E\left[\tilde{W}'\right]=\sum_{t=0}^{\infty}\beta^t U\left((1+CE)\tilde{c},\tilde{l}\right) \tag{3.43}$$

TABLE 3.6 summarizes the welfare cost and change in debt one period after each respective shock in percent. All policy experiments entail a welfare cost with the exception to a decrease in government spending. A one percent decrease in government spending relative to its steady state results in a welfare gain of 0.07 percent. A decrease in government spending increases consumer income, as there are more resources in the economy and welfare is increased. We find that a one percent increase in the capital or labour tax rate leads to a comparable level of welfare loss and that this welfare loss is significantly smaller than the loss in welfare resulting from a decrease in lump sum transfers. In comparing the resulting change in the debt, we find that the largest decline in debt from its steady state level occurs following a transfers shock and government spending shock.

TABLE 3.6 Welfare costs of fiscal policy rules

Fiscal rule	Welfare gain (loss) in percent	Debt change in percent
Government spending	0.069	-1.97
Capital tax rate	-0.031	-0.72
Labour tax rate	-0.029	-0.54
Consumption tax rate	-0.007	-0.61
Lump sum transfers	-0.188	-3.32

The largest welfare cost is associated with the transfers' rule, where a one percent decrease in lump sum transfers from its steady state creates a welfare loss of 0.19 percent. Overall, our findings indicate that an increase in tax rates (capital and labour) is less costly in terms of welfare than a decrease in transfer payments. The representative household varies consumption much more aggressively to a reduction in transfer payments compared to when they face a higher capital or labour tax rate. These results would seem to suggest that when following contractionary fiscal policy, if the fiscal authority cares about welfare effects, government spending is the best fiscal policy instrument, followed by tax rates and lastly transfer payments. We suggest caution in this interpretation of the results since government spending in our model is unproductive and does not affect the private marginal product schedules.

3.9 Robustness for structural parameters

To test the sensitivity of the structural parameters to the chosen priors we perform a robustness exercise that varies the mean and the standard deviation and we analyze the resulting posterior distribution from this subsequent estimation. If the posterior distributions of our structural parameters display significant differences when compared to the initial estimation results, then this would indicate that the choice of the priors have strongly influenced the posterior estimates. TABLE 3.7 and TABLE 3.8 displays the prior selections and posterior results for all parameters.

Our robustness exercise shows little variation in the posterior estimates when the mean, standard deviation and in the case of some parameters the distribution category of our priors are changed. To choose a new set of priors for our parameters we look to Smets and Wouters (2003, 2007) as it is an influential Bayesian study and is most commonly cited in the literature. For some parameters where the priors in Smets and Wouters (2003, 2007) vary from priors chosen for Canadian data we follow the prior choices in Justiniano and Preston (2010) as we believe these choices more accurately reflect our dataset.

We reduce the prior mean and standard deviation for the risk aversion parameter to 1 and 0.37 as in Smets and Wouters (2003) and Justiniano and Preston (2010). We change the distribution governing the inverse Frisch elasticity parameter from a normal distribution to the beta distribution and increase the standard deviation from 0.5 to 0.75. For the investment adjustment cost parameter, we switch from the gamma distribution to the normal distribution, reducing the prior mean to 4 and increasing the standard deviation to 1.5. The same applies to the capital utilization cost parameter, where we select the normal distribution, a prior mean value of 0.2 and a prior standard deviation of 0.75.

We set new priors for the parameters in the fiscal rules. We keep the choices for the distribution of these parameters the same and double the prior mean and standard deviation values. Specifically, we are interested in the sensitivity of these structural parameters to our prior selections. All debt coefficients (corresponding to the elasticity of the fiscal instruments to debt) in the fiscal rules are assigned a prior mean of 0.8 and a standard deviation of 0.4. Similarly, prior selections for all output coefficients and tax-co term coefficients are also increased by a scale factor of 2.

TABLE 3.7 Prior and posterior distribution of structural parameters

Parameter		Prior Distribution			Posterior Distribution			
		Distrib.	Mean	Std.	Mode	Mean	5%	95%
γ	Risk Aversion	Normal	1.00	0.37	0.26	0.10	0.02	0.18
κ	Inv. Frisch Elasticity	Normal	2.00	0.75	5.47	5.27	4.53	6.03
H	Habit persistence	Beta	0.70	0.10	0.91	0.98	0.96	0.99
χ	Inv. Adj Cost	Normal	4.00	1.50	10.58	11.64	9.88	13.06
δ_2	Capital Util. Cost	Normal	0.20	0.07	0.25	0.24	0.13	0.36
γ_g	Gov. Spending B coeff.	Gamma	0.80	0.40	0.15	0.17	0.11	0.22
γ_{tk}	Cap. Tax B coeff.	Gamma	0.80	0.40	0.40	0.26	0.16	0.35
γ_{tl}	Labor Tax B coeff.	Gamma	0.80	0.40	0.10	0.14	0.03	0.25
γ_z	Transfer B coeff.	Gamma	0.80	0.40	0.80	0.76	0.62	0.90
φ_{tk}	Cap. Tax Y coeff	Gamma	2.00	0.60	1.63	1.53	1.25	1.82
φ_{tl}	Labor Tax Y coeff.	Gamma	1.00	0.50	0.44	0.37	0.15	0.57
φ_g	Gov. Sp Y coeff.	Gamma	0.14	0.20	0.02	0.05	0.00	0.10
φ_z	Transfer Y coeff.	Gamma	0.40	0.20	0.64	0.48	0.13	0.83
ϕ_{kl}	Cap./Labor co-term	Normal	0.50	0.20	0.00	0.03	-0.03	0.09
ϕ_{kc}	Cap./Cons co-term	Normal	0.10	0.20	-0.08	-0.11	-0.15	-0.06
ϕ_{lc}	Labor/Cons. co-term	Normal	0.10	0.20	0.00	-0.04	-0.1	0.01

TABLE 3.8 Prior and posterior distribution of shock processes

Parameter		Prior Distribution			Posterior Distribution			
			Mean	Std.	Mode	Mean	5%	95%
ρ_a	Tech AR coeff.	Beta	0.85	0.10	0.95	0.97	0.96	0.99
ρ_b	Pref. AR coeff.	Beta	0.85	0.10	0.71	0.60	0.54	0.67
ρ_l	Labor AR coeff.	Beta	0.85	0.10	0.84	0.84	0.81	0.87
ρ_i	Inv. AR coeff.	Beta	0.85	0.10	0.85	0.75	0.69	0.81
ρ_g	Gov. Sp AR coeff.	Beta	0.85	0.10	0.97	0.98	0.97	0.99
ρ_{tk}	Cap. Tax AR coeff.	Beta	0.85	0.10	0.99	0.98	0.97	0.99
ρ_{tl}	Labor tax AR coeff.	Beta	0.85	0.10	0.92	0.95	0.92	0.98
ρ_{tc}	Cons. Tax AR coeff.	Beta	0.85	0.10	0.78	0.89	0.85	0.93
ρ_z	Transfer AR coeff.	Beta	0.85	0.10	0.99	0.99	0.98	1.00
σ_a	Tech. std.	I.Gamma	0.40	2.00	0.85	0.77	0.68	0.81
σ_b	Pref. std.	I.Gamma	0.20	2.00	2.40	2.77	2.36	3.15
σ_l	Labor std.	I.Gamma	1.00	2.00	4.63	4.53	3.75	5.24
σ_i	Inv. Std.	I.Gamma	0.10	2.00	2.75	1.96	1.61	2.30
σ_g	Gov. Spend std.	I.Gamma	0.30	2.00	1.93	2.04	1.87	2.21
σ_{tk}	Cap. Tax std.	I.Gamma	0.30	2.00	1.68	1.75	1.58	1.92
σ_{tl}	Labor Tax std.	I.Gamma	0.30	2.00	1.90	1.88	1.71	2.03
σ_{tc}	Cons. Tax std.	I.Gamma	0.30	2.00	2.76	2.79	2.55	3.03
σ_z	Transfer std.	I.Gamma	0.30	2.00	2.91	3.02	2.76	3.27

We follow Smets and Wouters (2003) in setting the priors for persistence parameters. Since the beta distribution is most commonly selected for this parameter we keep this prior choice fixed. Instead we increase the mean value to 0.85 and decrease the standard deviation to 0.1. The prior mean for the standard deviation of the technology variable is set at 0.4 with a standard deviation of 2. This selection comes from Smets and Wouters (2003) but is lies close to the priors selected in Justiniano and Preston (2010) for this parameter.[74] The priors for the remaining standard deviation parameters are also set following Smets and Wouters (2003) and are summarized in TABLE 3.8.

In the estimation of the structural parameters, we set out to estimate the posterior mode of the distribution and as before by using a Metropolis Hastings algorithm to approximate the distribution around the neighbourhood of the posterior mode. We run 2 chains of the algorithm, where each chain is set to select 5,000,000 draws. The acceptance rates for each chain are 30.45 per cent and 30.30 per cent and the Laplace approximation is -3421.9.

3.10 Conclusion

The application of Bayesian techniques to DSGE models of fiscal policy has become increasingly popular in the recent fiscal policy literature. In this chapter we examine the effects of fiscal policy on the Canadian economy and estimate the structural parameters of a small open economy model using a Bayesian approach. The fiscal structure of the model consists of fiscal

[74] Justiniano and Preston (2010) select priors for the standard deviation of technology by setting the mean to 0.5 and the standard deviation to 1.

debt rules that react by adjusting to a gap in aggregate output and a gap in public debt in the economy. The model features five fiscal rules: capital tax rule, labour tax rule, consumption tax rule, government spending rule and transfers rule. These debt rules are estimated with Bayesian techniques using Canadian macroeconomic data, to determine which fiscal instruments have played an important role in stabilizing public debt levels historically in the Canadian context.

The estimation of the small open economy model for Canada yields several key results worth highlighting. The parameters for the estimated debt rules provide evidence of reliance on spending instruments over taxation instruments. Our results indicate that fiscal policy primarily highlightedd government spending restraint, followed by reductions in transfer payments to stabilize public debt in Canada. Our estimation results do not provide evidence for the use of taxation instruments to lower debt levels. These findings are in line with the existing literature on fiscal adjustments in Canada that highlight declines in public expenditures as the driving force in successful fiscal consolidation episodes. Our results also support the long stated political commitments of the federal government to follow fiscal policy featuring low taxation rates. The results from our welfare exercise also lend support for the federal government's policy reliance on a government-spending rule.

The main contribution of the chapter lies in the empirical estimates obtained for the fiscal parameters of the model. There are no comparable estimates for fiscal debt rules in Canada, as the literature has mainly focused on estimating fiscal rules for the U.S and Europe. Furthermore, we feel that an understanding of the fiscal policy landscape, with respect to debt management, will be an important initial step in the development of a future consolidation strategy.

4 Canadian Fiscal Policy in a Small Open Economy with Heterogeneous Households

4.1 Introduction

A new economic environment has ensued after the financial crisis of 2008-2009 that reassesses the stabilizing role of fiscal policy, leading governments to search for more sustainable fiscal frameworks in the form of systematic fiscal policies. A large part of the conversation about systematic fiscal policies is centered on the use of countercyclical fiscal rules. The International Monetary Fund (IMF) Fiscal Affairs Department has taken great interest in documenting the instance of fiscal rules and more recently analyzing the scope of rules based fiscal policies. [75] Moreover, numerical fiscal rules have been identified in many studies as a key response to the late financial crisis. [76]

In Canada, fiscal rules have been widely used at the provincial and federal levels of government throughout history. In 2015, a balanced budget rule (The Balanced Budget Act) was implemented by the Conservative led government, that legally requires the government to achieve fiscal balance. In 2016, a change in political leadership led the Balanced Budget Act to be repealed by the Liberal party. The new political leaderships' spending policies will generate budget deficits and violate the fiscal rule that requires a balanced budget. As a result, a

[75] Please see Budina, Kinda, Schaechter and Weber (2012), Kopits (2013), Bova, Ruiz-Arnaz, Toscani and Ture (2016), Kotia and Lledo (2016).
[76] Budina, Kinda, Schaechter and Weber (2012), and Wyplosz (2012).

dissolution of the legislated fiscal rule was proposed in Budget 2016. The fiscal plans over the next few years consist of deficit financed investment spending totaling to 1.39 billion[77] aimed at spurring economic growth. The Liberal government has also communicated an intention to follow fiscal policies that increase targeted transfer payments to financially constrained families. One example of this commitment is the replacement of existing child tax transfers (Universal Child Tax Benefit, Canada Child Tax Benefit, and the National Child Benefit Supplement) with the Canada Child Benefit. This transfer payment unlike its predecessors is tied to household income, and so serves to deliver higher transfers to financially constrained families as opposed to wealthy families. The course of fiscal policy in coming years will lead to consecutive deficits and an increased level of debt in the economy. With the dissolution of the balanced budget rule and the accumulation of public debt that will result from budget deficits, policy makers must make fiscally prudent choices to maintain a sustainable debt level. Given the fiscal authority's orientation towards financially constrained households any debt stabilization policy that will replace the balanced budget rule will have to consider the welfare of these households under the new policy.

Recently the fiscal policy literature motivated by the seminal contribution of Taylor (1993) in the form of the monetary policy rule, has begun the search for a fiscal counterpart. The simple interest rate rule (Taylor Rule) has proved to be a practical tool for policy makers and researchers who aim to find a fiscal equivalent. While many specifications for the conceptual fiscal rule have been proposed, the literature has not yet converged to adopt a standard framework. Another

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[77] Please see the Liberal Fiscal Plan and Costing (2015), www.liberal.ca/files/2015/09/The-Liberal-fiscal-plan-and-costing.pdf

important development in the fiscal literature has also emerged that recognizes the presence of credit market constraints in the form of liquidity-constrained households as in Galí, López-Salido, and Vallés (2007). The liquidity-constrained feature has become an important propagation mechanism in the fiscal policy literature, with many studies finding a significant stabilizing role for fiscal policy when a subset of the population faces credit constraints.

The presence of liquidity-constrained agents has traditionally been studied in the context of developing countries, so little analysis exists on their importance in industrialized countries. However, the post financial crisis environment can be described as one in which credit constraints are more pressing even in advanced economies. Taylor (2000) points out that fiscal policy can have an important stabilizing role if we consider a fixed exchange rate environment, when nominal interest rates are near the zero lower bound, or when a large part of the population is liquidity constrained. The current economic environment is characterized by both low interest rates that limit how much monetary policy can provide support for the economy and a larger number of households that are financially strained. Exploring the impact of these features within a rules based fiscal framework in advanced small open economies is now more important than ever before.

This chapter analyzes the scope of countercyclical fiscal rules by extending the small open economy model from the previous chapter to recognize the presence of heterogeneous agents. We simplify the model by eliminating some frictions and keeping tax rates constant so as to focus our attention to the interaction of heterogeneous agents and fiscal rules. Our model features traditional Ricardian agents and liquidity-constrained agents who are unable to smooth consumption inter-temporally. We propose and analyze a suite of fiscal rules that consist of a balanced budget rule, a government-spending rule, and a transfer payments rule. These simple rules are specified such that government expenditures respond to an output gap in order to stabilize the business cycle in the short run and to a debt gap to ensure debt sustainability in the long run. This quantitative small open economy model is applied to the case of Canada, allowing us to analyze impulse responses and conduct welfare analysis.

We pose the following questions in this chapter: What are the welfare implications that arise for the aggregate economy and households that differ in their access to credit markets when fiscal policy moves from following a balanced budget rule to debt rules? How are the effects of fiscal shocks under different rules transmitted in the presence of liquidity-constrained households? Lastly, when the fiscal authority adopts debt rules, what are the welfare implications for households when the economy is hit with an unexpected technology shock, government spending shock and transfers shock?

We find that debt rules improve aggregate welfare in the economy compared to a balanced budget rule. This improvement in aggregate welfare is driven by the welfare gains of a large share of Ricardian households in the population. Debt rules are unable to increase the welfare of liquidity-constrained agents because the ability of governments to use deficit financing only benefits Ricardian households but does not alleviate the market imperfection that arises from the presence of liquidity constrained households. If the fiscal authority's main objective is to choose a fiscal rule that maximizes aggregate welfare, then the debt rules are the preferred policy tool even though they make a subset of the population worse off. When following debt rules, we find that the government's decision to stabilize debt through reductions in transfer payments as opposed to government spending increases the volatility of liquidity constrained households' income, thereby reducing welfare gains significantly.

The plan of this chapter is as follows: section 2 reviews the literature, section 3 introduces the heterogeneous agent small open economy model, section 4 defines a competitive equilibrium, section 5 discusses our calibration to the Canadian economy, section 6 reports our impulse response analysis results, section 7 presents the welfare analysis, and section 8 concludes.

4.2 Literature Review

Recently the literature on systematic fiscal policy has been extended beyond the new normative macroeconomic approach to include a welfare perspective in a heterogeneous agent framework. Bi and Laxton (2011), González, López, Rodriguez and Téllez (2013), and Kumhof and Laxton (2013) have identified the presence of liquidity-constrained households as in Mankiw (2000) as a powerful propagation mechanism that has received little attention in the literature. While liquidity constraints can take many forms, Galí, López-Salido, and Vallés (2007), Bartolomeo and Rossi (2007) and Bilbiie (2008) represent the literature that connects it to limited asset market participation. Alongside households that optimize in a traditional (Ricardian) sense, there exists liquidity-constrained households that do not have access to financial markets and cannot hold public debt. These households cannot smooth consumption using credit markets, which gives rise to a market imperfection and violates Ricardian equivalence. Although this may appear to be an extreme assumption, many empirical works (Mankiw (1989), Galí, López-Salido, and Vallés (2007), Bartolomeo and Giuli (2011) confirm the quantitative importance of liquidity constrained individuals. The share of liquidity constrained households in the total population has been estimated to be as high as 0.5 in many developed countries. Bartolomeo and Giuli (2011) use Bayesian estimation techniques and find the fraction of liquidity-constrained households to be 0.3 in Canada.

Unlike the earlier strand of literature (Schmitt-Grohé and Uribe (2007), Bilbiie (2008) and Rossi and Zubairy (2011)) that focused on the determinacy properties of monetary and fiscal rules in the presence of liquidity constrained households, the new strand of literature that examines the intersection of liquidity constrained households and fiscal policy, focuses on analyzing the welfare properties and outcomes of this framework. These works show that optimized fiscal rules (rules that maximize welfare) lend far greater welfare benefits than optimized monetary policy rules. This literature also shows that within a general set of fiscal rules, structural surplus rules deliver better outcomes in terms of macroeconomic volatility and welfare than balanced budget rules and countercyclical rules.

A key contribution has been the design of strongly countercyclical fiscal rule specifications that emphasize strong automatic stabilizers. These rules perform better in a welfare (of liquidity constrained households) sense than balanced budget rules when they are geared towards stabilizing the incomes of liquidity-constrained households through the inclusion of a tax revenue gap as opposed to an output gap. Instead of having a rule that adjusts tax rates or fiscal spending to smooth deviations of aggregate output from its steady state level the rule smooths deviations of tax revenues from its long run level. Consider a negative shock to the income of liquidity-constrained households. This leads to a shortfall in tax revenues through the tax base. A fiscal authority that systematically responds to a tax revenue gap in a countercyclical fashion would then reduce government spending and transfers. Kumhof and Laxton (2013) argue that instead the government should respond by increasing targeted transfers to liquidity constrained households and smooth consumption inter-temporally on their behalf. When considering several policy tools, Bi and Laxton (2011) and Kumhof and Laxton (2013) show that targeted transfers maximize welfare of liquidity-constrained households.

The empirical literature has also identified an important role for transfer payments as an anti-cyclical policy instrument.[78] Reicher (2014) estimates fiscal rules for a cross section of OECD countries, showing that transfer payments respond strongly to short run fluctuations in the cycle and that countries with a large rate of transfer payments demonstrate less volatility in output growth. These findings support the recent efforts of Bi and Laxton (2010), Motta and Tirelli (2012), McKay and Reis (2013) and Kumhof and Laxton (2013) in the theoretical literature that have moved beyond analyzing the fiscal impact of government spending and tax rates and focused on transfer payments.

In this chapter we aim to contribute to this recent strand of literature that assesses the role of transfer payments as a policy instrument within the conduct of systematic rules based fiscal policy. Our work differs from the above-mentioned papers in various respects but mainly in its analysis of countercyclical rules in which government spending and lump sum transfers common to all households respond to the output gap and debt gap. Since Canada does not operate under a structural surplus rule[79] we do not consider a tax revenue gap or a commodity revenue gap and instead focus on balanced budget and debt rules. Another key difference is the determination of coefficients of the fiscal rules. In the above papers, these coefficients are obtained by finding the value that maximizes aggregate welfare in the economy. In our analysis we use coefficients from the Bayesian estimation of fiscal rules performed in chapter 3. These coefficients are based on

[78] Please see Debrun and Kapoor (2010) and Fatàs and Mihov (2001) who find a negative cross correlation between government size and output volatility.

[79] Countries following structural surplus rules include Brazil, Chile, Sweden and Switzerland.

Canadian macroeconomic time series data and reflect the actual systematic behaviour of fiscal aggregates to changes in the output gap and debt gap.

We hope to make a contribution to the theoretical literature by proposing simple debt rules for the Canadian economy and conducting welfare analysis to shed light on the heterogeneous effects of fiscal policy. We evaluate countercyclical debt rules using the results of the structural parameters of the model from the previous chapter and the estimated fraction of liquidity constrained households from empirical evidence, to assess the welfare costs that arise from a regime inversion. We find that with one third of the population being liquidity-constrained agents, debt rules yield a higher aggregate welfare gain relative to a balanced budget rule. Our results add to the literature by showing that the implementation of fiscal rules that respond to an output and debt gap in developed countries is welfare reducing for these agents. We also show that using transfer payments as a tool for debt stabilization further exacerbates welfare losses for non-Ricardian households by increasing the volatility of their income. As much of the welfare analysis of fiscal policy rules in the presence of liquidity-constrained households has focused on developing countries, by focusing on Canada we provide evidence for developed small open economies.

4.3 Heterogeneous agent small open economy model

The economy consists of two types of representative households, a perfectly competitive firm that produces a final good, and a fiscal authority. The two types of households mainly differ in their ability to participate in financial markets. Ricardian households (RIC) have access to financial markets in the rest of the world (ROW) and borrowing from these markets allows them to smooth consumption inter-temporally. Liquidity constrained households (LIQ) on the other hand do not participate in financial markets and are limited to consume the sum of their after tax labour income and transfers received by the fiscal authority in each period. The fraction of LIQ households in the economy is represented by, θ , and the share of RIC households is represented by $(1-\theta)$. All households supply labour, consume output and face uniform labour tax rates and wages.

We introduce two types of fiscal rules that the fiscal authority takes as given. The first type of fiscal rule is a balanced budget rule that sets taxation revenues equal to total government expenditures. Under a balanced budget rule, the fiscal authority cannot accumulate debt and the deficit is zero. Under this rule, RIC households in the small open economy can borrow from abroad. The second type of fiscal rule is a debt rule. Based on our results in chapter 3 we consider the most stabilizing rules for the debt gap. Under these two debt rules, the fiscal authority has the ability to borrow from abroad, increasing debt levels that are stabilized either through government expenditure or transfers payment instruments. The different categories of fiscal rules have different welfare implications for RIC and LIQ agents and on the aggregate level. The welfare implications under a balanced budget rule and debt rules will be explored in section 4.7.

4.3.1 Ricardian Households

We use a utility function common to both household types given by (4.1). RIC households maximizes the following inter-temporal utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\gamma} \left(c_t^{RIC} - hC_{t-1}^{RIC} \right)^{1-\gamma} + \psi \frac{\left(1-l_t^{RIC}\right)^{1+\kappa}}{1+\kappa} \right] \quad (4.1)$$

$$\gamma, \kappa > 0$$

where utility depends on consumption of a single good, c_t^{RIC} , relative to habit stock, measured by the product of the habit persistence parameter and lagged aggregate consumption, hC_{t-1}^{RIC} , and leisure**,** $\left(1-l_t^{RIC}\right)$ **,** where, l_t^{RIC} , represents the share of time spent working. We denote, E_0 , as the expectations operator at time zero, $\beta \in (0,1)$, is the subjective discount factor, γ , is the risk aversion parameter and, κ , is the inverse of the Frisch labour supply elasticity. The inverse Frisch labour supply elasticity measures the change in labour supply when the wage rate changes holding consumption constant. X_t , represents the aggregate level of any variable, x_t , which denotes a variable in per capita terms. The model features some of the same set of frictions as the estimated model in chapter 3. A discussion of the intuition behind including these frictions can be found in section 3.3.

Ricardian households face the following budget constraint:

$$\left(1-\tau^l\right) W_t l_t^{RIC} + \left(1-\tau^K\right) R_t^k k_t + z_t^{RIC} - R_t b_t^{RIC} = \left(1+\tau^c\right) c_t^{RIC} + i_t - b_{t+1}^{RIC} \quad (4.2)$$

where, τ^L , is the labour tax rate, W_t , is the wage rate, R_t^k , is the return on capital, τ^k , is the capital tax rate, k_t , is capital, z_t^{RIC} , is lump sum transfer payments to RIC households by the fiscal authority, R_t , is the interest rate on foreign held debt, b_t^{RIC} , is holdings of one period risk free foreign debt[80], τ^c , is the consumption tax rate, and, i_t , is investment. Labour income is given by the after tax return on the amount of labour supplied by households in a given period,

[80] We make this assumption to allow for a comparison between a fiscal regime where the fiscal authority pursues a balanced budget rule and an alternative regime in which there are debt rules.

$\left(1-\tau^{l}\right)W_{t}l_{t}^{RIC}$. Capital income is given by the after tax return on the amount of capital services supplied to firms, $\left(1-\tau^{k}\right)R_{t}^{k}k_{t}$. Thus the household's total income consists of labour income, capital income, foreign debt holdings, b_{t}^{RIC} , and income from lump sum transfers by the government, less interest payments on bond holdings by foreigners, $R_{t}b_{t}^{RIC}$. The interest rate, R_{t} , is given by the sum of the world interest rate, R^{w} , and $p\left(B_{t}\right)$, a country specific interest rate premium where, B_{t} , denotes total external debt holdings in the economy and, B_{t}^{f} , represents foreign debt held by the fiscal authority.

$$B_{t}=b_{t}^{RIC}+B_{t}^{f} \tag{4.3}$$

$$R_{t}=R^{w}+p\left(B_{t}\right) \tag{4.4}$$

The premium over the world rate is given by, $p\left(B_{t}\right)$, and is assumed to be strictly increasing in the level of external debt. The specification for the risk premium is adopted from Schmitt-Grohé and Uribe (2003) to circumvent the problem of a unit root in debt accumulation in the small open economy framework.[81] The functional form used for the country specific interest rate premium is given by:

$$p\left(B_{t}\right)=\psi_{2}\left(e^{B_{t}-\bar{B}}-1\right) \tag{4.5}$$

where, ψ_{2} , and, $\bar{B}$, are constant parameters and the latter represents the aggregate external level of public debt in the steady state.

The stock of capital evolves according to:

$$k_{t+1}=i_{t}+\left(1-\delta\right)k_{t}-\frac{\phi}{2}\left(k_{t+1}-k_{t}\right)^{2},\ \phi>0 \tag{4.6}$$

[81] Schmitt-Grohé and Uribe (2003) use a debt elastic interest rate or interest rate premium to determine the steady state net foreign asset position only in terms of the parameters of the model to eliminate the unit root in foreign debt.

where, δ_2 , represents the depreciation rate of the capital stock and, $\frac{\phi}{2}\left(k_{t+1}-k_t\right)^2$, is an investment adjustment cost following Mendoza (1991) and Schmitt-Grohé and Uribe (2003).

RIC households choose the following processes, $\left\{c_t^{RIC}, l_t^{RIC}, k_{t+1}^{RIC}, b_{t+1}^{RIC}\right\}$, to maximize the utility function in (4.1) subject to (4.2) - (4.6). The first order conditions for the RIC maximization problem are summarized below[82]:

$$\frac{\left(c_t^{RIC}-hC_{t-1}^{RIC}\right)^{-\gamma}}{\left(1+\tau^c\right)}=\beta E_t\frac{\left(c_{t+1}^{RIC}-hC_t^{RIC}\right)^{-\gamma}}{\left(1+\tau^c\right)}\left[\left(1-\tau^k\right)r_{t+1}^k+\left(1-\delta\right)\right] \tag{4.7}$$

$$-\psi\left(1-l_t^{RIC}\right)^{\kappa}+\frac{\left(c_t^{RIC}-hC_{t-1}^{RIC}\right)^{-\gamma}}{\left(1+\tau^c\right)}\left(1-\tau^l\right)W_t=0 \tag{4.8}$$

$$\frac{\left(c_t^{RIC}-hC_{t-1}^{RIC}\right)^{-\gamma}}{\left(1+\tau^c\right)}=\beta \mathrm{E}_t\frac{\left(c_{t+1}^{RIC}-hC_t^{RIC}\right)^{-\gamma}}{\left(1+\tau^c\right)}r_{t+1}$$

$$W_t=\left(1-\alpha\right)\frac{y_t}{l_t} \tag{4.9}$$

$$R_t^k=\alpha\frac{y_t}{k_t} \tag{4.10}$$

4.3.2 Liquidity constrained households

LIQ households share the same expected lifetime utility function as RIC households given by

[82] Where (4.7) is the RIC household consumption Euler, (4.8) is the RIC household intra-temporal condition and bond Euler, and (4.9) and (4.10) are the real wage rate and the real rental rate of capital.

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\gamma} \left(c_t^{LIQ} - hC_{t-1}^{LIQ} \right)^{1-\gamma} + \psi \frac{\left(1 - l_t^{LIQ}\right)^{1+\kappa}}{1+\kappa} \right] \tag{4.11}$$

where LIQ household's utility depends on habit adjusted consumption, LIQ consumption is represented by, c_t^{LIQ} , and leisure, $\left(1-l_t^{LIQ}\right)$. LIQ households face a budget constraint that differs from the budget constraint of RIC agents in (4.2) by restricting LIQ agents to only consume their current income. This implies that LIQ agents do not smooth consumption in response to shocks to current income and nor do they engage in inter-temporal substitution with respect to changes in the interest rate. The budget constraint for LIQ agents is given by

$$\left(1-\tau^l\right) W_t l_t^{LIQ} + z_t^{LIQ} = \left(1+\tau^c\right) c_t^{LIQ} \tag{4.12}$$

where, $\left(1-\tau^l\right) W_t l_t^{LIQ}$, represents after tax labour income and, z_t^{LIQ} , represents transfer payments targeted towards LIQ agents and paid by the government. LIQ households chose $\left\{c_t^{LIQ}, l_t^{LIQ}\right\}$, to maximize their expected lifetime utility in (4.11) subject to (4.12). The first order condition for the maximization problem of LIQ agents is as follows:

$$-\psi \left(1-l_t^{LIQ}\right)^{\kappa} + \frac{\left(c_t^{LIQ} - hC_{t-1}^{LIQ}\right)^{-\gamma}}{\left(1+\tau^c\right)} \left(1-\tau^l\right) W_t = 0 \tag{4.13}$$

4.3.3 Aggregation

Aggregate variables are summarized by taking a weighted average across household types where, C_t , is aggregate consumption over both types of households, L_t , is aggregate hours worked, and, Z_t , is aggregate lump sum transfers. Transfers for liquidity constrained households and Ricardian households are a proportion of total lump sum transfers and depend on the share of the household in the total population.

$$C_t = \theta c_t^{LIQ} + (1-\theta) c_t^{RIC} \tag{4.14}$$

$$L_t = \theta l_t^{LIQ} + (1-\theta) l_t^{RIC} \tag{4.15}$$

$$Z_t = \theta z_t^{LIQ} + (1-\theta) z_t^{RIC} \tag{4.16}$$

4.3.4 Firms

The representative firm rents labour from RIC and LIQ households and capital from RIC households as inputs for production. The firm chooses capital and labour to maximize profits as follows:

$$u_t^a k_t^a l_t^{1-\alpha} - W_t l_t - R_t^k k_t$$

where, $\alpha \in (0,1)$, and denotes capital's share of income, u_t^a , is a neutral technology shock following an AR (1) process given by

$$\ln(u_t^a) = \rho^a \ln(u_{t-1}^a) + \varepsilon_t^a \tag{4.17}$$

$$\varepsilon_t^a \sim N(0,1)$$

Total output in period t, is given by a Cobb-Douglas production function, where capital and labour services serve as inputs.

$$y_t = u_t^a k_t^\alpha l_t^{1-\alpha} \tag{4.18}$$

4.4 Fiscal authority

4.4.1 Balanced budget rule

Canadian fiscal policy has emphasized a balanced budget target since the 1980s when deficits reached historic highs. Fiscal policy in recent decades has also highlighted a deficit reduction strategy and expenditure restraint to maintain a low debt to GDP target. For this reason, we chose to adopt a balanced budget rule as the baseline specification of our fiscal rule and feel that it is most reflective of the fiscal policy stance in Canada.

The fiscal authority faces the following budget constraint under a balanced budget rule:

$$\tau^k R_t^k K_t + \tau^l W_t L_t + \tau^c C_t = G_t + Z_t \tag{4.19}$$

The fiscal authority is required to set taxation revenues coming from capital taxes, $\tau^k R_t^k K_t$, collected from RIC households, labour taxes, $\tau^l W_t L_t$, and consumption taxes, $\tau^c C_t$, from both household types equal to the sum of government expenditures, G_t , and total lump sum transfer payments, Z_t .

4.4.2 Debt rules

We propose debt rules for the expenditure instruments available to the fiscal authority as an alternative to balanced budget rules based policy in Canada. According to the IMF fiscal rules database in Budina, Kinda, and Schaechter (2012), debt rules are the most commonly adopted rule specification for purposes of debt sustainability, and our estimation results in chapter 4 find significant debt coefficients in Canadian time series data.

Under expenditure debt rules, the fiscal authority can issue bonds abroad and its budget constraint is represented by:

$$\tau^k R_t^k K_t + \tau^l W_t L_t + \tau^c C_t - R_t B_t^f = G_t + Z_t - B_{t+1}^f \qquad (4.20)$$

In this scenario both Ricardian households and the fiscal authority have access to financial markets and can borrow from abroad. A combination of the budget constraints (4.2) and (4.20) results in the consolidated resource constraint for the economy displayed in (4.25). The fiscal authority has four sources of revenue: revenue from the sales of one period risk free government bonds abroad, B_t^f , capital tax revenue, $\tau^k R_t^k K_t$, collected from RIC households, labour tax revenue, $\tau^l W_t L_t$, and consumption tax revenue, $\tau^c C_t$, from both household types. The government`s revenue is spread across interest payments on the stock of outstanding debt, $R_t B_t^f$, government expenditures, G_t , and total lump sum transfer payments, Z_t , that adjust to balance the budget.

The fiscal policy rules described below represent the remaining component of fiscal policy.

$$\hat{G}_t = -\varphi_g \hat{Y}_t - \gamma_g \hat{B}_t + \hat{u}_t^g \qquad (4.21)$$

$$\hat{Z}_t = -\varphi_z \hat{Y}_t - \gamma_z \hat{B}_t + \hat{u}_t^z \qquad (4.22)$$

where hats denote log deviations of the variables from the steady state and, u_t^g , u_t^z are assumed to follow AR (1) processes given by:

$$\hat{u}_t^g = \rho_g \hat{u}_{t-1}^g + \varepsilon_t^g \qquad (4.23)$$

$$\varepsilon_t^g \sim N(0,1)$$

$$\hat{u}_t^z = \rho_z \hat{u}_{t-1}^z + \varepsilon_t^z \tag{4.24}$$

$$\varepsilon_t^z \sim N(0,1)$$

where the error terms are distributed NIID (0, 1), all parameters are positive and, $\rho_i \in (0,1)$, for $i = \{g, z\}$.

4.4 Competitive Equilibrium

A competitive equilibrium in the small open economy, consists of prices, $\{W_t, R_t^k\}_{t=0}^{\infty}$, and allocations for the representative firm and households, $\{c_t^{RIC}, c_t^{LIQ}, l_t^{RIC}, l_t^{LIQ}, k_t^{RIC}, b_t^{RIC}, C_t, L_t\}_{t=0}^{\infty}$, and the fiscal authority, $\{G_t, Z_t^{IC}, Z_t^{LIQ}, Z_t, B_t^f, B_t\}_{t=0}^{\infty}$, such that given prices, the allocation of the representative firm solves the firm's problem, the allocation of the RIC households satisfies (4.1) - (4.10), the allocation of the LIQ households satisfies (4.11) - (4.13) taking as given the government's policy rules given by (4.19) under a balanced budget rule or (4.20) - (4.22) under debt rules. Markets clear satisfying the market clearing condition below subject to the transversality conditions for debt and capital accumulation and the exogenous processes (4.17), (4.23) - (4.24). All per capita variables are equal to aggregate variables in equilibrium. Regardless of which fiscal rule is in use the final goods market equilibrium condition is given as follows**:**

$$Y_t = C_t + I_t + G_t + R_t B_t - B_{t+1} \tag{4.25}$$

Aggregate production is spread across aggregate demand for consumption, investment, government expenditures and interest payments on external debt. The first order conditions of the model are summarized in (4.26) - (4.29).

$$\frac{\left(c_t^{RIC}-hC_{t-1}^{RIC}\right)^{-\gamma}}{\left(1+\tau^c\right)}\left[1+\phi\left(k_{t+1}-k_t\right)\right]=\beta E_t\frac{\left(c_{t+1}^{RIC}-hC_t^{RIC}\right)^{-\gamma}}{\left(1+\tau^c\right)}\left[\left(1-\tau^k\right)R_{t+1}^k+1-\delta+\phi\left(k_{t+2}-k_{t+1}\right)\right] \tag{4.26}$$

$$-\psi\left(1-l_t^{RIC}\right)^{\kappa}+\frac{\left(c_t^{RIC}-hC_{t-1}^{RIC}\right)}{\left(1+\tau^c\right)}\left(1-\tau^l\right)W_t=0 \tag{4.27}$$

$$\frac{\left(c_t^{RIC}-hC_{t-1}^{RIC}\right)^{-\gamma}}{\left(1+\tau^c\right)}=\beta E_t\frac{\left(c_{t+1}^{RIC}-hC_t^{RIC}\right)^{-\gamma}}{\left(1+\tau^c\right)}R_{t+1} \tag{4.28}$$

$$-\psi\left(1-l_t^{LIQ}\right)^{\kappa}+\frac{\left(c_t^{LIQ}-hC_{t-1}^{LIQ}\right)^{-\gamma}}{\left(1+\tau^c\right)}\left(1-\tau^l\right)W_t=0 \tag{4.29}$$

Equation (4.26) and (4.28) represents the inter-temporal Euler equations for RIC decisions about investment and debt holdings and equations (4.27) and (4.29) represent the intra-temporal conditions for RIC and LIQ agents. The Euler equations imply in equilibrium the marginal rate of substitution between consumption in period t and t+1 is equivalent to the rate at which the market allows the RIC household to shift consumption from period t to t+1. The intra-temporal conditions equate the loss of utility (in terms of consumption) of supplying an extra unit of labour to the gain (wage rate).

4.5 Calibration

We use Canadian time series data from the period 1961q1 to 2012q2 to calibrate model parameters. TABLE 4.1 summarizes the values assigned to the calibrated parameters. Most of these parameters were chosen or estimated in Chapter 3. The value for the discount factor is set at, $\beta = 0.993$, which implies an annual steady state interest rate of 4.03%. This parameter value is adopted from Letendre (2007). The capital share parameter is set to, $\alpha = 0.32$, corresponding to a steady state share of labour income of 70%. The depreciation rate, $\delta = 0.025$, is set as in Leeper, Plante and Traum (2010) and suggests an annual steady state depreciation rate of 10%. The parameter values for the ratios of government spending to output, debt to output and the steady state tax rates represent the respective average ratios in the sample. As for the household preference parameters, we set the risk aversion parameter, $\gamma = 1.27$, and the habit persistence, $h = 0.6$, following Justiniano and Preston (2010). We set steady state aggregate labour supply equal to 1/3, which implies an inverse Frisch elasticity of labour supply of -3.98. The parameter, ψ, in the utility function is set to 10 following Chari, Kehoe and McGrattan (2002). The investment adjustment cost parameter, $\phi = 0.78$, set to match the volatility of investment in Canadian data.

We set the fraction of LIQ households at, $\theta = 0.3$, following Bartolomeo, Rossi and Tancioni (2011) who using Bayesian techniques find one third of Canadian households to be liquidity constrained.[83] The coefficients on the policy rules, the autocorrelation coefficients and the standard deviations for the shocks in the model are calibrated to reflect the Bayesian estimation results in chapter 3 (See section 3.6). We perform a first order Taylor approximation in Dynare to solve and simulate the model. In light of the evidence in Kim and Kim (2003) of spurious welfare reversals in open economy models due to approximation errors during linearization we also perform a second order Taylor approximation. Our welfare results do not change from the

[83] The "spenders" in Bartolomeo, Rossi and Tancioni (2011) are constrained to the same extent as in our model. These households are defined as those who "do not own any asset, cannot smooth consumption and therefore consume all their current disposable income."

case of a first order approximation. At second order linearization, the impulse response functions are the result of Monte Carlo simulations of future shocks. These shocks end up summing to zero and the limit since they are averaged between each Monte Carlo sequence and do not end up having much of an impact on our results.

TABLE 4.1 Calibrated parameter values

Parameter	**Description**	**Value**
β	Discount factor	0.993
δ	Depreciation rate	0.025
α	Capital share of income	0.320
G/Y	Ratio of government spending to output	0.230
B/Y	Ratio of public debt to output	0.270
τ^k	Steady state capital tax rate	0.380
τ^l	Steady state labour tax rate	0.058
τ^c	Steady state consumption tax rate	0.099
R^w	World interest rate	1.010
ψ_2	Risk premium coefficient	0.001
H	Habit persistence	0.600
γ	Risk aversion	1.270
κ	Inverse Frisch Elasticity	-3.980
θ	Fraction of LIQ households	0.300
Ψ	Utility function parameter	10.000
ϕ	Investment adjustment cost parameter	0.780
φ_g	Government spending output coefficient	0.050
φ_z	Transfers output coefficient	0.160
γ_g	Government spending debt coefficient	0.260
γ_z	Transfers debt coefficient	0.160

4.6 Results

In this section we present the impulse response analysis for a temporary expansionary shock to technology, government spending, and lump sum transfer payments under the balanced budget rule and two debt rules. All shock sizes correspond to one standard deviation. The impulse responses are depicted in FIGURE 4.1 –FIGURE 4.15. In each figure, the horizontal axis represents quarters and the vertical axis measures deviations from steady state, with the exception of any debt variables for which changes are in levels. First we discuss the impulse responses to various shocks under a balanced budget rule. We then present and discuss the impulse responses if instead of a balanced budget rule, the fiscal authority followed debt rules. We proceed to contrast the impulse responses under these two differing rule regimes to shed light on the impact on key macroeconomic aggregates. Lastly, in section 4.7 we perform a welfare exercise in which the welfare impact of a balanced budget rule system and a debt rule system are analyzed for the consumption paths of RIC and LIQ agents respectively.

4.6.1 Impulse response analysis

FIGURE 4.1 – FIGURE 4.3 depicts the impulse responses to a temporary unanticipated positive technology shock under a balanced budget rule. The increase in the marginal productivity of labour translates into higher output in the economy and a higher real wage generating a positive income effect. Aggregate consumption and investment increase, as households chose to consume more with the increase in resources. Ricardian households borrow from abroad to finance investment and take advantage of the higher rate of return on holding capital. All households chose to consume more leisure causing a decrease in aggregate labour supply. Tax revenues rise, as increased investment leads to higher capital tax revenues, increased consumption leads to

higher consumption revenues and a higher wage rate boosts labour tax revenues. Under a balanced budget rule, lump sum transfers rise sharply to balance the budget. Both RIC and LIQ households increase their consumption and decrease their labour supply in response to a positive technology shock. The income effect from a higher real wage for LIQ consumers combined with inability to save means that these consumers must consume all of their disposable income within the period and increase leisure. The inability to smooth consumption through investment on the part of LIQ households explains the higher change in consumption of LIQ agents' relative to RIC agents.

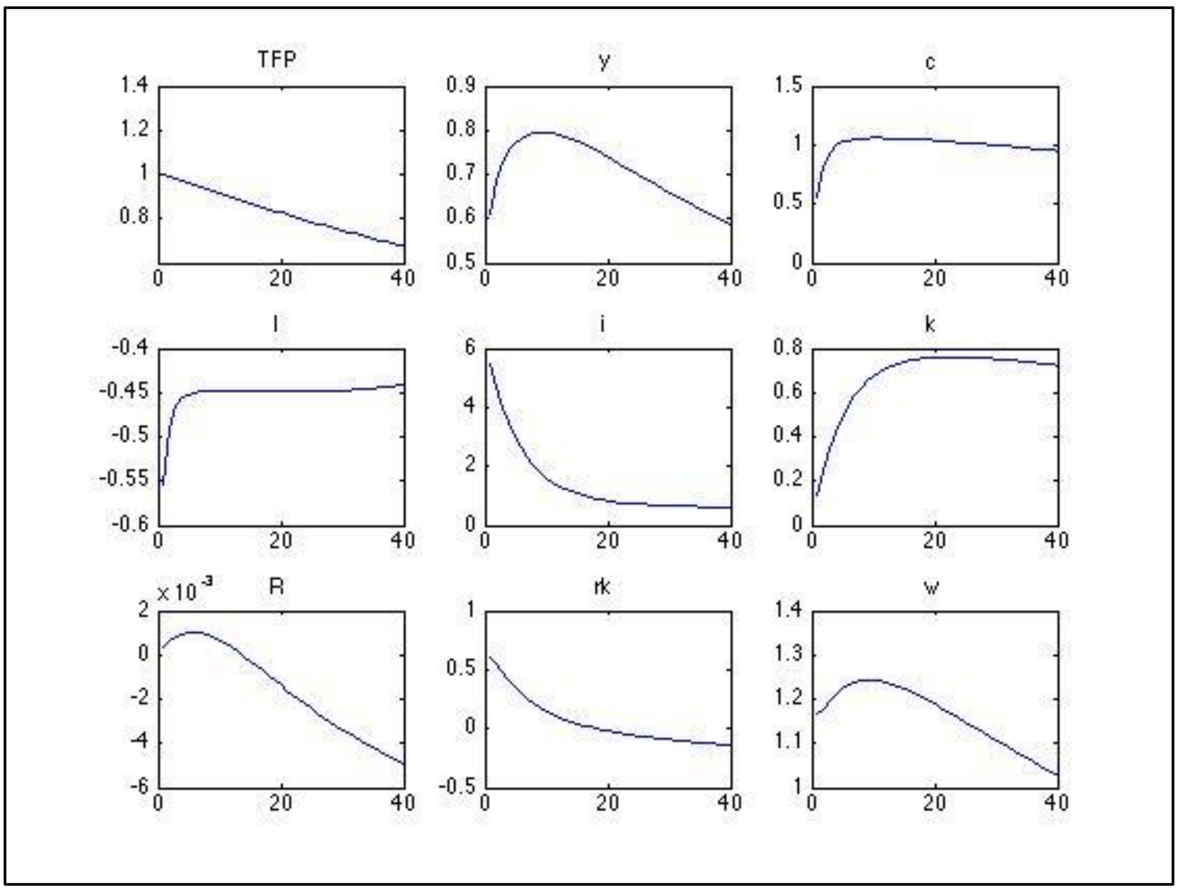

FIGURE 4.1 Impulse response to a positive one standard deviation technology shock in the balanced budget rule case

FIGURE 4.4 – FIGURE 4.6 displays the impulse responses for an unanticipated expansionary technology shock under debt rules. Similar to the balanced budget rule, a positive shock to technology causes an increase in aggregate output, consumption, leisure, and investment. Taxation revenues rise as result and are used to pay down external public debt. Similar to the balanced budget rule case, RIC agents wanting to take advantage of a high return on the rental rate of capital engage in foreign borrowing to finance increased investment. The foreign borrowing on behalf of RIC households dominates the rise in public debt the total level of debt in the economy to rise for about a year. After the second year, the total level of debt in the economy declines steadily. The increase in aggregate output and aggregate debt trigger a change in fiscal aggregates through the fiscal policy rules. An increase in the level of output above the steady state or an increase in the level of debt requires a negative adjustment of expenditure instruments causing government spending and transfers to fall respectively. When the fiscal authority follows expenditure debt rules, the relative consumption and labour dynamics of RIC and LIQ agents remain the same as when they follow a balanced budget rule.

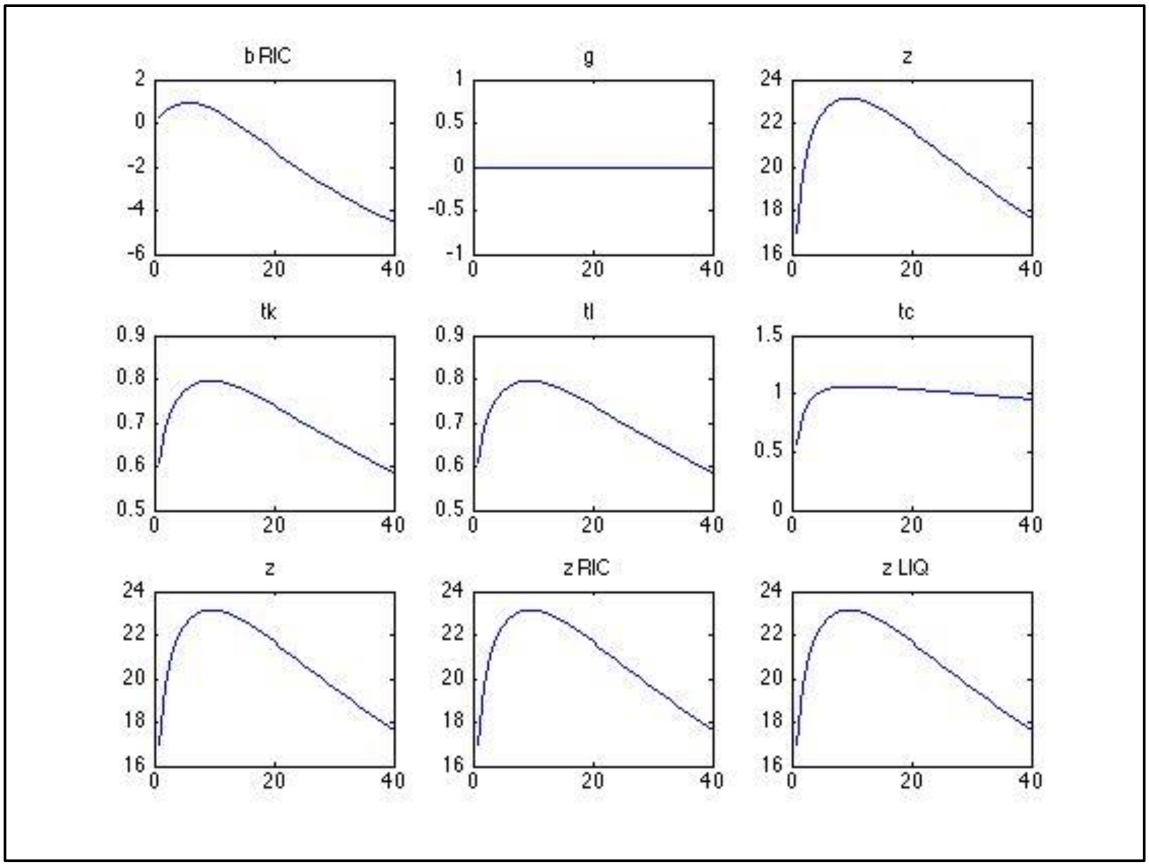

FIGURE 4.2 Impulse response to a positive one standard deviation technology shock in the balanced budget rule case

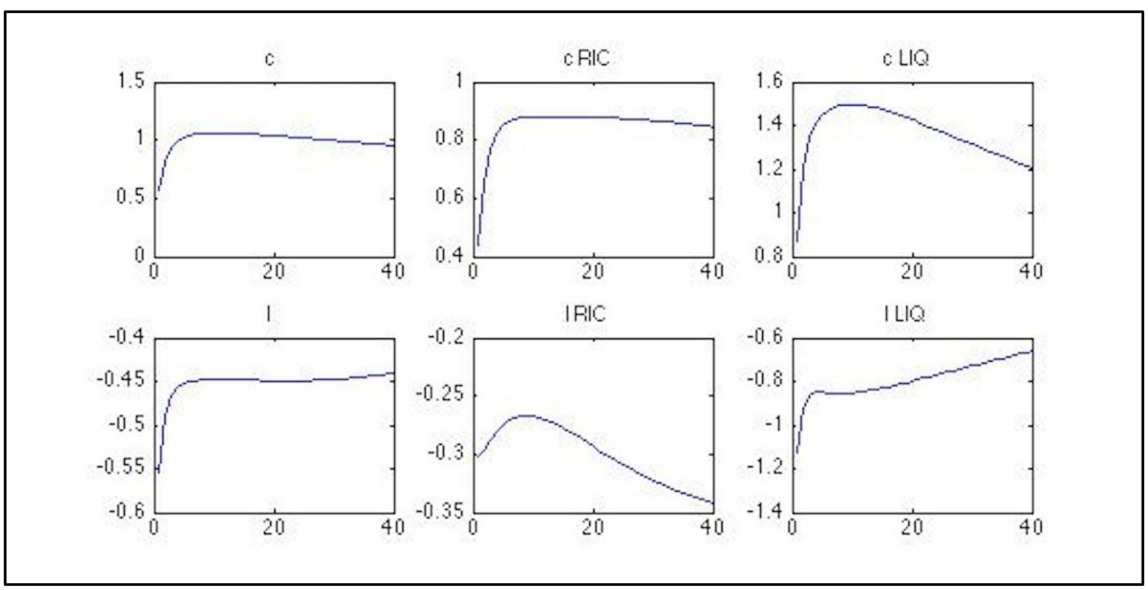

FIGURE 4.3 Impulse response to a positive one standard deviation technology shock in the balanced budget rule case

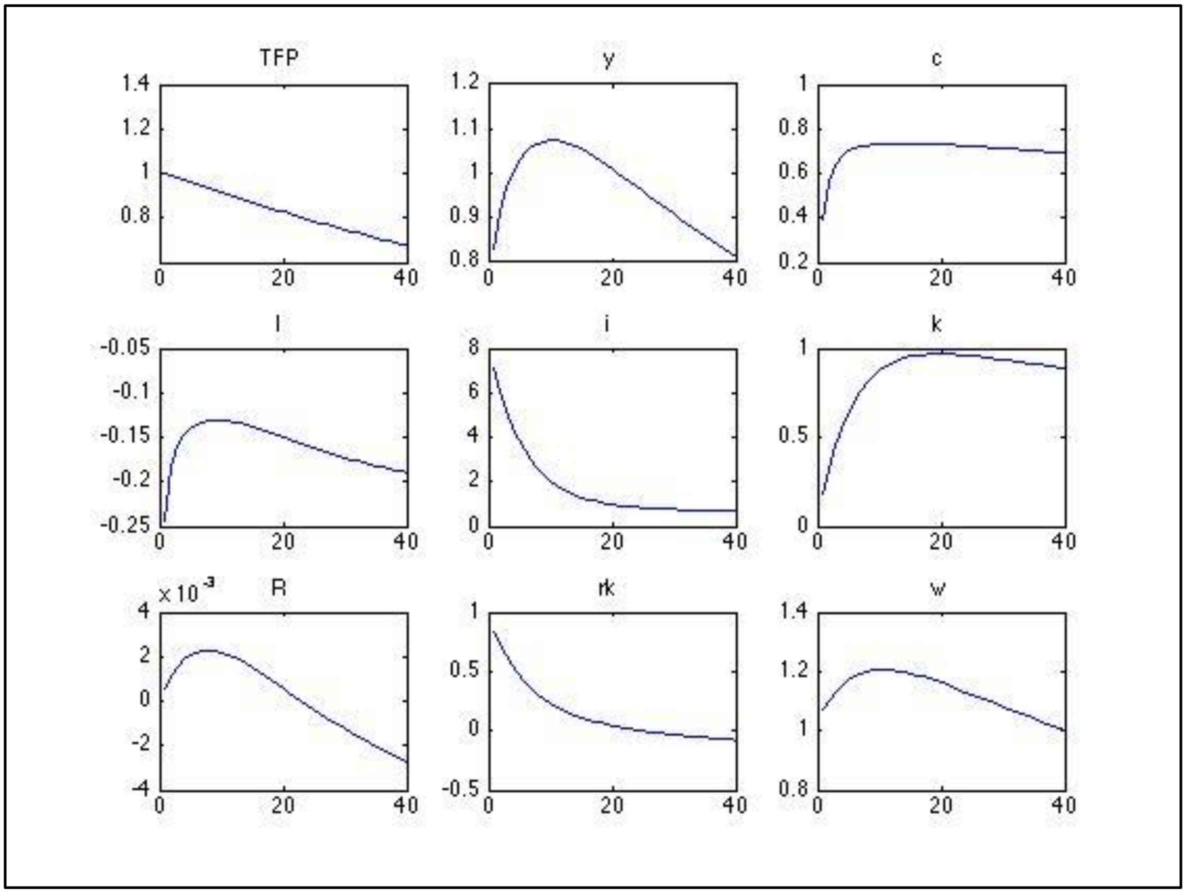

FIGURE 4.4 Impulse response to a positive one standard deviation technology shock in the debt rules case

In comparing the impulse responses of key endogenous variables to a positive technology shock under a balanced budget specification relative to a debt rules specification we are able to observe some differences. The increase in productivity expands output more under the debt rules than a balanced budget rule. Another notable difference is that the increase in aggregate consumption is half the size of the consumption increase under a balanced budget rule, and the decline in labour supply is also significantly smaller. The smaller contraction in labour supply in the economy explains the further increase in aggregate output. Investment is also higher under the debt rules, explained by a higher rental rate on capital that encourages RIC households to substitute consumption for investment.

Higher taxation revenues under the debt rules enable the fiscal authority to pay down external debt and results in a decline in the aggregate level of debt. The main mechanism explaining the difference in household consumption and leisure choices come from the ability of the fiscal authority to borrow from abroad and the corresponding debt rules in place to ensure debt sustainability. In the balanced budget rule case, the increase in taxation revenues forces an increase in the transfer payments received by households to balance the budget. The increase in transfers exacerbates the positive income effect and causes a further increase in consumption and a corresponding decrease in labour supply.

However, under the debt rules transfer payments and government spending act as debt stabilizing instruments. The increase in aggregate output and debt requires a downward adjustment in transfers. On the other hand, government spending falls on impact in response to the rise in output and then rises in response to the fall in total debt. The decrease in transfers discourages household consumption. For Ricardian households the decrease in government spending crowds in consumption and discourages the supply of labour with a net effect of Ricardian consumption rising and labour supply falling. For liquidity constrained households, the negative income effect from a fall in transfer payments is dominated by the rise in the real wage. The net effect for liquidity-constrained households is a rise in consumption and a fall in their labour supply.

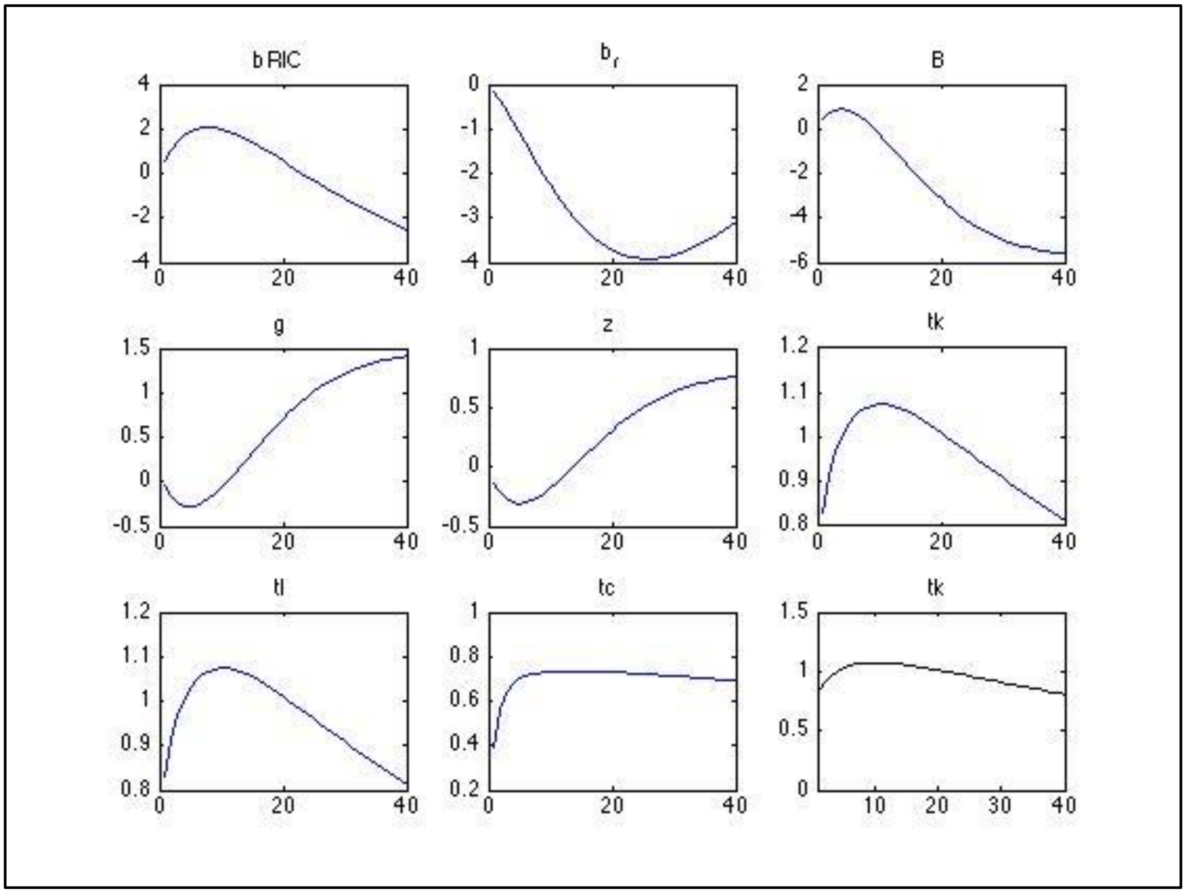

FIGURE 4.5 Impulse response to a positive one standard deviation technology shock in the debt rules case

FIGURE 4.7 – FIGURE 4.9 displays the impulse responses to a temporary unanticipated positive government spending shock. Under the balanced budget rule, an increase in government spending is financed by a decrease in transfer payments, as the government is unable to engage in deficit financing. The decrease in transfers generates a negative wealth effect, causing aggregate consumption to decline.

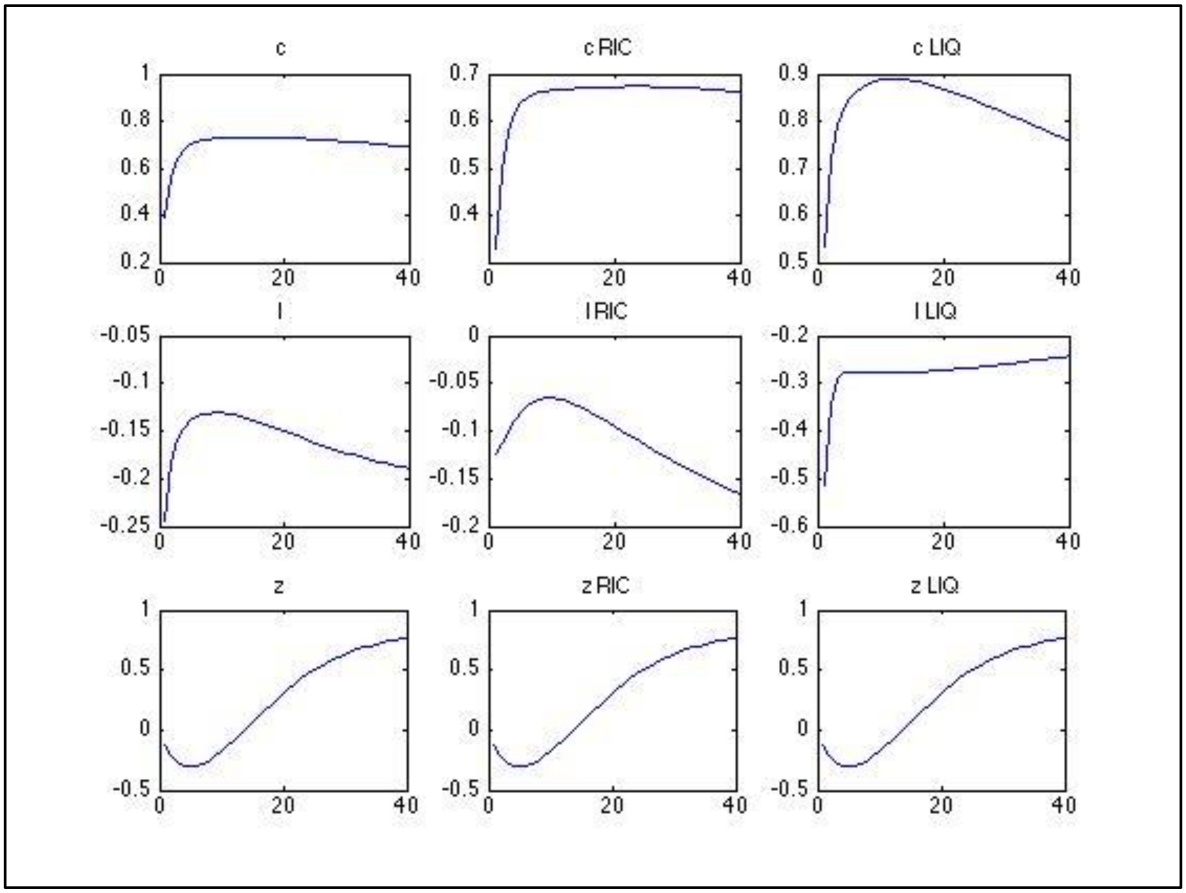

FIGURE 4.6 Impulse response to a positive one standard deviation technology shock in the debt rules case

The crowding out of consumption due to a government spending shock is consistent with the predictions of neoclassical real business cycle models (see Baxter and King (1993)) and with consumption behaviour in the data. In chapter two our VAR analysis of Canadian time series showed that a temporary increase in government expenditures lead to a reduction in private consumption for the period 1961q1 to 2001q4. Following a temporary shock to government expenditures, households decrease leisure and are incentivized to work harder since fewer resources are available to them. Investment rises in response to the government spending shock as the Ricardian household substitutes investment for consumption.

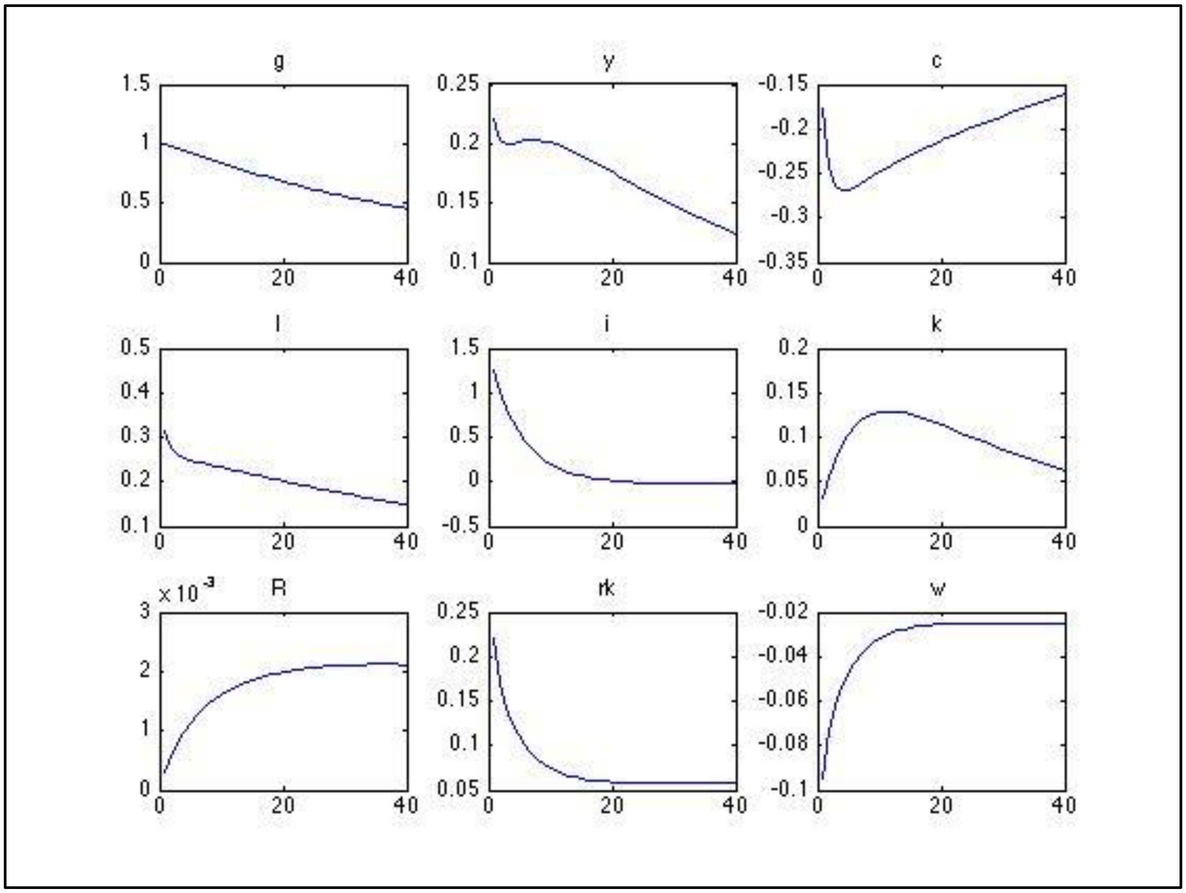

FIGURE 4.7 Impulse response to a positive one standard deviation government spending shock in the balanced budget rule case

Ricardian agents with access to financial markets are able to engage in consumption smoothing and borrow from abroad to finance investment in capital stock. Capital tax revenues increase due to a higher level of investment, as do labour tax revenues when aggregate labour hours in the economy rise. The decrease in consumption leads to a fall in consumption tax revenue. The government spending shock has a stronger negative effect on LIQ agents, decreasing their consumption more and leading to a larger increase in their labour supply relative to RIC agents. The inability to borrow internationally means that LIQ agents are more sensitive to changes in the wage rate and transfer payments, as they cannot use this channel to smooth consumption.

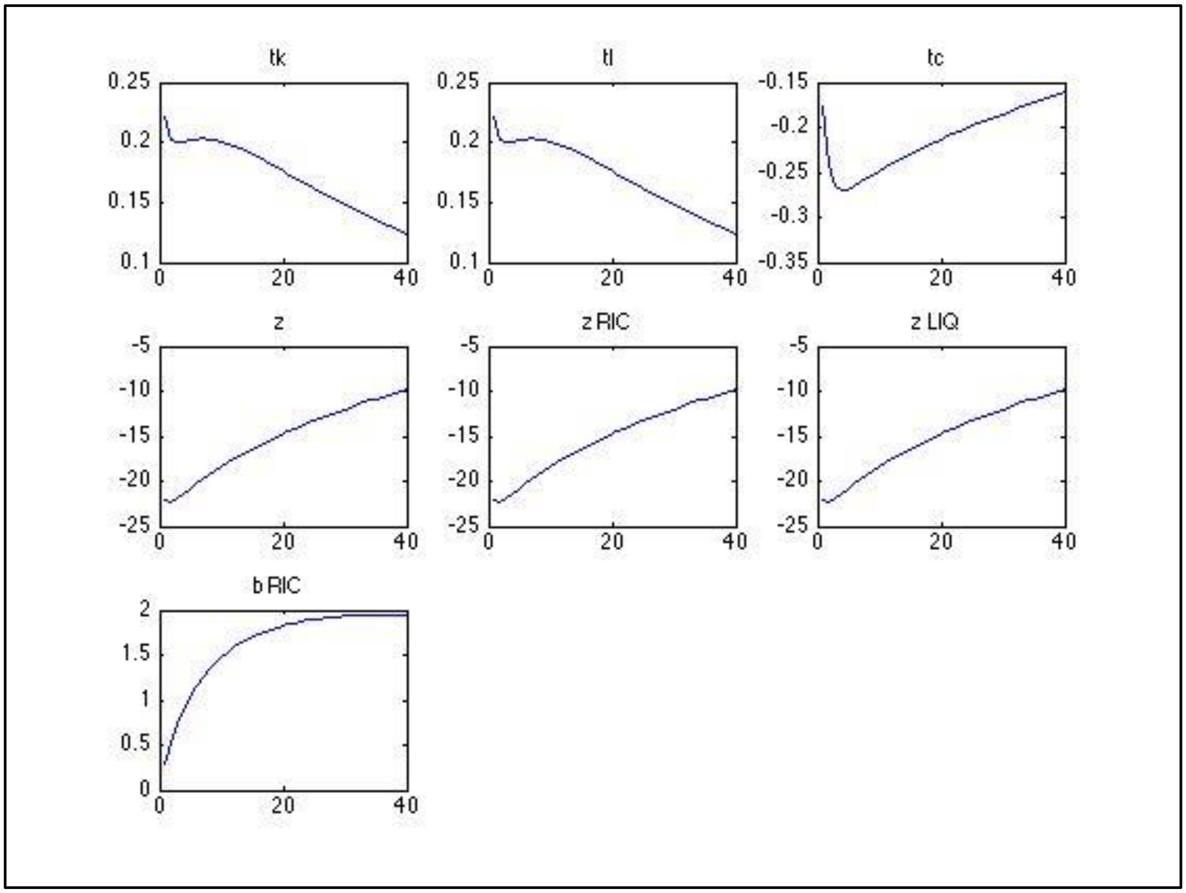

FIGURE 4.8 Impulse response to a positive one standard deviation government spending shock in the balanced budget rule case

FIGURE 4.10- FIGURE 4.12 displays the impulse responses of an expansionary government spending shock under debt rules. The impulse responses for output, consumption, labour, and investment are qualitatively the same as in the balanced budget rule case and in agreement with the predictions of standard real business cycle models. With debt rules in place, the government uses deficit financing to increase government spending, causing an increase in the level of debt in the economy. The expansion in aggregate debt is driven by the fiscal authority's acquisition of foreign debt and triggers the transfer rule to re-stabilize debt levels.

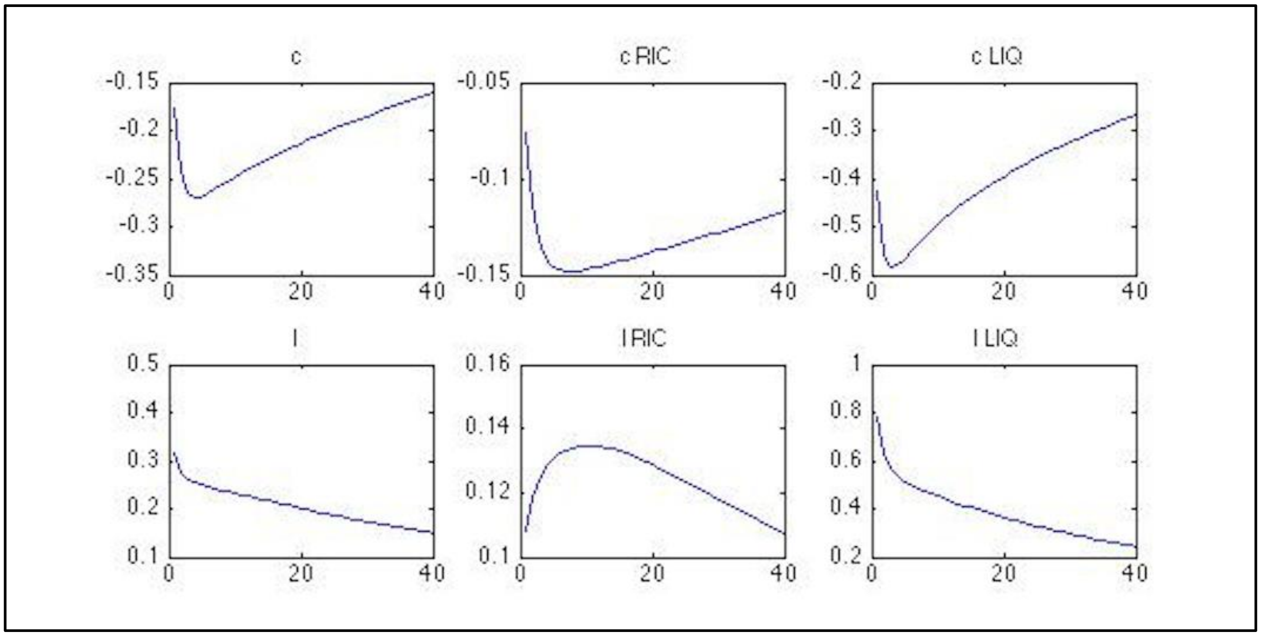

FIGURE 4.9 Impulse response to a positive one standard deviation government spending shock in the balanced budget rule case.

Through the fiscal rule, transfers to both households must adjust downwards. Since aggregate transfers is the mechanism that adjusts debt under a debt rules regime and ensures a balanced budget rule is satisfied, we find that a temporary government spending shock has a similar impact on key variables under both policy rules.

FIGURE 4.13 – 4.15 displays the impulse responses to a temporary positive lump sum transfers shock when the fiscal authority follows debt rules. An unanticipated increase in transfer payments received by households creates a positive wealth effect. As households find themselves endowed with more resources, they chose to increase their consumption leading to a rise in the aggregate consumption level in the economy. The wealth effect also has the impact of discouraging work, causing a decrease in aggregate labour supply and as a result in aggregate output.

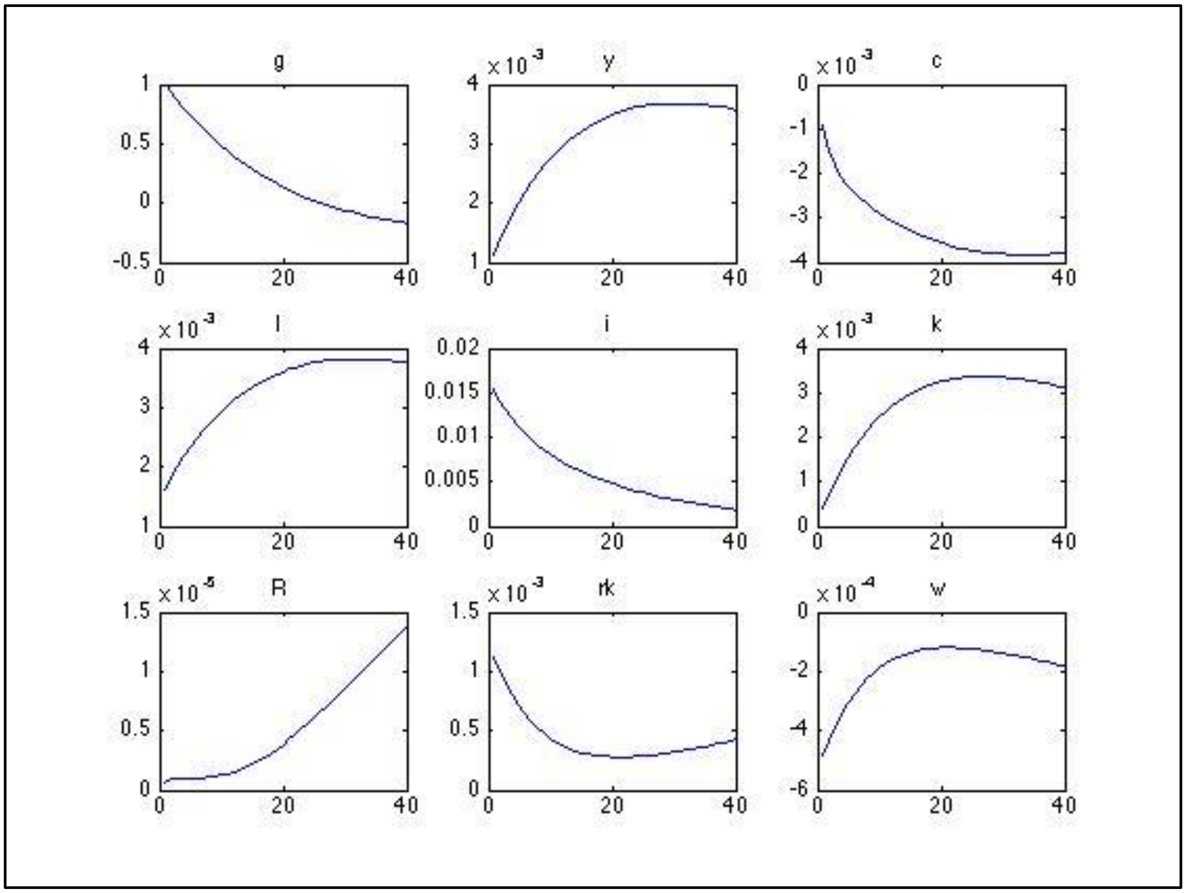

FIGURE 4.10 Impulse response to a positive one standard deviation government spending shock in the debt rules case

The decrease in investment can be explained by the substitution effect, as households chose to consume more and save less. The temporary increase in resources through transfers discourages RIC households to hold foreign debt, as they are able to increase consumption through higher transfers. The increase in transfer payments is deficit financed and causes an increase in the stock of debt in the economy, driven by the increase in external borrowing on behalf of the government.

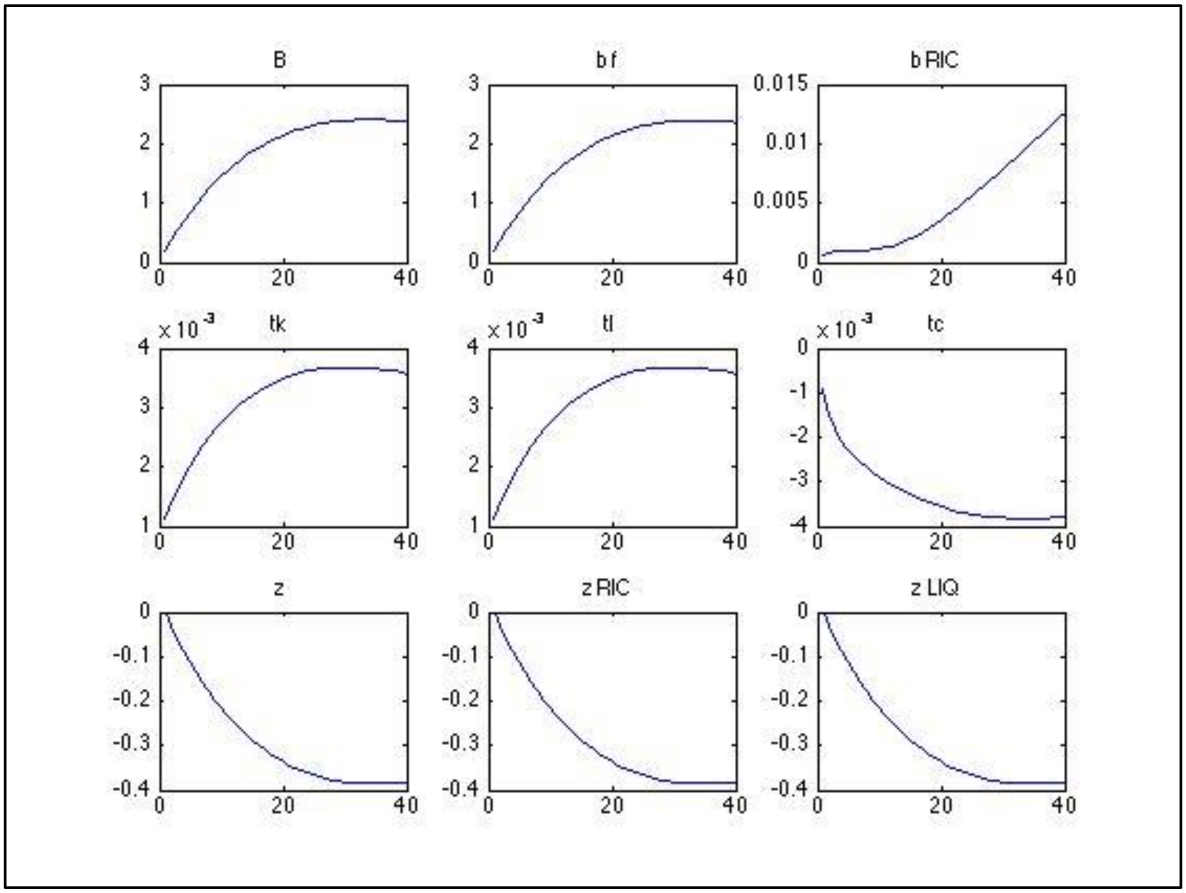

FIGURE 4.11 Impulse response to a positive one standard deviation government spending shock in the debt rules case

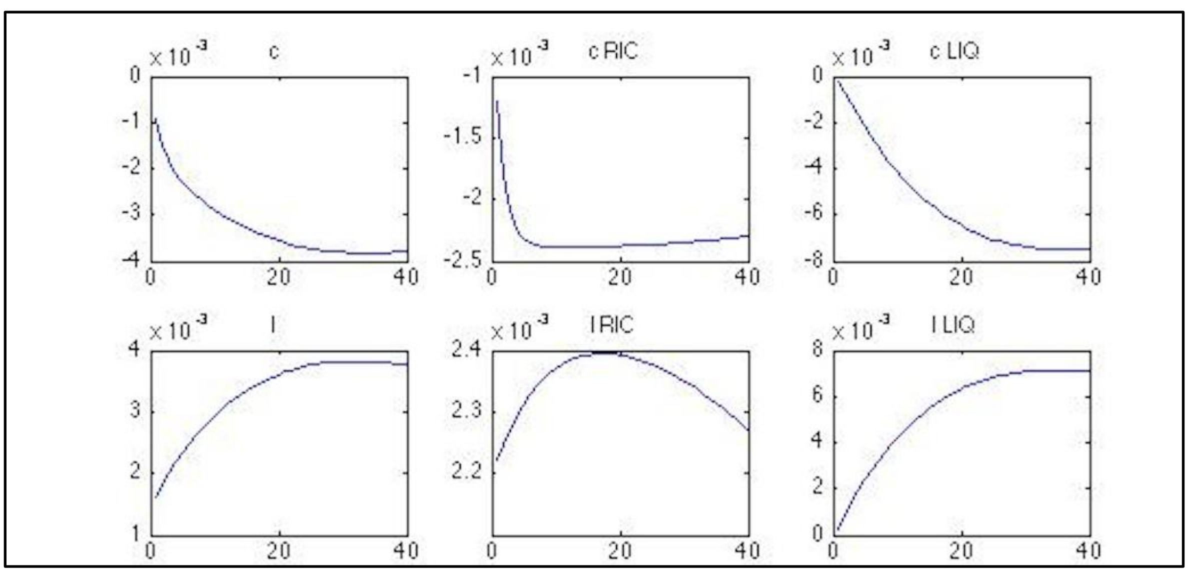

FIGURE 4.12 Impulse response to a positive one standard deviation government spending shock in the debt rules case

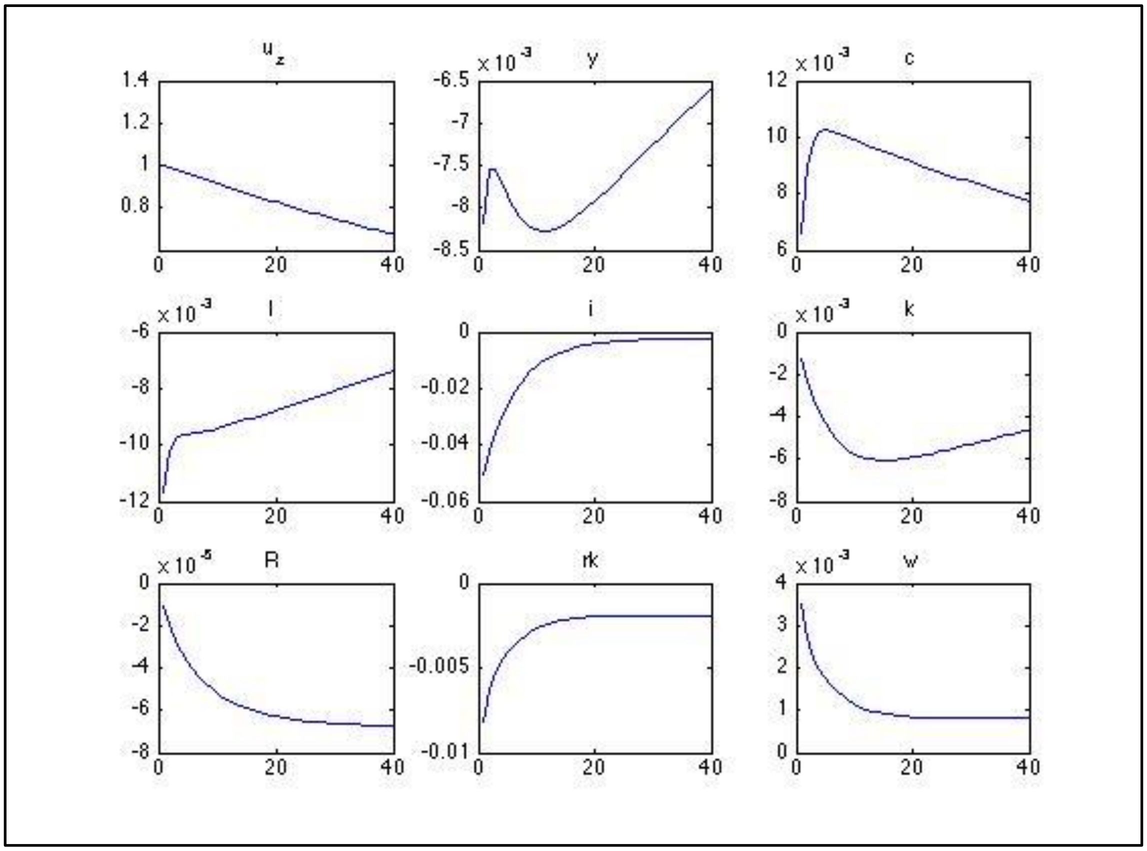

FIGURE 4.13 Impulse response to a positive one standard deviation transfer shock in the debt rules case

Government spending is the main instrument through which debt levels are re-stabilized. The decline in output triggers a small increase in spending working through the fiscal rules and subsequently a large downward adjustment in spending. Capital and labour tax revenues decrease while consumption tax revenues increase. The increase in transfer payments translates into greater benefits to LIQ agents relative to RIC agents, boosting LIQ consumption and leisure more than RIC agents. The increase in transfers initially generates a positive income effect, which is further strengthened by the subsequent decrease in government expenditures.

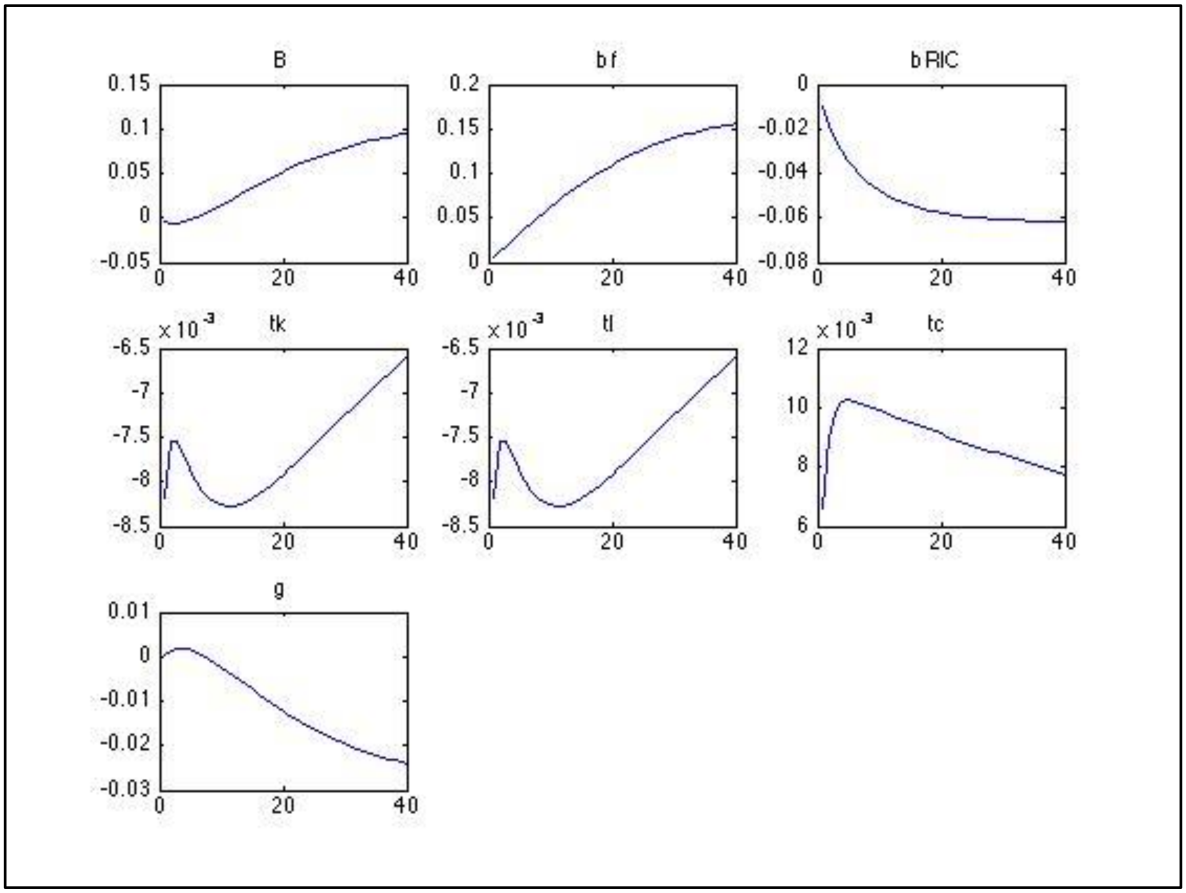

FIGURE 4.14 Impulse response to a positive one standard deviation transfer shock in the debt rules case

Although both households are incentivized to increase consumption and reduce labour supply, LIQ agents are unable to save the temporary increase in income and must direct all of the extra resources towards consumption. On the other hand, RIC agents engage in inter-temporal substitution to increase current consumption and investment. The downward adjustment in government expenditures has a strong crowding out effect on investment leading to a net decline in investment.

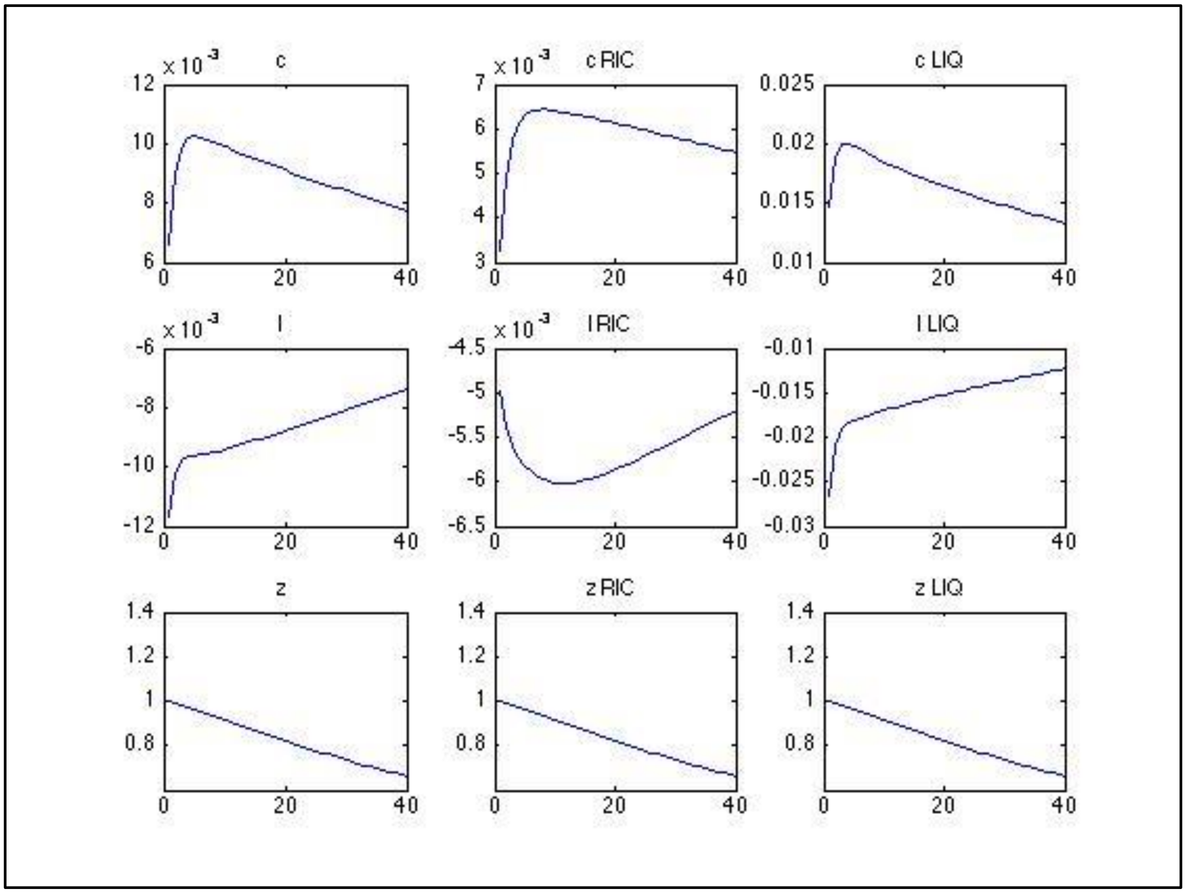

FIGURE 4.15 Impulse response to a positive one standard deviation transfers shock in the debt rules case

4.7 Welfare Analysis

The welfare costs of policy changes in macroeconomic models have become increasingly highlighted in the recent literature.[84] This section discusses the welfare effects of temporary positive shocks to technology, government spending and lump sum transfers. The welfare costs and in some cases gains are computed in the steady state and along the transition path for both types of households when the fiscal authority moves from a balanced budget rule to a debt rule.

[84] Please see Cooley and Hansen (1992), Schmitt-Grohé and Uribe (2007) and Mansorrian and Michelis (2016).

We define the compensating consumption variations, η^{RIC}, and , η^{LIQ} , following Lucas (1987) as the constant quantity of consumption under the fiscal policy rules that makes each type of household as well off after an unexpected temporary shock as the agent was before the shock. In other words, the consumption equivalent (CE) is the amount of consumption in per cent that compensates the consumer for the policy change.

The unconditional expected utility of RIC and LIQ households is given by

$$W_t^{RIC} = U_t^{RIC} + \beta E_t W_{t+1}^{RIC} \tag{4.30}$$

$$W_t^{LIQ} = U_t^{LIQ} + \beta E_t W_{t+1}^{LIQ} \tag{4.31}$$

where, U_t^{RIC}, and, U_t^{LIQ}, represents the utility of RIC and LIQ households at time t. Following Bilbiie (2008), Laxton and Bi (2011) and Kumhof and Laxton (2013) we define aggregate welfare as the population weighted average of compensating consumption variations, given by

$$\eta = (1-\theta)\eta^{RIC} + \theta\eta^{LIQ} \tag{4.32}$$

Unconditional welfare and compensating consumption equivalents are obtained by performing a first order approximation of the model in DYNARE[85].

Our welfare analysis consists of two parts. First, we present the implications that arise when the economy moves from a balanced budget rule to debt rules. We show that debt rules increase aggregate welfare in the economy and offer an improvement over balanced budget rules. We also

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[85] Please see Stéphane Adjemian, Houtan Bastani, Michel Juillard, Frédéric Karamé, Ferhat Mihoubi, George Perendia, Johannes Pfeifer, Marco Ratto and Sébastien Villemot (2011), “Dynare: Reference Manual, Version 4,” Dynare Working Papers, 1, CEPREMAP.

present distributional welfare results by analyzing the differing welfare implications across households that arise when the fiscal authority moves from a balanced budget rule to debt rules. In the second part of our analysis, we present the welfare results associated with an unanticipated temporary positive technology shock, negative government spending shock and a negative transfer payments shock when the fiscal authority follows debt rules. Our results indicate that the preferred debt-stabilizing instrument is government spending.

4.7.1 Welfare under alternative rules

TABLE 4.2 displays the compensating consumption variations that result when the fiscal authority moves from a balanced budget rule to adopting debt rules for government spending and transfer payments. In the table, a negative (positive) value corresponds to a welfare gain (loss) as this is the consumption equivalent required to equate the unconditional expected utility before and after the change in policy. An aggregate welfare gain results when fiscal policy follows debt rules. This is consistent with the findings in Bi and Kumhof (2011), that show the welfare gains associated with the adoption of countercyclical fiscal rules relative to a balanced budget rule increase with the counter cyclicality of the rule. The estimated coefficients $\left(\varphi_g, \varphi_z, \gamma_g, \gamma_z\right)$ of our debt rules reflect the historical behaviour of fiscal instruments in Canada and can be described as mildly countercyclical. Increased counter-cyclicality of these rules through higher coefficient values can translate to higher welfare gains under rules based fiscal policy in Canada. We find that our estimated debt rules improve the overall welfare measure in the economy in the presence of a sizeable (30 percent) fraction of liquidity-constrained households.

TABLE 4.2 Consumption equivalents under alternative fiscal rules

	Consumption Equivalent (%)
Aggregate	-0.006
RIC	-0.016
LIQ	0.031

However, the welfare implications of moving from a balanced budget rule to rules based fiscal policy that feature debt rules vary for RIC and LIQ agents. TABLE 4.2 shows that the move to debt rules result in a welfare gain (0.016) for RIC agents and result in welfare losses (-0.031) for LIQ agents. Kumhof and Laxton (2013) also find evidence of differential welfare impacts on consumers who are liquidity constrained as opposed to consumers who behave in a Ricardian manner when considering a policy change from a balanced budget rule to a structural surplus rule for Chile. They show welfare improvements emerge when transfers targeted specifically to LIQ agents are used so that the fiscal authority smooths consumption on behalf of LIQ agents. A similar result is found in González, López, Rodriguez and Téllez (2013) for Columbia, when evaluating the welfare implications for LIQ and RIC agents for balanced budget rule, debt rule and structural surplus rule. Both these models feature a structural surplus rule (in place in Columbia and Chile) that use part of revenues from the resources sector in these economies to reduce debt and use targeted transfers as an instrument that relaxes the liquidity constraint faced by LIQ agents.

In our model following debt rules, the government's ability to borrow from abroad does not translate into a relaxation of this liquidity constraint. Consider a scenario in which output is below its respective steady state level, and debt is above its steady state level through the fiscal rules transfers must fall to provide stabilization. The increased volatility in transfer payments increases the volatility of current income for LIQ households who are unable to smooth shocks to current income. As a result, these households reduce consumption aggressively and experience a welfare cost. Although the welfare results for the two types of agents move in opposite directions when the fiscal authority moves from a balanced budget rule to debt rules, aggregate welfare increases because the welfare gains of a larger share of RIC agents outweigh the welfare losses of a smaller proportion of LIQ agents. A fiscal policy strategy that aims to achieve maximizing aggregate welfare would imply that debt rules are the preferred fiscal rule. Fiscal policy operating under debt rules does mean that a subset of the population will be worse off compared to a fiscal regime in which governments maintain a balanced budget. However, the welfare losses of LIQ households can be mitigated if the government redistributes the welfare gains from RIC households to LIQ households through targeted transfers. We do not consider targeted transfers in our model but earmark this fiscal instrument for future work.

4.7.2 Welfare under debt rules

TABLE 4.3 displays the compensating consumption variations for an unanticipated increase in the productivity shock, a decrease in the government spending shock and a decrease in the transfers' shock. All shock sizes correspond to one standard deviation. We consider negative fiscal shocks to determine the welfare effects arising from the fiscal authority following debt stabilization policies. Following a positive productivity shock aggregate welfare in the economy rises as both types of households realize welfare gains. The increased productivity leads to larger welfare gains for LIQ agents relative to RIC agents. The presence of a liquidity constraint means that LIQ agents must consume their income entirely every period. The positive effect of the wage rate increase dominates the negative effect from the decrease in transfers to stabilize higher debt levels, resulting in higher income that must be consumed. On the other hand, RIC agents can smooth their consumption and use the higher income in part to increase their current consumption and in part to invest. As a result, the productivity shock results in a greater increase in LIQ consumption and leisure relative to RIC consumption.

TABLE 4.3 Consumption equivalents under various shocks

	Aggregate CE (%)	RIC CE (%)	LIQ CE (%)
Debt Rules			
TFP shock	-0.7243	-0.718	-0.739
Government spending	-0.0156	-0.012	-0.024
Transfers shock	0.0383	0.029	0.06

A temporary negative government spending shock results in a small aggregate welfare gain. A decrease in government spending results in an increase in the consumption levels of both types of agents and a reduction in their labour supply. The decrease in government spending generates welfare gains for RIC and LIQ agents. LIQ agents realize welfare gains that are twice as large as their RIC counterparts. Again, as in the case of the productivity shock the welfare gain is closely tied to the liquidity constraint. A decrease in government spending leads to a decline in aggregate debt levels since increased consumption tax revenues are used to decrease debt obligations. Through the fiscal rules, transfer payments must rise in response to a lower level of debt. LIQ agents must consume the increase to their income from transfer payments and therefore face a stronger positive wealth effect.

Following a temporary unanticipated negative transfers shock, the economy experiences a welfare loss. LIQ agents realize a larger welfare loss relative to RIC agents, as they are unable to borrow from abroad to smooth consumption. The negative impact of a decrease in transfer payments to LIQ consumption is further exacerbated by the increase in government spending that works through the fiscal rules to respond to a lower level of aggregate debt in the economy.

Our welfare analysis results show that a one standard deviation decrease in government spending is welfare improving relative to a one standard deviation decrease in transfer payments. This result is subject to a caveat in that government expenditures in our model are wasteful (they do not directly enter the utility function or production function) thus decreases in this type of expenditure increase consumption. Kumhof and Laxton (2013) find government spending to be "unambiguously welfare reducing" in structural surplus rules. However, in our model countercyclical government spending increases consumption in good times as it makes more resources available in the economy and does not reduce the income of LIQ agents.

The dissolution of the Balanced Budget Rule in Canada raises a question about the fiscal framework that follows. Debt rules may seem like a welfare improving alternative but the fiscal authority under debt rules would eventually have to adjust tax rates, government spending or transfer payments. In our model we treat tax rates as constant, thereby removing it from the possible set of policy instruments on the basis of our fiscal rule estimation results in chapter 3, where we show Canadian fiscal policy to have historically favoured spending policy as opposed to tax policy. In this chapter, we show that the move from a balanced budget rule to debt rules is in fact welfare improving in an aggregate sense but it reduces the welfare outcomes of liquidity-constrained agents. Under debt rules, the policy instrument used to stabilize debt levels also has disproportionate welfare impacts on households that are unable to smooth their consumption paths. We find that adjustments in transfer payments that reduce debt are far more welfare reducing than adjustments in government expenditures.

4.5 Conclusion

This chapter examines the macroeconomic effects and welfare characteristics of rules based fiscal policy in Canada where a share of the population is credit constrained. Fiscal policy follows either a balanced budget rule or simple debt rules where government expenditures respond to the output gap and debt gap to meet the short run and long run policy objectives of the fiscal authority. Using estimated coefficients on debt rules for Canada, we find that simple debt rules offer a welfare improvement in an aggregate sense when compared to a balanced budget rule. We also find that under debt rules, the fiscal authority is unable to stabilize the negative income effects arising from unanticipated shocks for liquidity-constrained agents leading to a welfare cost. On the other hand, Ricardian agents benefit in welfare terms from a move to debt rules. These results imply that all households pay for the costs of public debt but only Ricardian agents enjoy the benefits. Our welfare analysis suggests that countercyclical debt rules are a good candidate for a fiscal authority that aims to maximize aggregate welfare as welfare gains increase with a higher degree of counter-cyclicality. If, however, the fiscal authority has an objective to stabilize the income of liquidity-constrained households, other fiscal rule specifications should be considered. Future work will focus on exploring alternative rule specifications that make sense in the Canadian context and that may be able to yield welfare improvements for liquidity-constrained households.

5. CONCLUSION

In recent decades' macroeconomic research has predominately focused on the effects and merits of systematic monetary policy. The financial crisis of 2008-2009 marked a shift in the discipline towards serious consideration of fiscal policy research. As fiscal policy research is revisited, there are several gaps in the various strands of literature that have become apparent and that must be addressed. Mainly, the theoretical and empirical literatures are disjointed and have focused on different issues of fiscal policy. The theoretical literature has broadly focused on topics such as fiscal transmission mechanisms, optimal fiscal policy, and government spending and tax multipliers. Whereas, the empirical literature has placed an emphasis on fiscal sustainability, monetary and fiscal policy interactions and quantifying fiscal consolidation episodes in industrialized countries. In this thesis, we have aimed to bring the two literatures closer together by integrating generally accepted empirical findings into canonical theoretical models that are used to study fiscal policy.

In the first chapter of this thesis, we apply a VAR model to quarterly time series data for the period 1961q1 to 2015q4 to understand the effects of fiscal policy shocks on the Canadian economy. Since much debate exists around the qualitative and quantitative impact of positive government spending shocks on the economy, both in theoretical and empirical work, we tackle this issue first. Traditionally, the SVAR approach in Blanchard and Perotti (2002) and the narrative approach in Ramey and Shapiro (1997) yield opposing results to fiscal shocks. We apply both these approaches to Canadian data and find that private consumption falls in response to a temporary positive government spending shock. Our empirical findings support the predictions of neoclassical macroeconomic models that show that an increase in government spending crowds out consumption through a negative wealth effect. Although, there exists a debate among academic circles about the effects of a positive government spending shock on private consumption in U.S data, in the first part of this thesis, we show that the opposing positions in the empirical literature do not extend to Canadian data. We find that temporary positive government spending shocks lead private consumption to decline using a vector auto regression analysis. This empirical finding provides clarity on the qualitative effects of fiscal shocks on macroeconomic variables that has been missing in the empirical literature. It also helps to reconcile the theoretical debate between the predictions of neoclassical and New Keynesian models, by lending support to the neoclassical class of models. Given that neoclassical predictions match observed Canadian data the best, we use this theoretical framework as the basis of our study of systematic fiscal policy in the remaining chapters.

In the second chapter, we develop a theoretical small open economy model for Canada featuring a wide array of fiscal policy rules that respond to a gap in the level of output and public debt. The estimation of the model using a Bayesian approach allows us to quantify systematic fiscal policy in Canada while accounting for the empirical evidence from our VAR analysis. We use a Bayesian approach that recognizes parameter uncertainty by applying filtering theory and Monte Carlo Markov Chain methods to confront our theoretical model with the data. Drawing from a priori beliefs about parameter value ranges, we assign a probability distribution to the structural parameters and combine it with the likelihood function implied by the statistical model. We optimize the joint prior probability densities and the likelihood function to compute posterior distributions. This Bayesian investigation uncovers a wide set of parameter values that are useful for inference and policy experiments. We find that government spending largely moves independent of the state of the Canadian economy but exhibits a strong negative relationship with the change in prior quarter's public debt level. Transfer payments (funds that flow to provincial levels of government for health and social programs) are counter-cyclical, automatically rising during economic downturns to stabilize the negative shock. Similar to government spending, we find that transfer payments in Canada have responded negatively to rising public debt, although to a lesser extent than government spending. Estimated tax rate elasticities reveal that capital and labour taxes are strongly pro-cyclical, with capital tax rates displaying the strongest adjustment to the state of the economy and both rates moving independent of public debt levels. We also find evidence of capital and labour tax rates moving together in Canadian data.

Using our theoretical model from chapter 3, in the final chapter, we build in household heterogeneity in the form of credit-constrained households as in Mankiw (2000) and Galí, López-Salido, and Vallés (2007). We emphasize a welfare analysis of our estimated fiscal rules by computing the Lucas (1987) compensating consumption variation for each household type under different rules. The findings in our last chapter relates to differentials in welfare impacts when using fiscal rules among heterogeneous households. We extend our estimated small open economy model where all households are Ricardian, to include non-Ricardian households. In an economy populated with only Ricardian households, a decision by the fiscal authority to replace a balanced budget rule with debt rules leads to a positive welfare impact. The presence of non-Ricardian households creates a market imperfection, as these households cannot smooth consumption from one period to another, leading to a welfare loss. At an aggregate level, we find a welfare improvement in exercising debt rules compared to a balanced budget rule, even in the presence of non-Ricardian agents. However, focusing on aggregate welfare distracts from the welfare losses that arise for the non-Ricardian subset of the population and raises questions about equitable policymaking.

While this thesis leads to several central findings that not only enrich the current theoretical and empirical literature, it also sheds light on avenues for future research. Our findings have helped to develop the branch of fiscal policy literature that provides a positive analysis of fiscal rules, but it also has the potential to contribute to another body of work that focuses on a normative analysis. The competing (normative) branch of the systematic fiscal policy literature studies fiscal rules in DSGE models by moving away from the specification of rules as ad hoc processes as in our work and others (Schmitt Grohé and Uribe (2006), Forni, Monteforte and Sessa (2009), Leeper, Plante and Traum (2010)) and towards determining optimal fiscal rules. This literature represents a promising direction for our work, as it is a natural extension of the last chapter of this thesis, where we begin to apply a normative lens to fiscal policymaking. In the final chapter, we show that households who face credit constraints (non-Ricardian) realize welfare losses under balanced budget rules and these welfare losses are higher under debt rules. The estimated countercyclical coefficients on the debt rules are hence not optimal, since they do not maximize welfare for any household type.

There are various dimensions to the literature on optimal fiscal policy that analyzes fiscal rules from a welfare-maximizing standpoint. The main difference in this approach is that fiscal rules embody an optimal specification that comes from maximizing the fiscal authority's problem as opposed to determining the coefficients of pre-specified linear rules using either calibration or estimation solution methods. We would like to extend our small open model by solving for the Ramsey planner problem as in Kollman (2003), Benigno and Woodford (2006) and Schmitt Grohe and Uribe (2007) to obtain optimal coefficients for our fiscal rules. We plan to use the structural posterior distributions from the Bayesian estimation of our model in chapter 3 to parameterize the model and determine the optimal equilibrium from a timeless perspective as in

Woodford (2003). Our approach would be most similar to Schmitt Grohé and Uribe (2007) and Kliem and Kriwoluzky (2011) in that once having solved for optimal fiscal rules, we would proceed to match the optimal rules with the estimated rules. Both these papers have found that simple linear rules that seem like ad hoc processes, in fact obtain the same level of welfare as the optimal Ramsey policy fiscal rules for models calibrated to the U.S. economy.

Our analysis of optimal fiscal rules and simple numerical fiscal rules would differ from the above papers and add to the literature for three reasons. First, Schmitt-Grohé and Uribe (2007) focus on monetary and fiscal rules jointly, and analyze fiscal rules in a framework where either the government has access to only lump sum taxation or distortionary taxation, but not both. Similarly, Kliem and Kriwolouzky (2011) only consider tax rate rules, ignoring government spending and lump sum transfers as fiscal instruments. Our analysis solely focuses on active fiscal policy and will jointly consider a wide set of instruments that includes lump sum transfers, government spending, capital, labour and consumption tax rates. Second, our approach will also differ from Schmitt-Grohé and Uribe (2007) who perform a second order welfare maximization of the model to approximate the optimal coefficients. We will use the empirically estimated coefficients computed in chapter 3, following a Bayesian approach that contains more information about the coefficients. Third, both these works do not consider heterogeneous agents in the determination of optimal fiscal rules. Our investigation of optimal fiscal policy will aim to uncover welfare maximizing fiscal rules in an economic setting where all households are Ricardian as in chapter 3, as well as an economic setting where Ricardian and non-Ricardian agents co-exist as in chapter 4. We will follow the approach in Kumhof and Laxton (2013) in finding the welfare (aggregate) maximizing coefficients on a broad set of fiscal rules.

Our research so far has focused primarily on balanced budget rules and debt rules, but we plan to extend our analysis to include structural surplus rules as in Bi and Laxton (2011) and Kumhof and Laxton (2013). Our analysis will differ in the calculation of the optimal coefficients, where we will consider the full set of fiscal tools instead of restricting the adjusting fiscal instrument to always be lump sum transfers (taxes). As part of investigating different rule specifications, we can add a broader set of macroeconomic variables to which fiscal instruments respond. These variables can include consumption, employment, investment, and capital stock as in Kliem and Kriwoluzky (2011). They find investment to be most important for the capital tax rate rule and employment for the labour tax rate rule. This is a valuable direction for our work as it can inform us about macroeconomic variables beyond the output and debt gap that are important in a welfare maximizing sense, to capturing systematic fiscal policy responses.

The research presented in this thesis aims to advance the literature on systematic fiscal policy in small open economies with an application to Canada. We have shown that historical time series data in Canada supports the predictions of neoclassical models with respect to the effects of temporary government spending shocks on the economy. Specifically, we have used a VAR analysis to confirm that private consumption falls in response to an unexpected rise in government spending in Canadian data.

Using a DSGE neoclassical model framework, we estimated simple linear fiscal rules to calculate the elasticity of fiscal aggregates to short run fluctuations in the state of the economy and to changes in the stock of public debt. Our estimation results provide a full set of robust fiscal parameter values, for which there are no comparable estimates to date. We found that tax rates demonstrate pro-cyclical behavior, adjusting to business cycles but do not respond to changes in the state of public finance. On the other hand, government spending has not adjusted to business cycle movements, but has displayed the strongest quantitative adjustment to changes in the public debt. These estimates represent an important development in the literature. Our results indicate that systematic fiscal policy in Canada has behaved differently than the United States and some European countries, where tax rates have carried either most or shared the burden of fiscal adjustment along with government spending in responding to public debt levels. We find that for Canada, government purchases and transfer payments instead have displayed a negative response to lagged public debt. Lump sum transfers have responded to the state of the economy and public finances equally. This evidence suggests that consolidation of debt has primarily occurred through adjustments to government purchases and transfer payments. It also highlights the important role that transfer payments have played as automatic stabilizers.

Using these implied relationships in the data, we introduced heterogeneity through the inclusion of non-Ricardian households in our model to determine the welfare impact of fiscal rules. This analysis allows us to contribute to the theoretical fiscal policy literature that highlights the role of credit-constrained households on the macro-economy. While most of the literature focuses on the inability of these households to save and optimize, creating a market imperfection through which fiscal policy has real effects on the economy, we focus on how fiscal policy decisions affect the welfare of these households. As the Balanced Budget Act is currently being repealed in Canada, we investigate the merits of our proposed debt rules from a welfare perspective. We compared a balanced budget rule alongside various debt rules and found that joint welfare rises with the adoption of debt rules. Given that credit constrained households, represent a small proportion of the total population, their welfare outcomes are not well represented by solely consulting the aggregate welfare measure. Examining the welfare implications of a change in fiscal rules to debt rules for each household type in isolation reveals that non-Ricardian households experience a welfare loss; whereas Ricardian households benefit through a welfare gain. These results are a meaningful addition to the literature and inform Canadian policymakers of a class of debt rules that could replace the balanced budget rule. The government should recognize that our proposed debt rules come at a small cost to the welfare of credit-constrained households.

Appendix A.2

A.2.1 Data construction for Blanchard and Perotti (2002) Approach

Subsample 1

Real GDP (rgdp): Table 380-0002, v1992067, quarterly, seasonally adjusted at annual rates, and chained (2002) dollars

rgdp = GDP at market prices

Real Government Spending (rgov): Table 380-0002, (v1992049, v1992050, v1992051), quarterly, seasonally adjusted at annual rates, and chained (2002) dollars

rgov = government current expenditures on goods and services + government gross fixed capital formation + government investment in inventories

Real private consumption (rcon): Table 380-0002, v1992044, quarterly, seasonally adjusted at annual rates, and chained (2002) dollars

rcon = personal expenditure on consumer goods and services

rcdur = personal expenditure on durable goods (v1992045)

rcndsv = personal expenditure on non-durable goods and services (v1992047, v1992048)

Real net tax revenues (rntax): Table 380-0007, (v498317, v498321, v498322, v498323, v498325, v498329, and v498330) quarterly, seasonally adjusted at annual rates, current prices

rntax = rev-trans

rev = taxes on income + contributions to social insurance plans + taxes on production and imports + other current transfers from persons – sales of goods and services

trans = current transfers to persons + current transfers to business

Gross domestic product at market prices, implicit price index, 2002 = 100 (pgdp), Table 380-0003, quarterly, (v1997756)

Subsamples 2 and 3

Real GDP (rgdp): Table 380-0064, v62305752, quarterly, seasonally adjusted at annual rates, and chained (2007) dollars

rgdp = GDP at market prices

Real Government Spending (rgov): Table 380-0064, (v62305731, v6230540, v6230541, v6230542), quarterly, seasonally adjusted at annual rates, and chained (2007) dollars

rgov = general governments final consumption expenditure + general governments gross fixed capital formation + investment in inventories –business investment in inventories

Real private consumption (rcon): Table 380-0064, v62305724, quarterly, seasonally adjusted at annual rates, and chained (2007) dollars

rcon = personal expenditure on consumer goods and services

rcdur = personal expenditure on durable goods (v62305726)

rcndsv = personal expenditure on non-durable goods and services (v62305728, v62305729)

Real net tax revenues (rntax): Table 380-0080, (v62425529, v62425536, v62425537, v62425540, v62425541, v62425544, v62425545, v62425552, and v62425554) quarterly, seasonally adjusted at annual rates, current prices

rntax = rev-trans

rev = taxes on income + contributions to social insurance plans + taxes on production and imports + other current transfers from households + current transfers from other non-profit institutions serving households – sales of goods and services

trans = current transfers to households + capital transfers + subsidies

Gross domestic product at market prices, implicit price index, 2002 = 100 (pgdp), Table 380-0066, quarterly, (v62307266)

A.2.2 Data for Ramey and Shapiro (1998) Approach

Data for the period: 1947q1-1997q4

Real GDP at market prices (rgdp): Table 380-0501, v87224024, quarterly, seasonally adjusted at annual rates, Millions of dollars, 1986 constant prices

Real Government spending (rgov): Table 380-0501, (v87224026, v87224027) quarterly, seasonally adjusted at annual rates, Millions of dollars, 1986 constant prices

rgov= government current expenditure on goods and services + government investment (fixed capital)

Real private consumption (rcon): Table 380-0501, (v87224025) quarterly, seasonally adjusted at annual rates, Millions of dollars, 1986 constant prices

Net tax revenues (rntax): Table 380-0506, (v87984403, v87984406, v87984407, v87984411), quarterly, seasonally adjusted at annual rates, Millions of dollars, current prices

rntax = rev-trans

rev= direct taxes from persons + indirect taxes + other current transfers from persons

trans = current transfers to persons

Gross domestic product indexes (1986=100), Table 380-0511, v88112188, quarterly, seasonally adjusted at annual rates

Appendix A.3

A.3.1 Data construction for Bayesian Estimation Approach

Consumption (C) is defined as personal consumption expenditure on non-durable goods (Table 380-002; v498090) and personal expenditure on services (Table 380-0002; v498091).

Investment (I) is defined as personal consumption expenditure on durable goods (Table 380-002; v498088) and business gross fixed capital formation (Table 380-0002; v1992052).

Consumption tax revenues $\left(T^c\right)$ is defined as excise taxes (Table 380-0034; v499743) and custom import duties (Table 380-0034; v499741).

Consumption tax rates:

Average consumption tax rate:

$$T^c = \frac{T^c}{C - T^c - T_s^c}$$

T_s^c = Sales taxes (Table 380-0033; v499829).

Capital and labor tax rates:

Average personal income tax rate:

$$\tau^p = \left[\frac{IT}{W + \frac{PRI}{2} + CI} \right]$$

IT = Direct taxes from persons (Table 380-0034; v499731).

W = Wages and salaries (Table 382-0001; 1961Q1–1996Q4), (Table 382-0006; 1997Q1 – 2012Q4)

PRI= Accrued net income of farm operators from farm production + Net income of non-farm unincorporated businesses (Table 380-0001; v498080, v498081).

CI = Corporation profits before taxes + Interest and miscellaneous investment income + PRI/2 (Table 380-0001; v498077), (Table 380-0001; v498079).

Average labor income tax rate:

$$\tau^{l} = \left[\tau^{p} \frac{\left(W + \frac{PRI}{2} \right) + CSI}{EC + \frac{PRI}{2}} \right]$$

EC = Wages, salaries and supplementary labor income (Table 380-0001; v498076).

CSI = Contributions to social insurance plans (by employers and employees), (Table 380-0034; v499737).

Average capital income tax rate:

$$\tau^{k} = \frac{\tau^{p} * CI + CT}{CI + PT}$$

CT = Direct taxes from corporations and government business enterprises

(Table 380-0034; v499734).

PT = Real property taxes (Table 380-0033; v499841).

Capital and labor tax revenues:

$T^{k} = t^{k} * \text{Taxbase}$

$T^{l} = t^{l} * \text{Taxbase}$

Capital tax base = CI + PT

Labor tax base = EC + PRI/2

Government expenditure (G) is defined as government current expenditures on goods and services, government acquisition of non-financial assets (includes gross capital formation) minus capital consumption allowances. Table 380-0034; v499762, v499803, v499802, v499801.

Transfers (TR) is defined as net current transfers (NCT), net capital transfers (NKT) (Table 380-0034; v499807) and subsidies (Table 380-0506; v87984432; 1960Q1– 1980Q4), (Table 380-0080; v62425654; 1981Q1-2012Q4) minus the tax residual.

NCT = Current Transfer Payments (CTP) – Current Transfer Receipts (CTR)

CTP = Current transfers to persons + Current transfers to business + Current transfers to non-residents + Current transfers to government. (Table 380-0034; v499768, v499778, v499779, v499782)

CTR = Other current transfers from persons + Current transfers from government. (Table 380-0034; v499750, v499751)

Tax Residual

Tax residual = A - T

A = Current tax receipts + Contributions to social insurance plans+ Investment income

+ Remitted profits of government business enterprises. (Table 380-0034; v499753), (Table 380-0034; v499753).

Current tax receipts = Direct taxes from persons + Direct taxes from corporation and government business enterprises + Direct taxes from non-residents + Indirect taxes. (Table 380-0034; v499743; v499741; v499731, v499734, v499736).

Total tax revenue (T) = Consumption tax revenue + Labor tax revenue + Capital tax revenue

Government debt B_t^h is defined as

$$BT = NB - Seinoirage + B_{t-1}$$

Seignoirage = $\left(M_t - M_{t-1}\right)$, where M is the Bank of Canada's monetary base (notes and coin in circulation, chartered bank and other Canadian Payments Association members' deposits with the Bank of Canada). Table 176-0025; v37145.

Net Borrowing (NB) = G + INT + TR – T

where INT represents interest payments to persons and businesses and to the rest of the world (Table 380-0034; v499798). Additionally, the starting value for the debt series was obtained from CANSIM (Table 385-0010) the debt value used was for 1960Q1 = 20399.

Hours worked (L) is defined as average weekly hours of employees paid by the hour (Manufacturing), (SEPH = Survey of employment, payroll and hours) quarterly (Table 281-0022; v75536; 1961Q1–1982Q4), (Table 281-0004; v254480; 1983Q1-2012Q4).

Hours worked (L) = HSA* Emp * 12

Employment (Emp) is defined as employment, both sexes, 15 years and over, measured in thousands, seasonally unadjusted (LFS = Labor Force Survey), quarterly (Table 282-0020; v74973 for 1976Q1 – 2012Q4). I use Employment Indexes, Industrial Composite (SEPH) to find employment for 1961Q1–1983Q4 (Table 282-0001; v2091072). The series was seasonally adjusted in STATA.

Population (Pop) is defined as estimates of population, Canada, provinces and territories, quarterly (persons, thousands), (Table 051-0005).

A.3.2 Steady States

$$\bar{r} = \frac{1}{\beta}$$

$$\bar{r}^k = \left[\frac{\frac{1}{\beta} - 1 + \delta}{(1 - \tau^k)} \right]$$

Setting $\bar{l} = \frac{1}{3}$

$$\bar{k} = \left(\frac{\bar{r}^k}{\alpha} \right)^{\frac{1}{\alpha - 1}}$$

$$\bar{y} = \bar{k}^{\alpha} \bar{l}^{1-\alpha}$$

$$\bar{i} = \delta \bar{k}$$

$$\bar{w} = (1 - \alpha) \frac{y}{l}$$

Using calibrated values for $\left(\frac{G}{Y} \right)$ **and** $\left(\frac{B^f}{Y} \right)$ **determines** $\bar{G}$ **and** $\bar{\mathbf{B}}^f$

$$\bar{Z} = \bar{B} - \bar{R}\bar{B} + \tau^k \bar{R}^k + \tau^l \bar{W}\bar{L} + \tau^c \bar{C} - \bar{G}$$

A.3.3 Estimation Diagnostics

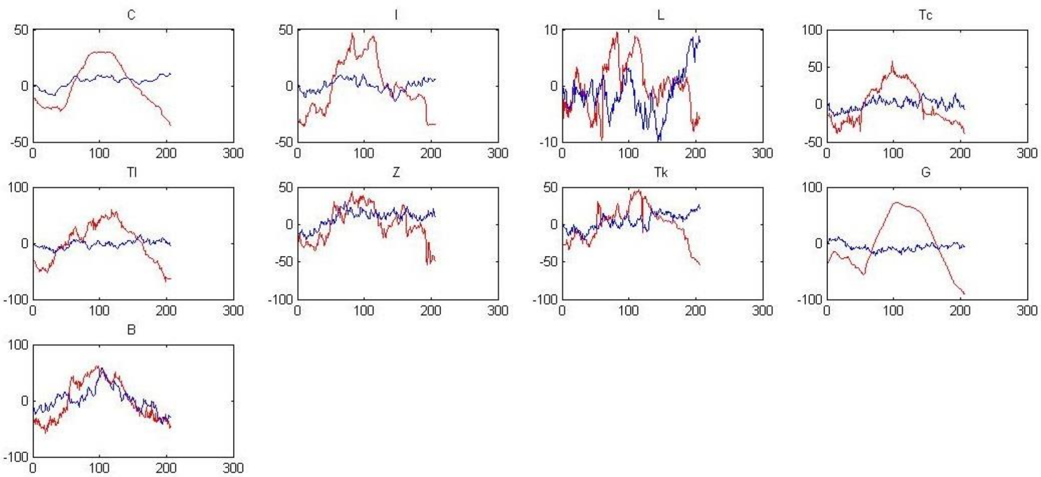

FIGURE A.3.1 Time paths of observables (red) and their model-simulated counterparts (blue)

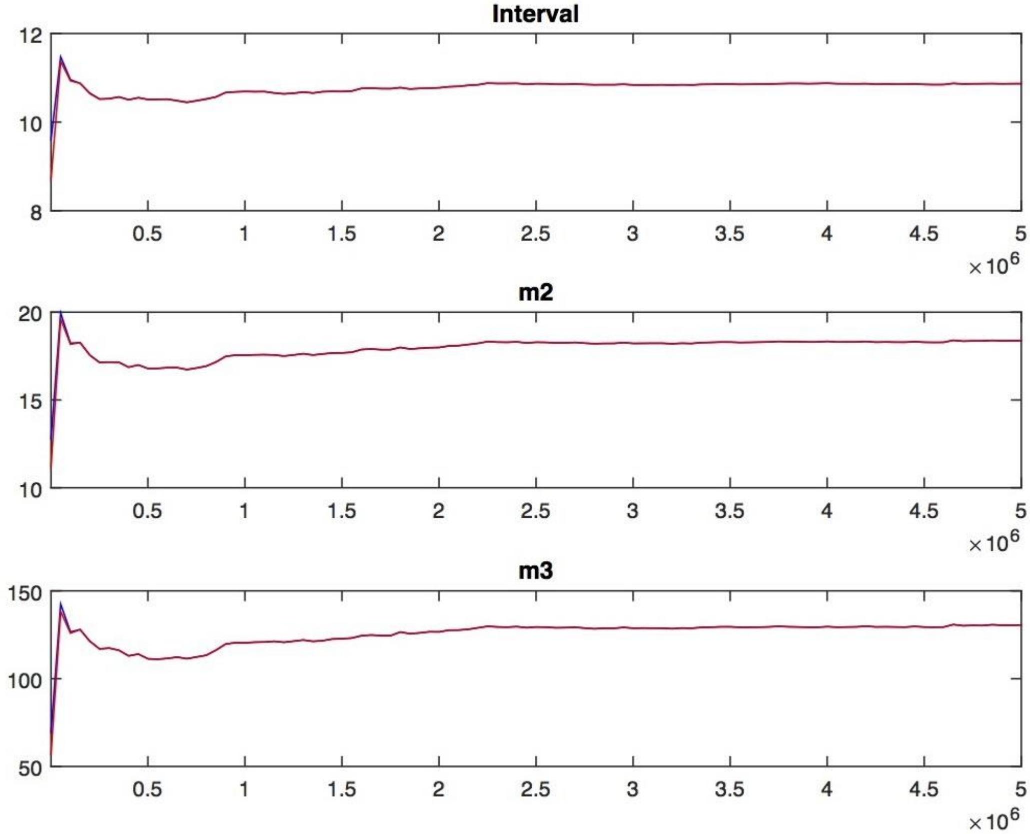

FIGURE A.3.2 Multivariate convergence diagnostics

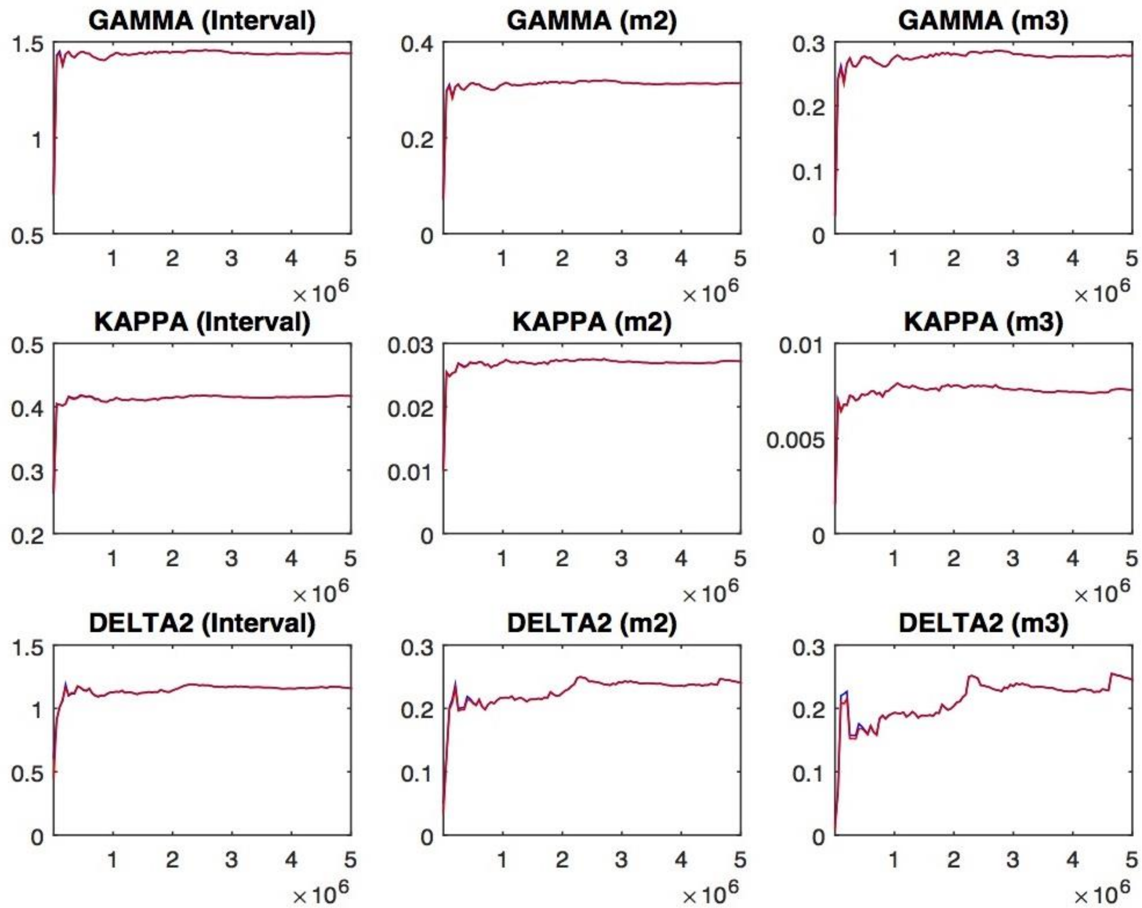

FIGURE A.3.3 Univariate convergence diagnostics

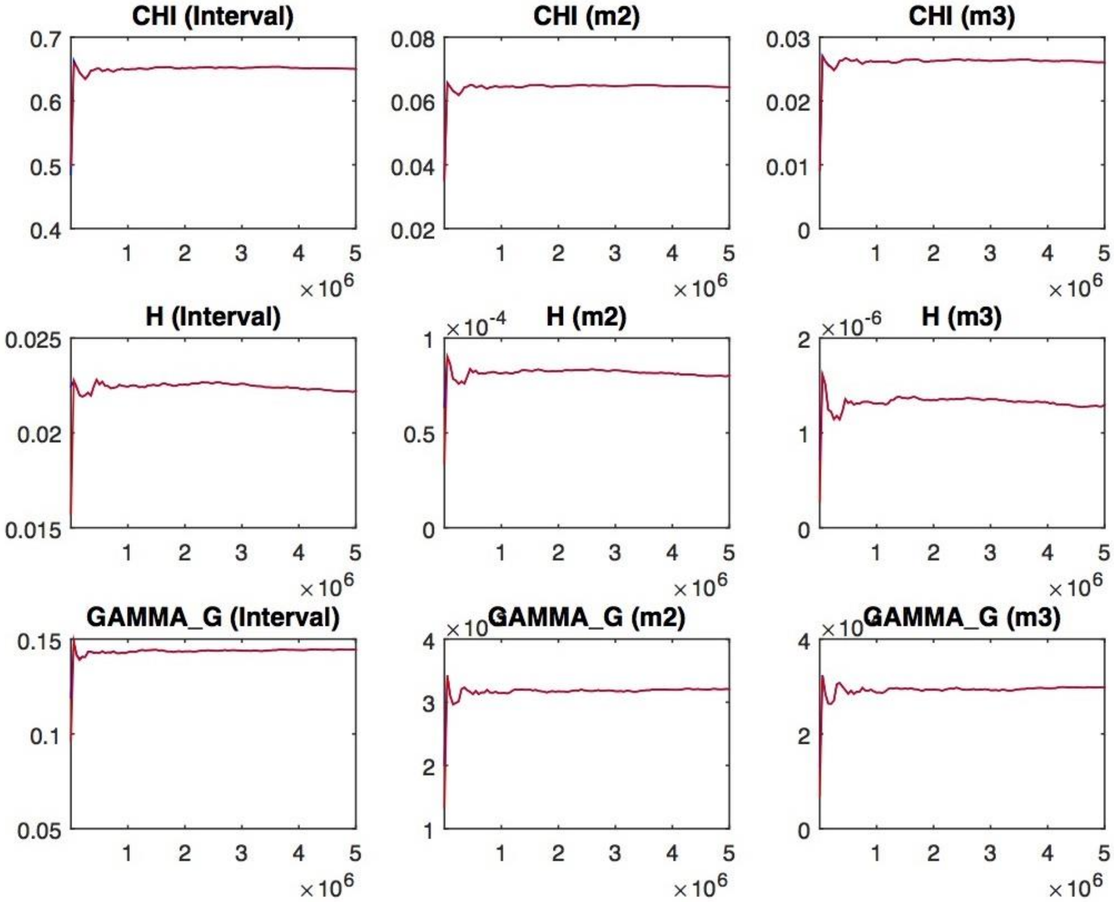

FIGURE A.3.4 Univariate convergence diagnostics

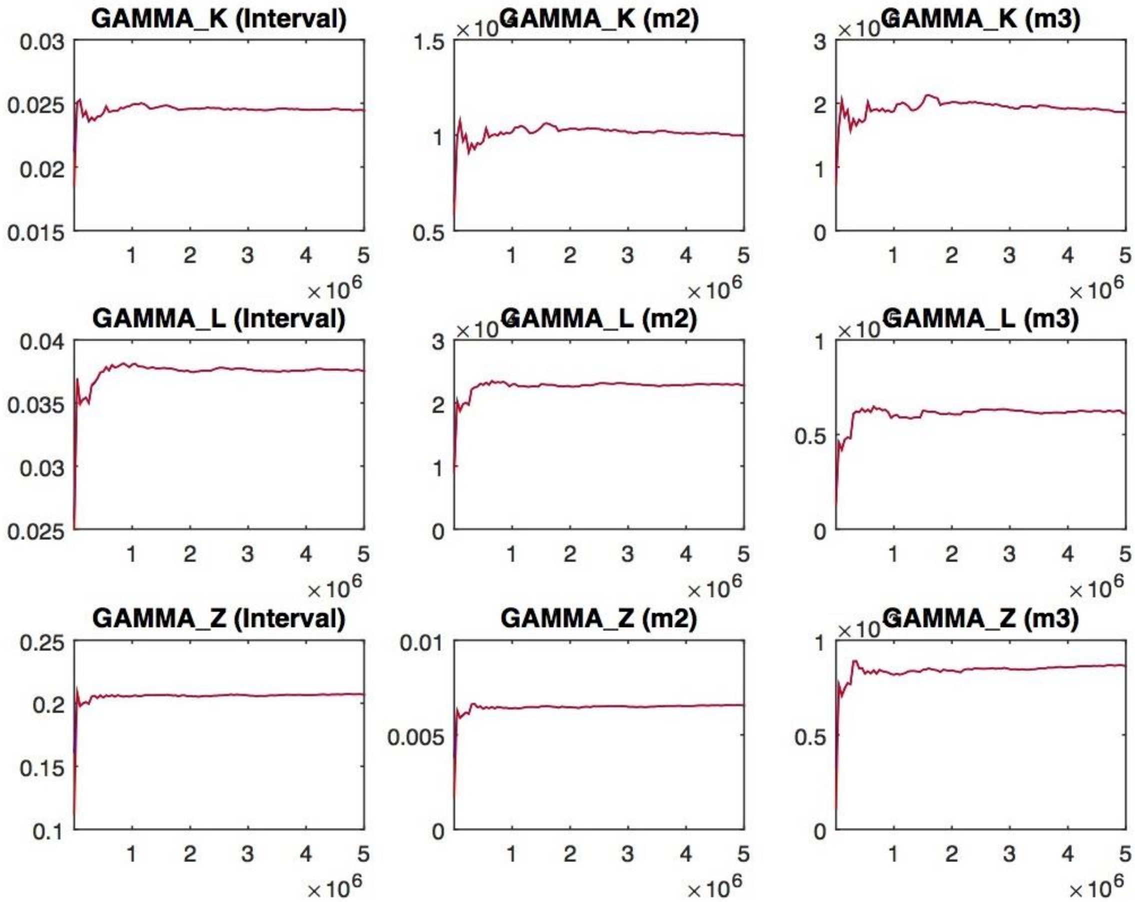

FIGURE A.3.5 Univariate convergence diagnostics

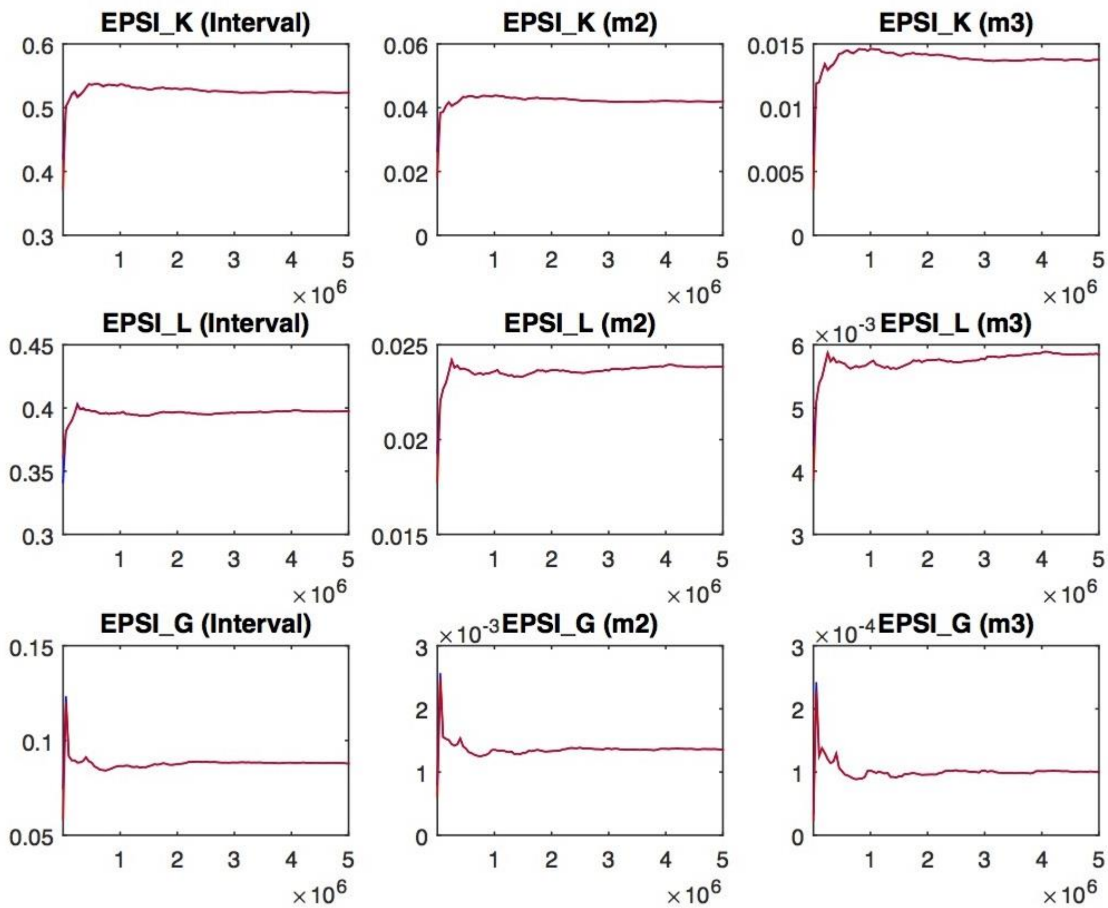

FIGURE A.3.6 Univariate convergence diagnostics

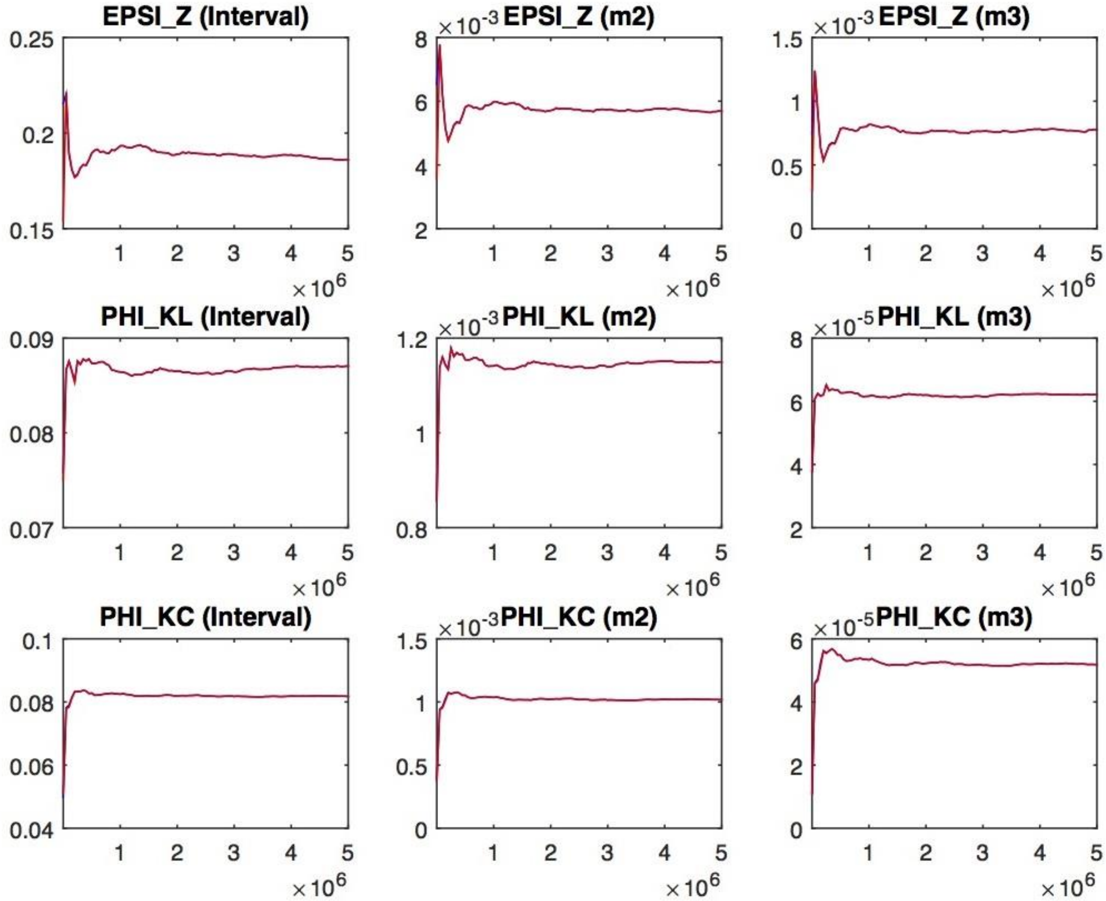

FIGURE A.3.7 Univariate convergence diagnostics

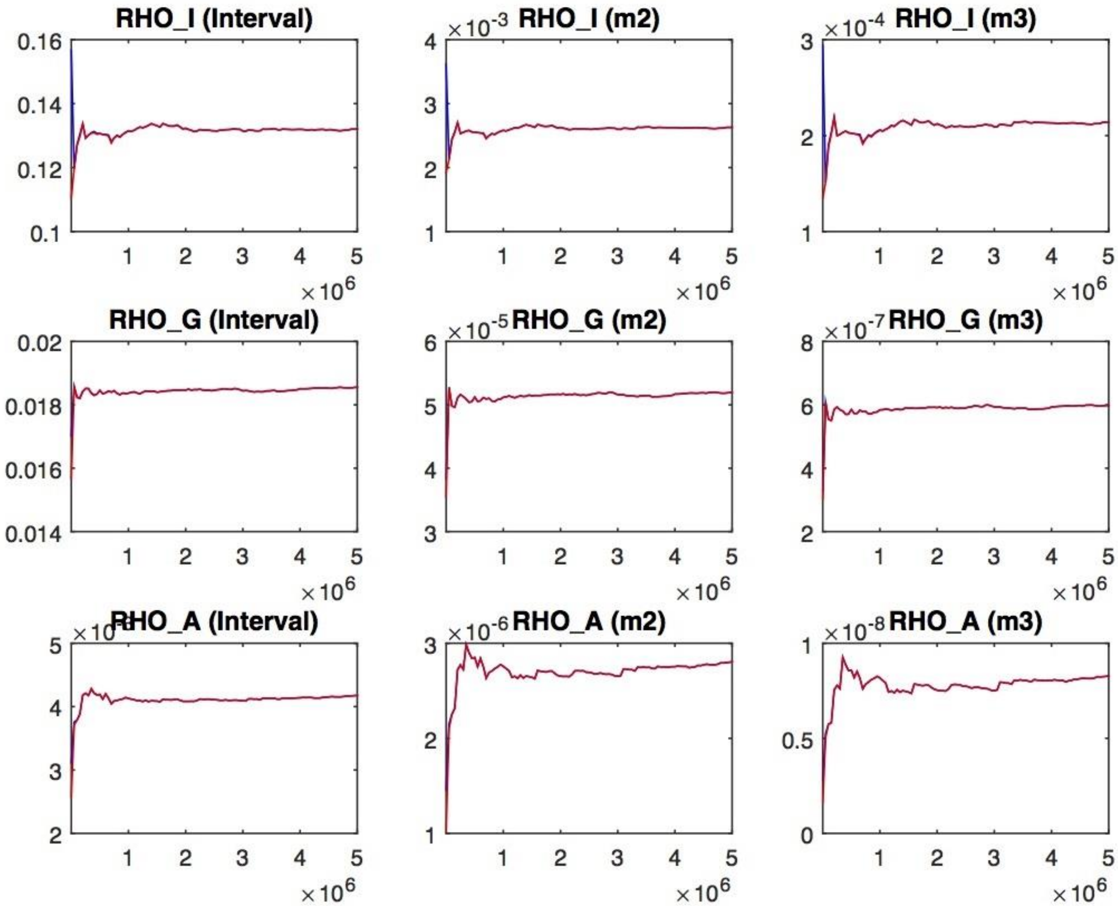

FIGURE A.3.8 Univariate convergence diagnostics

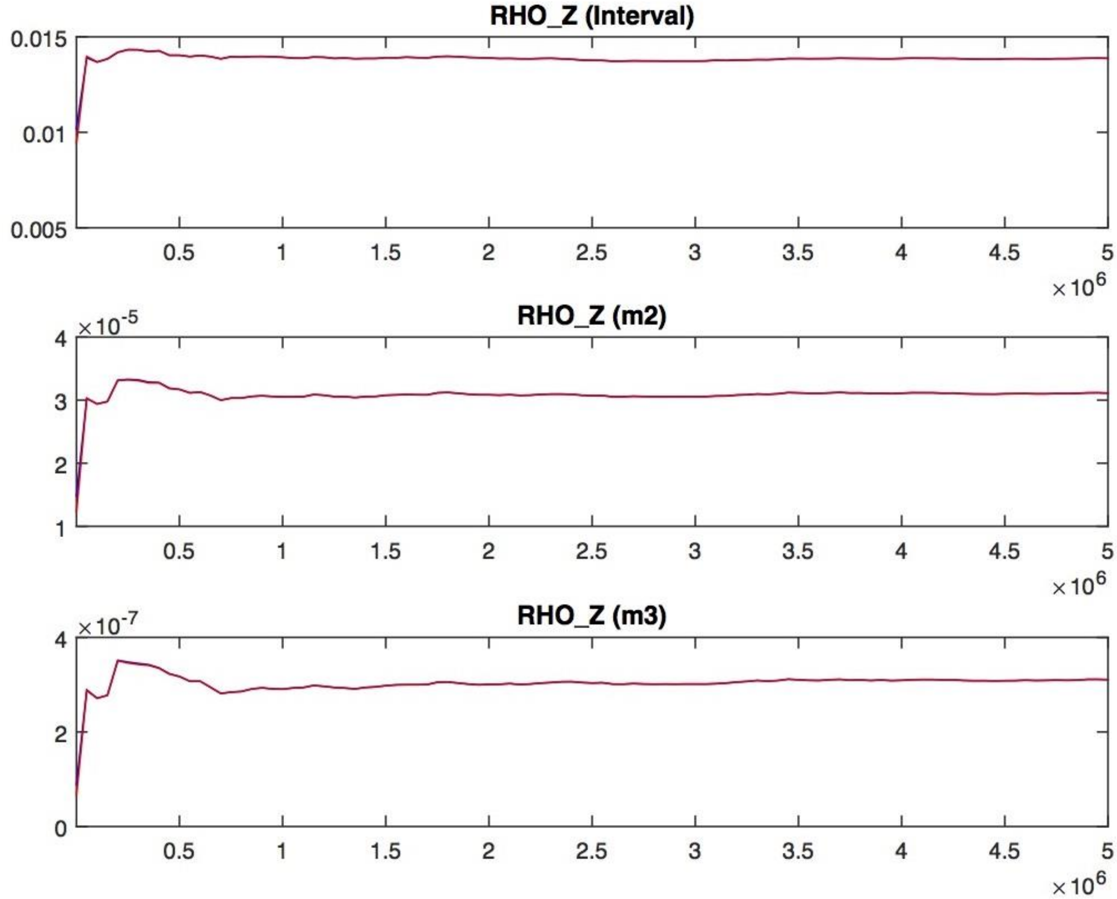

FIGURE A.3.9 Univariate convergence diagnostics

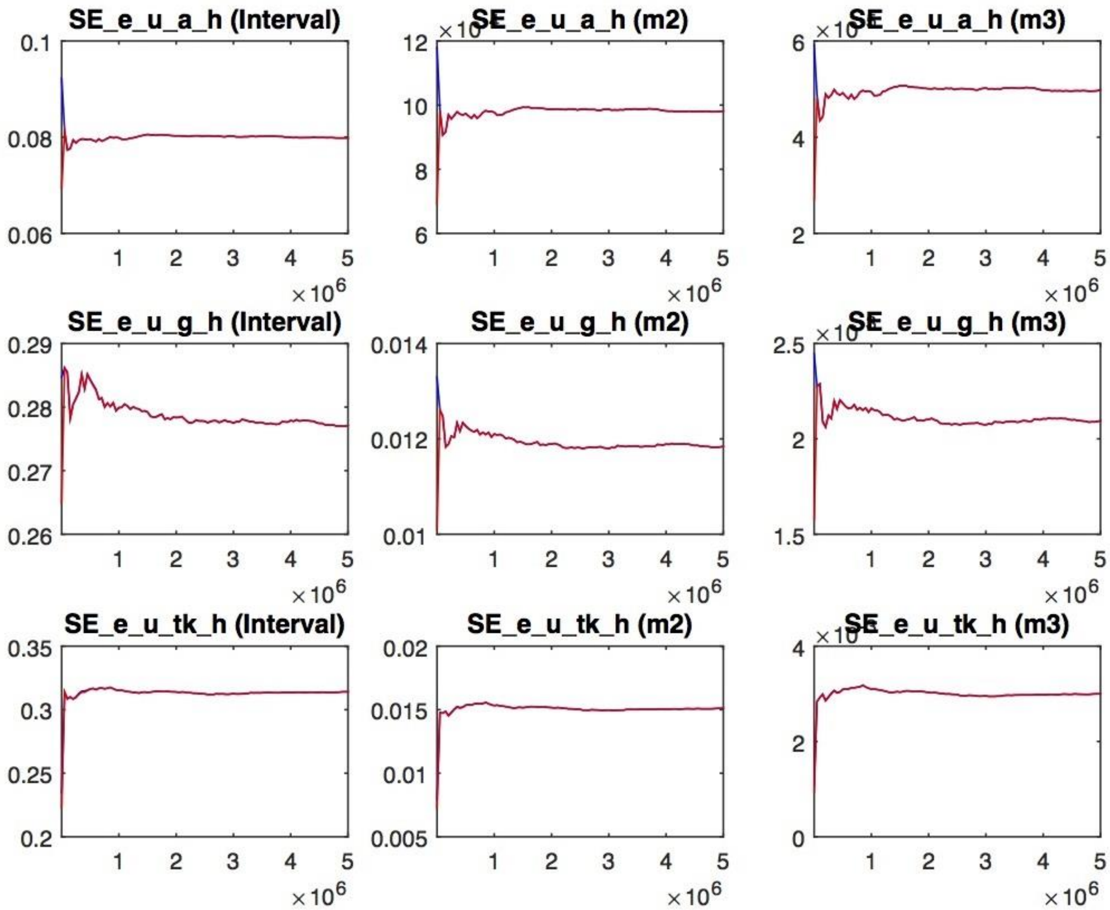

FIGURE A.3.10 Univariate convergence diagnostics

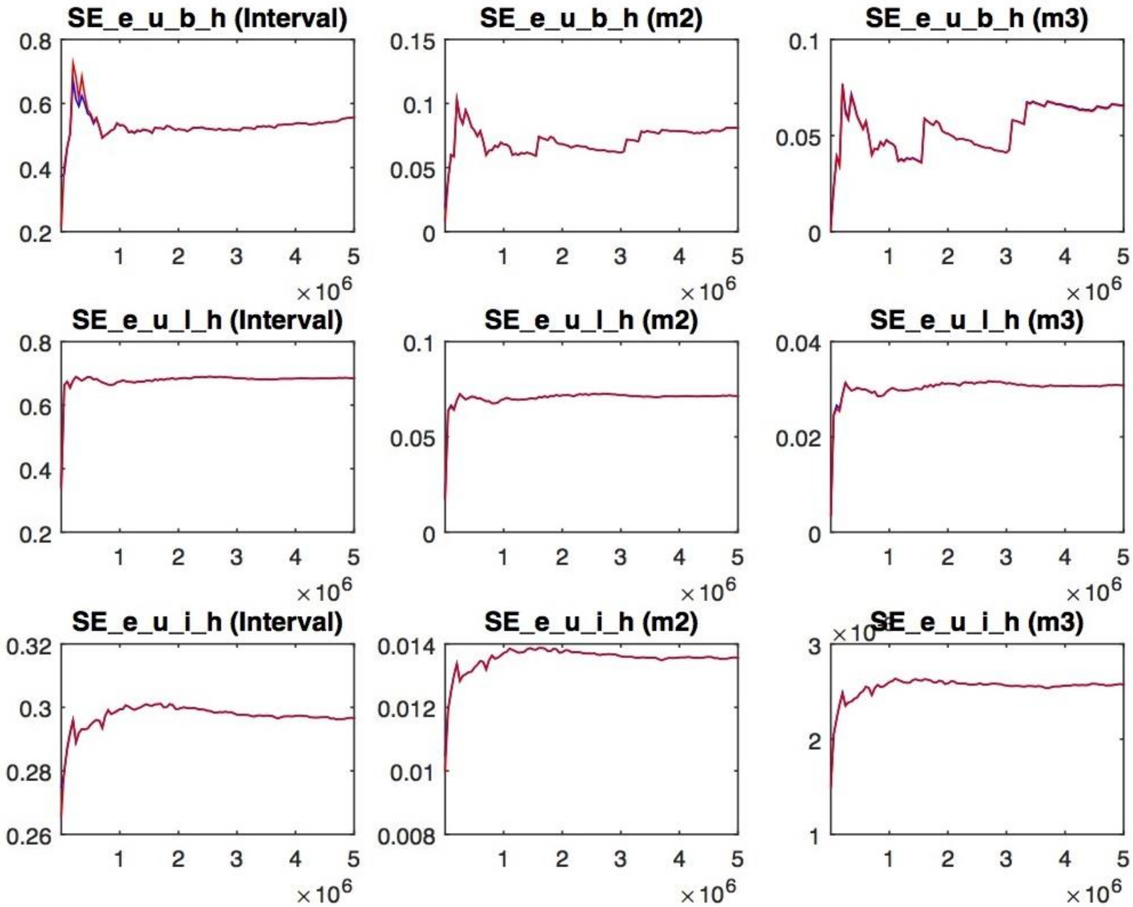

FIGURE A.3.11 Univariate convergence diagnostics

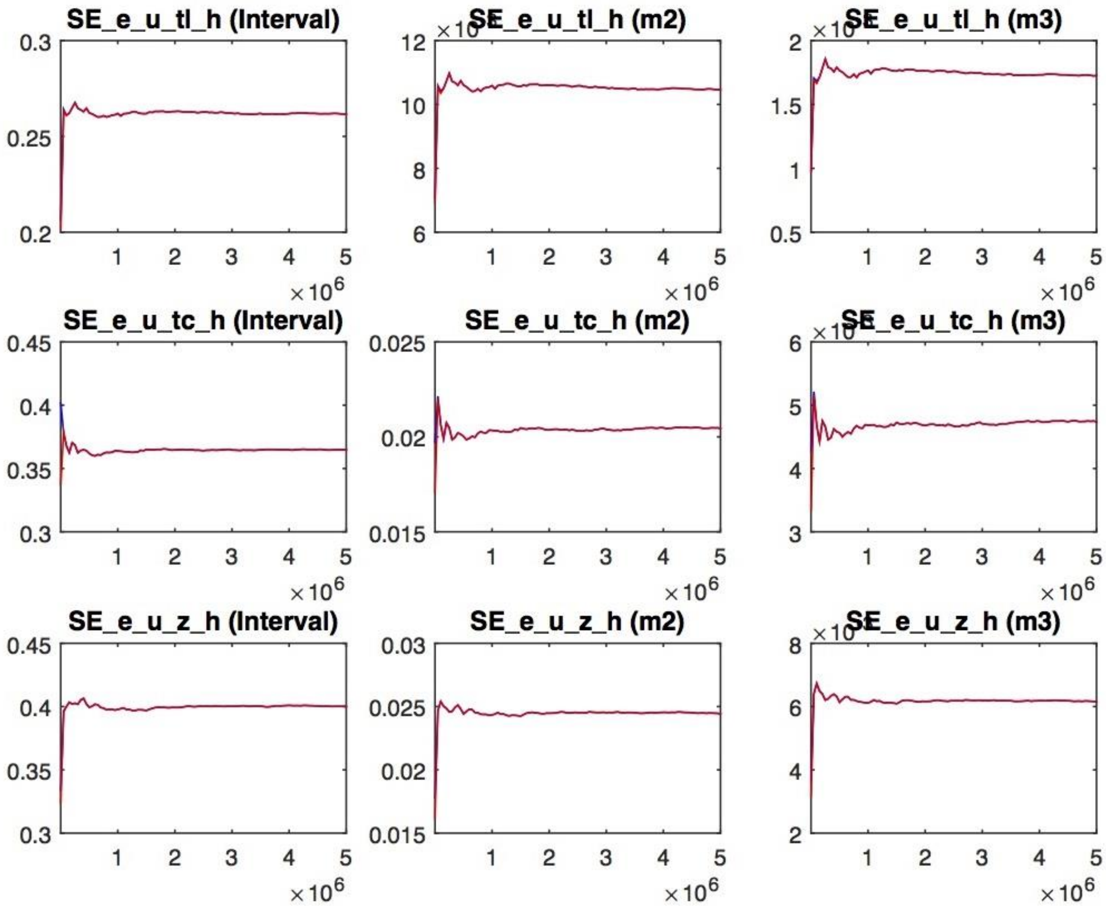

FIGURE A.3.12 Univariate convergence diagnostics

A.3.4 Estimated Posterior Distributions

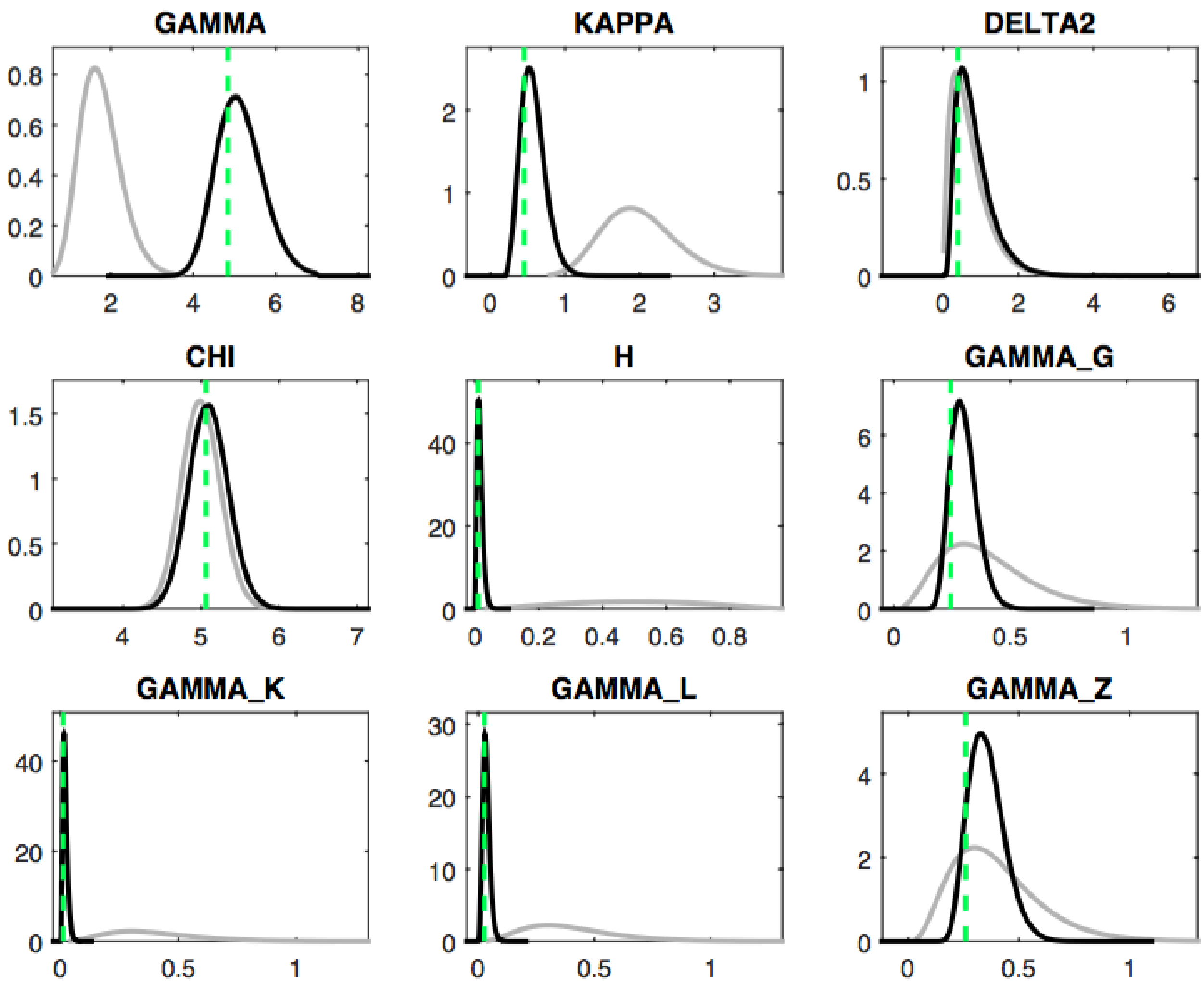

FIGURE A 3.13 Baseline prior and posterior distributions

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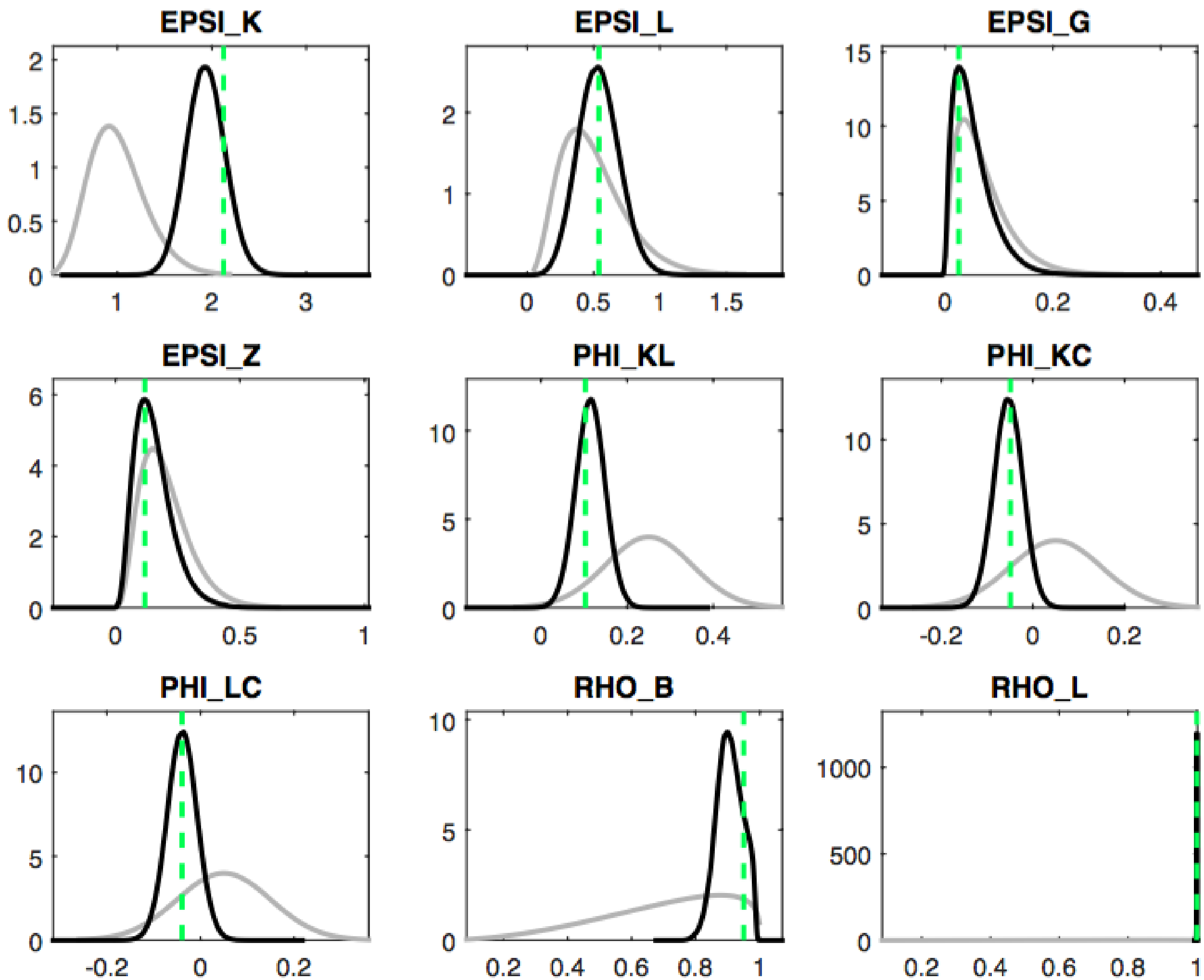

FIGURE A 3.14 Baseline prior and posterior distributions.

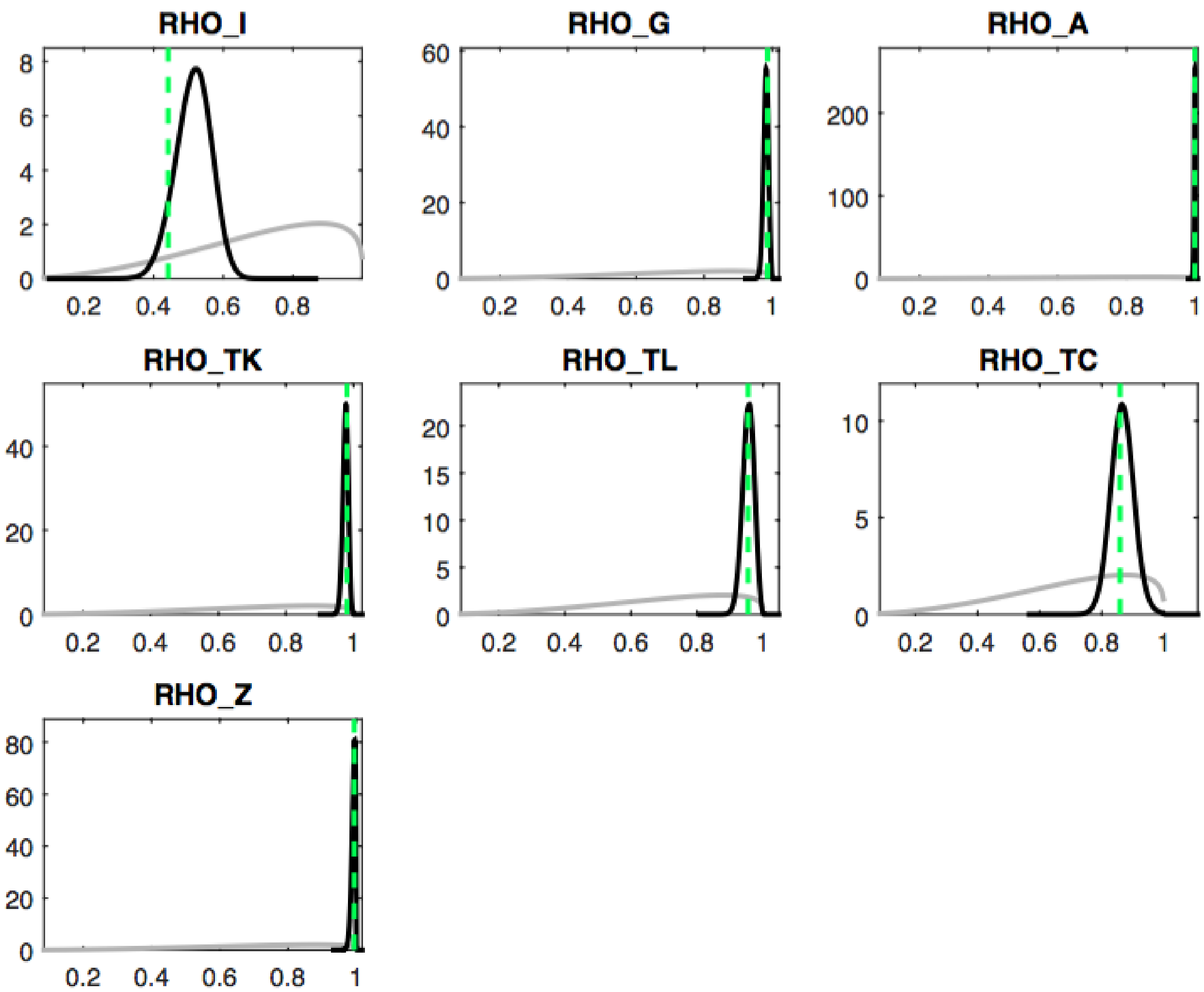

FIGURE A 3.15 Baseline prior and posterior distributions.

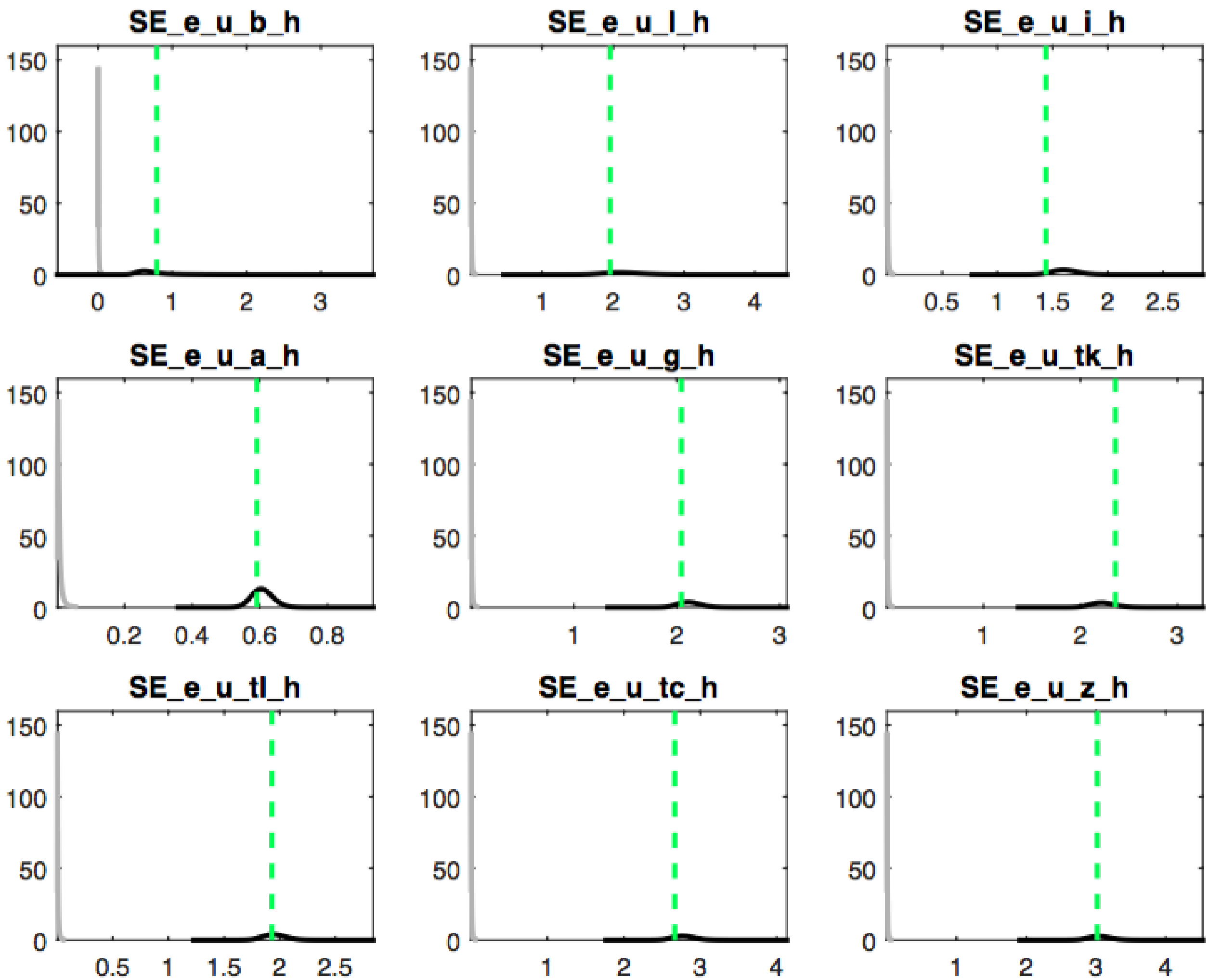

FIGURE A 3.16 Baseline prior and posterior distributions.

TABLE A 3.1 Posterior distributions of the Baseline and the Alternative model

Parameters		Distribution	Baseline	Alternative
γ	Risk Aversion	Gamma	5.12	4.82
κ	Inv.Frisch Elasticity	Beta	0.57	0.52
h	Habit persistence	Gamma	0.01	0.02
χ	Inv. Adj Cost	Gamma	5.09	5.07
δ_2	Cap. Utility Cost	Gamma	0.83	0.82
γ_g	Gov. Spending B coeff.	Gamma	0.30	0.26
γ_{tk}	Cap. Tax B coeff.	Gamma	0.02	--
γ_{tl}	Labour Tax B coeff.	Gamma	0.03	--
γ_z	Transfer B coeff.	Gamma	0.35	0.16
φ_{tk}	Cap.Tax Y coeff.	Gamma	1.93	1.73
φ_{tl}	Labour Tax Y coeff.	Gamma	0.54	0.41
φ_g	Gov. Spending Y coeff.	Gamma	0.05	0.05
φ_z	Transfers Y coeff.	Gamma	0.15	0.16
ϕ_{kl}	Cap./Labour co-term	Gamma	0.11	0.11
ϕ_{kc}	Cap./Cons. Co-term	Gamma	-0.05	-0.04
ϕ_{lc}	Labour/Cons. Co-term	Gamma	-0.04	-0.03
ρ_a	Tech. AR coeff.	Beta	0.99	0.99
ρ_b	Pref. AR coeff.	Beta	0.91	0.93
ρ_l	Labour AR coeff.	Beta	0.99	0.99
ρ_i	Inv. AR coeff.	Beta	0.51	0.48
ρ_g	Gov. Spend. AR coeff.	Beta	0.98	0.98
ρ_{tk}	Cap.Tax AR coeff.	Beta	0.98	0.97
ρ_{tl}	Labour Tax AR coeff.	Beta	0.95	0.96
ρ_{tc}	Cons. Tax AR coeff.	Beta	0.86	0.85
ρ_z	Transfer AR coeff.	Beta	0.99	0.99
σ_a	Tech. std.	Beta	0.60	0.60
σ_b	Pref. std.	I.Gamma	0.76	0.80
σ_l	Labour std.	I.Gamma	2.15	2.03
σ_i	Inv. std.	I.Gamma	1.61	1.55
σ_g	Gov. Spend. std	I.Gamma	2.12	2.11
σ_{tk}	Cap. Tax std.	I.Gamma	2.23	2.20
σ_{tl}	Labour Tax std.	I.Gamma	1.95	1.95
σ_{tc}	Cons. Tax std.	I.Gamma	2.78	2.78
σ_z	Transfer std.	I.Gamma	3.05	3.06

A.3.5 Baseline Results and Model Comparison

This section presents the estimation results of the baseline small open economy model with five fiscal rules. We also conduct a log marginal data density comparison of both versions of the small open economy model to determine the best fitting model to Canadian data. Table A.3.1 summarizes the estimated posterior mean for the baseline model alongside the estimates for the small open economy model.

The posterior mean parameter values are similar with a few exceptions. The baseline specification yields a higher mean value for the risk aversion parameter. We conclude that the risk aversion parameter has not been estimated precisely in either estimation procedures and calibrate it. When comparing estimated fiscal parameters in the two models, we find the parameter estimate for the transfer debt coefficient varies significantly. The transfer debt coefficient is estimated to be much higher (0.35 vs. 0.16) in the baseline estimation than in the alternative estimation. The coefficients on the estimated fiscal rules suggest that the strongest adjustment to debt innovations comes from transfers (0.35) and government spending (0.30). This result implies that with the alternative model specification transfers are less important for debt stabilization than in the baseline model. The estimated tax instrument debt coefficients reveal that capital and labour tax rates have not historically responded to changes in debt levels in Canada. Leeper, Plante and Traum (2010) also do not find evidence of labour taxes adjusting to debt innovations, however their estimation results indicate that capital taxes have played a very an important role in debt management for the U.S. In fact, they report a capital tax debt coefficient (0.39) that is larger than the government spending debt coefficient (0.23) but smaller than the transfers debt coefficient (0.5).

These findings lend support to the importance of distortionary taxation instruments for the U.S government in achieving debt sustainability. On the other hand, our fiscal parameter estimates only finds support for spending instruments stabilizing debt in Canada. These differences in results arise mainly from differences in fiscal policies between the countries. The fiscal rule specification requires an increase in respective tax rates in response to a high level of debt. However, a historical account of fiscal policy in Canada reveals a political commitment to low taxes. During the late 1970's and early 1980's tax cuts (corporate and excise) were implemented to achieve balanced budgets. In 2001-02, the government decided to cut personal income and corporate taxes for a five-year period. In Budget 2006, the government renewed its commitment to tax cuts of an additional $21.2 billion lasting until 2008. Fiscal policy after the Great recession has continued to focus on low tax rates despite increases in the debt level. The Canadian federal government has a firm stance on restricting upward adjustments in tax rates as communicated in the Budget 2009 -2015. Our results confirm that the Canadian federal government's fiscal policy is not consistent with increasing tax rates in response to fiscal imbalances.

The Bayesian approach allows for model selection via comparison of the out of sample forecast performance of a suit of models over the same dataset. The marginal likelihood represents a respective model's out of sample prediction performance and is commonly used as a measure for comparing the performance of DSGE models with alternative specifications. There is a large literature documenting evidence of the superior performance of Bayesian estimates when compared to VAR (VAR) models and Bayesian Vector-Auto regression (BVAR) models[86].

[86] Smets and Wouters (2003, 2007), Fernandez-Villaverde and Rubio-Ramirez (2004).

We follow Geweke (1999) to calculate the log marginal density using the Laplace Approximation around the posterior mode and the modified harmonic mean to compare across the different specifications of the model.[87]

The marginal likelihood of a given model X is as follows:

$$M = \int_{\theta} p(\theta \mid X)\, p(Y_T \mid \theta, M)\, d\theta$$

where $p(\theta \mid X)$ is the prior density of the vector of parameters θ conditional on the model X, and $p(Y_t \mid \theta, X)$ is the likelihood function of the vector of observables Y_T, conditional on the set of parameters and the model. The marginal likelihood of the model M reflects the likelihood of the model given the data. We use the marginal likelihood to choose the model that will best fit the data and provide superior prediction performance. Based on the log marginal density of the two models summarized in Table A.3.2, the alternative model results in a higher marginal likelihood for both the Laplace Approximation and Modified Harmonic Mean techniques. This implies that the alternative model does a better job at predicting the nine observable variables over the period 1961Q1 to 2012Q2, making it the preferred model for Canada.

TABLE A 3.2 Marginal likelihood comparison

Log Marginal Density Measures	Baseline Model	Alternative Model
Laplace Approximation	-3132.8	-3119.6
Modified Harmonic Mean	-3124.1	-3102.9

[87] See Geweke (1999) for a detailed discussion on different techniques in calculating the marginal likelihood for model comparison purposes.

The comparison of the two models provides evidence of the alternative specification outperforming the baseline model based on log marginal density measures. This suggests that the most important fiscal tool for debt stabilization in Canada has been government spending, followed by transfers. Additionally, the estimation results imply that distortionary taxes such as capital and labour taxes do not play a role in adjusting debt and has not been used by the Canadian government as a tool to target debt stabilization.

A.3.6 Estimation Results using Hodrick Prescott Filter

As a robustness check, we re-estimate the baseline small open economy model using an HP filter and compare our results to the results obtained when using linear de-trended observables. The estimation uses two MH chains, with acceptance rates of 46.15 percent and 45.70 percent. These acceptance rates are slightly higher than the reported rates (36.67 and 36.45 percent) when the model was estimated using linear de-trending methods to remove deterministic trends from the data. We select a burn in period of 0.25 by dropping the first quarter of the draws from the MH prior to the posterior simulations. The log data density for the estimation was -14023.59 and the Laplace approximation was -14122.60.

The estimation results for the structural parameters of the alternative model are summarized in TABLE A.3.3 . Here we report three sets of results, the estimated posterior mode, the estimated posterior mean and the 5 and 95 percentile of the posterior distribution. FIGURE A.3.5 –A.3.7 plots the prior (grey line) and posterior (black line) distributions as well as the posterior mode (horizontal dashed green line). The estimation results indicate that all structural parameters of the model are significantly different from zero except for the capital and labour tax rate coefficients on the debt gap and the persistence parameter for labour. The prior and posterior plots reveal that the posteriors lie closely to the selected priors.

As one would expect the estimated posterior means resulting from the estimation of HP-filtered observables are different from their counterparts from when the data is treated with linear de-trending methods. However, these differences do not change the major results in chapter 3. We report an estimated value of 1.21 for the risk aversion parameter. This estimate is lower than the previous estimated value of 5.12 and is more consistent with estimates found in the Canadian literature. We find a posterior mean value of 0.22 for the inverse Frisch elasticity, implying a value of 4.55 for the Frisch elasticity of labour supply. This parameter was previously estimated at 1.75 in the baseline model (1.92 in the alternative model), a value that closely matches the range of estimates for DSGE models that find values between 1 and 2. The estimation using HP filtered observables yields a reliable value for the habit persistence parameter, h, at 0.2. In the previous estimations, we were unable to find a dependable estimate and calibrated the parameter. However, the habit persistence parameter estimate is still lower than the range of estimates found in other studies. The estimation results for the investment adjustment cost parameter, (4.34 vs. 5.09 in the baseline model and 5.07 in the alternate model) and capital utilization cost parameter, (1.13 vs. 0.83 in the baseline model and 0.82 in the alternative model) are not reported to be significantly different across the two de-trending methods.

In the case of estimated coefficients on the fiscal rules, some differences arise, but the main findings in chapter 3 remain the same. We find that government spending and transfer payments have responded the most to deviations of the public debt from its steady state level. The estimation results in TABLE A.3.3. show that the government spending debt coefficient mean value is 0.35 and the transfers' debt coefficient is 0.37. These estimates reinforce the finding that government spending and transfer payments are more important for Canada at cyclical frequencies when observables are de-trended using an HP filter. The estimates for the tax rate coefficients on debt are reported to be insignificant irrespective of how observables are de-trended. We find some minor differences in the estimated coefficients for the output gap that do not change the interpretation of our results. TABLE A.3.3. reports an estimated coefficient for the capital tax rate and labour tax rate of 0.56 and 0.46. For the expenditure instruments, the reported estimates are 0.13 for government spending and 0.19 for transfer payments. In comparing these estimates with the estimation results under linear de-trending, we find that the estimates for the labour tax rate coefficient and the transfer coefficient on the output gap are very similar (0.46 vs. 0.41 for the baseline model and 0.54 for the alternative model) across the de-trending methods. However, when the HP-filter is used, we find that capital tax rates respond less (0.56 vs. 1.93 for the baseline model and 1.73 for the alternative model) and government spending (0.19 vs. 0.005 for both the baseline and alternative model) responds more strongly to the output gap. These coefficients are still in line with findings in the literature.

In comparing the persistence of the shocks and the standard deviations, we find, as expected the persistence of shocks to have lower estimated values with HP filtered data. On the other hand, as reported in TABLE A.3.3. the standard deviations corresponding to most shocks are estimated to be higher than the estimated values when we use linear de-trending. The standard deviation of government spending and the consumption tax rate are especially high with an estimated value of 9.55 and 6.72 compared to 2.12 and 2.78 in the baseline model. Since our main contribution comes from the estimated coefficients on the debt gap that we have shown to be robust across de-trending methods, we follow the commonly adopted method of linearly de-trending the observables in our estimation.

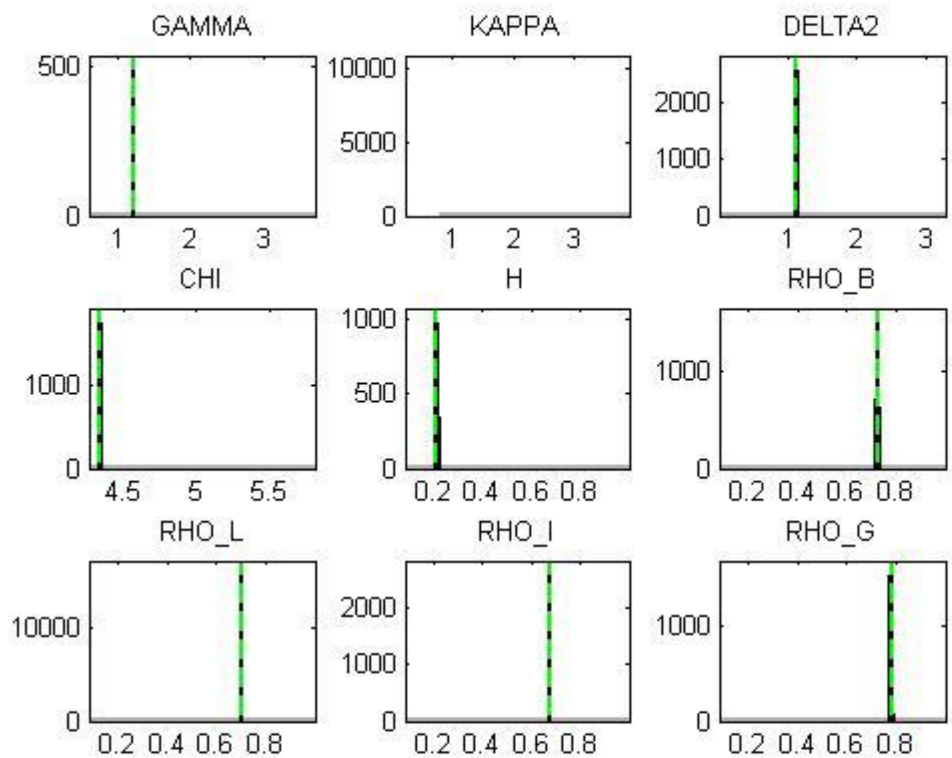

FIGURE A.3.17 Priors and posteriors for estimated model using HP filtered observables

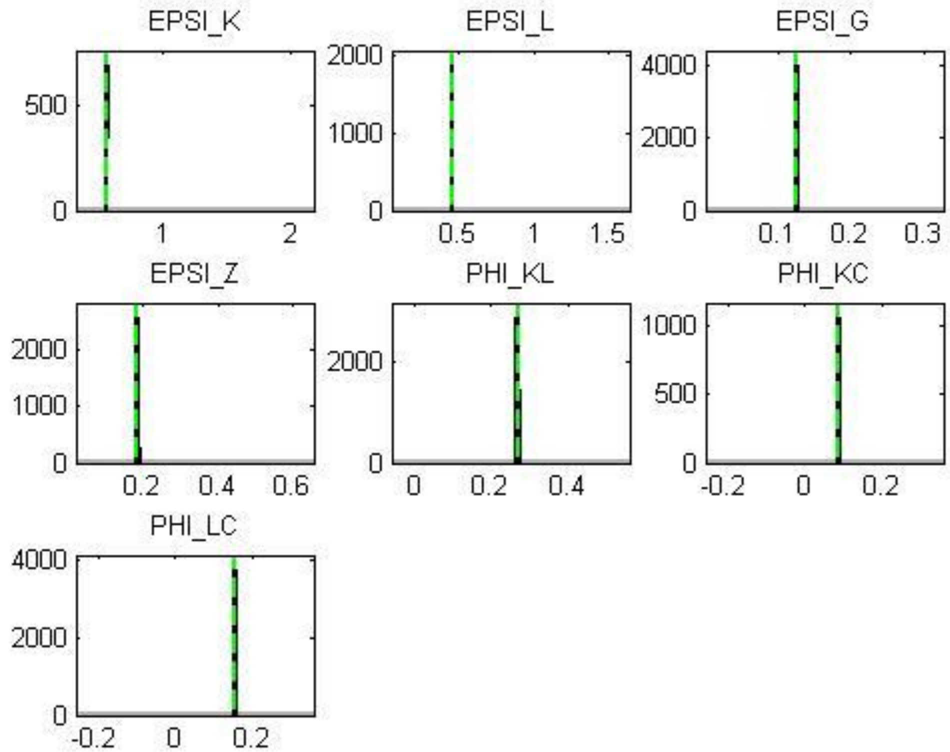

FIGURE A.3.18 Priors and posteriors for estimated model using HP filtered observables

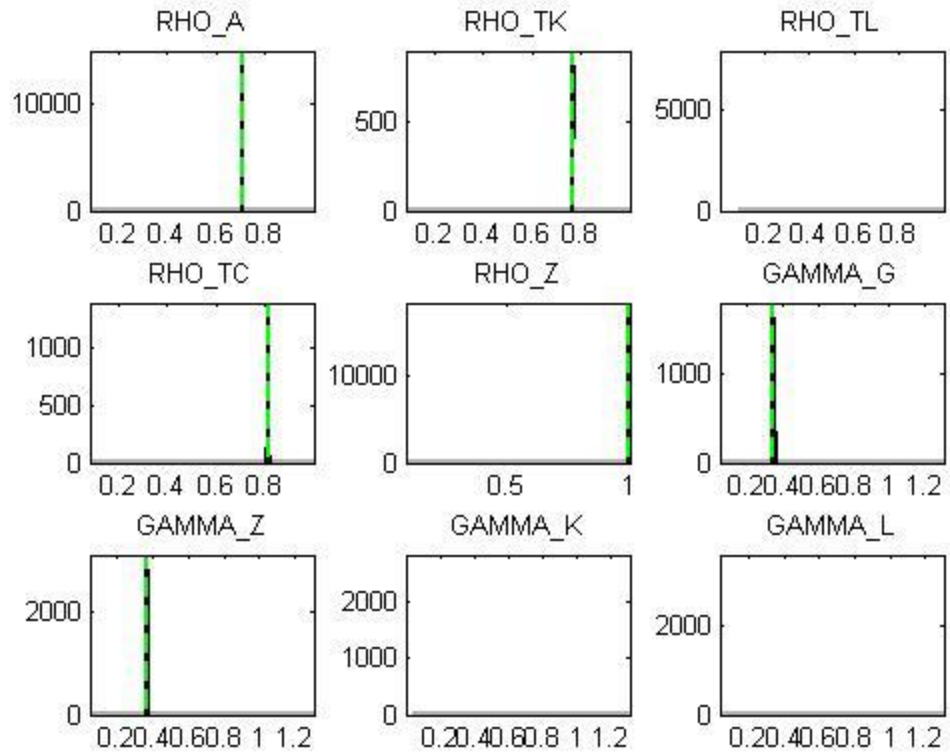

FIGURE A.3.19 Priors and posteriors for estimated model using HP filtered observables

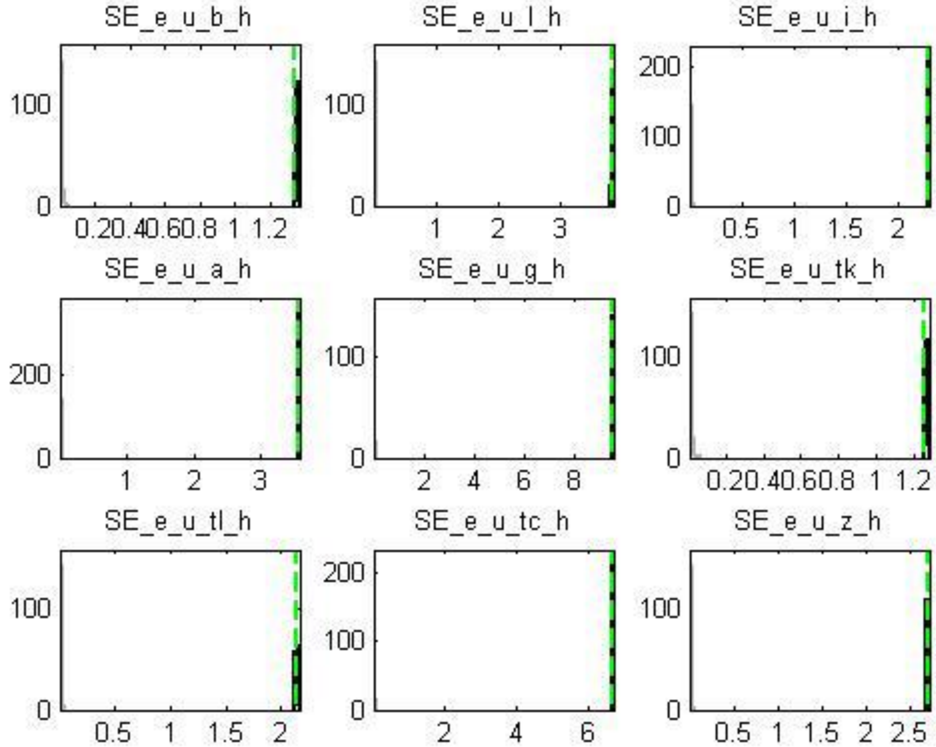

FIGURE A.3.20 Priors and posteriors for estimated model using HP filtered observables

Parameter		Prior	Posterior Distribution			
		Mean	Mode	Mean	5% C.I	95% C.I
γ	Risk Aversion	1.75	1.21	1.21	1.21	1.21
κ	Inv. Frisch	2.00	0.22	0.22	0.22	0.22
h	Habits	0.70	0.21	0.21	0.21	0.21
χ	Inv. Adj Cost	5.00	4.34	4.34	4.34	4.34
δ_2	Capital Util. Cost	0.70	1.13	1.13	1.13	1.13
γ_g	Gov. Spending B	0.40	0.35	0.35	0.35	0.35
γ_z	Transfer B coeff.	0.40	0.37	0.37	0.37	0.37
γ_{tk}	Cap. Tax B coeff.	0.40	0.00	0.00	0.00	0.00
γ_{tl}	Lab.Tax coeff.	0.40	0.03	0.03	0.03	0.03
φ_{tk}	Cap. Tax Y coeff.	1.00	0.13	0.13	0.13	0.13
φ_{tl}	Labour Tax Y	0.50	0.19	0.19	0.18	0.18
φ_g	Gov. Spending Y	0.07	0.56	0.56	0.56	0.56
φ_z	Transfer Y coeff.	0.20	0.46	0.46	0.46	0.46
ϕ_{kl}	Cap. /Labour co-	0.25	0.27	0.27	0.27	0.27
ϕ_{kc}	Cap. /Cons co-	0.05	0.09	0.09	0.09	0.09
ϕ_{lc}	Labour/Cons. co-	0.05	0.15	0.15	0.15	0.15
ρ_a	Tech AR coeff.	0.70	0.70	0.70	0.70	0.70
ρ_b	Pref. AR coeff.	0.70	0.72	0.72	0.72	0.72
ρ_l	Labour AR coeff.	0.70	0.70	0.70	0.70	0.70
ρ_i	Inv. AR coeff.	0.70	0.67	0.67	0.67	0.67
ρ_g	Gov. Spend AR	0.70	0.78	0.78	0.78	0.78
ρ_{tk}	Cap. Tax AR	0.70	0.76	0.76	0.76	0.76
ρ_{tl}	Labour tax AR	0.70	0.00	0.00	0.00	0.00
ρ_{tc}	Cons. Tax AR	0.70	0.78	0.81	0.81	0.81
ρ_z	Transfer AR coeff.	0.70	1.00	1.00	1.00	1.00
σ_a	Tech. std.	0.01	3.56	3.56	3.56	3.56
σ_b	Pref. std.	0.01	1.34	1.35	1.34	1.35
σ_l	Labour std.	0.01	3.83	3.82	3.81	3.83
σ_i	Inv. std.	0.01	2.28	2.28	2.27	2.28
σ_g	Gov. Spend std.	0.01	9.56	9.55	9.54	9.55
σ_{tk}	Cap. Tax std.	0.01	1.26	1.27	1.26	1.27
σ_{tl}	Labour Tax std.	0.01	2.13	2.13	2.12	2.15
σ_{tc}	Cons. Tax std.	0.01	6.72	6.72	6.71	6.72
σ_z	Transfer std.	0.01	2.68	2.68	2.67	2.69

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