WAR AND PEACE: INVESTIGATIONS INTO THE MACROECONOMIC EFFECTS OF FISCAL POLICY

Adina Popescu

A Dissertation Submitted to the University of London

for the Degree of Doctor of Philosophy in Economics

Department of Economics

London Business School

University of London

September 2008

Contents

1 Introduction **1**

1.1 Foreword 1

1.2 Literature Review 5

1.3 Empirical Evidence on the Effects of Government Spending Shocks 6

1.3.1 Stylized Facts 6

1.3.2 Controversies 7

1.4 Methodological Approaches to the Identification of Government Spending Shocks 10

1.4.1 The Ramsey-Shapiro (Dummy Variables) Approach 10

1.4.2 The VAR Approach 14

1.4.2.1 The Recursive Identification 14

1.4.2.2 The Structural VAR Identification 15

1.4.2.3 The Sign Restrictions Identification 16

1.5 Theoretical Models of the Effects of Government Spending Shocks 17

1.5.1 The Neoclassical Literature 17

1.5.2 The New-Keynesian Literature 19

1.6 A Preliminary Look at the Data 21

1.6.1 Components of Government Expenditures 21

1.6.2 Heterogeneity in the Measures of Government Spending Shocks used in the Literature 22
1.6.3 Historical Trends in US Defense and Civilian Government Consumption Spending 24

2 Is Government Spending Expansionary or Contractionary for Private Consumption? Results from a Sign Restriction Identification Procedure 37

2.1 Introduction 37
2.2 The Identification Framework Using Sign Restrictions 40
2.2.1 Model and Empirical Based Identification 42
2.3 Relaxed Sign Restrictions 44
2.3.1 "Pure" Government Spending Shocks Identification 45
2.3.2 Deficit-Financed Government Spending Shocks Identification 47
2.4 Results 49
2.4.1 Effects of "Pure" Government Spending Shocks 50
2.4.2 Effects of Deficit-Financed Government Spending Shocks 52
2.4.3 The Effect of Disaggregation 52
2.4.4 Robustness 53
2.4.4.1 Robustness to Different Measures of Hours and Wages . . . 54
2.4.4.2 Changes in the Effects of Government Spending Shocks over Time 55
2.4.4.3 The Effect of Anticipated Fiscal Shocks 57
2.4.5 Comparison with Some of the Recent Literature 59
2.5 Conclusion 60
2.6 APPENDICES 62
2.6.1 Appendix A. Definitions and Sources of the Variables in the VAR . . 62
2.6.2 Appendix B. The Sign Restrictions Methodology 63

2.6.2.1 General VAR Estimation 63
2.6.2.2 Implementation of the Sign Restrictions Methodology 65
2.6.2.3 Comparison with Related Sign Restrictions Papers 69
2.6.2.4 Advantages and Limitations of the Methodology 70

3 The Response of Private Consumption to Government Spending Shocks - An Explanation from the Optimal Neoclassical Perspective 80

3.1 Introduction 80
3.2 The Model Economy 84
3.2.1 Disaggregating Government Spending 84
3.2.2 The Agent's Problem 85
3.2.3 The Optimal Ramsey Problem 88
3.2.4 Functional Forms and Calibration 89
3.3 Simulation Results 93
3.3.1 The Optimal Policy - Simulated Impulse Responses 94
3.3.2 Sensitivity Analysis: Fiscal Policy Multipliers 96
3.4 Assessment of the Model and Comparison with the Previous Literature . . . 99
3.5 Conclusion 101
3.5.1 Appendix A. Characterization of the Solution 102
3.5.1.1 Appendix A1. The Recursive Formulation 102
3.5.1.2 Appendix A2. Equilibrium Conditions 104
3.5.2 Appendix B. Numerical Procedure 107

4 An "Agnostic" Approach for Validating Competing Models 113

4.1 Introduction 113
4.2 A Tale of Two Models 117
4.2.1 An RBC Model with Utility-Yielding Government Spending 117
4.2.2 A DNKY Model with Rule-of-Thumb Consumers 119

4.3 Methodology 122
4.3.1 Finding Robust Sign Restrictions for Each Model 123
4.3.2 Recovering the True Model on the Basis of the Imposed Restrictions . 124
4.3.3 Functional Forms and Calibration 126
4.4 Results 128
4.4.1 Robust Signs for the Considered Models 128
4.4.2 Testing the Two Models against each Other 130
4.4.3 Comparison with the Literature 134
4.5 Conclusions 135

List of Tables

1.1 Unit Root Tests: Defense and Civilian Government Consumption 32
1.2 Defense Spending in OECD countries (2002) 33
1.3 Comparison of Volatilities of Key Macro Variables 34

2.1 Effects of Government Spending Shocks 43
2.2 Effects of Productivity Shocks 44
2.3 Effects of Labor Supply Shocks 45
2.4 Sign Restrictions Identification Scheme 1 47
2.5 Sign Restrictions Identification Scheme 2 49
2.6 Sign Restrictions Identification Scheme 3 54
2.7 Estimated Fiscal Multipliers - Consumption 77
2.8 Estimated Fiscal Multipliers - Output 77
2.9 Impact Multipliers to Anticipated Civilian Shocks 79
2.10 Impact Multipliers to Anticipated Military Shocks 79

3.1 Structural Parameters 91
3.2 Steady State 93

4.1 Structural Parameter Values and Ranges 137
4.2 Robust Signs of the Impulse Responses for the Considered Models 138

4.3 Probability of Correctly Signed Impact Wage Responses to Government Spending for Various Identified Shocks and Horizons 142
4.4 Probability of Correctly Signed Impact Wage Responses to Government Spending when both Private Consumption and the Real Wage are Left Unsigned . 142
4.5 Probability of Correctly Signed Impact Wage Responses to Government Spending when Changing the Variance of the Identified Shocks 143

List of Figures

1.1 US Post-WWII Military Government Consumption Spending as Percent of GDP and of Total Government Consumption 28

1.2 US Post-WWII Civilian Government Consumption Spending as Percent of GDP and of Total Government Consumption 29

1.3 US post Great Depression (1929) Defense and Civilian Government Consumption Spending as a Share of GDP 30

1.4 US post Great Depression (1929) Defense and Civilian Government Consumption Spending in Real per Capita Terms (Logs, 2000 Prices) 31

1.5 US post Great Depression (1929) Defense and Civilian Government Consumption Spending Y-o-y per Capita Growth Rates (scale 1=100 percent) 35

1.6 US post-WWII Defense and Civilian Government Consumption Spending Q-o-q per Capita Growth Rates (scale 1=100 percent) 36

2.1 Impulse Responses to Identification Scheme 1 (Part I) 71

2.2 Impulse Responses to Identification Scheme 1 (Part II) 72

2.3 Impulse Responses to Identification Scheme 2 73

2.4 Impulse Responses to Identification Scheme 3 74

2.5 Robustness to Sectoral Differences - Military Shock 75

2.6 Robustness to Sectoral Differences - Civilian Shock 76

2.7 Comparison of Impulse Responses to a Government Spending Shock from a VAR versus a War-Dummies Identification, from Perotti (2007) 78

3.1 Impulse Responses to a Shock to Exogenous Government Consumption . . . 109

3.2 Impulse Responses to a Shock to the Preference for Endogenous Government Consumption 110

3.3 Impact Multipliers to a Government Spending Preference Shock 111

3.4 Impact Multipliers to an Exogenous Government Spending Shock 112

4.1 Responses to the technology, labor supply and government spending shocks in the modified RBC model 139

4.2 True and Estimated Impulse Responses in the Modified DNKY Model 141

I hereby declare that I am the sole author of this thesis.

I authorize the University of London to lend this thesis to other institutions or individuals for the purpose of scholarly research.

I further authorize the University of London to reproduce this thesis by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research.

In spite of extensive research on the effects of fiscal policy on the macroeconomy, the response of private consumption to government spending shocks remains controversial both from an empirical and theoretical perspective.

In this dissertation we argue that our understanding of this relationship can be enhanced by considering the disaggregation of government spending into an exogenous component, assimilated to military expenditures, and a utility-yielding part, which is comprised of civilian government expenditures such as education, health-care, etc. We explore empirically whether these two types of spending have different effects on private sector variables. We then move on to offer a theoretical justification for the observed dichotomy in a simple neoclassical optimal fiscal policy model. Finaly, we discuss a methodology for checking the robustness of our results versus alternative explanations, thus offering a strategy for validating the link between the model and the empirical results.

In the first paper we reconsider the evidence on the effects of government spending shocks on private consumption by distinguishing between military and nonmilitary shocks which are identified using sign restrictions motivated by both the theoretical and empirical literature. The main findings are that civilian government spending has positive multipliers on private consumption, while the defense government spending has negative multipliers.

In the second paper we study whether a suitably altered dynamic general equilibrium model in which the agent's preferences include the government provided goods can explain the response of private consumption to government spending shocks, without resorting to assumptions about sticky prices or wages. We show that in this model the utility-yielding component of government expenditure crowds in private consumption while the exogenous part crowds it out, generating values for the fiscal multipliers which are consistent with the US post-war evidence.

In the final paper, we show that it is possible to distinguish between two different explanations for the response of private consumption to government spending shocks (the in-the-utility public good model of proposed in this dissertation and the DNKY model with rule-of-thumb consumers in Galí et al. (2005)) using the type of sign restrictions identification procedure put forward in the first paper.

This dissertation would not have been possible without the help and encouragements of many people.

On the academic front, I owe my greatest intellectual debt to my supervisor Andrew Scott, whose guidance and support has been invaluable all along. I would also like to thank a number of people who have helped me hone my skills as an economist and who represent outstanding mentors: Fabio Canova, Wouter Denhaan, Albert Marcet and Tom Sargent.

A number of colleagues from London Business School and the European Central Bank have provided valuable comments and suggestions at various stages of this project: Alexis Anagnostopoulos, Alina Barnett, Giacomo Carboni, Luca Dedola, Georg Kaltenbrunner, Flaviu Mihaescu and Roland Straub.

I am particularly indebted to Alina for her friendship and encouragements at an important stage of this project, as well as for sharing a lot of her expertise with me. I owe an innumerable number of coffees to H. and want to thank him for moral support whenever needed.

Last but not least, I owe immense gratitude to my parents for their love and steadfast belief in me.

Chapter 1

Introduction

1.1 Foreword

The effects of fiscal policy on the macroeconomy and the design of optimal fiscal policy have been at the core of modern macroeconomics ever since the seminal work of Keynes. However, in spite of an extensive literature and considerable progress in our understanding of this type of government intervention in the economy, a number of important controversies remain. Strong debate continues over the effects and transmission channels of government spending shocks, in particular pertaining to key variables as private consumption and labor market variables like the real wage.

In a survey article, Perotti (2001) takes a critical view of the state of the literature where *"despite some methodological advances, there is absolutely no consensus on even the basic effects of fiscal policy on the macroeconomy."* While this assessment is quite strong, six years on, the same author deplores the apparent inability of the fiscal policy research to reach a consensus on some important stylized facts, in comparison, for example, with the successes in the monetary economics: *"most economists would agree that a hike in the federal funds rate will cause some slowdown in growth and inflation, and that the bulk of the empirical evidence is consistent with this statement. But perfectly reasonable economists can and do* *disagree even on the basic effects of a shock to government spending on goods and services ..."* (Perotti (2007)).

Partly as a result of the ongoing lack of consensus in the fiscal policy literature, the current benchmark DSGE models for macroeconomic research and policy analysis[1], which incorporate a large number of realistic features, are however quite simplistic on the fiscal side, which is generally considered exogenous. A consequence of this approach is that while such models are sufficiently rich to capture the dynamics of the data with respect to the effects of a range of supply and demand side shocks, they are however less successful in explaining some of the effects of government spending shocks.

In particular, when evaluating the performance of such DSGE models with Bayesian VARs, one of the main weaknesses is the inability of the models to match the positive response of private consumption to government spending shocks, which has generally been documented in the data. For example, Smets and Wouters (2003) comment: "*One feature of the impulse responses to various "demand" shocks which may be less in line with existing evidence is the strong crowding out effect. This is particularly the case for the government consumption shock. While the strong crowding out effect of a government consumption shock is not in line with evidence for the US over the post-Bretton Woods sample period (see, for example, Fatas and Mihov, 2001), recent international evidence by Perotti (2002) shows that such effects are not uncommon in the more recent period and in other countries* ".

In this dissertation we argue that the performance of the standard benchmark DSGE models on the fiscal dimension can be improved by introducing a more realistic role for fiscal expenditures. It is quite apparent from the existing literature that one type of government expenditures which is considered wasteful by the agents is insufficient to describe the complexities in the data. We suggest a simple disaggregation of government spending in two components.

The first part can be thought of as being more exogenous (from a macroeconomic per-

[1] See, e.g. Smets and Wouters (2003) for the Euro area and Christiano et al. (2005) for the US.

spective) and we assimilated it in the data to military expenditures. The second part can be realistically assumed to be utility-yielding and chosen by the planner according to some economic optimality criterion (here we include civilian government spending). This simple modification of otherwise standard models is able to lead to responses of private consumption which are more complex and better match the data. At the same time, this explanation is in line with the behavior of other macroeconomic variables of interest and sheds light on the transmission channel of fiscal policy through the labor market.

In the first chapter of this dissertation, we provide a review of both the theoretical and the empirical literature and explore whether the heterogenous nature of government spending can be distinguished in the data.

In the second chapter, we reconsider the evidence on the effects of government spending shocks on private consumption by distinguishing between military and nonmilitary shocks which are identified using a new strategy. We employ sign restrictions motivated by both the theoretical and empirical literature, which are robust to model and parameter uncertainty and additionally are consistent with results from other empirical methodologies.

The main findings are that civilian government spending has positive multipliers on private consumption, while the defense government spending generates negative multipliers. These results are robust irrespective of whether the government spending shocks are deficit financed or tax-financed. Moreover, allowing for anticipation effects, we find that the responses of private consumption to both types of shocks are quantitatively stronger.

In the third chapter we study whether a suitably altered dynamic general equilibrium model can explain the effects of government spending shocks without resorting to assumptions about sticky prices or wages. We propose a Ramsey neoclassical model augmented to account for different roles for two types of government spending. Therefore, the model is standard except in one key aspect: the standard utility function in private goods and leisure is enhanced to comprise the government provided good. The model is solved under the Ramsey assumptions of a planner able to perfectly commit to the set of policies at her discretion.

The main findings are that in this model the utility yielding component of government expenditure crowds in private consumption while the exogenous parts crowds it out. A number of additional frictions, such as time varying external habits in both private and government consumption, investment adjustments costs and productive government investment, insure that the model generates realistic values for the fiscal multipliers and is consistent with US post-war data along a number of other dimensions. Such an empirical validation is used to show that the introduction of differentiated government spending improves the predictive performance of the benchmark RBC model and thus yields it more useful for macroeconomic policy analysis.

The final chapter discusses an "agnostic" methodology for testing two alternative explanations for the crowding in of private consumption: on the one hand a simplified version of the model discussed in the previous chapter and on the other hand a competing explanation in the New Keynesian vein (the model with rule-of-thumb consumers of Galí et al. (2005)). The procedure is used to test whether the relatively weak identification procedures through sign restrictions proposed in the second chapter allows to differentiate between the two models on the basis of the transmission channel through the labor markets.

This chapter thus brings together the empirical and theoretical parts in the dissertation proposing a simulation exercise aimed at assessing the robustness of our main explanation, when comparing it with an influential alternative theory. We find that the empirical procedure through sign restrictions is generally quite powerful in correctly recognizing the qualitative features of the true DGP. Together with the empirical findings in Chapter 2, we interpret these results as pointing to the data being more supportive of a neoclassical channel, rather than of a nominal rigidities channel, in order to explain the response of private consumption to government spending shocks.

1.2 Literature Review

In spite of significant progress made in the understanding of fiscal policy, important questions, such as the effects of government spending shocks on key macroeconomic variables, still elicit considerable debate both in the theoretical and empirical literature.

Most of the early interest in the literature has focused on the consequences or the optimal way for the government to finance an exogenous stream of military spending, identified through changes in military purchases, which are recovered from historical data on the military engagement episodes during the Cold War period. The empirical findings of this literature seemed to broadly support the neoclassical paradigm by documenting a strong crowding out effects of government spending on private consumption, coupled with a decline in the real wage.

However, over time the composition of government spending has shifted and the relative importance of military spending in the total government budget has receded. Accordingly, a more recent literature has focused instead on the effects of total government spending, challenging some of the results and explanations in the neoclassical literature. The findings of this strand of research appear to offer more support to New-Keynesian type effects, with positive multipliers of government spending shocks not only on output but also on private consumption, coupled with an increase in real wages, which neoclassical models in general have a hard time to match.

More recently, a number of authors have considered the disaggregation of government purchases according to different categories, implicitly recognizing that the heterogenous nature of these expenditures may lead them to play widely distinct economic roles. Attempts have been made using disaggregated government spending to solve the existent puzzles regarding the responses of various macro variables, in particular government consumption, wages, hours and investment.

In the following section we proceed to discuss in detail the main results in the literature for key macroeconomic variables, by focusing first on the points of consensus and then highlighting the remaining areas of contention.

1.3 Empirical Evidence on the Effects of Government Spending Shocks

Reviewing the results of such a large and diverse literature needs is not an easy undertaking, given the heterogeneity of the papers in terms of empirical methodology, data set and the particular measures of government spending shock(s) employed. Therefore, the purpose of this section is to offer a brief overview of several empirical facts on which a broad consensus has emerged in the literature, at least qualitatively (so-called stylized facts). We then move on to present the effects of government spending shocks on macroeconomic variables which are still the subject of considerable debate, both from a qualitative and a quantitative perspective. This discussion will mostly focus on the US, although a number of results for the Euro area are quoted as well for comparison.

1.3.1 Stylized Facts

An overall assessment of the estimations over various postwar samples of US data, reveals that an expansionary shock to various measures of government purchases has lead to:

Fact 1: **a significant and persistent increase in output** (see, e.g. Ramey and Shapiro (1997), Edelberg et al. (1998), Fatas and Mihov (2001), Burnside et al. (2004), Blanchard and Perotti (2001), Mountford and Uhlig (2002), Peersman and Straub (2004), Perotti (2004), Galí et al. (2005), Cavallo (2005), Peersman and Straub (2006), etc.). However, some authors have noted that the way government spending is financed may play a role. In this direction Mountford and Uhlig (2002) find only a small increase in output to a deficit spending shock and even a small decline in the scenario of a balanced budget financed expansion. Looking at a sectorial disaggregation of output, Cavallo (2005) finds that such shocks generate a rise in total output significant only at peak, a non-significant rise private output, but a significant rise in government output.

***Fact 2*: an increase in employment and hours** (see, e.g. Ramey and Shapiro (1997), Edelberg et al. (1998), Fatas and Mihov (2001), Burnside et al. (2004), Galí et al. (2005), Cavallo (2005), etc.). While the sign of the response is generally undisputed, some authors do not find the result to be very strong. Considering a sectorial perspective, Cavallo (2005) documents that only government hours rise significantly, while total hours and private hours rise insignificantly. In a country comparison, Peersman and Straub (2006), Peersman and Straub (2004) find an insignificant response of hours in both the US and the Euro area.

***Fact 3:* an increase in short-term real and nominal interest rates** (see, e.g. Fatas and Mihov (2001), Canzoneri et al. (2002), Mountford and Uhlig (2002), Perotti (2004), Peersman and Straub (2004), Peersman and Straub (2006), etc.). Additionally, Canzoneri et al. (2002) and Perotti (2004) also find a positive effect on the long term (i.e. 10-year) real interest rates. Considering again a number of more complex fiscal policy mixes (both on the expenditures and revenue side), Mountford and Uhlig (2002) find that the increase in interest rate is not always very significant.

1.3.2 Controversies

As mentioned before, the literature remains divided on a number of issues, which seem to be sensitive to a number of factors in the specification and methodology.

***Issue 1*: Private consumption.** The whole range of possible results has been documented with respect to private consumption:

- it falls, according to: Ramey and Shapiro (1997), Edelberg et al. (1998), Burnside et al. (2004), Peersman and Straub (2004), Cavallo (2005), Peersman and Straub (2006), etc. A number of differences and nuances can be mentioned here. Ramey and Shapiro (1997) find a small fall in the consumption of nondurables and services and a very high increase in the consumption of durables on impact followed by a large and significant fall (which they explain through panic buying at the onset of a war). Edelberg et al. (1998) find a small fall in the consumption of nondurables and services and a rise in the consumption of durables on impact. Cavallo (2005) finds a small fall in total private consumption which is significant for less than one year. Peersman and Straub (2006) find the decline in consumption to be highly significant in the US while less so in the Euro area.

- it increases, according to: Blanchard and Perotti (2001), Perotti (2004), Galí et al. (2005), Bouakez and Rebei (2003), Fatas and Mihov (2001), etc. All these papers document a large and persistent increase in consumption in response to government spending shocks, generally identified as purchases of goods and services, i.e. consumption plus investment.

- the response is not significant, according to: Mountford and Uhlig (2002), Burnside et al. (2004), etc. In particular Mountford and Uhlig (2002) find a small increase in the case of a deficit spending shock and a small decline in the scenario of a balanced budget financed expansion, but in both cases the effects are borderline. Burnside et al. (2004) on the other hand find a small but insignificant increase several quarters after a Ramey-Shapiro episode.

Issue 2. **Real wages.** Regarding real wages, the entire spectrum of responses has been documented as well, ranging from:

- a fall, according to: Ramey and Shapiro (1997), Edelberg et al. (1998), Burnside et al. (2004), Cavallo (2005), etc.;

- an increase, according to: Galí et al. (2005), Perotti (2007), etc.;

- an insignificant response, according to Fatas and Mihov (2001), Peersman and Straub (2004), Peersman and Straub (2006), etc.

One may however note that at least part of the discrepancy in results may be attributable to the sectorial measures of wages used, as well as to the deflation method.

Issue 3. **Private investment.** The response of private investment is also very heterogenous and efforts have been made to differentiate between the effects on different types of investment. In particular, the main findings are:

- total investment falls, according to: Blanchard and Perotti (2001), Mountford and Uhlig (2002), Perotti (2004), Galí et al. (2005), Peersman and Straub (2006), etc. In terms of international comparisons, Peersman and Straub (2006) find the decline is significant on impact in the US while it has a 4 quarter lag in the Euro area;

- non-residential investment rises, while residential investment falls, according to: Ramey and Shapiro (1997), Edelberg et al. (1998), etc.;

- overall investment increases, while residential investment increases and non-residential investment falls, according to Fatas and Mihov (2001);

- the response is not very significant or not very persistent, in that aggregate investment rises little or for a short time, according to: Burnside et al. (2004), Cavallo (2005), etc. For example Cavallo (2005) finds a persistent rise, but it is significant only for about 1 year.

Issue 4: Prices. The response of prices, measured either as consumer prices, producer prices or the GDP deflator seems to be also quite controversial, in that the evidence would point to:

- an increase, according to: Edelberg et al. (1998), Peersman and Straub (2004), Peersman and Straub (2006), etc. Edelberg et al. (1998) find that shocks to government purchases, identified as the Ramey-Shapiro episodes, lead to a significant and humped increase in both the CPI and GDP deflator. Peersman and Straub (2006) find a similar positive and persistent response of prices in both the US and the Euro area.

- a decrease, according to: Fatas and Mihov (2001), Mountford and Uhlig (2002), Canova and Pappa (2003), etc. Mountford and Uhlig (2002) find, by looking at both the GDP deflator and the PPI, significant and persistent price falls (for over 25 quarters) after their identified government spending shocks.

We identify two potential dimensions which may be responsible for a large part of the heterogeneity in the second series of results: the methodology employed for the identification of the government spending shocks and differences in the data set (in terms of the way of defining and measuring government spending shocks, the set of variables included in the estimation and the specific time sample used). In the following sections we consider how these differences relate to the results in more detail.

1.4 Methodological Approaches to the Identification of Government Spending Shocks

An important potential source of heterogeneity in the results discussed before stems from the methodology employed for the identification of the shocks. This is a highly controversial aspect, given the nature of the way fiscal policy is implemented, which gives rise to significant timing and endogeneity issues. Overall, one can distinguish between two main strands in the literature.

1.4.1 The Ramsey-Shapiro (Dummy Variables) Approach

In a seminal contribution, Ramey and Shapiro (1997) propose a "historicist" approach, which focuses on explaining the effects of large shocks to military expenditures associated with wars or other episodes of military buildups in post-war US history. The Ramey-Shapiro episodes are modelled as a war dummy variable, which takes a value of unity in 1950:Q3, 1965:Q1 and 1980:Q1 (the original dates), to which Eichenbaum and Fisher (2005) and Ramey (2007) have added 2001:Q3. These correspond, respectively, to the onset of the Korean War, the Vietnam War, the Carter-Reagan military build-up and the September 11, 2001 terrorist attacks. The strategy has been employed also in a VAR setup (see, e.g. Edelberg et al. (1998), Burnside et al. (2004), Cavallo (2005)), as:

$$X_t = A(L)X_{t-1} + B(L)D_t + U_t$$

where X_t, D_t, U_t represent, respectively, the vectors of: endogenous variables, dummy variables and reduced form residuals, while A(L), B(L) are lag polynomials of various orders.

The main findings of the war dummies literature are fully consistent with relevant stylized facts of the prototypical RBC model, in particular a crowding out of private consumption, an increase in work effort and a negative response of the real wage.

The advantages of this methodology inspired by event studies are at least two-fold: first, these episodes are clearly exogenous and second, they are also unanticipated, as the moment of shock, which may precede the effective start of military operations, is isolated through an attentive reading of historical accounts. For example, Ramey and Shapiro (1997) corroborate information from the financial press (*Business Week*) and professional forecasters to determine the moment when the public have formed expectations regarding an increase in future military spending. The careful consideration which this method places on the timing is important, because military build-ups are usually anticipated by up to several quarters before they actually take place.

However, the dummy variable approach has also been criticized on several counts. First, the selection of the events, the choice of the moment of impact as well as assumptions made on the size and duration of the shocks may have important consequences on the results. For example, it is not clear whether the selection of the Ramey-Shapiro dates is based on the "character" or the size of the events. Regarding the first criterion, only two of the episodes are "classic" wars, the Carter-Reagan "Star Wars" initiative is a "cold war" gradual defensive build-up, while the September 11 terrorist attacks also represent a different type of shock (the so-called "war on terror"), which only subsequently became a "classic" military engagement (in Afghanistan and then Iraq).

It is also apparent that the war dummied literature seems concerned with "exceptionally" large episodes. However, some divergence exists also on this point. Some authors have even argued that since the Korean war by far dominates in size the other post war period episodes, it should be excluded for potentially distorting the results (while the post September 11 increase in spending is by comparison almost negligible). Other authors have on the contrary suggested that large conflagrations such as WWII should be included as particularly informative episodes and have tried to analyze longer-term data, starting from the end of the 19th century (see e.g. Ramey (2007), however, using such long term series faces additional problems regarding data availability and quality).

In order to address the issue that the war dummy variable attributes the same effect to each military shock, Burnside et al. (2004) and Eichenbaum and Fisher (2005) advocate the scaling of the variable to allow for different sizes of the build-ups (e.g. Eichenbaum and Fisher (2005) assign a value of 1 to Korea, 0.3 to Vietnam, and 0.1 to Carter-Reagan, while Ramey (2007) uses 0.1 for September 11). This version estimates an equation of the type

$$X_t = A(L)X_{t-1} + \sum_{i=1}^{4} B(L)\theta_i D_{i,t} + U_t$$

where θ_i are the scalars which measure the intensity of each episode.

Additionally, as Perotti (2007) points out, the Ramey-Shapiro identification is based on assuming that the dummy variables should not be correlated with the residuals of each equation up to a number of lags (which gives the length of the episodes), however, this does not preclude that the dummy captures at least partly the effect of some other shocks, fiscal or otherwise (e.g. the Korean war dummy may capture some of the delayed effect of the 1948 tax cut).

This discussion begs the question of how should we think about defense spending shocks: are they particularly large episodes (and according to which benchmark) or are they defined by the nature of the expenditures themselves ? If one takes the second view, namely that it is the nature and not the level which defines military spending shocks, it is possible that the

Ramey-Shapiro episodes may miss smaller shocks and they also exclude negative shocks.

Examples of smaller episodes not considered in the original Ramey-Shapiro episodes are: the Berlin blockade (1948–49), the Berlin Crisis of 1961, Cuban Missile Crisis of 1962, the Sputnik crisis of 1957 or the First Gulf War of 1990-1991 (see also Figures 1.1 and 1.6). To comment on one particular episode which the Ramey-Shapiro dummies miss, the "Sputnik crisis" is a relatively less known yet consequential episode both from both a military point of view and from a budgetary perspective. It was sparked by the unexpected launch by the Soviet Union of the first artificial satellite (October 4, 1957) and spurred a whole chain of U.S. defense initiatives, aimed at winning the "space race". In particular, it dramatically increased support for military scientific research and led to the creation of the National Aeronautics and Space Administration (NASA). As a result of the crisis, military expenditures increased by 7.2 percent between 1958-1959, which is comparable with the increase of 7.1 percent between 1984-1985 (part of the Carter-Reagan military build-up, included in the original Ramey-Shapiro episodes).

An additional issue of concern is that the Ramey-Shapiro episodes identify solely increases in military spending. However, one can argue that a series of negative (albeit smaller) shocks have characterized the end of Cold War and post-Cold War of presidencies of George Bush and Bill Clinton. In particular, funding for national defense declined by about 16.9 percent between the last Reagan Administration defense budget and the last Bush Administration budget. By comparison, under the Clinton Administration, funding for defense declined by 13.1 percent.

A closely related question refers to whether one should think of military shocks as a one time shock, or as a sequence of smaller shocks ? While identifying one-off shocks is relatively easy, it is not clear that this is the best way of capturing the effects of defense spending on the economy. After all, the length of the military engagement (or build-up) and in particular the cost is difficult to estimate from the beginning. Thus, even after the initial shock of starting a military engagement, agents may still be surprised by further increases in military spending (a recent example in this sense is the case of the Iraq war, whose length and costs were not predicted even by military experts).

Overall, it appears that the war dummies approach, while offering advantages from the perspective of carefully identifying the timing of the shocks, does not fully exploit the quantitative information embedded in the entire path of military spending.

1.4.2 The VAR Approach

Unlike the war dummies literature, the VAR literature uses entire the time series of government spending. In general, the findings of this strand of research are more in line with Keynesian effects of government spending shocks, in particular, an increase in private consumption and real wages. It should also be noted that another key difference to the war dummies approach appears to be that most of the VAR literature identifies shocks to *total* government spending rather than shocks to defense spending alone (we discuss this difference in detail in a subsequent section).

The VAR identification of fiscal shocks faces several challenges. One key issue is distinguishing the automatic response of certain components of government spending to the state of the economy from the pure (discretionary) policy shock. A second important aspect are timing assumptions used, since due to policy and implementation lags, government spending shocks are often anticipated well in advance.

Overall, one can distinguish three main VAR identification strategies which have been used in the fiscal policy literature.

1.4.2.1 The Recursive Identification

Borrowing from the literature on monetary policy, a number of papers have used the recursive (Cholesky) approach to identify expenditure shocks, based on assumptions regarding the sequencing of fiscal shocks and their macroeconomic effects (e.g. Fatas and Mihov (2001), Favero (2002), Bouakez and Rebei (2003), Galí et al. (2005), etc.). This strategy implies a causal ordering of variables with zero restrictions on the impulse response of variables ordered before the variable that is hit by the shock.

Crucial for these papers, the ordering of the variables reflects specific assumptions made on the timing, policy lags and the interpretation of the meaning of a fiscal policy shock. The most frequent assumption is to take the government spending variable as predetermined with respect to the other macroeconomic shocks and order it first in the VAR.

An important criticism which can be levied at this strategy is that the impulse responses may be biased due to the effects of anticipated fiscal shocks. In particular, in a recent contribution, Ramey (2007) finds that VAR government spending shocks (she focuses on defense) are forecastable with information that was available up to 4 quarters in advance, therefore she argues that the recursive VARs miss the impact of the shock. In particular, she claims that this timing issue has important consequences for the responses of private consumption, real wages and hours.

In an approach which addresses this question, Fatas and Mihov (2001) try to account for the effects of anticipated fiscal shocks in a recursive VAR with government spending ordered first, by including on the right-hand side private and official projections of revenue and expenditure variables. Even with this adjustment, their results are still very much supportive of New Keynesian transmission channels.

1.4.2.2 The Structural VAR Identification

A number of papers employ structural VARs (see, e.g. Blanchard and Perotti (2001), Perotti (2004), Perotti (2007), etc.), which rely on institutional information in order to quantify the importance of automatic stabilizers and thus differentiate them from the pure fiscal policy shock. Blanchard and Perotti (2001) argue that there are no institutional reasons to believe that any of the spending components reacts automatically to the changes in the state of the macroeconomy. They use a combination of a structural VAR with an event-study approach, in which they trace the episodes of obviously discretionary changes in both government expenditures and taxation. On the other hand, Perotti (2004) and Perotti (2007) use a two-step procedure in which, in the first step, they filter out the cyclically adjusted taxes and government expenditures using institutional information and in the second stage analyze the effects of the "pure" fiscal policy shocks.

Compared with the recursive identification approach, which imposes a large number of zero contemporaneous restrictions, the structural VAR allows for more complex interactions between government spending, taxes and the business cycle. However, even this approach is not devoid of assumptions which may have important consequences. For example, in the Blanchard and Perotti (2001) approach, potential issue are fixing the size of the automatic stabilizers, when they may be time-varying or some timing assumptions, such as that government spending decisions are being taken before revenue decisions.

1.4.2.3 The Sign Restrictions Identification

A more recent group of papers employ VARs identified using sign restrictions of the impulse response functions (see e.g. Canova and de Niccolo (2002), Mountford and Uhlig (2002), Peersman and Straub (2004), Pappa (2004), Peersman and Straub (2006), etc.). This approach does not impose zero restrictions on the contemporaneous impact of certain shocks, rather, it restricts the sign of the impulse responses for a number of quarters after the onset of the disturbance. Additionally, the sign methodology allows for the identification of more complex and realistic fiscal policy shocks, combining elements on the spending and on the revenue side. For example Mountford and Uhlig (2002) report three policy experiments: a deficit financed spending shock, a balanced budget finance expansion and a deficit-financed tax cut, finding slightly different results from the previous literature, which identifies "pure" government spending shocks.

While the sign approach presents the attractive aspect of imposing less arbitrary constraints on the contemporaneous relation between reduced form and structural disturbances, the results (in particular their significance) do seem however to be sensitive to the specification in a number of ways. While some authors use a "pure" sign restrictions approach (e.g. Canova and de Niccolo (2002), Peersman and Straub (2004), Pappa (2004), Peersman and Straub (2006), etc.), an alternative approach uses an ad-hoc penalty function, designed to minimize a loss function of impulse responses deviating from their restrictions (see, e.g. Mountford and Uhlig (2002)).

Also, as it is customary in this literature, a number of shocks are identified through a system of restrictions, which however raises the prospect of misinterpretation and/or of attributing the effects to the "wrong" structural disturbance. For example, in Mountford and Uhlig (2002) the business cycle shock is identified by the requirement that both output and revenues rise for 4 quarters after the shock. This identification strategy thus ascribes to a business cycles shock a dynamics which actually may be due to an episode of "expansionary fiscal contractions". In such occurrences, which have been documented in the literature (see Giavazzi and Pagano (1990)), a fiscal consolidation leads to expectation of permanently lower future paths of government consumption and taxation, and thus provides a powerful stimulus to private consumption and output.

1.5 Theoretical Models of the Effects of Government Spending Shocks

1.5.1 The Neoclassical Literature

In the benchmark neoclassical paradigm, absent distortionary taxation, (see e.g. Aiyagari et al. (1992), Baxter and King (1993), Christiano and Eichenbaum (1992), etc.) a permanent government spending increase, modelled as wasteful, generates a negative wealth effect for the household, who internalize the fact that the current increase in spending would need to be financed through higher taxation. With standard preferences, this induces a reduction in consumption and an increase in labor, resulting in higher output. In the context of a shift in the labor supply and absent any changes in labor demand, this channel would imply a reduction in the real wage. At the same time, the increase in the marginal product of capital stimulates investment and capital accumulation, which eventually brings back the wage to its equilibrium level. The economy converges to a new steady-state with lower consumption and higher employment.

If the government spending shock is temporary, the wealth effect is smaller. The dynamics of the key variables is the same as with a permanent shock, in particular, hours rise and consumption declines, however, depending on the persistence of the shock, the response of investment is ambiguous. Absent distortionary taxation, the increase in labor leads to an increase in the return to capital and thus in investment. However, with distortionary taxation, the effect on investment is driven by the after-tax rate of return and the persistence of the labor supply, which makes the response contingent on the calibration.

A number of "adjustments" to the standard neoclassical benchmark have been proposed in order to account for a possible positive response of either or both the real wage and private consumption. One can differentiate between models which incorporate additional structure on the production side of the economy and models which rely on assumptions regarding preferences.

Devereux et al. (1996) employ increasing returns to specialization to explain how higher government spending raises the equilibrium number of firms that can operate in the intermediate good sectors, thus resulting in an outward shift in the labor demand curve which is able to compensate for the standard negative wealth effect sufficiently to generate an increase in the real wage.

Rotemberg and Woodford (1992) incorporate imperfect competition to explain how, in response to a government spending shock which increases aggregate demand, oligopolistic firms would reduce their mark-ups, since this is the only incentive compatible collusive agreement.

A similar mechanism relying on countercyclical mark-ups is proposed in Ravn et al.

(2008), where the demand faced by producers is split into a price-elastic component which is a function of aggregate demand and a price-inelastic component which depends on the producer specific habit. Thus, an increase in government spending increases the share of the price-elastic component and thus the elasticity of demand, leading to a countercyclical mark-up.

An alternative explanation offered by Linnemann (2002) relies on the utility function being non-additively separable in consumption and leisure *and* quasiconcave. Essentially, in this case, consumption and leisure are very strong substitutes, thus a government expenditure shocks which increases labor raises the marginal utility of private consumption sufficiently to overturn the negative wealth effect and to make the household consume more.

Bouakez and Rebei (2003) on the other hand explain the increase in consumption following government spending shocks based on the complementarity between private and public goods in the utility function.

1.5.2 The New-Keynesian Literature

The benchmark DNKY model predicts that expansionary government spending shocks, modelled as non-productive, generate a negative wealth effect which leads to a crowding *out* of both private consumption and investment. Total output undisputedly increases, because the wealth effect makes agents feel poorer, thus they substitute away from leisure and increase labor supply. Labor demand also increases as aggregate demand has risen which results in an uncontroversial increase in employment and hours. The response of real wages within the DNKY framework itself seems sensitive to the assumed structure of the labor market and to parametrization, as some authors find an indeterminate response (e.g. Peersman and Straub (2006)), other papers document a significant and positive response (e.g. Smets and Wouters (2003)).

In New-Keynesian models, as in the neoclassical paradigm, a number of additional frictions are generally needed in order to overcome the strong negative wealth effects induced by the very persistent nature of government spending shocks and to generate an increase in private consumption and real wages. Essentially, the presence of price and wage stickiness is used to generate a shift in the labor demand curve and thus, produce an increase in the real wage which would be large enough to offset the negative wealth effect and induce an increase in consumption.

In Linnemann and Schabert (2003) for example, the presence of imperfect competition generates a positive externality, by which an increase in aggregate demand raises output and profits, which mitigates the negative wealth effect. Additionally, with sticky prices labor demand reacts stronger than labor supply, which potentially can lead to an increase in real wages. However, a positive response of private consumption is contingent on monetary policy being sufficiently accommodative, since even a modestly aggressive policy rule can be contractionary for private consumption, whose response is dominated by the extremely persistent government spending shock.

In Galí et al. (2005), the negative wealth effect is reduced by positing that a significant share of consumers are hand-to-mouth. If these consumers represent a large share of the economy, then it becomes possible to generate a positive effect on private consumption, since the non-Ricardian agents would consume all of their windfall income, thus total consumption would also increase.

Both explanations, however, rely a strong positive demand effect from increased government consumption in order to compensate for the loss to the agent's lifetime income, through an increase in the real wage, which, however, is disputed empirically. Additionally, the result in Galí et al. (2005) depends crucially on the parameter which calibrates the weight of the naive consumers, and Coenen and Straub (2005) find that a high value is not plausible empirically, while more realistic calibrations are unable to unwind the puzzle.

A number of conclusions emerge from this brief overview of the literature. While an increase in private consumption seems to be the prevalent empirical result, it seems that the standard models in both the neoclassical and the New-Keynesian literature would most often generate the opposite result. Moreover, a number of additional mechanisms have been proposed, which are able to replicate one of the particular sets of empirical facts that the researcher believes to be true. At the same time, understanding transmission channel(s) of the fiscal policy shock seems to be of paramount importance for explaining the behavior of private consumption and of real wages.

1.6 A Preliminary Look at the Data

The previous literature has often used various measures of government spending, which thus seems that to be at least one of the factors able to explain the discrepancy between empirical results. Therefore, we proceed by discussing the main components of government spending which have been analyzed in the literature. We then provide a description of the historical evolution of these time series, in order to investigate whether there are any important difference in the behavior of certain types of government spending which may be worth investigating further.

1.6.1 Components of Government Expenditures

A widely used category in the literature is "government purchases", sometimes also referred to as "government spending", which corresponds to "Government Consumption Expenditures and Gross Investment" in the US national accounts terminology. It comprises of both government consumption (which are short-term or current goods and services), the government investment (which consists of fixed assets, mainly with a maturity of at least one year). Both categories can be further split according to the destination of these expenses in general public service, defense, public order and safety, public transportation, housing, health-care, education, culture, etc.

An alternative classification of government spending is into federal and state and local. The former (federal) comprises of defense and non-defense consumption and investment expenditures (since in the US the military is financed solely at national level), while the latter consists entirely of civilian spending items. Both federal and state and local spending are expended on goods and services which form part of the gross output of general government, and they consist, mainly, in the compensation of government employees (wages), consumption of government fixed capital and purchases of intermediate and final goods and services for the functioning of the government institutions and the provision of government services.

1.6.2 Heterogeneity in the Measures of Government Spending Shocks used in the Literature

As mentioned before, several measures of government expenditures have been most widely used in order to identify government spending shocks.

The papers in the war dummies literature (Ramey and Shapiro (1997), Edelberg et al. (1998), Burnside et al. (2004), Cavallo (2005), etc.) identify government spending shocks with changes in military purchases associated with wars (or more precisely, with the moment when large rises in defense spending started to be predicted by *Business Week* and professional forecasters). The defense spending series itself (consumption plus investment) has been used in a VAR setup by Ramey (2007) and Perotti (2007).

The conclusions are mixed: while the dummy representation generally produces a crowding out of private consumption, the VAR estimation yields borderline results (i.e. nonsignificant), possibly with the exception of the case when longer time series are used (in particular, including the WWII or possibly going back to the 19th century), in which case the crowding out of consumption appears to be quite strong.

Another major group of papers generally identifies total government spending on goods and services, thus including both consumption and investment (see e.g. Galí et al. (2005), Blanchard and Perotti (2001), Perotti (2004), Bouakez and Rebei (2003), Mountford and Uhlig (2002), etc.), generally finding a strong crowding in of private consumption. This approach may potentially lead to a combination of various effects due to the heterogenous nature of government spending.

A number of recent papers have considered disaggregating government spending into different components, most often as a robustness exercise on the side of more general results.

Galí et al. (2005) look at the effects of non-defense government spending in a recursive VAR, finding that they tend to lead to larger (positive) multipliers on private consumption and output than total government spending. However, they do not investigate separately the effects of defense spending itself.

Fatas and Mihov (2001) consider a decomposition in government investment, wage spending and non-wage spending in a recursive VAR, finding that in all cases consumption goes up following spending shocks, however, the most pronounced increase occurs in response to the government wage expenditures shock.

Pappa (2004) distinguishes between shocks to government consumption, investment and employment in a VAR setting, finding that all three generate a strong increase in real wages (consistent with the transmission mechanism of a New-Keynesian sticky price model), thus she concludes that the evidence is not supportive of the predictions of the RBC model.

Perotti (2007) finds that shocks to both defense and civilian government spending (identified recursively in a VAR) generate a positive response in private consumption. However, the response is much stronger for the non-defense shocks, while in the case of military spending shocks it may be insignificant.

Ramey (2007) confirms the insignificant response of consumption to defense shocks, when the identification is done using recursive VARs, however, she finds a negative response when the identification is done using the Ramey-Shapiro dummies. She further documents that the Ramey-Shapiro episodes Granger cause the defense shocks identified in a VAR and interprets these results as pointing to the importance of correct timing, which she argues is being adequately captured by the Ramey-Shapiro episodes, but missed in a VAR specification.

These results appear to suggest that there is a difference in the response of private consumption to defense and civilian spending shocks. It seems therefore interesting to investigate separately the properties of military versus non-military government spending and in particular, of public consumption expenditures (given our interest in explaining the behavior of private consumption). This is the purpose of the following section.

1.6.3 Historical Trends in US Defense and Civilian Government Consumption Spending

In the US, the structure of government spending has undergone substantial changes over the past fifty years. In particular, the composition of government spending has shifted in terms of the relative importance of military spending in the total government budget and in GDP, which has markedly declined (see Figure 1.1)[2]. Military government consumption spending after the Korean War has followed a downward trend, declining from approximately 11 percent of GDP at the peak of the Korean war to a minimum of 3.3 percent during the Clinton presidency, currently amounting for approximately 4 percent of total output.

Non-defense government consumption expenditures have in the meantime steadily increased from 6 percent of GDP in 1948 to 11.5 currently, after reaching a peak of 12.5 percent in 1975 during the Ford administration (see Figure 1.2). As a share of total government consumption, defense consumption expenditures have declined from approximately 64 percent to about 27 percent in 2005.

Putting this evolution into a longer historical perspective, Figures 1.3 and 1.4 depict the evolution of defense and civilian government consumption starting with the Great Depression (1929) both as ratios to output and in per capita levels (deflated by the work force). Figure 1.3 reveals that prior to the Second World War, the non-defense government spending share of output was comparable to the higher post-war levels, i.e. over 10 percent. The major increase in military spending during the Second World War (which at the peak accounted

[2] While we focus on government consumption expenditures, similar trends have characterized government investment spending.

for 27 percent of GDP) lead to a significant crowding out of civilian spending, which then recovered gradually, stabilizing after 1975 at a ratio of around 12 percent of output.

Looking at the low-frequency properties of the two series in real per capita terms, Figure 1.4 reveals that non-defense government spending is upward trending. The increase in non-defense government consumption per capita after the Great Depression has been more than tenfold, from approximately USD 400 in 1929 to close to USD 4300 in 2005 (in 2000 prices).

Formal tests[3] (see Table 1.1) do not offer clear evidence on whether the trend in civilian government consumption is stochastic or deterministic. The null of unit root including an intercept is rejected by the ADF test at the 10% level and by the PP test at 5%, but not lower, while the null of unit root including both intercept and trend cannot be rejected by either test.

Military consumption expenditures, on the other hand, experienced a level shift during WWII (see Figure 1.4), however, in the post-war period, they have been quite stable, fluctuating around an average of approximately USD 1000 per capital (in 2000 prices). Table 1.1 shows that non-stationarity is clearly rejected for this series in the post WWII period. In particular, the ADF test provides strong evidence of stationarity, while the PP test supports stationarity at conventional levels as well.

The phenomenon of the relative decline in the importance of military expenditures from its peaks in the Cold War period is not unique to the US. Rather, in comparison with other OECD economies, the US still has a relatively high defense budget, while other OECD countries (with the notable exceptions of Greece and Korea) expend on average only 2 percent of GDP on military goods and services and about 20 percent on other government spending items (see Table 1.2). Thus, understanding the effects of civilian spending shocks appears an interesting exercise also from an international perspective.

Turning to the high-frequency properties of the data, we compare the volatilities of mili-

[3] We apply the unit root tests to the post WWII sample, due to the larger number of observations (approximately triple the size of the yearly sample).

tary and civilian government consumption with private consumption, output and investment. Table 1.3 presents the standard deviation of real per capita growth rate for 3 samples of various length (including the pre-WWII period), at yearly and quarterly frequency, deflated by the work force or by population. We notice that military spending exhibits a high volatility comparable only to that of private investment, which is several times higher than the volatility of private consumption, civilian government consumption and output. Looking at the post-WWII sample, the standard deviation of the growth rate of nondefense government consumption (0.019) is more than double that of private consumption (0.008), however, it is only half the standard deviation in the growth rate of military expenditures (0.038).

In an alternative way of analyzing the two types of public spending, Figure 1.5 presents, using post-1930 data, the year-on-year growth rates of civilian and military government consumption.

Military government consumption has been characterized by large shocks, in particular WWII and the Korean War, both followed by large military spending cuts. After the end of the Korean war, the shocks to defense spending are by comparison more subdued (with the year-on-year growth rate well below 10 percent, with the exception of the Vietnam War, when a 13 percent acceleration in military spending was recorded in 1966).

Civilian government spending has also been very volatile from the 1930s until the late 1950s (with the year-on-year growth rate exceeding +/- 10 percent on a number of occasions). Starting with the 1960s, the shocks to this component of public expenditures become significantly smaller and much more persistent.

Looking at post-WWII data at quarterly frequency, Figure 1.6 shows more clearly the "moderation" in both military and civilian government spending dynamics after the 1960s.

One can distinguish the relatively large positive shocks in military spending due to the Korean War, the Vietnam War, the Reagan-Carter build-up and the Afghanistan and Iraq wars (which are used in the construction of the original Ramey-Shapiro episodes). Additionally, one can note smaller episodes of military budget increases, associated with the Sputnik

Crisis (1957), the Berlin Crisis of 1961 and the Cuban Missile Crisis of 1962, as well as the First Gulf War (1990-1991).

Unlike military spending, civilian government spending after the 1960s has been characterized by a series of mostly positive and very persistent shocks, which helps explain the increasing share of this component of government spending in GDP.

Overall, several important conclusions emerge from this descriptive analysis of military versus civilian government consumption spending. Military government consumption behaves differently from civilian government consumption, in that it appears to be mean-reverting in per capita levels, after WWII, while being dominated by large positive and negative shocks. It is also significantly more volatile than civilian government consumption, private consumption and output in general. Nondefense government spending, in particular after the 1960s, seems to be characterized by smaller, more persistent and mostly positive shocks, thus the series is trending.

The evidence presented to far suggest that studying the macroeconomic effects of the two types of government spending (civilian and military) is an interesting endeavour and may potentially yield important insights into their effects on private sector variables as well.

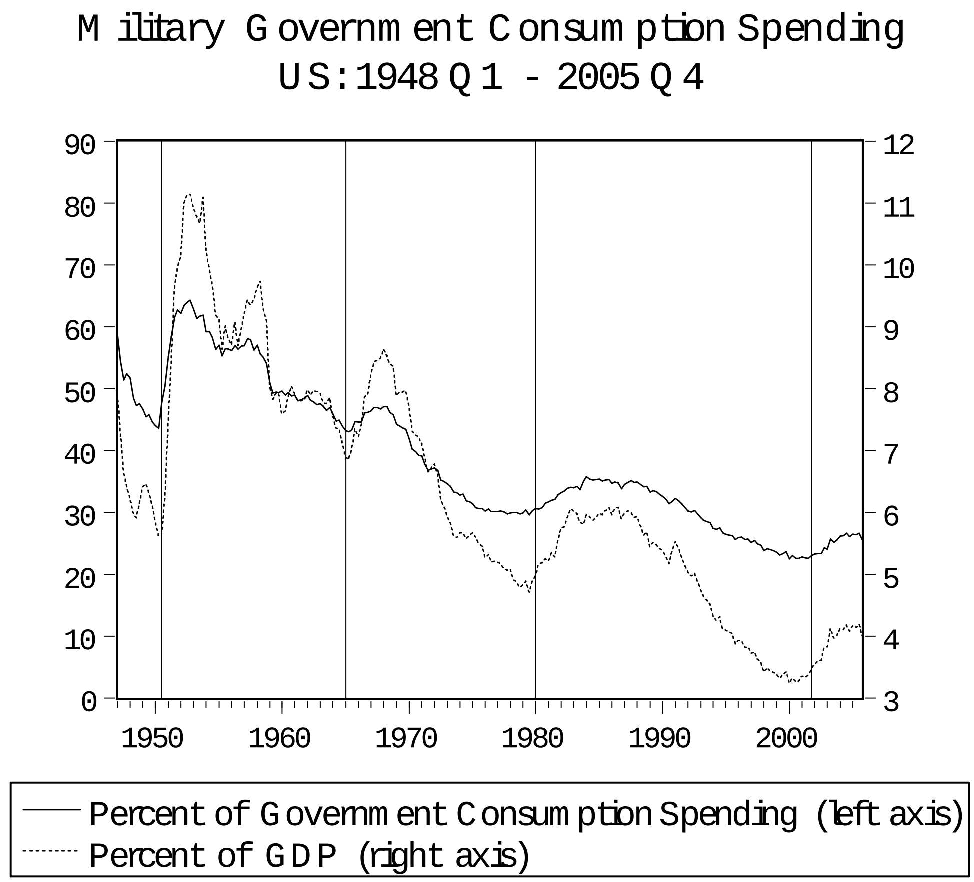


Figure 1.1: US Post-WWII Military Government Consumption Spending as Percent of GDP and of Total Government Consumption

Note: The vertical lines represent, in order, the Ramey-Shapiro war dummies (see Ramey and Shapiro (1997) and Ramey (2007)). They correspond, respectively, to 1950:Q1 (Korean War), 1965:Q1 (Vietnam War), 1980:Q1 (Carter-Reagan military build-up) and 2001:Q3 (September 11 terrorist attacks).

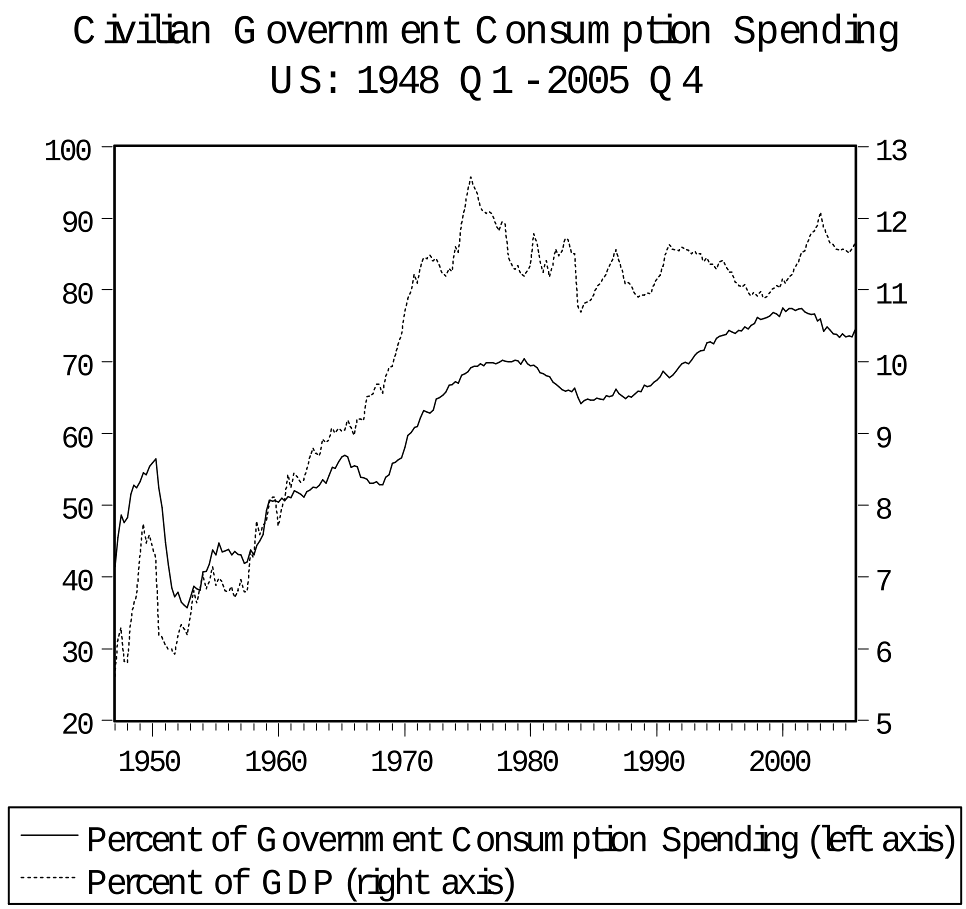


Figure 1.2: US Post-WWII Civilian Government Consumption Spending as Percent of GDP and of Total Government Consumption

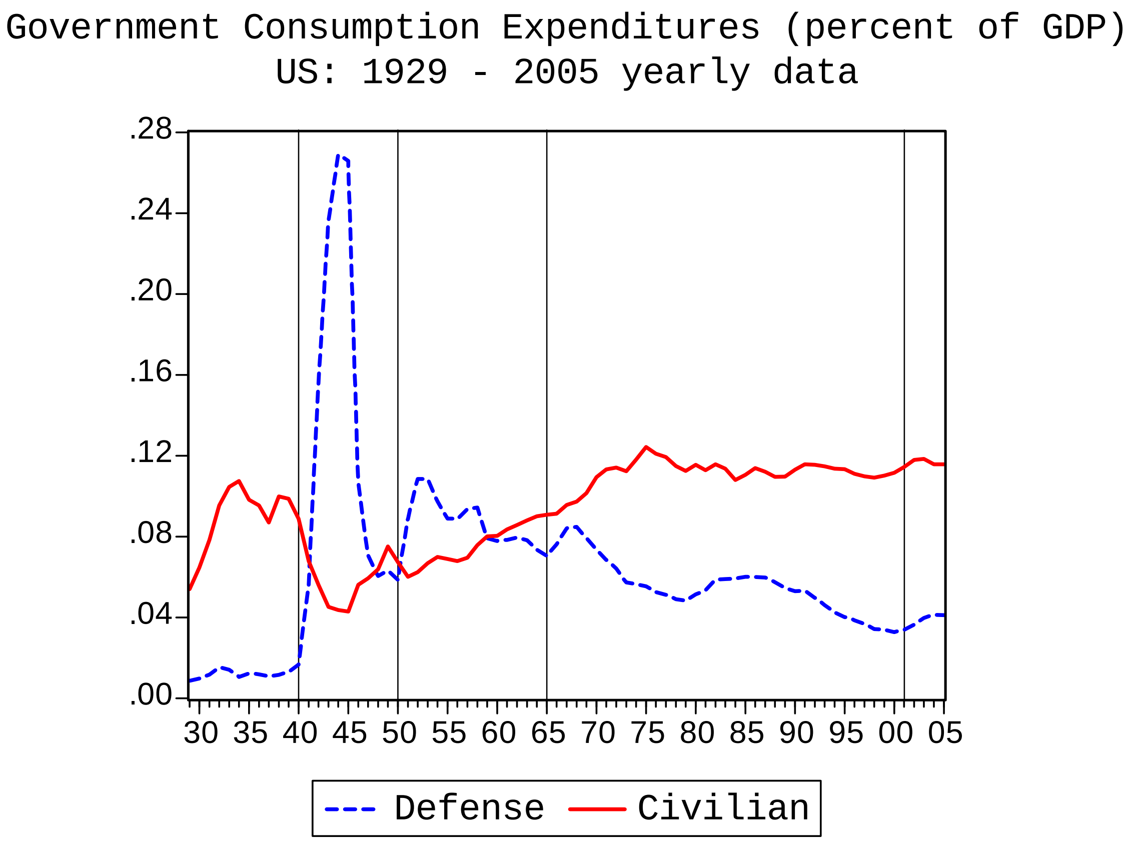


Figure 1.3: US post Great Depression (1929) Defense and Civilian Government Consumption Spending as a Share of GDP

Note: The vertical lines represent the onset of wars and major military build-ups: 1940 (Second World War), 1950 (Korean War), 1965 (Vietnam War), 1980 (Carter-Reagan military build-up) and 2001 (Afghanistan and Iraq Wars).

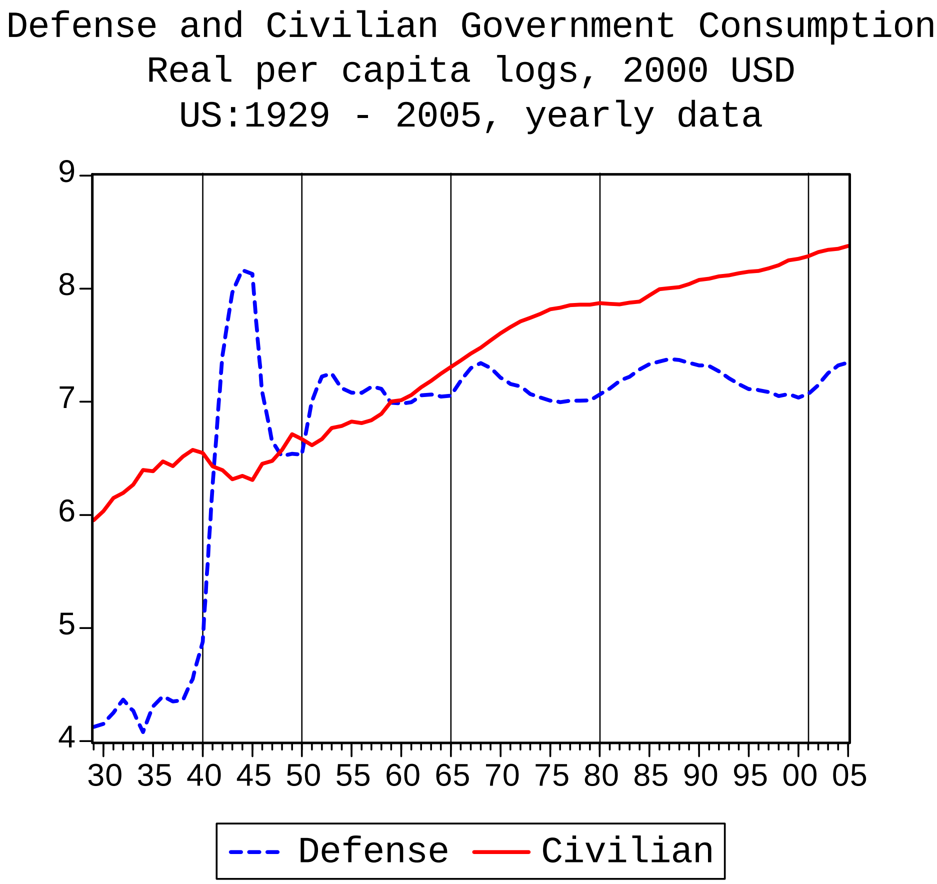


Figure 1.4: US post Great Depression (1929) Defense and Civilian Government Consumption Spending in Real per Capita Terms (Logs, 2000 Prices)

Note: The vertical lines represent the onset of wars and major military build-ups: 1940 (Second World War), 1950 (Korean War), 1965 (Vietnam War), 1980 (Carter-Reagan military build-up) and 2001 (Afghanistan and Iraq Wars).

Table 1.1: Unit Root Tests: Defense and Civilian Government Consumption

		Levels		Differences	
Test	Specification	Test statistic	p-value	Test statistic	p-value
	Defense Government Consumption (1948:Q1 - 2005:Q4)				
ADF	Constant	-4.060	0.001	-5.410	0.000
ADF	Constant+Trend	-4.346	0.003	-4.728	0.000
PP	Constant	-3.172	0.023	-11.38	0.000
PP	Constant+Trend	-3.239	0.079	-11.43	0.000
	Civilian Government Consumption (1948:Q1 - 2005:Q4)				
ADF	Constant	-2.678	0.0793	-15.881	0.000
ADF	Constant+Trend	-1.617	0.7832	-16.249	0.000
PP	Constant	-3.058	0.0312	-15.838	0.000
PP	Constant+Trend	-1.621	0.7818	-16.226	0.000

Notes: For ADF automatic lag length specification based on SIC. For PP Bartlett kernel spectral estimation method and Newey-West automatic bandwidth selection

Table 1.2: Defense Spending in OECD countries (2002)

	As a share of GDP	As a share of government spending
US	4.16%	22.20%
Australia	1.93%	10.76%
Belgium	1.29%	5.90%
Canada	1.12%	6.05%
Czech Republic	2.13%	9.45%
Denmark	1.54%	5.96%
France	2.50%	10.79%
Germany	1.48%	7.75%
Greece	4.35%	27.96%
Hungary	1.77%	8.20%
Italy	1.92%	10.95%
Japan	0.99%	5.71%
Netherlands	1.63%	6.99%
Norway	1.88%	8.44%
Poland	1.97%	11.12%
Portugal	2.28%	12.86%
Republic of Korea	2.79%	23.07%
Spain	1.20%	6.83%
UK	2.37%	11.82%

Table 1.3: Comparison of Volatilities of Key Macro Variables

Standard deviation of real per capita growth rates

Sample	Y	C	I	CIV	MIL
1930 - 2005 (yearly, defl. by population)	0.050	0.030	0.293	0.045	0.284
1940 - 2005 (yearly, defl. by labor force)	0.047	0.020	0.195	0.040	0.308
1948:2 - 2005:4 (quart, defl. by labor force)	0.010	0.008	0.055	0.019	0.038

Legend: Y - output
C - private consumption
I - private investment
CIV - civilian government consumption
MIL - military government consumption

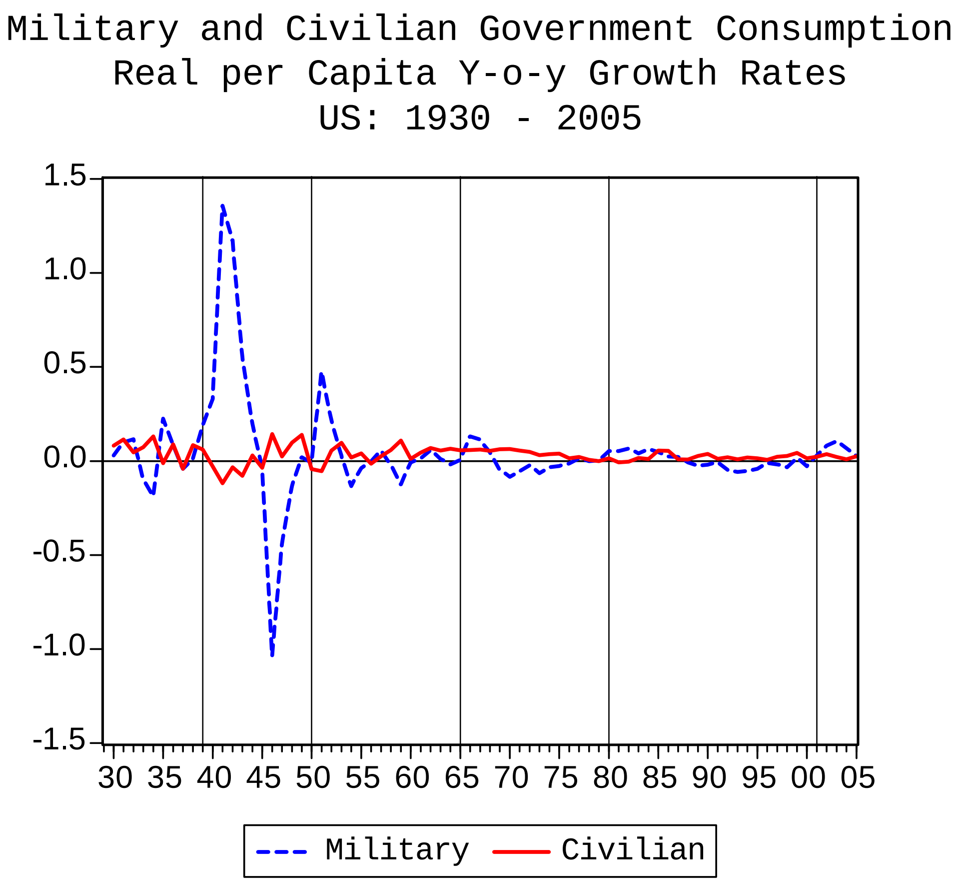


Figure 1.5: US post Great Depression (1929) Defense and Civilian Government Consumption Spending Y-o-y per Capita Growth Rates (scale 1=100 percent)

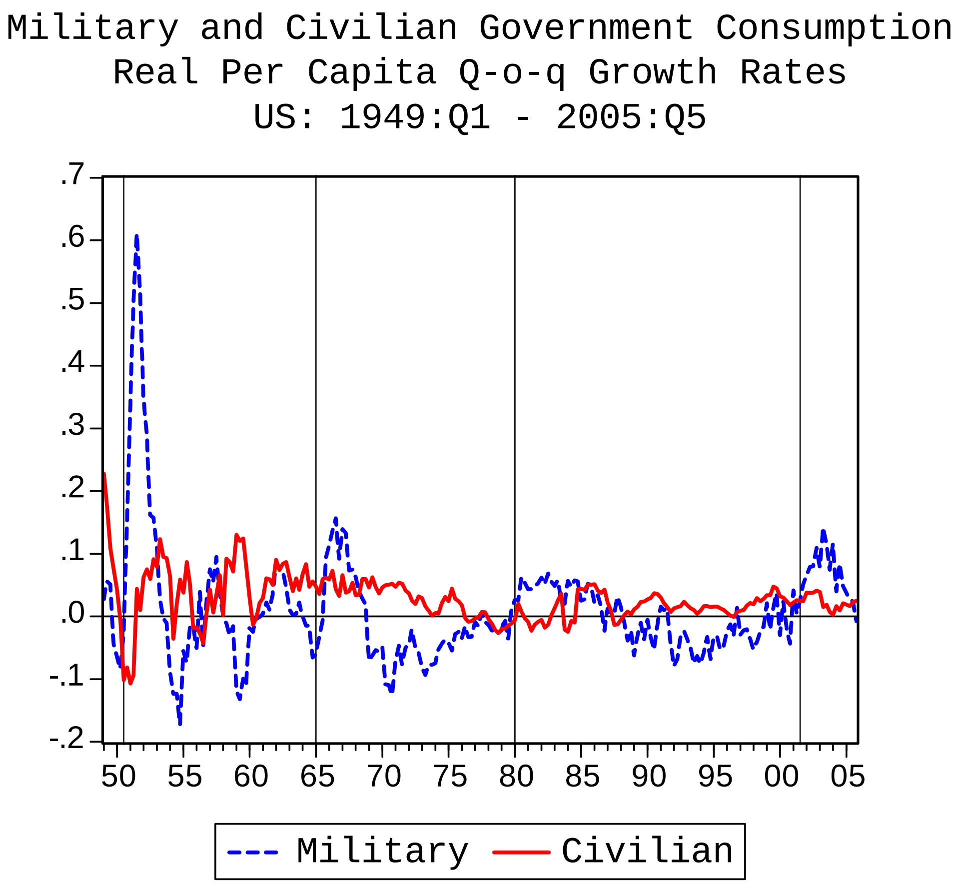


Figure 1.6: US post-WWII Defense and Civilian Government Consumption Spending Q-o-q per Capita Growth Rates (scale 1=100 percent)

Chapter 2

Is Government Spending Expansionary or Contractionary for Private Consumption? Results from a Sign Restriction Identification Procedure

2.1 Introduction

In spite of significant research on the topic, the effects of government spending shocks on private consumption are still controversial. In this paper we provide new evidence on this issue, drawing a distinction between different categories of government spending and using an new identification strategy. More precisely, we estimate the effect of government spending shocks, differentiated in defense and non-defense, on private consumption and other macroeconomic variables, employing VARs identified using sign restrictions on postwar US data. We show that this identification goes a long way towards explaining the much debated response of private consumption to government spending shocks.

In particular, military government consumption shocks have a negative effect of approximately one year on private consumption, which is consistent with what wealth effects would predict. On the other hand, non-defense government spending shocks significantly and persistently crowd *in* private consumption over the medium term (2-3 years). Moreover, we find evidence that if fiscal shocks are anticipated for up to several quarters, the magnitude of the multipliers on private consumption of both defense and non-defense shocks is augmented.

This paper is part of a growing literature using sign restrictions, which avoids the sometimes questionable imposition of rigid short-term or long-term constraints in favor of more diffuse theoretical and empirical priors, thus allowing the data more freedom to speak for itself. The methodology has been pioneered by Faust (1998), Canova and de Niccolo (2002) and Mountford and Uhlig (2002) for monetary policy and has more recently been also used to identify fiscal policy shocks (see, e.g. Mountford and Uhlig (2002), Canova and Pappa (2003), Peersman and Straub (2004), Peersman and Straub (2006), Pappa (2004), etc.).

In this paper, we employ sign restrictions derived from a set of stylized "facts" which are common to both RBC and new-Keynesian models and moreover, have been validated empirically by a broad literature. The procedure is used to test for two main identification strategies as well as for a number of robustness exercises, in particular with respect to alternative measures for key variables, different sub-samples as well as the effects of anticipated fiscal shocks.

This paper contributes to the literature on the effects of government spending shocks. One direction of research has used the Ramey-Shapiro war dummies approach[1], which identifies government spending shocks with changes in military purchases associated with wars (or more precisely, with the moment when large rises in defense spending started to be predicted by *Business Week* and professional forecasters). This literature generally finds a negative

[1] See, e.g. Ramey and Shapiro (1997), Edelberg et al. (1998), Burnside et al. (2004), Cavallo (2005), Ramey (2007), etc.

multiplier on private consumption, which is interpreted as supportive of the neoclassical wealth channel.

Another large strand of the literature has studied the consequences of total government purchases considered as a homogenous quantity[2], usually employing some type of VAR identification and finding typically a positive response of private consumption to government spending shocks, or in some cases, an insignificant one.

More recently, a number of papers have looked at the effects of disaggregating government spending according to a defense and a non-defense component. For the structural or recursive VAR literature, this disaggregation does not seem to matter much. Galí et al. (2005) find that the multipliers of total government spending (consumption plus investment) on private consumption are almost always positive across various specifications, but that they are significantly larger for non-defense spending. Perotti (2007) also finds that shocks to both defense and civilian government spending generate a positive response in private consumption, however, the response is much stronger for the non-defense shocks, while in the case of military spending shocks it can be insignificant.

However, in the war dummies approach, this differentiation seems to matter, possibly due to the more precise identification of the correct timing of the shocks. In particular, comparing the two approaches, Ramey (2007) finds a negative response of consumption to defense spending shocks, when identified using the Ramey-Shapiro episodes and an insignificant response, when the identification is done using recursive VARs. She interprets the results as pointing to the importance of correct timing, which she argues is being adequately captured by the Ramey-Shapiro episodes, but missed in a VAR specification.

The paper is organized as follows. Section 2 described the sign restrictions methodology we employ drawing on a large theoretical and empirical literature. In particular, we discuss the consequences of productivity shocks, labor supply shocks and disaggregated government

[2] See, e.g. Blanchard and Perotti (2001), Perotti (2004), Fatas and Mihov (2001), Favero (2002), Galí et al. (2005), Bouakez and Rebei (2003), Canova and de Niccolo (2002), Mountford and Uhlig (2002), Peersman and Straub (2006), Peersman and Straub (2004), etc.

spending shocks. Section 3 presents the two main identification schemes we employ for the identification of a "pure" government spending shock and respectively of a deficit-financed government spending shock. Section 4 discusses the main results and further robustness checks. Section 5 concludes.

2.2 The Identification Framework Using Sign Restrictions

The identification of fiscal shocks in VARs is in general quite difficult and controversial (for example compared to monetary policy shocks) for a number of reasons. On the one hand, the interpretation of the meaning of a fiscal shock is not always clear, because fiscal policy comprises of a mix of measures of various nature, either on the spending or on the financing side and quite often in practice, of a combination of these. Secondly, one needs to distinguish between the "pure" fiscal shock and the automatic response of fiscal variables to the macroeconomic conditions or to other fiscal policies. A third issue is the difficulty of correctly identifying the timing of such shocks, due to the presence of hard to estimate policy and implementation lags. Measures relating to both the spending and the taxation side of fiscal policy are in general widely debated on the political scene before being adopted. Besides, further lags are caused by usual delays between the announcement of a fiscal policy decisions and their implementation. These features of fiscal policy cast doubt on the ability of VARs to truly identify the impact of fiscal shocks, since agents may rationally adjust their behavior to expectations of policy changes before these are effectively put into place.

Given these problems confronting fiscal policy VARs, it is not surprising that some of the results are very sensitive to the methodology and the assumptions made in order to identify the shocks. In particular, as discussed in detail in the Introduction to this dissertation, the main empirical strategies used so far in the literature (namely dummy variables and structural VARs) both suffer from certain shortcomings. In particular, the various VAR identifications can be most often challenged on the basis of the timing assumption they employ. The dummy variables scheme in its turn, while potentially addressing the timing issue better, is liable to criticism for a certain degree of arbitrariness and also for difficulties in accounting for military spending shocks of different magnitudes.

Compared with these approaches, the sign restrictions methodology presents several advantages for the identification of fiscal shocks. On the one hand, it makes away with rigid assumptions regarding sequentially, by allowing more complex timing assumption, including the study of anticipated fiscal shocks. Another important advantage consists in the ability to characterize the effects of complex fiscal policies (for example a deficit-financed spending increase), in an environment in which other shocks are also identified. Finally, the information captured in the entire path of the government spending series is taken into account, which allows for government spending shocks of different magnitudes.

The empirical specification we choose in terms of the variables to be included in the VAR and the restrictions which are imposed is guided by several principles: (i) the VAR should be large enough to capture adequately both the private sector and government sector dynamics, (ii) it should contain variables and identify shocks about which significant empirical and theoretical consensus had emerged and (iii) should also be parsimonious enough to enable robust estimation with post-war US data. Based on these criteria, we decide to include in the VAR the following variables: private consumption, output, investment, real wages, hours, civilian and military government consumption spending[3], prices and the government surplus. Definitions of all the variables, including the sources and the transformation applied to the data are to be found in Appendix A.

Two main specifications are estimated (each is a 8 variable VAR comprising of the first seven variables listed above and either prices or the government surplus). In the first VAR, we aim to identify a generic government spending shock, irrespective of the way it is financed.

[3]Unlike most of the literature, where both government investment and consumption are lumped together, we investigate the effects of government consumption shocks only, which are most likely to matter for the behaviour of private consumption.

In the second VAR, we study the effects of an empirically very relevant case, that of deficit-financed expansionary fiscal policy.

Given our set of variables and the existing theoretical and empirical evidence, we aim to identify up to four types of underlying disturbances: two government spending shocks (defense and non-defense)[4] and two supply-side shocks: a productivity shock and a labor supply shock.

There are several reasons for the identification of additional shocks apart from the government spending ones[5]. On the one hand, this "filters" more of the variance and thus allows us to potentially identify shocks more clearly. As the sign restrictions methodology relies on weak identifying assumption, in order to generate strong enough predictions for the unconstrained impulse responses, it is important that a sufficiently large number of restrictions should be imposed and also that large shocks are correctly identified. The technology and the labor supply shocks have both been found to play an important role in explaining macroeconomic fluctuations in the US, so they are natural candidates.

2.2.1 Model and Empirical Based Identification

The strategy of this paper is to start from widely accepted "stylized facts" derived from a careful reading of both the empirical and the theoretical literature. For example, we consider as a "fact" the implication that a productivity shock should raise output for a number of periods after the shock and we impose this constraint as a non-negative response of output to productivity shocks on impact and several quarters afterwards. In order to derive such restrictions, we conduct a thorough review of the literature to document impulse responses whose signs could qualify as consensus view. After collecting a summary of facts, we proceed to select a minimum of necessary restrictions which are sufficient to identify the shocks, in

[4] The previous sign restrictions literature which looks into the effects of government spending shocks (see, e.g. Mountford and Uhlig (2002), Peersman and Straub (2004), Peersman and Straub (2006)) has not looked into this dissagregation.

[5] The final chapter of this dissertation contains a more detailed discussion of this issue.

Table 2.1: Effects of Government Spending Shocks

Variable	*RBC Model*	*DNKY Model*	*Empirical*
Output	+	+	+
Private Consumption	+/-	+/−	+/−
Private Investment	−	−	+/−
Hours	+	+	+
Real Wage	+/−	+/0	+/−
Prices		+	+/−

Note: *A "+/−/ 0" mean that the impulse response of the particular variable has been found to be positive, negative and/or not significant*

that we retain all solutions which do *not* produce implausible responses.

We proceed by discussing the consequences of each type of shock, starting with the demand (government spending) shocks and going on to the supply-side shocks.

The effects of an expansionary (usually aggregate) government spending shock can be summarized as in Table 2.1[6]. Essentially, apart from the response of output and hours (employment), which uncontroversially increase both in the benchmark DNKY and RBC model and empirically, most other responses are controversial from both a theoretical and an empirical perspective.

The effects of a productivity (RBC) shock are generally less controversial (see Table 2.2). In particular, there is broad agreement, both empirically and theoretically, on a positive and quite persistent response of output, consumption, investment and the real wage. However, the DNKY and RBC offer different conclusions regarding the effects of productivity shocks on the behavior of hours/employment. In particular, one of the main elements of debate between the sticky-prices and non sticky-prices model is that DNKY models imply a fall in labor in response to a positive technology shock, while RBC models predict an increase[7].

[6] The reader is referred to Introduction for a detailed literature survey on these results.

[7] While Galí et al. (2000), Shea (1998), Basu and Kimball (1999), Francis and Ramey (2002) and Francis et al. (2003) find a negative effect, Christiano et al. (2004), Peersman and Straub (2004), Uhlig (2004), Dedola and Neri (2004) and Canova and Gambetti (2004) find a positive impact.

Table 2.2: Effects of Productivity Shocks

Variable	*RBC Model*	*DNKY Model*	*Empirical*
Output	+	+	+
Private Consumption	+	+	+
Private Investment	+	+	+
Hours/Employment	+	-	+/-
Real Wage	+	+	+/0
Prices		-	-/0

Note: *A "+/–/ 0" mean that the impulse response of the particular variable has been found to be either positive, negative or not significant*

Labor supply shocks (which affect the intra-temporal elasticity of substitution between consumption and leisure in the utility function) are also found to generate a number of robust stylized facts (see Table 2.3). In both the DNKY and RBC models, a shock that decreases the marginal utility of leisure leads to a shift in the labor supply curve out, thus real wages fall, agents work more, firms increases investment and overall output rises. In the DNKY framework, the fall in the real wage leads to a fall in the marginal cost and thus in inflation (see e.g. Smets and Wouters (2003)). The empirical evidence is also generally supportive of the increase in output and the fall in the real wage (see, e.g. Peersman and Straub (2004), Peersman and Straub (2006), Francis and Ramey (2002), Fleishman (1999), etc.). However, the responses of consumption, investment and hours are not always found to be significant empirically.

2.3 Relaxed Sign Restrictions

We restrict our attention to those restrictions which are accepted both in the theoretical literature and have been validated also by previous empirical research. In particular, we avoid imposing any of the responses which constitute ongoing controversies between the DNKY

Table 2.3: Effects of Labor Supply Shocks

Variable	*RBC Model*	*DNKY Model*	*Empirical*
Output	+	+	+
Private Consumption	+	+	+/0
Private Investment	+	+	+/0
Hours/Employment	+	+	+/0
Real Wage	-	-	-
Prices		-	-

Note: *A "+/–/ 0" mean that the impulse response of the particular variable has been found to be either positive, negative or not significant*

and the RBC models. However, in order to uniquely disentangle the structural shocks, only a subset of the restrictions discussed in Section 2 that are sufficient to generate orthogonal shocks is needed. By not imposing all the restrictions about which we have information, we allow the data more freedom to speak for itself and have additional robustness checks.

We propose two main identification schemes. The first one aims to determine the effects of "pure" government spending shocks, independent from the way they are financed. This identification scheme thus does not feature variables on the revenue side. Instead, identification is achieved through the behavior of prices, which allows us to distinguish between demand and supply shocks.

The second identification scheme allows us to investigate a very relevant case for fiscal policy, namely that of deficit financed government spending shocks. Thus, this VAR features the government surplus instead of prices. We next discuss these two schemes and their respective restrictions in detail.

2.3.1 "Pure" Government Spending Shocks Identification

The first identification scheme (see Table 2.4) uses as an overall principle the distinction that supply shocks generate negative contemporaneous correlations between output and prices, while demand shocks cause a positive comovement.

Apart from an increase in the variable itself, both government spending shocks are identified through the restrictions that they generate an increase in hours and output (as seems to be the consensus view). In order to distinguish between the two government spending shocks, we do not have further restrictions, neither empirically nor theoretically.

To solve this difficulty, we follow the relative restrictions approach suggested by Peersman and Straub (2006). Specifically, we impose *relative* sign restrictions in the following manner: the increase in the type of government spending which suffers the shock should be larger or equal to the change in the other type of government spending. This type of impact restrictions, can be summarized as[8]:

$$\frac{R^{MIL}_{CIV,t+k}}{R^{MIL}_{MIL,t+k}} \leqslant 1, k = 0$$

$$\frac{R^{CIV}_{MIL,t+k}}{R^{CIV}_{CIV,t+k}} \leqslant 1, k = 0$$

The RBC shock is pinned-down as one which generates a nonnegative response in output, consumption, investment and the real wage and a non-positive effect on prices. Since RBC models predict, in contrast to DNKY models, a positive impact of technology shocks on labor, we impose no restriction on hours. The response of defense and non-defense government consumption are also left unsigned, since we have little information on their behavior.

The labor supply shock is identified as one which has a nonnegative effect on output and a non-positive effect on prices and the real wage. These constrains suffice to distinguish it both from a productivity shock (through the response of real wages) and from aggregate demand shocks (through the response of prices). The theory summarized in Section 2.1 would also suggest that a labor supply shock implies an increase in consumption, investment and hours, however, the evidence on the significance of these responses does not seem to be entirely conclusive, so we prefer not to impose these restrictions and instead to use them for

[8] Notation: $R^i_{j,t+k}$ is the impulse responses to shock i of variable j at time t and at lag k. CIV and MIL stand for civilian and respectively defense spending shocks.

Table 2.4: Sign Restrictions Identification Scheme 1

Variable	*Supply Shocks*		*Demand Shocks*	
	Productivity	*Labor*	*Gvt. (Military)*	*Gvt. (Civilian)*
Private Consumption	+	(+)		
Private Investment	+	(+)		
Hours		(+)	+	+
Real Wage	+	−		
Military Gvt. Cons.			+	*relative*
Civilian Gvt. Cons.			*relative*	+
Output	+	+	+	+
Prices	−	−	+	+

Notes: A " + / − " *means that the corresponding impulse response has been restricted to be nonnegative/nonpositive, a blank means no restriction has been imposed. A sign in brackets means that this is the expected IRF sign, however it has not been imposed. "Relative" means a restriction relative to another variable, see in the text for details.*

robustness checks.

The restrictions we eventually impose are summarized in Table 2.4 (Identification Scheme 1). All restrictions are imposed for 4 quarters, with the exception of the relative ones, which are imposed on impact only.

2.3.2 Deficit-Financed Government Spending Shocks Identification

The identification scheme discussed in the previous section may be liable to criticism due to the restrictions we impose on the response of prices. In particular, we have identified supply shocks by requiring that prices uncontroversially decline for several quarters after the shocks, while demand shocks have been required to produce opposite effects. However, in the case of productivity shocks, while a majority of authors would agree on a negative impact on prices, some papers find evidence of a delayed effect (see e.g. Dedola and Neri

(2004)). Also, while government spending shocks are generally found to increase the price level, a number of authors (see e.g. Mountford and Uhlig (2002), Canova and Pappa (2003), Fatas and Mihov (2001)) actually document a drop in inflation.

To some extent, these different conclusions may reflect a different response of monetary policy, however, Scheme 1 does not allow for the separate identification of this shock. Instead of expanding the VAR on the monetary side (with possibly further complication, for example due to controversies such as the price puzzle), we prefer to enhance the VAR on the fiscal side. The importance of the financing side of fiscal policy for the identification of government spending shocks has been pointed out in the literature before[9]. We thus study an alternative specification, in which we include the government surplus instead of prices (while keeping the other variables).

Certainly, there are numerous fiscal policy mixes which can not be accounted for by this paper. We restrict our attention to a case which is relevant for policy, namely that of deficit-financed spending shocks. We define a deficit-financed spending shock as an increase in government expenditures which is not accompanied by a similar increase in revenues, generating a deficit for a number of periods. Tax revenues thus may increase, decline or be constant, which can be due either to the marginal tax rate being adjusted, to the tax base increasing due to the expansionary effects of the increased public demand, or both.

Given our variables, in Identification Scheme 2, we can identify only three shocks: two government spending shocks (defense and non-defense) and the productivity shock. The difference between the supply and demand-side shocks is now given by the response of the government surplus. A technology shock, which increases the tax base, would, caeteris paribus, generate an increase in revenues and the government surplus. However, an increase

[9] Mountford and Uhlig (2002) discuss various mixes of fiscal policies on the spending and revenue side, which they find to have quite different effects. Perotti (2007) documents that, while tax revenues increased during the Korean war, due to an ideological aversions of President Truman to budget deficits, they increased only with a lag during the Carter-Reagan build-up, while they actually fell in the Vietnam and Bush build-ups. At the same time, he finds that private consumption *increases* in response to the Korean war dummy, while it declines significantly in all other three episodes, in line with the typical neoclassical dynamics. The differences in these episodes seem to suggest that the different pattern of taxation may play a role.

Table 2.5: Sign Restrictions Identification Scheme 2

Variable	*Supply Shocks*	*Demand Shocks*	
	Productivity	*Gvt. (Military)*	*Gvt. (Civilian)*
Private Consumption	(+)		
Private Investment	(+)		
Hours		+	+
Real Wage	+		
Military Gvt. Cons.		+	*relative*
Civilian Gvt. Cons.		*relative*	+
Output	+	+	+
Gvt. Budget Surplus	+	−	−

Notes: A " + / − " *means that the corresponding impulse response has been restricted to be nonnegative/nonpositive, a blank means no restriction has been imposed. A sign in brackets means that this is the expected IRF sign, however it has not been imposed. "Relative" means a restriction relative to another variable, see in the text for details.*

in government spending would not immediately generate an increase in output and the tax base, thus, the government deficit would increase at least for several periods after the shock. Apart from this differentiation, the restrictions imposed are similar to those in Scheme 1 (see Table 2.5).

2.4 Results

The model is estimated with 4 lags, which are given by the standard information criteria. The algorithm for identifying the shocks (described in more details in Appendix II), consists in bootstrapping the variance-covariance matrices of residuals and extracting impulse response which satisfy *all* restrictions. We iterate until at least 1000 solutions are found (from a minimum of 100 bootstraps, in general no more than 200 are needed) and order the accepted solutions period-by-period. For the selected impulse responses, we report the median (continuous line), which is the most likely outcome in line with our *a priori* identifying assumptions. The large dashed lines represent the 2.5th and the 97.5th percentiles and the dotted lines represent the 16th and 84th percentiles (to enable comparison with the previous literature, which reports either).

It is important to note the fact that the interpretation of the error bands is different than that of the confidence intervals reported in standard VARs. Here the uncertainty is over models, while in the latter, it is one of sampling,. The impulse responses we report represent the results of a range of structural decompositions compatible with our sign restrictions, thus, while one is more confident than with classical identification schemes to capture the "true" model, interpreting the magnitudes and comparison with results from standard VARs needs to be undertaken with caution (see also Fry and Pagan (2007)).

2.4.1 Effects of "Pure" Government Spending Shocks

Figures 2.1 and 2.2 display the impulse responses to the restrictions imposed in Identification Scheme 1. The figures show the responses to a one standard deviation of the identified shock.

Military spending exhibits a hump-shaped response, which is highly significant for 2-3 years after the onset of the shock. This dynamics is to a large extent explained by the pattern of gradual build-up during military engagements in post WWII US history. The impact of military spending shocks has been constrained to be expansionary on output and hours for a year, however, we notice that the effects are more persistent (in particular the strong negative wealth effect on hours).

Interestingly, private consumption is crowded *out* significantly for approximately 3 to 4 quarters, which is consistent with the finding in the war dummies literature. Corroborating this with the strong negative response in the real wage, these results suggests that the evidence is more supportive of RBC type transmission channels than of New Keynesian models. In the neoclassical RBC model, the negative wealth effect of higher government spending causes the agent, under standard preference assumptions, to increase both consumption and labor, the resulting outward shift in labor supply is responsible for the fall in the real wage, absent changes in labor demand. New-Keynesian models, on the other hand, rely heavily on inducing an increase in the real wage in order to mitigate the negative wealth effect of government spending (see e.g. the model with imperfect competition of Linnemann and Schabert (2003) and with rule-of-the-thumb consumers and sticky prices and wages of Galí et al. (2005)).

Civilian government spending is more persistent than military consumption, with a half life of approximately 4 years (versus approximately 2 years). Unlike military shocks, civilian spending shocks crowd *in* private consumption and the effect is highly significant and persistent (over 2 years). Nevertheless, one needs to be careful in interpreting this strong positive response of private consumption as evidence in favor of New-Keynesian dynamics, since we notice that the response of real wages to this type of government spending is again strongly negative.

We thus offer some clarification in the controversy regarding the behavior of private consumption, which lies at the heart of the current debate between DNKY and RBC models. Our results show that the apparent contradiction may be due to the identification of the shocks. In the same VAR, we identify both strongly positive and strongly negative responses of private consumption to various types of government consumption spending. The differentiated effects of military and civilian government spending on private consumption appear to warrant the importance, in larger DSGE models with a fiscal side, of modelling them separately in order to better match the dynamics of the data. Relative to the literature which identifies total government spending shocks, it appears that in such papers aggregation obscures the true negative effect of defense shocks as the effect of the civilian component is dominant. We investigate this claim further in a subsequent section.

It is also reassuring to note that the identification scheme seems to recover quite realistic responses to both the productivity and the labor supply shock, in line with results obtained through different methodologies. In particular, productivity shocks strongly raise output, investment, consumption and the real wage. We find a fall in prices and a possibly significant decline in hours only in the medium-term. The labor supply shock, on the other hand, has strong expansionary effects on output and consumption, concomitant to an increase in labor which reduces the real wage, while prices also decline very persistently.

2.4.2 Effects of Deficit-Financed Government Spending Shocks

Figure 2.3 presents the results of Identification Scheme 2, which essentially pins down expansionary fiscal policies characterized by an increase in spending accompanied by an increase in the deficit.

The most important conclusion which emerges is that the identified responses are very similar to those from the previous identification strategy, not only from a qualitative perspective, but also quantitatively. In particular, the dichotomous response of private consumption (crowded in by civilian spending and crowded out by military spending) seems robust to this different identification scheme.

In particular, a military spending shock generates a very similar fall in consumption for 3 to 4 quarters, while the civilian spending shocks induces a more persistent increase in consumption, comparable with the previous identification scheme. In response to both types of shocks, real wages also fall, offering further support to a RBC-type transmission mechanism. The main conclusion is that the differentiated response of consumption to defense and non-defense shocks appears robust to whether the government spending is deficit-financed or not.

2.4.3 The Effect of Disaggregation

So far we have claimed that disaggregation matters and that failing to account for the heterogeneity in government spending would obscure these distinct effects. In order to enable comparison with the earlier non-sign VAR literature, we conduct an experiment in which we do not differentiate between types of government spending (as in Blanchard and Perotti

(2001), Perotti (2004), Galí et al. (2005), Bouakez and Rebei (2003), Fatas and Mihov (2001), etc.). We thus consider a 7 variable VAR allowing for one single government spending shock, identified as in Table 2.6, where the restrictions we impose are essentially the same as in Scheme 1.

Figure 2.4 presents the results from this VAR, respectively to a productivity shock, an aggregate government consumption spending shock and a labor supply shock. The conclusion which emerges is that looking at the effects of government spending in aggregate is likely to generate an increase in private consumption, possibly due to the dominant effect of strong positive comovement with the civilian part of government spending (which represents approximately two thirds of total government spending). However, we still do not find evidence supportive of a New-Keynesian transmission mechanism, since the response of real wage is negative in this case as well. The responses to the other shocks are very much in line with the expected dynamics (both from a theoretical and empirical perspective), and furthermore, they are close to the effects to identification schemes 1 and 2. We interpret these results as pointing to the fact that using total government consumption is the main cause why the response of negative private consumption to military spending shocks is obscured in some of the previous studies.

2.4.4 Robustness

The results presented in the previous section may be sensitive to a number of factors, in particular to the choice of variables to be included in the VAR, the sample period and the timing assumptions. We want to investigate more closely whether our main results hold in the context of these deviations from the benchmark specification.

Table 2.6: Sign Restrictions Identification Scheme 3

Variable	*Supply Shocks*		*Demand Shocks*
	Productivity	*Labor*	*Gvt. (total)*
Private Consumption	(+)	(+)	
Private Investment	(+)	(+)	
Hours		(+)	+
Real Wage	+	−	
Gvt. Consumption			+
Output	+	+	+
Prices	+	−	+

Notes: A " + / − " *means that the corresponding impulse response has been restricted to be nonnegative/nonpositive, a blank means no restriction has been imposed. A sign in brackets means that this is the expected IRF sign, however it has not been imposed.*

2.4.4.1 Robustness to Different Measures of Hours and Wages

While the results reported so far have been estimated using non-farm hours and wages, it is important to check whether the conclusion are consistent with other measures of labor market variables which have been used in the literature. Furthermore, sectorial evidence may shed light on the transmission mechanism of fiscal policy, because the effects may be more visible in those sectors where the impact of government spending is larger.

From a theoretical perspective, in a two-sector neoclassical model, in which frictions exist in the reallocation of capital between sectors (such as Ramey and Shapiro (1997)), the sector with the largest increase in government demand experiences an inflow in employment and a decline in the product wage. By contrast, in a New-Keynesian model with nominal price rigidities and some costs of reallocation between the sectors, the sector where the government spending is concentrated experiences the largest increase in the real product wage, as the markup falls more (see, e.g. Monacelli and Perroti (2007)).

In order to control for sectorial effects, using BEA data, we replicate the analysis undertaken before for the business and the manufacturing sectors. We determine real wages in the business sector deflating the average weekly compensation by the value added deflator in the business sector and the real wages in manufacturing by deflating hourly earnings in the sector by the manufacturing PPI (definitions and sources of the variables are found in Appendix II). We use the product wage rather than the consumption wage, based on the findings in Ramey and Shapiro (1997) who show, both empirically and theoretically that this difference matters for defense shocks. As such spending tends to be concentrated in a few industries, mostly manufactured goods, the product wage in the expanding industries may fall at the same time that the consumption wage is unchanged or rising.

We run the benchmark VAR (Identification Scheme I) for these measures and find that the results are robust, not only regarding the response of private consumption, but also of the other variables considered (see Figures 2.5 and 2.6). In particular, defense spending shocks seem to have a more negative effect on manufacturing wages and lead to a more persistent response in hours. This is consistent with the fact that military expenditures are to a large extent concentrated on the manufacturing sector. The effect of civilian spending shocks on the various sectors does not appear to be significantly different, possibly as a result of the fact than this part of government expenditures is more broadly distributed across various goods and services.

2.4.4.2 Changes in the Effects of Government Spending Shocks over Time

A number of studies (Galí et al. (2005), Blanchard and Perotti (2001), Fatas and Mihov (2001), Perotti (2004), Perotti (2007), etc.) have pointed out that the effects of fiscal policy in the postwar US economy have moderated over time. The discussion of the data in the Introduction reveals shocks to government spending (both defense and non-defense) seem to have become smaller, in particular after the early 1960s. In the period from the end of WWII until the 1960s, the standard deviation of the quarterly military spending growth rate has a number of times exceeded 10 percent, while the standard deviation of civilian government spending growth has also been higher than 5 percent on several occasions. After the 1960s however, the quarterly standard deviation of both components of government spending has more than halved.

In this section we investigate how the response of consumption to military and non-military shocks changes if one excludes the more volatile period until the end of the Korean war (we cut the sample in 1954:Q1). In order to enable the comparison, we present in Tables 2.7 and 2.8 the multipliers on consumption and output for the full and the reduced sample for both types of shocks, differentiated according to the timing[10].

The following conclusions emerge. Military government spending shocks have stronger negative multipliers on consumption in the full sample. In the post-Korean war period the crowding-out effect is stronger on impact, but relatively weak at longer horizons and may be even positive. Civilian spending shocks, on the other hand, have consistently positive and relatively large multipliers on private consumption. There is at the same time no strong evidence that the impact of non-defence shocks on private consumption has increased over time.

Regarding the effects on output, both shocks are found to have positive multipliers over both samples at almost all maturities (there seems to be an exception, regarding military spending shocks, which may have contractionary effects on output in the long-run). At the same time, the expansionary effects of civilian spending shocks appear to be significantly larger than those of military shocks, thus, civilian spending seems to be a better way to stimulate the economy.

In general, the values we find for the multipliers are in line with the ones computed for total government spending or total government consumption in other papers using other types of VAR identification (see, e.g. Galí et al. (2005), Blanchard and Perotti (2001), Fatas and Mihov (2001), Perotti (2004), Mountford and Uhlig (2002), Perotti (2007), etc.). In par-

[10] The multipliers are calculated according to the formula: multiplier for variable X = $\frac{\text{Response of Variable X at } t=k}{\text{Initial Government Spending Shock at } t=0} / \frac{\text{Long-run Share of Variable X in GDP}}{\text{Long-run Share of Government Spending Shock in GDP}}$. The multipliers can be interpreted as the effect in dollars of a one dollar increase in spending in the first quarter.The following long-term shares are used: consumption - 0.65, investment - 0.18, military government consumption - 0.06, civilian government consumption - 0.12.

ticular, while some papers have occasionally documented negative multipliers of government spending shocks (e.g. Galí et al. (2005)), this paper shows that such effects are dominant for military spending. Also, a negative long-term impact of government spending shocks on output has been found in Perotti (2004), which, again, according to our results, can to a large extent be attributable to military spending shocks.

2.4.4.3 The Effect of Anticipated Fiscal Shocks

So far we have shown that a negative response of private consumption to defense spending shocks is consistent with such shocks being identified through contemporaneous restrictions. However, changes in public spending may often be anticipated by up to several quarters before the actual expenditure increases, due to the decision and implementation lags typical in fiscal policy. Thus, if anticipation effects would be important, this may imply that, even if we are capturing the correct sign of the impulse responses, quantitatively the effects may be different.

In a recent paper, Ramey (2007) finds that Ramey-Shapiro war episodes Granger cause VAR military spending shocks, thus VAR shocks suffer from an incorrect timing and are capturing a delayed effect. This point is observed quite clearly from some graphs in Ramey (2007), which we report here for convenience (see Figure 2.7). In the pictures, the same quarterly VAR is identified first using a Cholesky ordering, with government spending ordered first, and second using the war dummies, in which the current dummy and four lags of the dummy variable for the military date are included. The figures show quite clearly that overall, the recursive VAR captures the response to the VAR dummies with a two to four quarters lag.

The "correct" moment of impact which one would like to capture is when the shocks become common knowledge, that is, when the agents internalize the negative wealth effect and start adjusting their behavior. Precisely identifying such a moment may be difficult, on the one hand because expectations are hard to measure, and on the other hand because there may not be one unique shock (but rather a sequence of smaller spending shocks).

For these reasons, we do not take a stance on precisely when expectations of fiscal policy adjust, but instead conduct several experiments taking as guiding values the "anticipation" leads found by Ramey (2007) (i.e. 1 to 4 quarters). For the case of defense shocks, Ramey (2007) finds that professional forecasts from *Business Week* and the Survey of Professional Forecasters anticipate the VAR defense spending shocks by up to four quarters. However, this observation can be reasonably extended to non-defense spending, which consists mostly of public programs which are also well known in advance.

In order to account for such anticipation effects, we modify our original sign restrictions strategy in a manner originally suggested by Mountford and Uhlig (2002). We restrict the increase in government spending to be zero for several periods after the shock (we experiment with 1 to 4 quarters) and to increase for 4 periods afterwards. At the same time, we allow the other macroeconomic variables to react immediately after the shock, according to the restrictions discussed in the previous sections.

Assuming a delayed response to government spending shocks identified as in Scheme I, we find that the impulse responses are very similar in shape to those reported in Figures 2.1 and 2.2, nevertheless, the impact effects are different. In order to assess these changes, in Table 2.9 we report the median, the 16th and 84th percentiles of the impact multipliers for consumption and output. The following conclusions emerge.

If agents are assumed to respond to news regarding fiscal policy, the estimated effects of public spending shocks are significantly larger. The response of consumption on impact to the civilian government spending shock is larger the sooner such shocks are incorporated into agent's behavior. The same is true for output, which rises more than proportionally 3 to 4 quarters prior to the government spending itself.

The second part of the Table 2.10 reports the multipliers to anticipated military spending shocks. These again reinforce the crowding out of private consumption effect found before, however, the response is larger the longer in advance these shocks are assumed to be known (the largest multiplier is 3 quarters in advance at -0.28). The multipliers on output gradually increase as the anticipation effect is smaller, pointing to a positive and humped response of output to defense shocks. The expansionary effects of military shocks thus appear to be more protracted and overall significantly smaller than those of civilian spending.

These results overall seems to lend support to the hypothesis that the sign VAR captures the corresct response of private consumption from a qualitative perspective, while missing the correct timing of the shocks by not capturing the anticipation effects seems to have mainly quantitative implications on the size of the public spending multipliers.

2.4.5 Comparison with Some of the Recent Literature

This paper investigates two main explanations for the current puzzle regarding the response of private consumption to government spending shock: the effect of disaggregation and the possibility of faulty timing. A number of recent papers are closely related in terms of main ideas.

Concerning ways of disaggregating government spending, Galí et al. (2005) study the effects of fiscal spending shocks using two measures of government spending (including and excluding defense), finding that the size of the multipliers is larger when military spending is excluded. However, Galí et al. (2005) do not explore whether their result would be due to the fact that defense expenditures may have negative multipliers on private consumption.

Perotti (2007) distinguishes between civilian and military shocks, however, he uses government spending, comprising of both consumption and investment. In a recursive VAR identification, he finds that civilian spending shocks crowd in private consumption strongly, while military spending shocks also crowd in private consumption, but much less or possibly insignificantly. However, it is not clear why one would include government investment in a VAR which is particularly concerned with the response of private consumption or whether this would somehow affect the identification of the shocks.

Ramey (2007) follows a similar disaggregation to Perotti (2007) into defense and non-defense government spending, finding that Cholesky identified military spending shocks have an insignificant response on consumption, while total government spending shocks have a strongly positive one. However, war dummies identified defense shocks have a clear negative effect on consumption. To reconcile this apparent contradiction, Ramey (2007)'s main argument is that it is due to the timing of the shocks, in that the recursive VARs misses the impact, compared to the war dummies approach, leading to opposite prediction regarding the response of both wages and consumption. Our results confirm the importance of timing, in the sense that allowing for anticipation effects magnifies the impact of government spending shocks. However, from our results it appears that the correct disaggregation is the main factor behind explaining the qualitative response of private consumption, respectively the crowding-out by defense shocks and the crowding-in by non-defense shocks.

2.5 Conclusion

This paper contributes to the debate on the effects of government spending shock on consumption by offering two main conclusions which go a long way towards explaining the puzzle. First, we show that the response of private consumption depends on the type of expenditures considered, with military consumption spending generating a crowding-out consistent with neoclassical models, while civilian consumption having expansionary effects on consumption. The latter finding, however, cannot be interpreted as supportive of New-Keynesian models, since we find that in response to both government spending shocks real wages (measured across a number of sectors) decline.

Second, we find evidence that the anticipation of fiscal shocks is important in determining the magnitude of the impact response. In particular, if fiscal shocks are known for several quarters, the response of private consumption is stronger (both positive and negative, since the expectations further magnify the opposite effects of defense and non-defense shocks). In this respect, employing an identification methodology which can take into account the formation of expectations by the private sector (such as the sign restrictions) seems to be of particular relevance in quantifying the effects of government spending shocks, although more work remains to be done in identifying the correct timing.

2.6 APPENDICES

2.6.1 Appendix A. Definitions and Sources of the Variables in the VAR

The model is estimated using quarterly data (1948:1-2005:4) for the US economy from the Bureau of Economic Analysis NIPA databases and US Department of Labor Bureau of Labor Statistics (BLS). The series representing components of output are seasonally adjusted, in real (deflated by the GDP deflator) per capita terms (normalized by working age population) and have been logged. Interest rates are in percentage points, prices are indices and have been also logged. We have not applied any filtering.

Output: this is 'Real Gross Domestic Product' (NIPA Table 1.5.6)

Private Consumption: this is 'Personal Consumption Expenditures' (NIPA Table 1.5.6)

Private Investment: this is 'Gross Private Domestic Investment' (NIPA Table 1.5.6)

Military Government Consumption Spending: this is 'Real National Defense Consumption Expenditures (NIPA Table 3.11.6)

Non-military Government Consumption Spending: this is computed as the difference between Real Government Consumption Expenditures (NIPA Table 3.9.6) and Real National Defense Consumption Expenditures (NIPA Table 3.11.6)

Tax Revenues: this is 'Government Current Receipts' (NIPA Table 3.1) minus 'Net Transfer Payments' (NIPA Table 3.1) and minus 'Net Interest Paid' (NIPA Table 3.1)

Government Surplus: this is the difference between 'Government Current Receipts' and 'Current Expenditures' (NIPA Table 3.1)

Hours: several measures are used, namely: 'Average Weekly Hours of Production Workers, Manufacturing' (BLS Series Id: EES30000005), 'Average Weekly Hours of Production Workers, Goods-producing' (BLS Series ID: CES0600000005), 'Business Sector: Hours of All Persons' (BLS Series ID: HOABS), 'Nonfarm Business Sector: Hours of All Persons' (BLS

Series ID: HOANBS)

Real Wage: several measures are used, defined as: 'Average Hourly Earnings of Production Workers Manufacturing' (BLS Series ID: EES30000006), 'Business Sector: Real Compensation Per Hour' (BLS Series ID: RCPHBS), 'Business Sector: Unit Labor Cost' (BLS Series ID: ULCB), 'Nonfarm Business Sector: Unit Labor Cost' (BLS Series ID: ULCNFB).

Prices: we use both the 'Consumer Price Index' and 'GDP Deflator' (NIPA Table 1.1.4)

Labor Force: this is 'Civilian Labor Force Level' (DOL Series ID: LNS11000000Q)

2.6.2 Appendix B. The Sign Restrictions Methodology

In spite of the success and popularity of VARs as a tool for macroeconometric analysis, the method of identification employed in VARs has always been subject of considerable debate. This has not lead to the demise of the VARs as such, but rather to refinements in the direction of making the identification less mechanic and more flexible to model and data-implied dynamics.

2.6.2.1 General VAR Estimation

As is well known, the main problem with using VARs to derive statistical conclusions rests in the identification procedure, which translates the reduced form residuals into a series of orthogonal structural shocks, to which the researcher attributes a specific macroeconomic interpretation. Starting with a structural model:

$$y_t = \sum_{i=0}^{p} A_i y_{t-i} + u_t$$

where A_i are the structural coefficients and u_t are the structural shocks, assumed to be mutually orthogonal, i.e. $E(u_t u_t') = I_n$.

The corresponding reduced for model is:

$$(I_n - A_0)y_t = \sum_{i=1}^{p} A_i y_{t-i} + e_t$$

where $e_t = (I_n - A_0)^{-1}u_t = Bu_t$ represent the reduced-form shocks and $B = (I_n - A_0)^{-1}$ represents the impact matrix of a one standard deviation of the structural innovation to the corresponding fundamental innovation. Also, let $\Omega = E(e_t e_t')$ and $\Pi_i = (I_n - A_0)^{-1}A_i = BA_i$ represent the reduced-form coefficient matrices. Define $\Pi(L) = I_n - \Pi_1 L - \Pi_2 L^2 - ... - \Pi_p L^p$,then the moving average matrix is given by $C(L) = \Pi(L)^{-1}$, with $C_0 = I_n$, so that the infinite moving average representation (MAR) of y_t is:

$$y_t = \Pi(L)^{-1}e_t = C(L)e_t = \sum_{s=0}^{\infty} C_s e_{t-s}$$

where the lag polynomial $C(L) = I_n + C_1 L + C_2 L^2 + ...$, and C_i represent the impulse responses of y_t to a unit change in e_t. The C_i matrices are determined by recurrent relationships in the following manner:

$$\begin{aligned} C_1 &= \Pi_1 C_0 \\ C_2 &= \Pi_1 C_1 + \Pi_2 C_0 \\ &\vdots \\ C_j &= \Pi_1 C_{j-1} + ...\Pi_p C_{j-p} \end{aligned}$$

If we are interested in writing y_t in terms of structural shocks, this is equivalent to:

$$y_t = \sum_{s=0}^{\infty} C_s B u_{t-s} = \sum_{s=0}^{\infty} D_s u_{t-s} = D(L)u_t$$

As $D(L)$ can be easily estimated by OLS, the identification problem of the VAR reduces to the estimation of the matrix A_0 which gives the matrix $B = (I_n - A_0)^{-1}$ linking contemporaneously the reduced form residuals to the structural shocks.

As the structural shocks are mutually orthogonal, the variance-covariance matrix Ω can be decomposed as:

$$\Omega = E(e_t e_t') = E(Bu_t u_t' B') = BB'$$

The historical decomposition takes the following form:

$$y_{t+j} = \sum_{s=0}^{\infty} D_s u_{t+j-s} = \sum_{s=0}^{j-1} D_s u_{t+j-s} + \sum_{s=j}^{\infty} D_s u_{t+j-s}$$

The last term represents the baseline projection, that is, the expectation of y_{t+j} given the information available at time t. The first term represents the difference between the realized series and the baseline projection due to the structural innovations in the variables subsequent to t, which is composed of the weighted sum of the contributions of each structural innovation to the system variables. In other words, we need to pick a base point moment in time, until which the model is estimated. Based on this model, the perfectly rational agents would predict that the economy would evolve according to the baseline projection. Their error would be made up by the structural innovations, which are the unpredictable shocks hitting the economy.

For the forecast error variance decomposition, the contribution of orthogonal innovations to a shock j to the variables y_t^i at horizon τ is computed as follows:

$$\varphi^{\tau}(i,j) = \frac{\sum_{s=0}^{\tau-1}(c_s^{ij})^2}{\sum_j \sum_{s=0}^{\tau-1}(c_s^{ij})^2}$$

2.6.2.2 Implementation of the Sign Restrictions Methodology

The traditional VAR literature imposes a minimum of $n(n-1)/2$ restriction on the matrix B. This can be done through various short-term and/or long-term restrictions, such as: the recursive ordering of the variables in the VAR in the Cholesky decomposition, imposing short-term structural relationships (e.g. Bernanke (1986) and Blanchard and Watson (1986)), long-term structural relationships (e.g. Blanchard and Quah (1989)) or via a combination of short-term and long-term structural relationships (e.g. Galí (1992)).

As the imposition of rigid short-term or long-term restrictions is sometimes questionable, recent work has instead turned towards the use of prior information and of sign restrictions, which allow the data more flexibility to speak for itself. In particular, the sign restrictions methodology, pioneered by Faust (1998), Canova and de Niccolo (2002) and Mountford and Uhlig (2002) for monetary policy avoids the sometimes questionable restrictions by using more diffuse theoretical and empirical priors, which are generally derived from the simulation of theoretical models or from (other) empirical evidence.

The variant of the sign restrictions methodology that we apply consists in a number of steps. We start the procedure from decomposing the variance-covariance matrix of the reduced for residuals Ω according to the eigenvalue-eigenvector decomposition. Let $\Omega = PDP'$, where P is the matrix of eigenvectors and D a diagonal matrix with the eigenvalues on the main diagonal, $B = PD^{\frac{1}{2}}$. The aim is to find decompositions into orthogonal shocks which satisfy all the *a priori* restrictions. For this purpose, we use as a starting point the eigenvalue-eigenvector decomposition, which we check whether it satisfies all the restrictions imposed. Even if it does not, there exists an infinity of orthogonal matrices Q, such that $QQ' = I_n$, for which

$$\Omega = BQQ'B'$$

such that different decompositions into structural shocks can be found. The essence of the iterative procedure procedure essentially consists in finding a method through which the entire space of orthogonal Q matrices is searched for solutions. To this effect we use rotation matrices which are defined in the following manner.

Let $Q_{m,n}(\theta_i)$ be a rotation (Givens) matrix of the form:

$$
Q_{m,n}(\theta_i) = \begin{pmatrix} 1 & ... & 0 & ... & 0 & ... & 1 \\ ... & \ddots & ... & ... & ... & ... & ... \\ 0 & ... & \cos(\theta_i) & ... & -\sin(\theta_i) & ... & 0 \\ \vdots & \vdots & \vdots & 1 & \vdots & \vdots & \vdots \\ 0 & ... & \sin(\theta_i) & ... & \cos(\theta_i) & ... & 0 \\ ... & ... & ... & ... & ... & \ddots & ... \\ 0 & ... & 0 & ... & 0 & ... & 1 \end{pmatrix} \tag{2.1}
$$

where $\theta_i \in [0, \pi]$, m and n are the indices corresponding respectively to the row and column which are rotated by the angle θ_i. It is easy to see that Givens matrices are orthogonal, thus they can be used to uncover equally valid decompositions of the reduced form variance-covariance matrix. Moreover, products of Givens matrices are also orthogonal.

In order to reduce an infinite problem to a finite one, we discretize the range for $\theta_i \in [0, \pi]$ into a grid of M=100 points and devise an algorithm which covers all possible combinations of angles θ_i thorough an iterative scheme. With n variables in the model, there are $n(n-1)/2$ bivariate rotations of the different elements of the VAR by every single angle θ_i. Further, we consider $n(n-1)/4$ combinations of bivariate rotations, by the same angle. We also implement combinations of bivariate rotations by 2, 3 and respectively 4 angles (the latter only for a 8 variable VAR).

For example, a bivariate rotation is constructed in the following manner. For the rotations by one angle, two variables (rows m and n) are rotated, keeping the other fixed, which is obtained covering all orthogonal combinations of the type:

$$Q_{m,n}(\theta) = \begin{pmatrix} 1 & ... & 0 & ... & 0 & ... & 1 \\ ... & \ddots & ... & ... & ... & ... & ... \\ 0 & ... & \cos(\theta)_{n,n} & ... & -\sin(\theta)_{n,m} & ... & 0 \\ \vdots & \vdots & \vdots & 1 & \vdots & \vdots & \vdots \\ 0 & ... & \sin(\theta)_{m,m} & ... & \cos(\theta)_{m,n} & ... & 0 \\ ... & ... & ... & ... & ... & \ddots & ... \\ 0 & ... & 0 & ... & 0 & ... & 1 \end{pmatrix} \tag{2.2}$$

Moving on, pairs of bivariate rotations are generated in the following way. Four variables are rotated, pair-wise, while keeping the orthogonality condition satisfied. They can be rotated by the same angle or by different angles. An example which rotates the row pairs (m, n) and respectively (p,q) is

$$Q_{(m,n),(p,q)}(\theta_i, \theta_j) = \begin{pmatrix} 1 & ... & 0 & ... & 0 & ... & 1 \\ ... & \ddots & ... & ... & ... & ... & ... \\ 0 & ... & \cos(\theta_i)_{n,n} & -\sin(\theta_i)_{n,m} & ... & ... & 0 \\ \vdots & \vdots & \sin(\theta_i)_{m,m} & \cos(\theta_i)_{m,n} & \vdots & \vdots & \vdots \\ 0 & ... & ... & ... & \cos(\theta_j)_{p,p} & -\sin(\theta_j)_{p,q} & 0 \\ ... & ... & ... & ... & \sin(\theta_j)_{q,q} & \cos(\theta_j)_{q,p} & ... \\ 0 & ... & 0 & ... & 0 & ... & 1 \end{pmatrix} \tag{2.3}$$

The same procedure is conducted to define triples of bivariate rotations and respectively quadruples of bivariate rotations.

For each of these matrices, we verify whether the restrictions are satisfied, that is, for each grid point we check the sign of the impulse responses of variable i to a shock j at time t for up to 4 quarters after the shock ($k = 1, 2, 3, 4$), which can generally be written as

$$R^i_{j,t+k} = \Pi(L)^{-1} B u^i_{j,t} \lesseqgtr 0$$

We select the decompositions which match the imposed sign restrictions on *all* shocks, while we eliminate those which match only partly the constraints. The method can be made more or less stringent by imposing signs of impulses for more or fewer periods k, which would have a bearing on the shape of the impulse response function.

Computation of the error bands is done in the following fashion: we bootstrap the reduced form residuals and the variance covariance matrix and re-run the VAR for each draw, checking the imposed restrictions each time as described above. Solutions that match all the restrictions are kept and the rest are discarded. The former are then ordered period-by-period and we extract the median, the 95 and respectively the 64 percentile bands (to enable comparison with the literature, which reports both).

2.6.2.3 Comparison with Related Sign Restrictions Papers

Within the sign restrictions literature, some variability exists in terms of the precise implementation of the procedure. Our identification strategy is what Uhlig (2005) calls a "pure" sign restrictions approach and is most closely related to the approaches in Peersman and Smets (2001), Canova and de Niccolo (2002), Peersman and Straub (2004), Peersman and Straub (2006) and Barnett and Straub (2007). An alternative identification is the penalty-function approach (as in Faust (1998), Mountford and Uhlig (2002) and Uhlig (2005)), which minimizes a criterion function which penalizes impulse responses deviating from their desired restrictions[11].

[11] Uhlig (2005) discusses some of the advantages and disadvantages of each method. The pure sign restrictions approach is "cleaner". The penalty function approach implies a degree of arbitrariness in choosing the functional form and it would be desirable to test the sensitivity of results to this choice, in particular since there is not clear econometric basis for choosing one function over another. The penalty function approach is generally implemented in such a way that large impulses away from the sign restriction are given more weight than small deviations, thus, the error bands tend to be narrower. As a matter of fact, the range of impulses selected by the penalty-function approach is a subset of the impulses retained by the pure-sign-restrictions approach. The choice of whether this "*sharpening*" of results is economically meaningful or not rests with the researcher.

Additionally, this paper employs restrictions on a number of periods after the onset of the shock (similar to Mountford and Uhlig (2002), Dedola and Neri (2004), Uhlig (2005), Peersman and Straub (2004) and Peersman and Straub (2006), etc.), while other papers use impact restrictions (see e.g. Faust (1998), Barnett and Straub (2007), etc.)

2.6.2.4 Advantages and Limitations of the Methodology

The sign identification possesses several advantages over traditional VAR identification schemes. While not being totally "agnostic", this procedure has the potential advantage of being more robust than classical VAR identification strategies, in that it identifies an entire set of potential solutions which, if one believes the generally lax restrictions, are bound to contain the true solution.

A number of limitations and caveats need to be exercised when applying the signs methodology and interpreting its results. In particular, the restrictions which are placed are rather weak information (essentially qualitative in nature) which may not be sufficient in order to generate sufficiently sharp predictions. The researcher needs to weigh the trade-off between imposing tighter restrictions (or somehow limiting the space of possible solutions through some weighting procedure, such as in the penalty function approach) versus allowing the data more freedom. This is a case-by-case procedure and substantial degree of experimentation is generally involved. However, as Uhlig (2005) points out "*there seems to be a degree of circularity in the way the literature currently draws its conclusions*". That is, there is the danger is that the experimentation process involved in choosing the impulse responses which match the constraints would produce the results that one is expecting. Robustness exercises and cross-checking with results from other methodologies seem particularly important to validate the results.

Figure 2.1: Impulse Responses to Identification Scheme 1 (Part I)

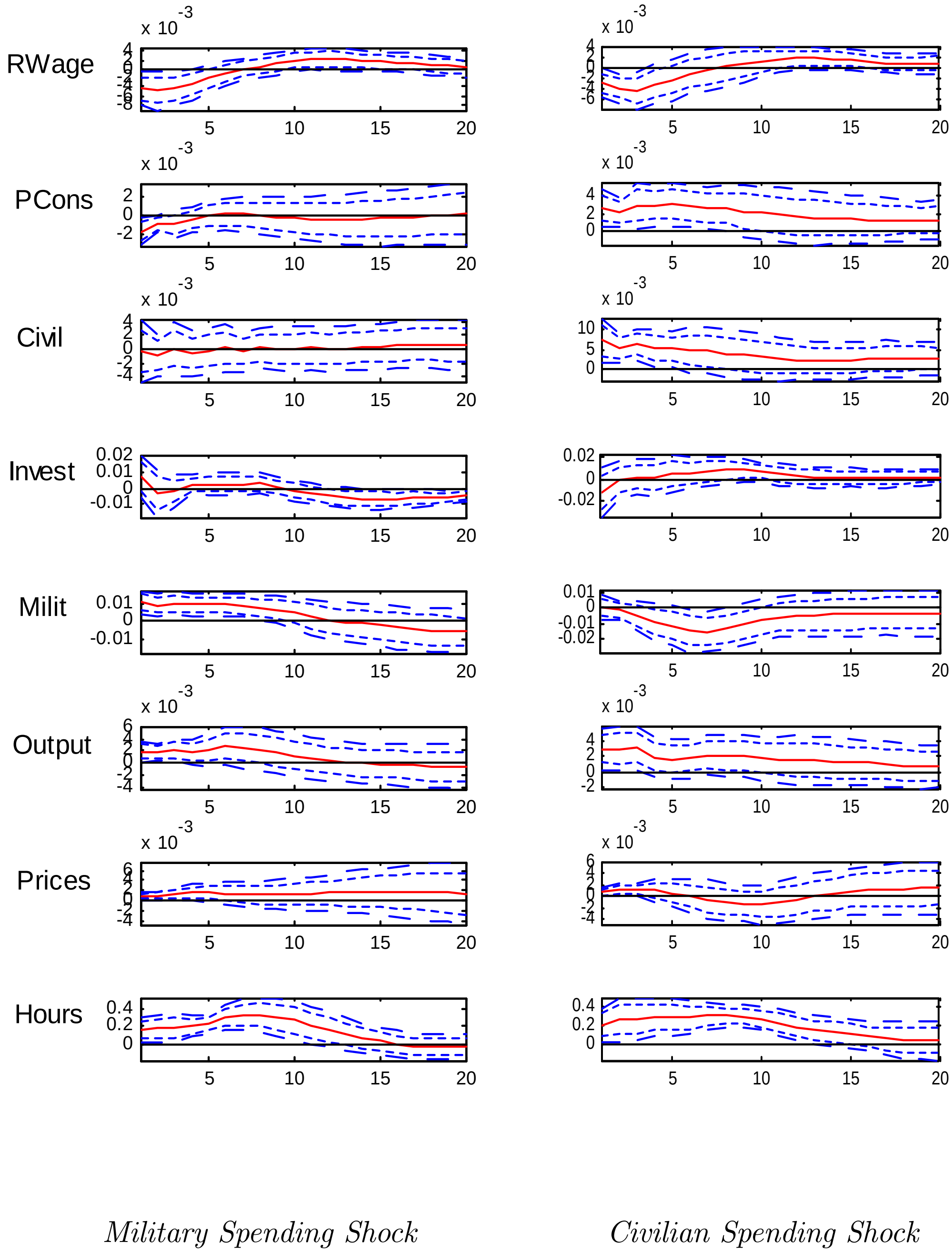
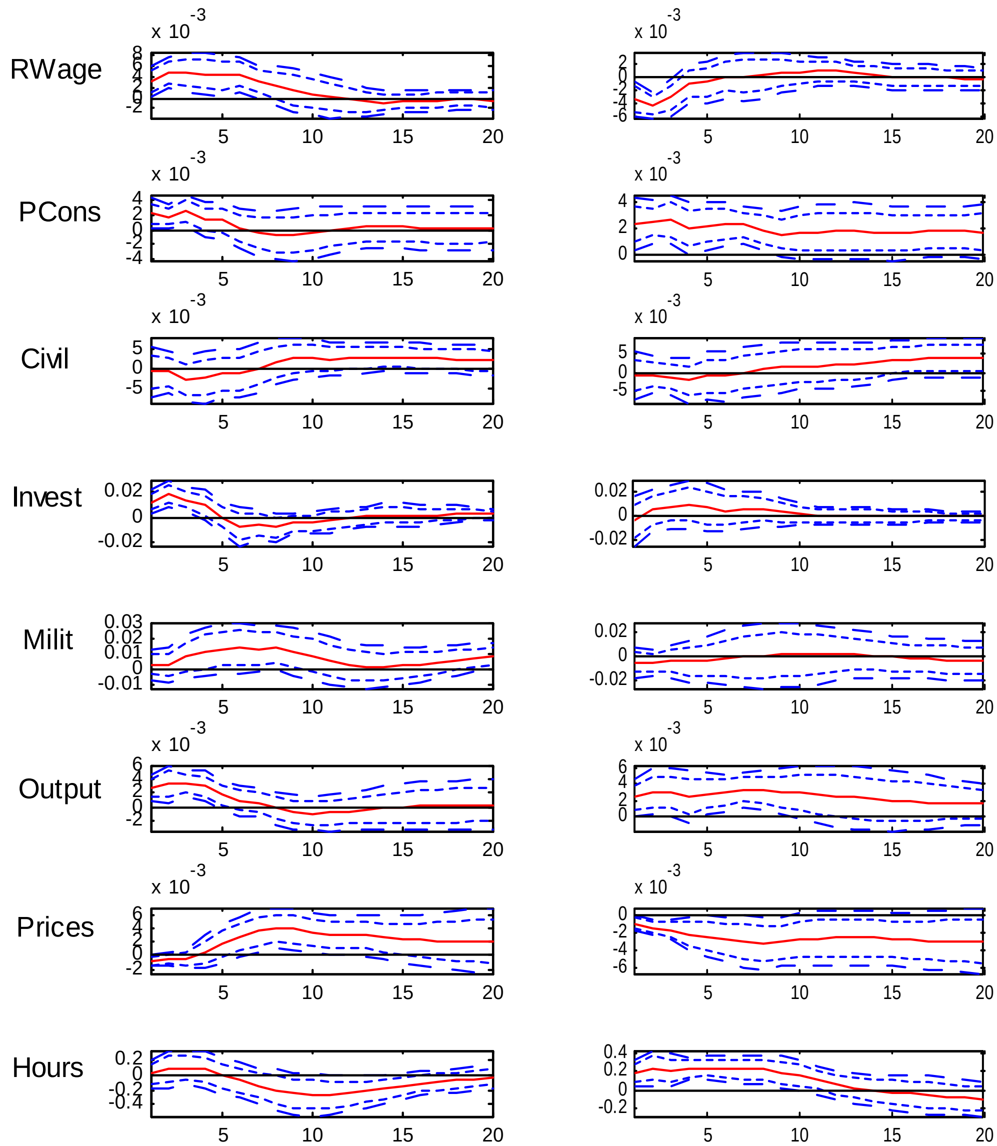
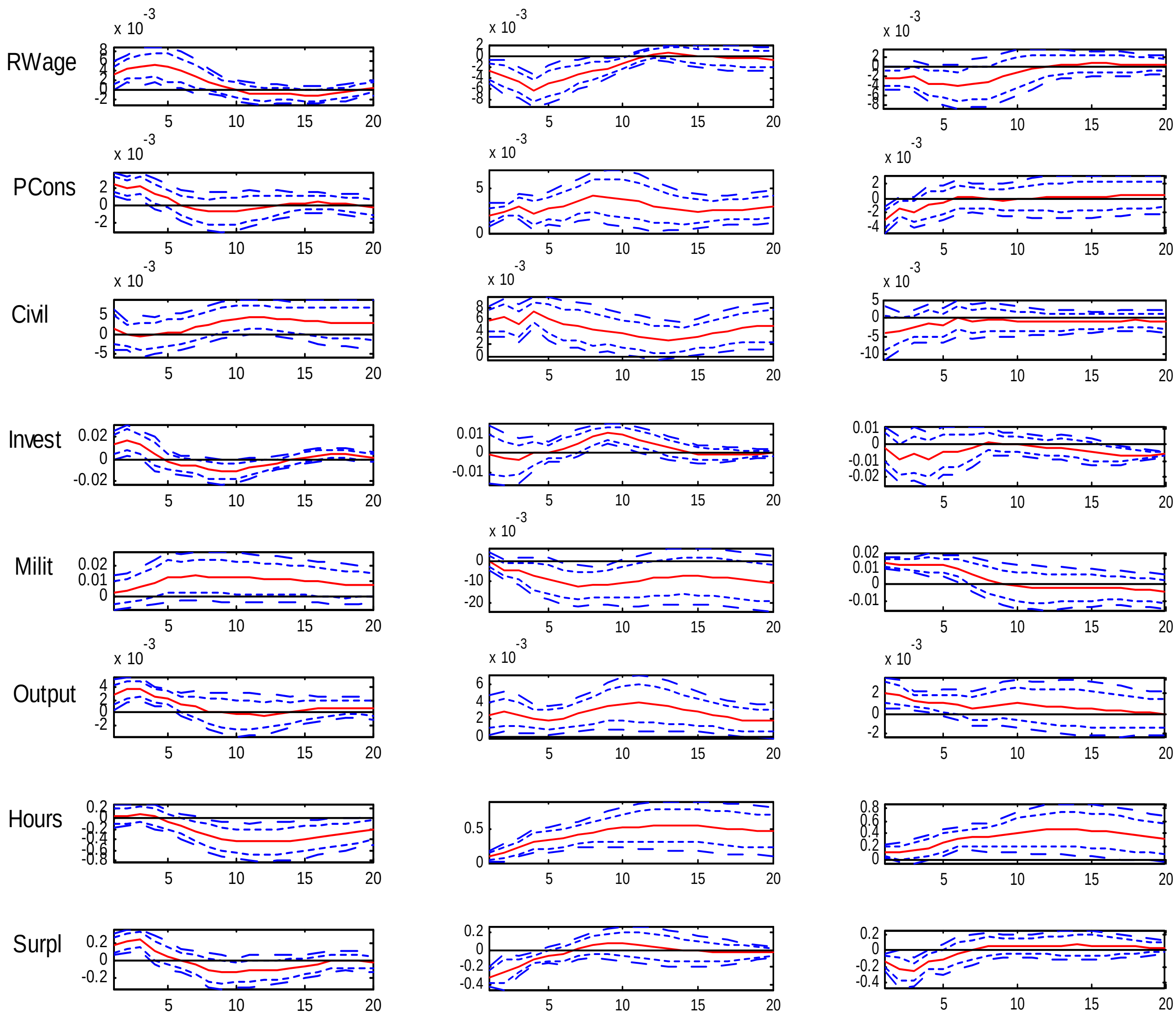


Figure 2.2: Impulse Responses to Identification Scheme 1 (Part II)



Productivity Shock *Labor Supply Shock*

Figure 2.3: Impulse Responses to Identification Scheme 2



Productivity Shock *Civilian Spending Shock* *Military Spending Shock*

Figure 2.4: Impulse Responses to Identification Scheme 3

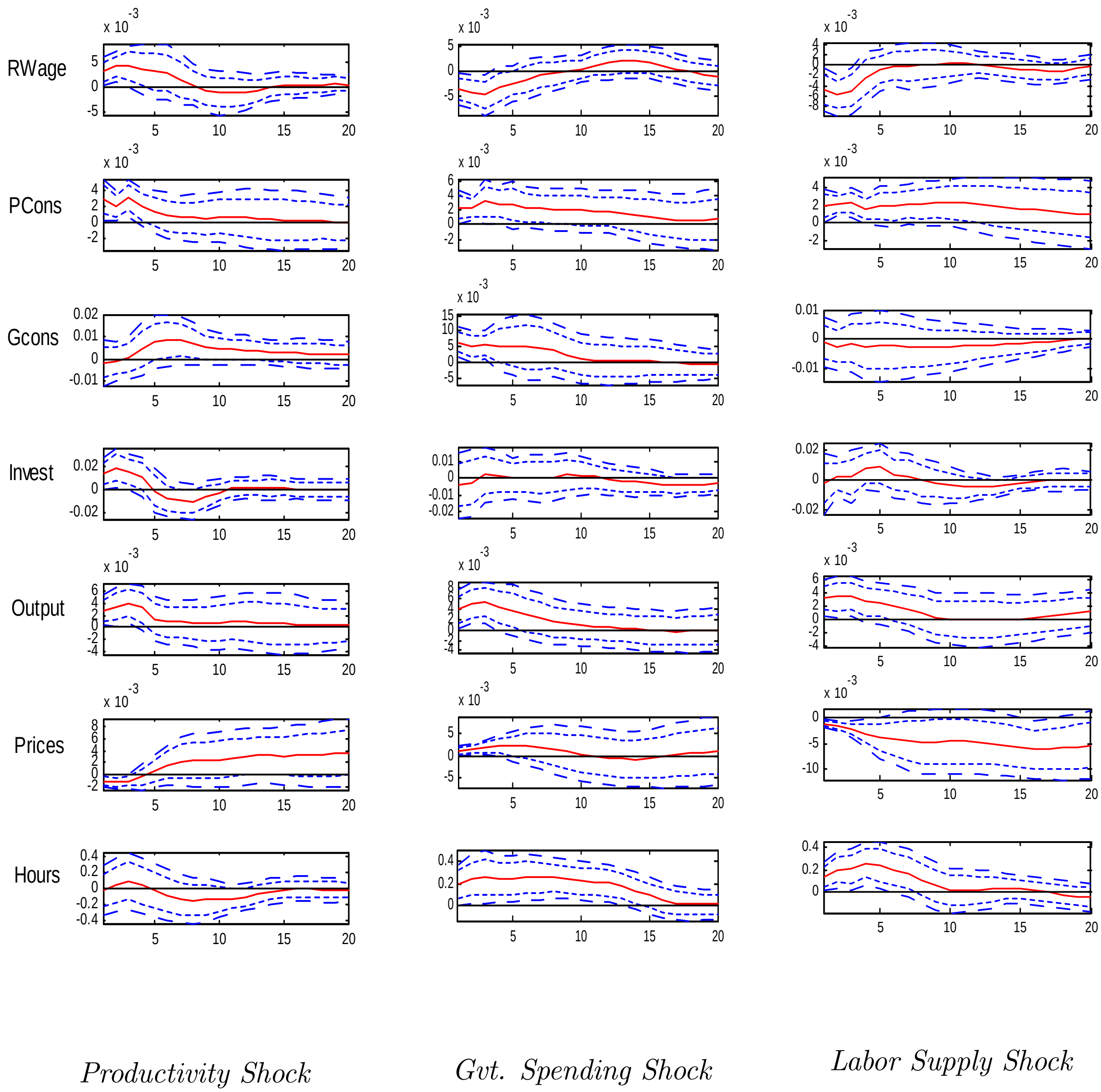
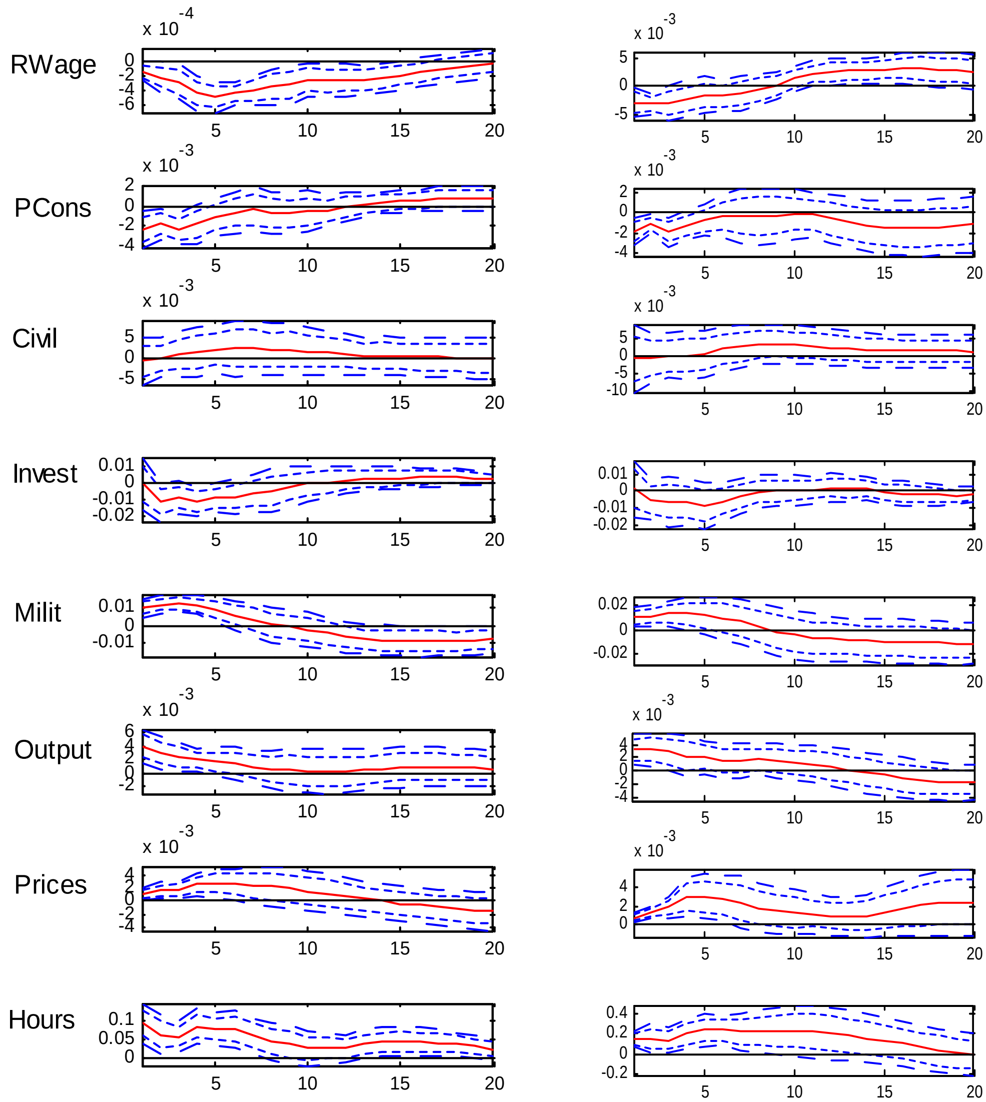
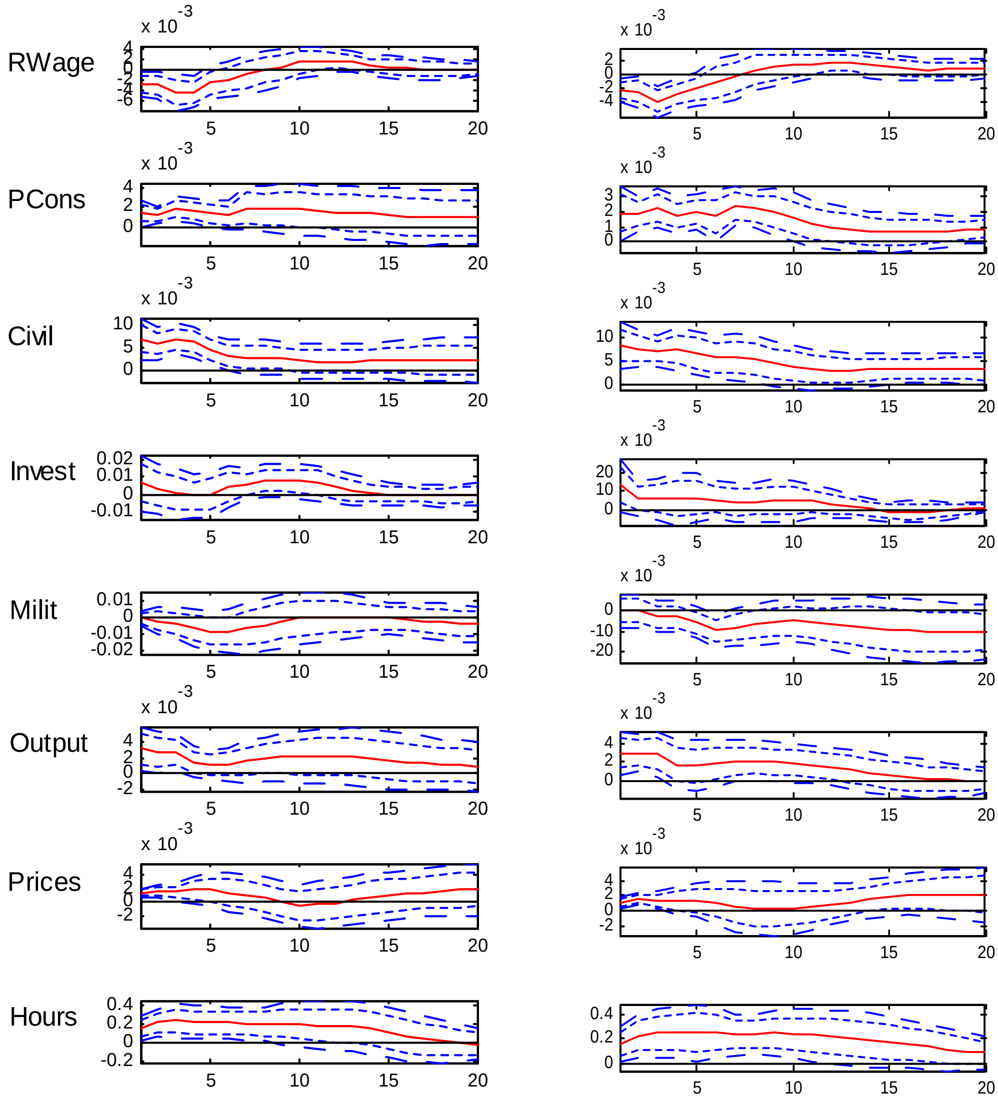


Figure 2.5: Robustness to Sectoral Differences - Military Shock



Manufacturing sector *Business sector*

Figure 2.6: Robustness to Sectoral Differences - Civilian Shock



Manufacturing sector *Business sector*

Table 2.7: Estimated Fiscal Multipliers - Consumption

Shocks	Impact	Maximum	Long-term (>5y)
		1948:I-2005:IV	
Defense	-0.16 [-0.40, -0.04]	0.00 [-0.15, 0.11]	-0.08 [-0.25, 0.06]
Civilian	0.27 [0.21, 0.33]	0.57 [0.56, 0.60]	0.20 [-0.20 0.36]
		1954:I-2005:IV (post-Korea)	
Defense	-0.09 [-0.25, 0.05]	0.04 [-0.08, 0.14]	0.00 [-0.12, 0.16]
Civilian	0.30 [0.15, 0.45]	0.49 [0.37, 0.60]	0.26 [0.15 0.39]

Note: Based on the IS1. The median responses are reported first, 16th and respectively 84th percentiles are in the brackets

Table 2.8: Estimated Fiscal Multipliers - Output

Shocks	Impact	Maximum	Long-term (>5y)
		1948:I-2005:IV	
Defense	0.20 [0.09, 0.31]	0.23 [0.20, 0.26]	-0.12 [-0.36, 0.03]
Civilian	0.44 [0.28, 0.50]	0.78 [0.58, 1.02]	0.22 [0.00, 0.42]
		1954:I-2005:IV (post-Korea)	
Defense	0.15 [0.04, 0.24]	0.42 [0.16, 0.68]	0.03 [-0.15, 0.23]
Civilian	0.56 [0.35, 0.79]	0.96 [0.68, 1.30]	0.52 [0.32, 0.70]

Note: Based on the IS1. The median responses are reported first, 16th and respectively 84th percentiles are in the brackets

Figure 2.7: Comparison of Impulse Responses to a Government Spending Shock from a VAR versus a War-Dummies Identification, from Perotti (2007)

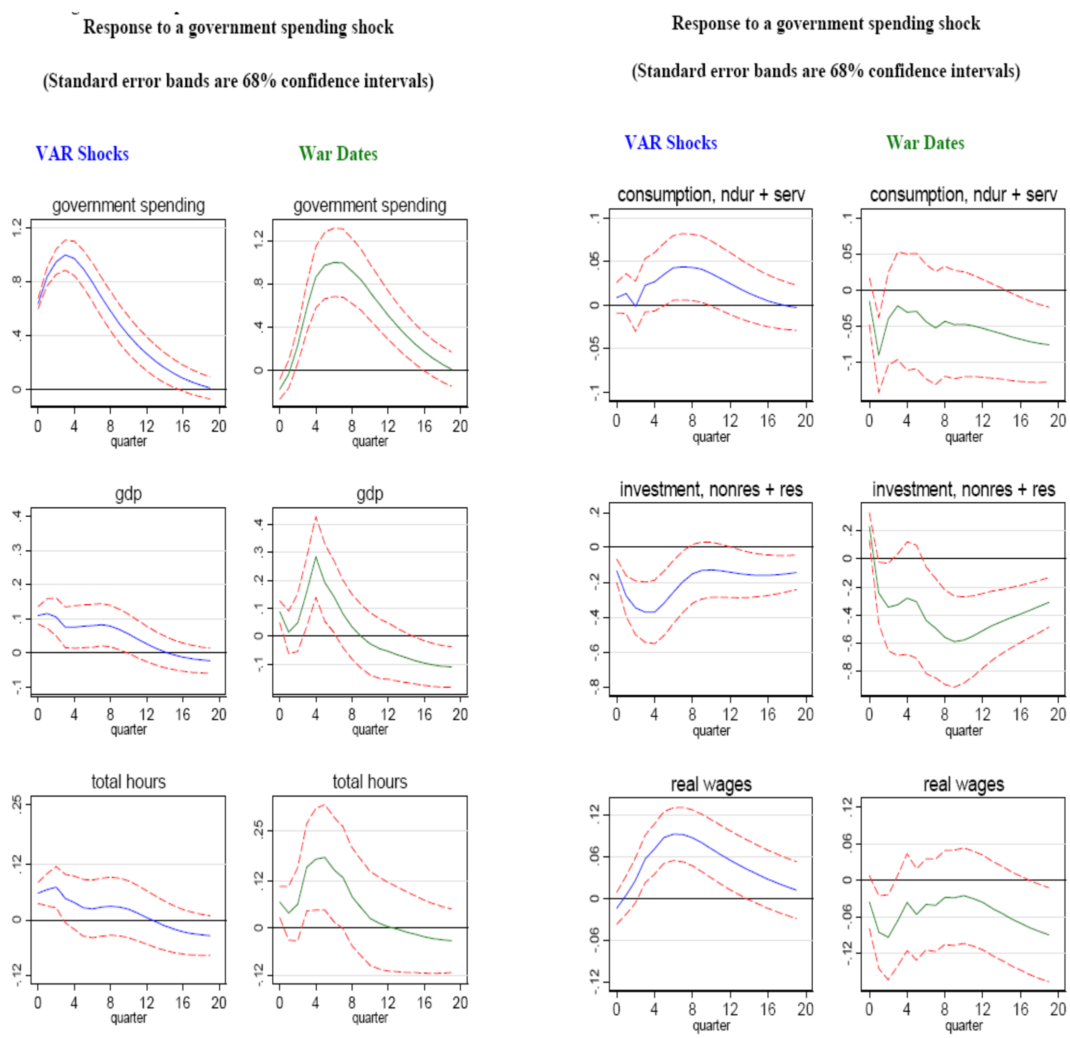


Table 2.9: Impact Multipliers to Anticipated Civilian Shocks

Anticipation	**Consumption**	**Output**
1 quarter	0.33 [0.20, 0.45]	0.53 [0.34, 0.72]
2 quarters	0.40 [0.24, 0.58]	0.84 [0.67, 0.91]
3 quarters	0.55 [0.43, 0.67]	1.15 [0.94, 1.36]
4 quarters	0.65 [0.34, 0.78]	1.37 [1.23, 1.64]

Table 2.10: Impact Multipliers to Anticipated Military Shocks

Anticipation	**Consumption**	**Output**
1 quarter	-0.12 [-0.23,-0.04]	0.22 [0.05,0.39]
2 quarters	-0.24 [-0.41,-0.05]	0.18 [0.02 0.34]
3 quarters	-0.28 [-0.39,-0.16]	0.13 [0.04 0.23]
4 quarters	-0.15 [-0.30, 0.02]	0.03 [0.00 0.08]

Chapter 3

The Response of Private Consumption to Government Spending Shocks - An Explanation from the Optimal Neoclassical Perspective

3.1 Introduction

The evidence on the effects of government expenditures on private consumption points to different types of spending shocks leading to opposite responses. In Chapter 2 of this dissertation we have shown that these results are not *"incompatible and mutually exclusive"*[1], but rather reflect a dichotomous response of consumption to various types of government spending. In particular, using a new identification scheme through sign restrictions, we found that government spending on civilian goods and services generate positive and large multipliers on private consumption, while public military expenditures produce crowding out effects, in particular when one considers the role of expectations.

[1] Linnemann and Schabert (2003).

From a theoretical perspective, attempts have been made to discriminate between the neoclassical and the New-Keynesian paradigms on the grounds of the observed response of private consumption[2]. However, both classes of models in their benchmark versions generate a strong *negative* response of private consumption to government spending shocks, due to the dominant wealth effect, which is unsatisfactory given the evidence of frequent crowding-in.

Attempting to solve this "puzzle", a number of recent New-Keynesian papers (e.g. Linnemann and Schabert (2003) and Galí et al. (2005)) have been able to generate a positive comovement of private consumption with government spending by extending the benchmark model to include rule-of-thumb consumers and price stickiness in both goods or labor markets. The intuition behind these results is that an exogenous increase in government spending increases aggregate demand, thus under certain assumptions the real wage and if the hand-to-mouth consumers are a large enough share of the economy, total private consumption may go up as well.

In the neoclassical framework, Bouakez and Rebei (2003) show that in a standard RBC model in which preferences depend on private and public spending which are complementary, a government spending shock can generate a positive response of consumption. Bouakez and Rebei (2003) however assumes that government spending is entirely an exogenous variable, which is not entirely satisfactory. While the exogeneity assumption may be more justifiable for some types of public expenditures (most typically military spending), it is probably reasonable to assume that the non-military expenditures are chosen endogenously by the government, which implies that there is scope for optimal fiscal policy.

This paper proposes precisely such a set-up. We show that a standard neoclassical optimal fiscal policy model, modified to allow for *two* different types of government spending, is able to account for the bimodal empirical evidence on the behavior of private consumption. This model thus provides an explanation for the empirical findings in Chapter 2 of this dissertation, where we have shown that distinguishing between defense and nondefense

[2] Galí et al. (2005)

government spending is essential in understanding the response of private consumption and offers a solution to the ambiguity in the earlier literature.

Incorporating this dichotomy into a model of optimal fiscal policy, we divide government spending into an exogenous and an endogenous part. In line with the earlier literature, we assume that the exogenous component, which we identify with defense spending, is determined outside the model (as motivated, for example, by strategic and political goals). One the other hand, the endogenous part, composed of civilian government spending and investment, is optimally chosen by the planner in order to enhance the welfare of the agent. In particular, nondefense government consumption is assumed to be utility-yielding and to affect the marginal utility of private consumption. Likewise, government investment is assumed to increase the efficiency of private investment. The model features optimal taxation for both labor and capital, though for simplicity we abstract from the presence of debt.

Enhancing the standard model in this way, we derive the Ramsey optimal policy in response to two types of shocks: a military spending shock and a shock to the preference for public goods, which affects the marginal rate of substitution between private and public consumption. As found by the earlier literature, the exogenous (military) spending shocks have strong crowding out effects on private consumption and investment. The new result, however, is that optimal fiscal policy which raises the utility-yielding part of government consumption generates a positive response of private consumption.

Thus, unlike New-Keynesian models which require assumptions on non-optimizing behavior and a number of market imperfections, the explanation we propose is much more simple. What mitigates the negative wealth effect of government expenditure shocks is the fact that at least part of this spending increases the agents' welfare. Thus, there is a second channel which operates through the complementarity effect in the utility function, which for plausible parameter values is able to generate a realistic positive response in private consumption. This mechanism is quite different from the proposed New-Keynesian explanation, in that real wages do not need to increase in order for consumption to go up.

While the mechanism may seem quite intuitive, it is not ex-ante entirely clear that the positive response of private consumption is Ramsey optimal. This is because the optimal problem of the planner involves a trade-off between increasing the provision of the public good, which the agent values and increasing the distortion in the economy through higher capital and labor taxation, which may induce the agent to consume less. Indeed, the crowding in effect on private consumption depends on the calibration of a key parameter, namely, the degree of complementarity between the private and the public good in the utility function, which has to be sufficiently high (in line with empirical estimates).

In robustness exercises in which we consider wider ranges for a number of key parameters characterizing preferences, we show that for relatively large intervals of plausible parameter values, the endogenous type of government spending has positive multipliers on private consumption of around 0.5. The exogenous part of government spending has small but negative multipliers on private consumption of around -0.1. Both types of government spending have a positive impact on output, with multipliers ranging between close but smaller than 1 for the endogenous component and around 0.2 for the exogenous one. They also both generate a crowding out effect on private investment, with maximum impact multipliers in the range of -0.5 to -1 for the endogenous part and close to -0.5 for the exogenous government spending.

This paper is not the first to consider ways of endogenizing government expenditures. In a non-optimal fiscal policy framework, consumer preferences depending on government spending have been used for example in Barro (1981), Aschauer (1985), Christiano and Eichenbaum (1982), Baxter and King (1993), Karras (1994), Ahmed and Yoo (1995), Ambler and Cardia (1997), Ambler and Cardia (1997), Amano and Wirjanto (1997), Cardia et al. (2003), Bouakez and Rebei (2003), etc. In an optimal fiscal policy model, utility-yielding government consumption has been used by Gorostiaga (2003), Yakadina (2001), Riascos and Vegh (2003), Klein et al. (2003), Hassler et al. (2004), etc. What this model does is to show that a simple way of incorporating heterogenous government spending renders the neoclassical optimal fiscal policy model consistent with different responses of private consumption to distinct types of government spending shocks.

The paper proceeds as follows. Section 2 starts by defining endogenous and exogenous government spending. We then present a Ramsey model with two types of government consumption spending and solve for the optimal path for the fiscal variables. The model is simulated and its impulse responses are discussed in Section 3, which also offers some robustness analysis. In Section 4 we compare our modified RBC model with the main competing neoclassical and New-Keynesian explanations for the positive response of consumption. The last section concludes.

3.2 The Model Economy

3.2.1 Disaggregating Government Spending

We define as *exogenous* government spending the part of public expenditures which, although under the control of the planner, is expended on goods and services that have no direct impact on private sector variables. In keeping with a long tradition in the literature, we identify this component in the data with military purchases. In considering defense spending exogenous, we do not claim that military expenditures are necessarily useless. Rather, our assumption is that the level of military expenditures is not determined by macroeconomic/business cycles considerations and thus it is decided outside the standard Ramsey planning problem.

We define as *endogenous* government spending the component which is chosen by the planner and is assumed to *directly* affect directly either the marginal utility of private consumption or the marginal productivity of private investment. Empirically we think about this component as being composed of nondefense public consumption and respectively investment.

3.2.2 The Agent's Problem

We consider a production economy populated by a large number of identical, infinitely-lived agents, who derive utility from the consumption of a private good, a government supplied good and who additionally value leisure. We assume that the degree of substitutability between the private and the public good is never infinite, so the agent would like to consume some combination of both goods.

Assume that the preferences of the representative consumer are described by the expected utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(C_t^* - hC_{t-1}^*, l_t) \tag{3.1}$$

where $0 < \beta < 1$ is a constant discount factor, l_t is leisure and

$$C_t^* = f(c_t, g_t^e, \zeta_t)$$

is a consumption aggregate in private consumption c_t and endogenous government consumption g_t^e, while ζ_t is a random preference shift affecting the marginal rate of substitution between the two. Preference shifts are motivated as changes in the policy preferences of the planner, with respect to the optimal level of public good provision, which can be modelled as exogenous shocks to the preference for public goods.

The utility function satisfies the usual properties with respect to c_t, l_t and g_t^e. We assume that the agents build habits in the consumption aggregate C_t^* (with the level of habit formation measured by the parameter $h \in [0, 1)$), which is equivalent to saying that they wish to smooth also the rate of change in the consumption of both types of goods[3].

Agents decide how much to consume of the private good and how much to invest in the capital stock, given the distortions caused by the capital and labor taxation. The household

[3] We assume that preferences exhibit non-separability across time in order to be able to improve the quantitative performance of the model. However, habit-forming preferences are not driving the results, but they help generate more realistic values for the fiscal multipliers by "dampening" the fluctuations.

budget constraint is thus given by:

$$c_t + i_t = (1 - \theta_t^k) r_t k_t + (1 - \theta_t^l) w_t (1 - l_t) \tag{3.2}$$

where i_t is private investment, r_t and w_t are factor prices and θ_t^k and θ_t^l are the tax rates on capital and respectively labor income.

Following among others Jones et al. (1993), we assume that government investment contributes to increasing the efficiency of the economy, by directly affecting the marginal productivity of private investment, so that capital accumulation follows:

$$k_{t+1} = (1 - \delta) k_t + G(i_t, g_t^i) \tag{3.3}$$

where g_t^i is government investment, δ is depreciation rate and G is homogenous of degree one in both arguments, concave and smooth.

The motivation for introducing productive government investment in the model is two-fold. On the one hand, it is in line with our approach of providing a thorough analysis of the various components of government spending, for which reason it would be problematic to lump it together with public consumption[4].

The second motivation for the inclusion of government investment is more technical in nature, in that it helps avoid the empirically counterfactual zero capital tax result[5]. We follow Correia (1996) and Jones et al. (1993), who have noted that when some production factors are for some reason not taxed, the result of the optimality of long-run zero capital tax disappears. Essentially, in this model, productive government investment plays the role of the non-taxed factor and thus the model deviates from the Chamley-Judd result and

[4] Public investment amounts to approximately 4 percent of GDP in the US. See, e.g. Straub and Tchakarov (2007) for a dedicated study.

[5] This is a classical result in the optimal fiscal policy literature. The result of zero steady-state taxation of capital was first derived in a deterministic set-up by Judd (1995) and Chamley (1986) and was extended to a stochastic environment with complete markets by Zhu (1992) and Chari et al. (1994). The intuition for the result is that fiscal policy does not affect the steady-state intertemporal marginal rate of subtitution and consequently, the optimal steady-state capital tax should be zero and the burden of taxation should be borne by the other factor(s).

generates strictly positive capital taxes.

The agent's problem consists in choosing state-contingent sequences for consumption c_t, leisure l_t and capital k_t in order to maximize the expected utility (3.1) subject to the budget constraint (3.2), the investment rule (3.3) and taking as given the sequence of capital taxes θ_t^k, labor taxes θ_t^l, endogenous and exogenous government consumption (g_t^e and g_t^x) and government investment g_t^i.

Using shorthand notation, the optimality conditions for the agent's problem are given by:

$$\beta E_t \Lambda_{t+1} \left\{ (1-\theta_{t+1}^k) r_{t+1} + \frac{1-\delta}{G_{i,t+1}} \right\} = \frac{\Lambda_t}{G_{i,t}} \tag{3.4}$$

$$\Lambda_t = \frac{\partial u(C_t^* - hC_{t-1}^*, l_t)}{\partial C_t^*} \frac{\partial C_t^*}{\partial c_t} + \beta E_t \frac{\partial u(C_{t+1}^* - hC_t^*, l_t)}{\partial C_t^*} \frac{\partial C_t^*}{\partial c_t} \tag{3.5}$$

$$u_{l,t} = (1-\theta_t^l) w_t \Lambda_t \tag{3.6}$$

Equation (3.4) is the traditional Euler equation, which determines the inter-temporal allocation of consumption as a function of the net real return on capital, here further distorted by the presence of the government investment externality. The second equation defines the stochastic discount factor of this economy, which is affected by the presence of habits. Equation (3.6) represents the intra-temporal consumption leisure choice, which is driven by the after tax return on labor.

On the production side, the representative agent supplies labor and owns the capital stock of the economy which she rents to the representative competitive firm, which pays each factor its marginal product in the standard way.

3.2.3 The Optimal Ramsey Problem

The planner provides consumption and investment goods and services which the agent values but cannot produce by herself. The planner also expends money on a good called "security", which is however determined by non-economic considerations, so for the purposes of this optimization problem we assume it is a stochastic shock. The government needs to finance its expenditures by levying distortionary taxes on labor and capital income. We shall further assume that the government can commit at the beginning of time to a particular path of fiscal policies as a way of solving the time-inconsistency problem. Given a stream of exogenous spending g_t^x, the government optimally chooses endogenous government consumption g_t^e, government investment g_t^i and tax rates θ_t^k and θ_t^l to maximize the expected utility (3.1), so that it balances its budget period-by-period[6]:

$$g_t^x + g_t^e + g_t^i = \theta_t^k r_t k_t + \theta_t^l w_t (1 - l_t) \tag{3.7}$$

We proceed now to define the Ramsey problem in the standard way.

Definition 1 A *competitive equilibrium* for this economy is a government policy set $\{\theta_t^k, \theta_t^l, g_t^e, g_t^i\}$, an allocation set for private agents $\{c_t, l_t, k_{t+1}\}$ and a set of prices $\{w_t, r_t\}$ such that given initial conditions k_0, a_0, g_0^x, ζ_0 and the exogenous processes $\{a_t, \zeta_t, g_t^x\}$:

i) the resulting allocation $\{c_t, l_t, k_{t+1}\}$ maximizes the consumer's utility (3.1) subject to the budget constraint (3.2) and the investment rule (3.3), given the government policy $\{\theta_t^k, \theta_t^l, g_t^e, g_t^i\}$ and prices $\{w_t, r_t\}$;

ii) the government budget constraint (3.7) is satisfied;

iii) markets clear.

[6] The extension of this model to include debt is left for further work. In particular, complete or incomplete capital markets for government debt seem to be an important difference (as shown by Scott and Marcet (2001)). With debt the planner would have the ability to better smooth taxes (both in the Barro (1979) and Lucas and Stokey (1983) sense), the wealth effect would be larger, but so will the substitution effects. Therefore, it is likely that the introduction of debt would not affect the main result.

Definition 2 A *Ramsey equilibrium* is a set of policies $\{\theta_t^k, \theta_t^l, g_t^e, g_t^i\}$ and an allocation rule $\{c_t, l_t, k_{t+1}\}$ such that given initial conditions k_0, a_0, g_0^x, ζ_0 and the exogenous processes $\{a_t, \zeta_t, g_t^x\}$:

i) the policy $\{\theta_t^k, \theta_t^l, g_t^e, g_t^i\}$ maximizes (3.1) subject to (3.2), (3.3), (3.4), (3.5), (3.6) and (3.7);

ii) the policy $\{\theta_t^k, \theta_t^l, g_t^e, g_t^i\}$ and the allocation $\{c_t, l_t, k_{t+1}\}$ constitute a competitive equilibrium.

This Ramsey problem is non-recursive in the original state space, due to the presence of expectations in the constraints (3.5) and (3.6). We employ the recursive contracts method suggested in Marcet and Marimon (1999) in order to characterize the solution of the planning problem (the details of the solution are relegated to the appendix).

3.2.4 Functional Forms and Calibration

We consider a broad class of utility functions which nests many of the functional forms used in the literature. The specification of preferences rests on two main assumptions. First, we assume additive separability between the consumption aggregate and leisure, which eliminates the wealth effect on labor supply. Second, the elasticity of substitution between private and public consumption is a constant ϵ. The general formulation is thus:

$$u(C_t^* - hC_{t-1}^*, l_t) = \begin{cases} \frac{(C_t^* - hC_{t-1}^*)^{1-\gamma} - 1}{1-\gamma} + \chi \frac{l_t{}^{1-\phi}}{1-\phi}, \gamma \neq 1 \\ \log(C_t^* - hC_{t-1}^*) + \chi \frac{l_t^{1-\phi}}{1-\phi}, \gamma = 1 \end{cases}$$

where

$$C_t^* = \begin{cases} \left(\sigma c_t^{\frac{\epsilon-1}{\epsilon}} + \zeta_t (1-\sigma)(g_t^e)^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}, \epsilon \neq 1 \\ \zeta_t c_t^\sigma (g_t^e)^{1-\sigma}, \epsilon = 1 \end{cases}$$

The interpretation of the parameters in the utility function is: γ is the risk aversion coefficient in the consumption aggregate, ϕ is the risk aversion in leisure, $\chi > 0$ is an elasticity parameter for the utility of leisure, $\sigma \in (0, 1)$ is the share of private consumption in the consumption basket, while $\epsilon > 0$ is the elasticity of substitution between the private and the public consumption goods. The shock ζ_t represents a stochastic preference shift affecting the marginal rate of substitution between private and government consumption.

For the calibration of the model we choose typical values for the US economy at quarterly frequency (see Table 3.1). Labor time is set to measure 25 percent of total time, which combined with a Frisch elasticity of the labor supply of 1.5 (in line with estimates from the micro labor literature), imply an elasticity with respect to the real wage $\phi = 2$. The degree of habit persistence is calibrated following Christiano et al. (2005) to $h = 0.65$.

The investment function is a CES aggregate with the elasticity of substitution between private and public investment equal to $\frac{1}{1+\psi}$ and a share ω of private investment (A is a parameter):

$$G(i_t, g_t^i) = A[\omega i_t^{-\psi} + (1-\omega)(g_t^i)^{-\psi}]^{-\frac{1}{\psi}}$$

The vector deep of structural parameters characterizing preferences and the investment function:

$$\Theta = (\epsilon, \sigma, \gamma, \omega, \psi, A)$$

needs to be calibrated from the data. Our identification strategy is to use first order moments from the post-war US data. The economy is calibrated to match the long-run properties of the US economy, through several key ratios (see Table 3.2). In particular, we employ the following moment conditions: the ratio of military spending to GDP ($\frac{\overline{g^x}}{\overline{y}} = 0.06$), the ratio of endogenous government consumption to GDP ($\frac{\overline{g^e}}{\overline{y}} = 0.12$), the ratio of private investment to GDP ($\frac{\overline{i}}{\overline{y}} = 0.18$), the ratio of private consumption to GDP ($\frac{\overline{c}}{\overline{y}} = 0.60$) and the ratio of the capital stock to GDP ($\frac{\overline{k}}{\overline{y}} = 8.91$[7]). Additionally, we also use the average long-run

[7] This value is taken from Ambler and Paquet (1996).

Table 3.1: Structural Parameters

Parameter	*Description*	*Value*
γ	Risk aversion in aggregate consumption	2
ϕ	Inverse of the elasticity of the labor supply	2
σ	Share of private consumption in aggregate bundle	0.93
ϵ	Elasticity of substitution between c_t and g_t^e	0.72
χ	Coefficient of leisure in the utility function	1.5
h	Habit persistence	0.65
A	Parameter in the investment function	1.54
ω	Share of private investment in investment function	0.74
ψ	Elasticity of substitution between i_t and g_t^i	0.92
α	Share of capital	0.36
δ	Depreciation rate	0.025
β	Discount factor	0.99
ρ_ζ	Serial correlation of the log of the preference shock ζ_t	0.77
σ_ζ	Standard deviation of the log of the preference shock ζ_t	0.012
ρ_{g^x}	Serial correlation of the log of exogenous government spending g_t^x	0.85
σ_{g^x}	Standard deviation of the log of exogenous government spending g_t^x	0.022

tax rate on labor ($\overline{\theta^l} = 0.27$)[8].

This identification strategy yields the following values for the structural parameters:

$$(\epsilon, \sigma, \gamma, \omega, \psi, A) = (0.72, 0.93, 2, 0.92, 0.74, 1.54)$$

These parameter values are consistent with a number of estimates from the empirical literature. The risk aversion parameter γ is in line with what many macro studies employ.

The parameter ϵ, which affects the degree of substitutability between c_t and g_t^e is implying complementarity between the two goods[9]. While the evidence on the intratemporal elasticity of substitution between private and government consumption is not undisputed[10], for CES aggregate functions like the one we use, most empirical studies find evidence of a complementarity relationship between the private and the public good on an aggregate level. For example Ni (1995), estimating Euler equations via GMM, finds an elasticity $\epsilon \in (0.56 - 0.91)$ and a share of private consumption $\sigma \in (0.93, 0.97)$). Bouakez and Rebei (2003), employing minimum-distance and maximum-likelihood estimation, find a lower $\epsilon \in (0.35 - 0.37)$ with a share $\sigma = 0.8$. We further discuss the robustness of the predictions with respect to a range of sensible values for the preference parameters in Section 3.

The process for exogenous government spending is estimated from US quarterly data on military purchases, which we HP filter and then fit with a stationary AR(1) process with i.i.d. and normally distributed shocks $\varepsilon_t^g \sim N(0, \sigma_g^2)$ and mean $\overline{g}^x$:

$$\log(g_{t+1}/\overline{g}^x) = \rho_g \log(g_t/\overline{g}^x) + \varepsilon_{t+1}^g$$

[8]Following Mendoza et al. (1994). The simple structure of the model does not allow us to pin down both capital and labor taxes at the same time. The reason for chosing the labor tax for calibration has to do with the fact that the former is more precisely estimated. Judd (1992) points out several reasons why the existing measures for ex-post capital taxes may be misleading.

[9]Government consumption g^e and private consumption c are Edgeworth complements (substitutes) when $u_{cg^e} > 0$ ($u_{cg^e} < 0$), i.e. government consumption increases (decreases) the marginal utility of private consumption (if $u_{cg^e} = 0$ they are Edgeworth independent, i.e. the utility is separable).

[10]See Ni (1995) for a review. Kormendi (1983), Aschauer (1985) and Ahmed and Yoo (1995) find a significant degree of substitutability, while Karras (1994), Nieh and Ho (2006), Bouakez and Rebei (2003) and Ni (1995) find evidence in favor of complementarity.

Table 3.2: Steady State

$\frac{\overline{g^e}}{\overline{y}}$	Nondefense Government Consumption / GDP	0.12
$\frac{\overline{g^x}}{\overline{y}}$	Defense Government Spending / GDP	0.06
$\frac{\overline{g^x}}{\overline{y}}$	Government Investment Spending / GDP	0.04
$\frac{\overline{i}}{\overline{y}}$	Private Investment / GDP	0.18
$\frac{\overline{c}}{\overline{y}}$	Private Consumption / GDP	0.60
$\frac{\overline{k}}{\overline{y}}$	Capital Stock / GDP	8.91
$\overline{l}$	Leisure	0.66
$\overline{\theta^k}$	Capital Tax Rate	0.10
$\overline{\theta^l}$	Labor Tax Rate	0.27

The preference shock is calibrated indirectly. Its role is to alter preferences to allow for shifts in the marginal rate of substitution between c_t and g_t^e. We interpret it as a change in the policy preferences of the planner and at the same time as a taste shock for the agent.

As preference shocks are not directly observable, we use the Taylor approximation of the intratemporal first order condition (3.6) to back out a sequence of preference shocks. Given data on private consumption, nondefense government consumption, real wage and labor input (and keeping the labor tax rate constant and equal to 0.27), we are able to estimate a series for the preference shifts. We then fit an AR(1) process with i.i.d. and normally distributed shocks $\varepsilon_t^\zeta \sim N(0, \sigma_\zeta^2)$ and mean equal to 1 to the logarithm of the preference shock series.

3.3 Simulation Results

The model is solved using perturbations methods, as described in more detail in the Appendix.

We proceed by comparing the results from simulating two fiscal policy experiments: an exogenous spending shock and a preference shock to the marginal rate of substitution between private and public consumption. To enable comparison, the size of the shock is normalized so that it leads to a one percent increase relative to steady state output in the respective government spending category. Given the above normalizations, the contemporaneous responses can be interpreted as impact multipliers.

3.3.1 The Optimal Policy - Simulated Impulse Responses

The impulse responses (see Figures 3.3 and 3.2) reveal that the two types of government spending shocks lead to opposite response of private consumption. A shock to the exogenous type of government spending crowds *out* private consumption while preference shocks to the endogenous government consumption crowd it *in.*

The basic intuition for these results is the following. Unlike defense spending which are essentially wasteful, shocks to the marginal rate of substitution between private and endogenous government consumption generate two effects. On the one hand, the increase in endogenous government consumption resulting from a preference shift leads to the usual negative wealth effect, which exerts downward pressure on private consumption. On the other hand, it raises the marginal utility of private consumption sufficiently to offset the contractionary effect, leading to an overall positive response of private consumption in line with the empirical evidence.

Comparing the responses to the two types of shocks provides interesting insights into the transmission channel of optimal fiscal policy. Following an the exogenous government spending shock, the agent sees her life-time income diminished, since the wasteful government spending needs to be financed through higher taxation currently and in the future. The level of the drop in current consumption falls depends on the risk aversion and on the habit formation parameters. As this agent feels poorer, she would want to work significantly more. In this context, the planner finds it optimal to tax the labor income higher. As this would have a dampening effect on labor and the marginal product of capital would tend to fall as a result, the planner would like to stimulate investment more, so it finds optimal to offer a tax break on capital.

When however the shock is to the preference for government consumption, there is still a negative wealth effect, due to the welfare loss induced by the distortionary taxation, however, it is much smaller than in the previous case, because what the government levies in taxes is expended for the benefit of the agent and increases her utility. In this case, through the effect of preferences, the agent's increase in public consumption induces her to also augment her consumption of the private good. This agent is no longer "hungry" as the previous one, so she would not like to work so much more. The planner needs to stimulate this agent to increase her labor supply, since otherwise the increase in government spending cannot be financed (as we do not allow for deficits). It thus becomes optimal for the planner to offer the agent a tax break on labor to incentivize her to work more. This indeed has the desired effect of the agent supplying more labor. As the marginal product of capital has increased, the planner also finds it optimal to increase the capital levy.

An increase in government spending, be it defense or nondefense, causes an increase in hours proportional to the elasticity of labor. As the supply of labor goes up, the marginal product of labor falls, which depresses the real wage in response to both types of shocks.

In both scenarios, a fiscal expansion has negative effects on the capital accumulation process due to the fact that private investment is crowded out. The impact effect of investment depends on the fall or increase in consumption (both private and public) as a function of both risk-aversion and habit formation. After the initial decline, investment gradually recovers, driven by the after-tax rate of return.

For exogenous spending shocks, there is a hump-shaped dynamics. In the first period, the marginal product of capital rises, but this is compensated by the declining capital tax. In the subsequent periods, the marginal product of capital declines, but the planner optimally gradually raises the capital tax. Overall, the effect of the optimal policy is a monotonic increase in investment. With endogenous shocks, the marginal product of capital and thus the real interest rate decline, however, this is compensated by the decline in the capital tax, so that the after-tax rate of return increases which encourages investment.

The dynamics of the economy is fine-tuned by the planner through balancing the distortion created by the two tax levies in order to achieve the optimal outcome from the point of view of maximizing and smoothing private and public consumption. This generally implies that capital and labor taxes behave in opposite ways, as explained before, although the signs of the response of the tax rates are not robust to parameter specification.

Intuitively, the planner faces a balancing act between extracting tax revenues from two production factors, out of which one is more inelastically supplied. In principle, in the short-run, capital is more inelastic, being a stock, while in the long-run, it is perfectly elastic, which would imply that the burden of financing temporary shocks should be bourne by capital on impact. However, when the agent's labor supply is very inelastic (for example because of a very strong negative wealth effect), it may become optimal for the planner to "front-load" labor taxation while granting capital a tax break.

3.3.2 Sensitivity Analysis: Fiscal Policy Multipliers

In this section we analyze the effects on the impact multipliers of varying certain structural parameters within reasonable ranges in order to shed light on the ability of our model with disaggregated government spending shocks to generate consistent implications for private consumption. Moreover, this exercise provides an assessment of the way in which key parameters affect the implications of fiscal policy shocks on private consumption, output and investment. The experiments are conducted by varying one parameter at a time *caeteris paribus* taking as reference the benchmark values in Table 3.1.

Figure 3.3 illustrates the sensitivity of the contemporaneous responses of output, private consumption and investment to a shock to preferences for government spending.

In the Figure 3.3, the elasticity of substitution between private and public consumption ϵ is allowed to vary between $[0.45, 0.95]$, which is consistent with the two goods being complements in the utility function. The picture reveals that as the elasticity of substitution increases, the multipliers on consumption and output decline and the crowding-in effect diminishes. As the public and private good tend to become better substitutes, this effect reinforces the negative wealth effect, since private consumption falls both due to distortionary effect of taxation and because of the agent substituting from private to more public goods.

The effect of varying the risk aversion parameter γ in a range standard in the macro literature (from 1, i.e. log preferences, to 5) are not particularly large, because the marginal rate of substitution between private consumption and endogenous government consumption is not affected[11]. The figure shows that the multipliers on consumption and output slowly decline with increasing risk aversion, while the one on investment slightly increases, as the agent wants to reduce the fluctuations in the aggregate consumption basket.

We also check for robustness with respect to varying the parameter σ characterizing the share of private and public consumption in the utility function, in the range from $[0.7, 0.99]$. As the share of private consumption increases, the marginal rate of substitution of public consumption for private consumption decreases, accordingly, so does the consumption multiplier. As σ approaches 1, endogenous government consumption becomes insignificant, therefore the multipliers converge to 0.

The graphs in Figure 3.4 summarize the changes in the impact multipliers on output, private consumption and investment to an exogenous government spending shock for the same parameters.

We notice that the negative multipliers on consumption becomes larger (in absolute terms) the lower the degree of substitutability between private and public consumption ϵ. The explanation resides on the following effect: in an optimal policy framework, the planner's objective of maximizing the agent's welfare can be also interpreted as minimizing the tax distortion. Therefore, as an exogenous spending shock hits the economy, the planner would reduce the endogenous type of spending, rather than raising taxes. For low elasticities, the fall in endogenous government spending also induces a decline in private consumption, which

[11] For our specification of preferences, $MRS_{cg^e} = \frac{U_C}{U_{g^e}} = -(\frac{\sigma}{1-\sigma})\left(\frac{c}{\zeta g^e}\right)^{-\frac{1}{\epsilon}}$.

reinforces the negative wealth effect, thus the multipliers are lower.

The effect of increasing the risk aversion parameter γ is also quite intuitive: as risk aversion increases, the consumption smoothing motive counterweights the negative wealth effect, so that private consumption falls by less. The multiplier on consumption is still negative, but for large enough values of γ it approaches 0. The multiplier on output also increases with risk aversion due to the dampened effect on consumption, while investment is not very sensitive.

The plot showing the sensitivity to σ emphasizes the fact that the levels of the multipliers for consumption and output decrease with the share of endogenous government consumption in the utility function. A higher the share of public goods exercises a dampening effect, reducing the negative effect on private consumption. In the limiting case in which σ would be 1 the model would converge to the standard RBC model and the multiplier of private consumption would be more strongly negative.

Overall, our sensitivity analysis reveals that the positive multiplier on private consumption of government preference shocks is primarily affected by the elasticity of substitution ε and by the share of private consumption in the utility function σ. Quantitatively, the level of the impact multiplier on consumption is around 0.5 around the most plausible parameter ranges. The multipliers on output are close though slightly smaller than unity. Private investment is also consistently crowded out of, with the most likely values for the multiplier in the range between -0.5 and -1.

At the same time, we are able to show that the effect of exogenous government spending shocks on private consumption is also robust. We find that the value of the multiplier on consumption is negative yet small in absolute terms, ranging in the most plausible parameter range from between -0.2 to 0. The multipliers on output are positive but smaller than for the previous type of government spending shock, of an order of magnitude between 0.1 and 0.3. The multiplier on private investment is negative and has a level of around -0.5.

3.4 Assessment of the Model and Comparison with the Previous Literature

This paper is closely related to a number of recent contributions. In order to make clear how this particular model enhances our understanding of the behavior of private consumption, we proceed to a brief comparison between our results and the main competing explanations, both in the New-Keynesian and in the RBC literature.

As we have mentioned in the introduction, several recent New-Keynesian models with imperfect competition (Linnemann and Schabert (2003)) and heterogenous (hand-to-mouth) consumers (Galí et al. (2005)) are able to account for the increase in private consumption in response to government spending shocks.

In Linnemann and Schabert (2003) for example, the presence of imperfect competition generates a positive externality, by which an increase in aggregate demand increases output and profits, which mitigates the negative wealth effect. Additionally, with sticky prices labor demand reacts stronger than labor supply, which potentially can lead to an increase in real wages. However, a positive response of private consumption is contingent on monetary policy being sufficiently accommodative, since even a modestly aggressive policy rule can be contractionary for private consumption, whose response is dominated by the extremely persistent government spending shock.

In Galí et al. (2005), the negative wealth effect is reduced by positing that a significant share of consumers are hand-to-mouth. If these consumers represent a large share of the economy (over fifty percent) then it becomes possible to generate a positive effect on private consumption, since the non-Ricardian agents would consume all of their windfall income, thus total consumption would also increase. However, this result depends on the parameter which calibrates the size of the naive consumers, and Coenen and Straub (2005) find that a high value is not plausible empirically, while more realistic calibrations are unable to unwind the puzzle.

Both the explanation by Linnemann and Schabert (2003)) and Galí et al. (2005) rely a strong positive demand effect from increased government consumption in order to compensate for the loss to the agent's lifetime income, through an increase in the real wage. However, this sharp increase in the real wage is problematic empirically. Sufficient evidence points out that the real wage may actually decrease in response to government spending shocks identified in various ways[12], so there is not a clear support for the demand channel.

A number of RBC papers are also related to this one. Cavallo (2005) proposes a different disaggregation of government spending, in expenditures on goods and expenditures on hours. In response to exogenous fiscal shocks, consumption is still crowded out, though *less* than if government spending was considered to be spent entirely on goods. The intuition is that shocks to government expenditures on hours represent income for the household and thus dampen the negative wealth effect on private consumption. However, this disaggregation provides an explanation of why the negative multipliers of defense shocks on private consumption may not be very large, but is not able to generate a positive response of private consumption.

An alternative explanation offered by Linnemann (2002) relies on the utility function being non-additively separable in consumption and leisure *and* quasiconcave. Essentially, in this case, consumption and leisure are very strong substitutes, thus a government expenditure shocks which increases labor raises the marginal utility of private consumption sufficiently to overturn the negative wealth effect and to make the household consume more. It is however not clear whether there is enough empirical evidence of preferences which exhibit these properties, i.e. that working more makes agents willing to also consume significantly more.

This paper is also close to Bouakez and Rebei (2003), who are able to generate an increase

[12] Such a conclusion can be inferred from the empirical analysis in Chapter 2 of this dissertation. Additionally, a number of other papers using different methodologies support the negative response of the real wage to government spending shocks, using various sectoral measures (e.g. Ramey and Shapiro (1997), Edelberg et al. (1998), Burnside et al. (2004), Cavallo (2005), etc.).

in consumption following government spending shocks based also on the complementarity between private and public goods. The main intuition is similar to this paper, however, Bouakez and Rebei (2003) consider a *homogenous* government consumption and investment good, which yields direct utility and is exogenously given. This paper takes the further step of endogenizing the government public provision and showing that in an environment with several realistic features, the optimal conduct of fiscal policy implies a positive comovement between private and public consumption.

3.5 Conclusion

This paper offers a model able to account for two different types of government spending shocks having either a positive or a negative effect on private consumption, which seems to be supported empirically, by proposing a simple modification to a standard neoclassical optimal fiscal policy model. We show that disaggregating government consumption into an endogenous and exogenous component renders the Ramsey optimal fiscal policy model consistent with the evidence on the behavior of private consumption.

The intuition for the main result of the paper is that allowing a part of government consumption to yield utility to the representative agent mitigates the strong negative wealth effect associated with fiscal expansions. To the extent that private consumption and public consumption are complements, the positive effect on private consumption is dominant. We are thus able to reconcile conflicting empirical evidence and to provide a simple and plausible explanation to a theoretical puzzle.

APPENDICES

3.5.1 Appendix A. Characterization of the Solution

3.5.1.1 Appendix A1. The Recursive Formulation

We present a detailed characterization of the Ramsey equilibrium using the recursive contracts approach developed by Marcet and Marimon (1999). Since the problem is not initially recursive in the standard dynamic programming sense due the presence of expectations of future variables in the constraints, we reformulate it by treating the Lagrange multipliers on the Euler equations as additional state variables. In terms of economic interpretation, the new state variables account for the "value of past promises" made by the planner to the agent[13].

In describing the equilibrium conditions, we use the following short-hand notation:

$$G_{i_t} = \frac{\partial G(i_t, g_t^i)}{\partial i_t}$$

$$G_{g_t^i} = \frac{\partial G(i_t, g_t^i)}{\partial g_t^i}$$

$$u_{l,t} = \frac{\partial u(C_t^* - hC_{t-1}^*, l_t)}{\partial C_t^*} \frac{\partial C_t^*}{\partial l_t}$$

$$u_{ll,t} = \frac{\partial u_{l,t}}{\partial l_t}$$

(3.5) thus becomes:

$$\Lambda_t = \frac{\partial u(C_t^* - hC_{t-1}^*, l_t)}{\partial C_t^*} \frac{\partial C_t^*}{\partial c_t} + \beta E_t \frac{\partial u(C_{t+1}^* - hC_t^*, l_t)}{\partial C_t^*} \frac{\partial C_t^*}{\partial c_t}$$

[13] The terminology we are using has been pioneered by Abreu et al. (1990) (in an alternative approach to Marcet and Marimon (1999)) which relies on the theory of sub-game perfect equilibria in dynamic games.

(3.4) can be rewritten as:

$$\beta E_t \Lambda_{t+1}[(1-\theta^k_{t+1})r_{t+1} + \frac{(1-\delta)}{G_{i,t+1}}] = \frac{\Lambda_t}{G_{i,t}}$$

(3.6) becomes:

$$u_{l,t} = (1-\theta^n_t)w_t\Lambda_t \tag{3.8}$$

Attaching multipliers $\lambda_t^{1-6}$to the various constrains on the planner's problem[14], the Lagrangian becomes:

$$\begin{aligned}\mathcal{L} = \min\ \max\ E_0 \sum_{t=0}^{\infty} \beta^t \{ & u(C^*_t - hC^*_{t-1}, l_t) + \lambda^1_t[\theta^k_t r_t k_t + \theta^n_t w_t(1-l_t) - g^e_t - g^x_t - g^i_t] + \\ & +\lambda^2_{t+1}\left[\beta E_t \Lambda_{t+1}[(1-\theta^k_{t+1})r_{t+1} + \frac{(1-\delta)}{G_{i,t+1}}] - \frac{\Lambda_t}{G_{i,t}}\right] + \lambda^3_t[(1-\theta^n_t)w_t\Lambda_t - u_{l,t}] + \\ & +\lambda^4_t[F(a_t,k_t,n_t) - i_t - c_t - g^e_t - g^x_t - g^i_t] + \lambda^5_t\left[(1-\delta)k_t + G(i_t, g^i_t) - k_{t+1}\right] + \\ & +\lambda^6_{t+1}\left[\frac{\partial u(C^*_t - hC^*_{t-1}, l_t)}{\partial C^*_t}\frac{\partial C^*_t}{\partial c_t} + \beta E_t \frac{\partial u(C^*_{t+1} - hC^*_t, l_t)}{\partial C^*_t}\frac{\partial C^*_t}{\partial c_t} - \Lambda_t\right]\}\end{aligned}$$

Marcet and Marimon (1999) prove that treating the multipliers λ^2_{t+1} and λ^6_{t+1} on the expectational constraints in the Lagrangian as stochastic *co-state* variables helps make the problem recursive, in the sense that it satisfies a saddle point functional equation (SPFE) which generalizes Bellman's equation.

Applying a transformation initially due to Abel, the Lagrangian is made recursive and the future controls are "eliminated", while the time-inconsistency aspect is captured by the law of motion for the multipliers λ^2 and λ^6. The main advantage of the method is that, by providing a recursive formulation for the problem, a solution through different numerical methods can be found.

[14]The multipliers on the expectational constraints are for reasons that will become clear immediately subscripted with time $t+1$.

After applying Abel's transformation (see Apostol (1974), p. 194), the Lagrangian for the Ramsey problem can be rewritten as:

$$\mathcal{L} = \min \ \max \ E_0 \sum_{t=0}^{\infty} \beta^t \{u(C_t^* - hC_{t-1}^*, l_t) + \lambda_t^1 [\theta_t^k r_t k_t + \theta_t^n w_t (1 - l_t) - g_t^e - g_t^x - g_t^i] +$$

$$+\lambda_t^2 \Lambda_t [(1 - \theta_t^k) r_t + \frac{(1-\delta)}{G_{i,t}}] - \lambda_{t+1}^2 \frac{\Lambda_t}{G_{i,t}} + \lambda_t^3 [(1 - \theta_t^n) w_t \Lambda_t - u_{l,t}] +$$

$$+\lambda_t^4 [F(a_t, k_t, n_t) - i_t - c_t - g_t^e - g_t^x - g_t^i] + \lambda_t^5 ((1-\delta) k_t + G(i_t, g_t^i) - k_{t+1}) +$$

$$+\lambda_{t+1}^6 \frac{\partial u(C_t^* - hC_{t-1}^*, l_t)}{\partial C_t^*} \frac{\partial C_t^*}{\partial c_t} + \lambda_t^6 \frac{\partial u(C_t^* - hC_{t-1}^*, l_{t-1})}{\partial C_{t-1}^*} \frac{\partial C_{t-1}^*}{\partial c_{t-1}} - \lambda_{t+1}^6 \Lambda_t \}$$

with the initial condition $\lambda_0^2 = \lambda_0^6 = 0$ (the transformation requires as a matter of technicality that the initial value of the co-states for forward looking conditions be set to 0, so that the value of the infinite summation is the same). Moreover, this condition has a ready economic interpretation, as the constraints including expectation are derived from the agent's optimization problem, thus, setting them to zero at time 0 it is equivalent to saying that the planner attaches no value to commitments made before the first period.

The problem is now recursive since it involves only state variables and current controls. It can be shown that under certain regularity assumptions (see Marcet and Marimon (1999)), the solution obeys a recursive saddle-point functional equation, in the sense that this new maximization problem is saddle-point stationary in the extended state space $(k, a, g^x, \zeta, \lambda^2, \lambda^6)$. Thus, time invariant policy rules exist and can be approximated by numerical methods.

3.5.1.2 Appendix A2. Equilibrium Conditions

We focus on the solution to the Ramsey problem which is optimal in a "timeless perspective". In other words, we describe the equilibrium polices and allocations after the initial transition period (the policy rules for period 0 are different since capital is inelastically supplied and the co-states are zero). The solution from period 1 onwards can be described by time-invariant policy functions for all the endogenous variables which solve the following system of equations (in shorthand notation):

$$c_t : \Lambda_t - \lambda_t^3 u_{lc,t} - \lambda_t^4 + \frac{\partial}{\partial c_t}\left[\lambda_{t+1}^6 \frac{\partial u(C_t^* - hC_{t-1}^*, l_t)}{\partial C_t^*}\frac{\partial C_t^*}{\partial c_t} + \lambda_t^6 \frac{\partial u(C_t^* - hC_{t-1}^*, l_{t-1})}{\partial C_{t-1}^*}\frac{\partial C_{t-1}^*}{\partial c_{t-1}}\right] = 0 \tag{3.9}$$

$$g_t^e : \frac{\partial u(C_t^* - hC_{t-1}^*, l_t)}{\partial C_t^*}\frac{\partial C_t^*}{\partial g_t^e} + \beta \frac{\partial u(C_{t+1}^* - hC_t^*, l_t)}{\partial C_t^*}\frac{\partial C_t^*}{\partial g_t^e} - \lambda_t^1 - \lambda_t^4 - \tag{3.10}$$

$$-\frac{\partial}{\partial g_t^e}\left[\lambda_{t+1}^6 \frac{\partial u(C_t^* - hC_{t-1}^*, l_t)}{\partial C_t^*}\frac{\partial C_t^*}{\partial c_t} + \lambda_t^6 \frac{\partial u(C_t^* - hC_{t-1}^*, l_{t-1})}{\partial C_{t-1}^*}\frac{\partial C_{t-1}^*}{\partial c_{t-1}}\right] = 0 \tag{3.11}$$

$$l_t : \frac{\partial u(C_t^* - hC_{t-1}^*, l_t)}{\partial C_t^*}\frac{\partial C_t^*}{\partial l_t} - \lambda_t^1 \theta_t^n w_t - \lambda_t^3 u_{ll,t} - \lambda_t^4 w_t - \frac{\partial}{\partial l_t}\left[\lambda_{t+1}^6 \frac{\partial u(C_t^* - hC_{t-1}^*, l_t)}{\partial C_t^*}\frac{\partial C_t^*}{\partial c_t}\right] = 0 \tag{3.12}$$

$$\Lambda_t : \lambda_t^2[(1 - \theta_t^k) r_t + \frac{(1-\delta)}{G_{i,t}}] - \lambda_{t+1}^2 \frac{1}{G_{i,t}} = \lambda_{t+1}^6 \tag{3.13}$$

$$\theta_t^k : \lambda_t^1 k_t r_t - \lambda_{t-1}^2 r_t \Lambda_t = 0 \tag{3.14}$$

$$\theta_t^n : \lambda_t^1 w_t n_t - \lambda_t^3 w_t \Lambda_t = 0 \tag{3.15}$$

$$k_{t+1} : \lambda_t^5 = \beta E_t[\lambda_{t+1}^4 r_{t+1} + \lambda_{t+1}^1 \theta_{t+1}^k r_{t+1} + \lambda_{t+1}^5 (1-\delta)] \tag{3.16}$$

$$w_t = F_n(a_t, k_t, n_t) \tag{3.17}$$

$$r_t = F_k(a_t, k_t, n_t) \tag{3.18}$$

$$i_t : \frac{\partial}{\partial i_t}\left[\lambda_t^2 \Lambda_t \frac{(1-\delta)}{G_{i,t}} - \lambda_{t+1}^2 \frac{\Lambda_t}{G_{i,t}}\right] + \lambda_t^5 G_{i,t} = \lambda_t^4 \tag{3.19}$$

$$g_t^i : \frac{\partial}{\partial g_t^i}\left[\lambda_t^2 \Lambda_t \frac{(1-\delta)}{G_{i,t}} - \lambda_{t+1}^2 \frac{\Lambda_t}{G_{i,t}}\right] + \lambda_t^5 G_{g_t^i,t} = \lambda_t^4 \tag{3.20}$$

$$\lambda_t^1 : g_t^x + g_t^e + g_t^i = \theta_t^k r_t k_t + \theta_t^n w_t (1 - l_t) \tag{3.21}$$

$$\lambda_t^2 : \beta E_t \Lambda_{t+1}[(1-\theta_{t+1}^k) r_{t+1} + \frac{(1-\delta)}{G_{i,t+1}}] = \frac{\Lambda_t}{G_{i,t}} \tag{3.22}$$

$$\lambda_t^3 : (1-\theta_t^n) w_t \Lambda_t = u_{l,t} \tag{3.23}$$

$$\lambda_t^4 : c_t + i_t + g_t^x + g_t^e + g_t^i = F(a_t, k_t, n_t) \tag{3.24}$$

$$\lambda_t^5 : (1-\delta) k_t + G(i_t, g_t^i) = k_{t+1} \tag{3.25}$$

$$\lambda_t^6 : \Lambda_t = \frac{\partial u(C_t^* - hC_{t-1}^*, l_t)}{\partial C_t^*}\frac{\partial C_t^*}{\partial c_t} + \beta E_t \frac{\partial u(C_{t+1}^* - hC_t^*, l_t)}{\partial C_t^*}\frac{\partial C_t^*}{\partial c_t} \tag{3.26}$$

3.5.2 Appendix B. Numerical Procedure

The model is solved through second order perturbation, following a procedure that has been described by Judd (1995) and Schmitt-Grohe and Uribe (2004).

The set of equilibrium conditions can be written in state-space form representation as:

$$E_t f(y_{t+1}, y_t, x_{t+1}, x_t) = 0$$

where $f : \mathbb{R}^{n_y} \times \mathbb{R}^{n_y} \times \mathbb{R}^{n_x} \times \mathbb{R}^{n_x} \to \mathbb{R}^n$, y_t is the size $(n_y \times 1)$ vector of controls and x_t is the the size $(n_x \times 1)$ state vector. In our case, the system of equations consists of the equilibrium conditions (10) - (27).

The vector of endogenous variables y_t is given by:

$$y_t = (c_t, g_t^e, l_t, g_t^i, i_t, k_t, \theta_t^k, \theta_t^n, r_t, w_t, k_{t+1}, \lambda_t^1, \lambda_{t+1}^2, \lambda_t^3, \lambda_t^4, \lambda_t^5, \lambda_{t+1}^6, \Lambda_t)$$

The states vector is given by $x_t = (k_t, a_t, g_t^x, \zeta_t, \lambda_t^2,_t \lambda_t^6)$, which can be further partitioned as $x_t = [x_t^1; x_t^2]$,where x_t^1 consists of the endogenous state variables, in our case $x_t^1 = (k_t, \lambda_t^2, \lambda_t^6)$ and x_t^2 consists of exogenous state variables, i.e. $x_t^2 = (a_t, g_t^x, \zeta_t)$.

We assume that the exogenous state variables follow the process:

$$x_{t+1}^2 = M x_t^2 + \eta \sum \varepsilon_{t+1}$$

where the vector ε_t is assumed to have bounded support and to be independently and identically distributed, with mean zero and variance/covariance matrix I. The eigenvalues if M are assumed to be all smaller than 1 in modulus.

We denote the solution of the model by the functions $g : \mathbb{R}^{n_x} \times \mathbb{R}^+ \to \mathbb{R}^{n_y}$ and $h : \mathbb{R}^{n_x} \times \mathbb{R}^+ \to \mathbb{R}^{n_x}$, such that

$$y_t = g(x_t, \sigma)$$

and

$$x_{t+1} = h(x_t, \eta) + \eta\Omega\varepsilon_{t+1}$$

where $\Omega = \begin{pmatrix} 0 \\ \sum \end{pmatrix}$.

The system may thus be rewritten as:

$$E_t f(g(x_{t+1}, \sigma), g(x_t, \sigma), h(x_t, \eta) + \eta\Omega\varepsilon_{t+1}, x_t) = 0$$

and even further as:

$$E_t f(g(h(x_t, \eta) + \eta\Omega\varepsilon_{t+1}, \sigma), g(x_t, \sigma), h(x_t, \eta) + \eta\Omega\varepsilon_{t+1}, x_t) = 0$$

The perturbation method consists in taking a higher order approximation (we use second-order) around the non-stochastic steady state, where $x_t = x$ and $\sigma = 0$. The system is solved using the generalized Schur decomposition algorithm proposed by Klein (1998) and the package for the perturbation method provided by Schmitt-Grohe and Uribe (2004). The model exhibits saddle-path stability, so an equilibrium can be shown to exist and be unique.

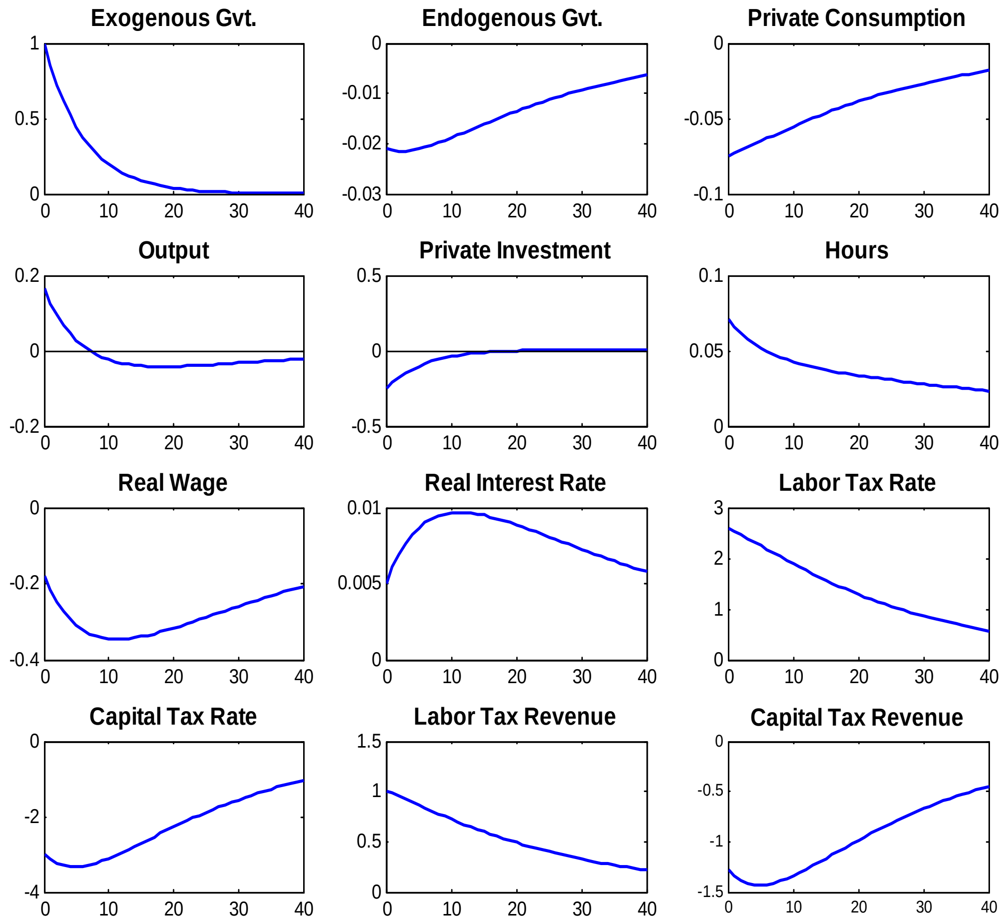


Figure 3.1: Impulse Responses to a Shock to Exogenous Government Consumption

Note: The figure depicts the dynamic responses of selected variables to an increase of one percent of steady state output in exogenous government consumption.

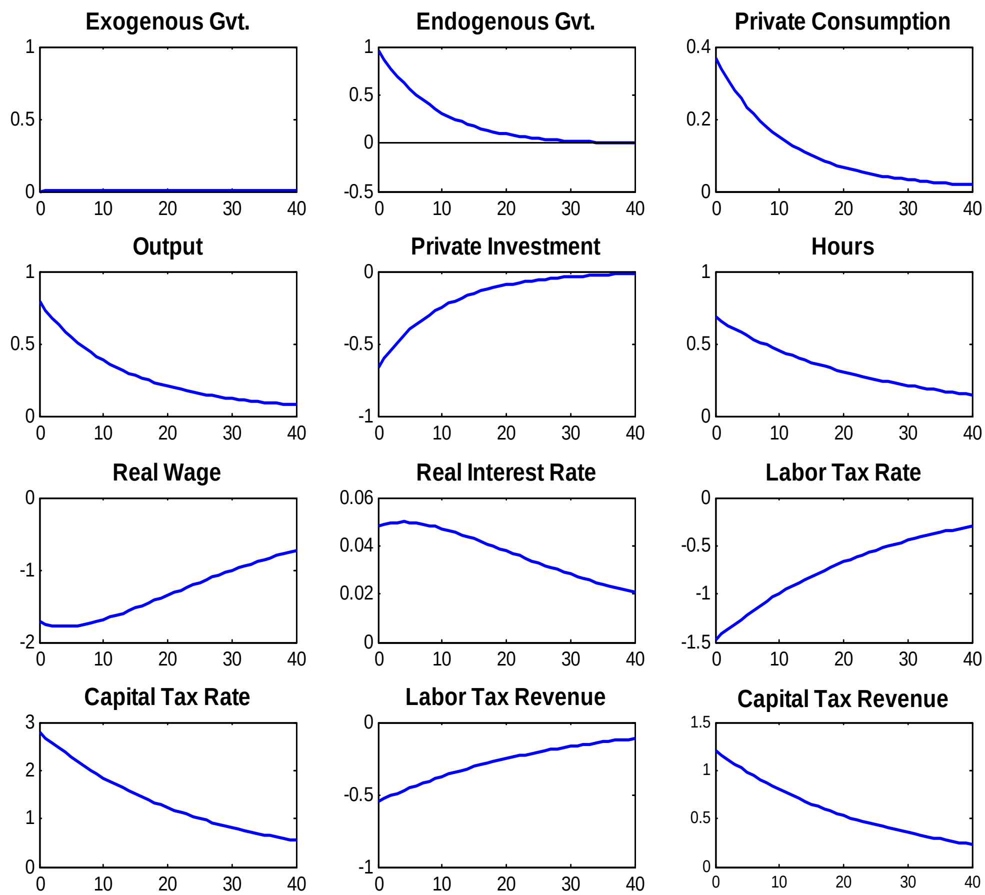


Figure 3.2: Impulse Responses to a Shock to the Preference for Endogenous Government Consumption

Note: The figure depicts the dynamic responses of selected variables to a preferences shock which leads to an increase of one percent of steady state output in endogenous government spending.

Figure 3.3: Impact Multipliers to a Government Spending Preference Shock

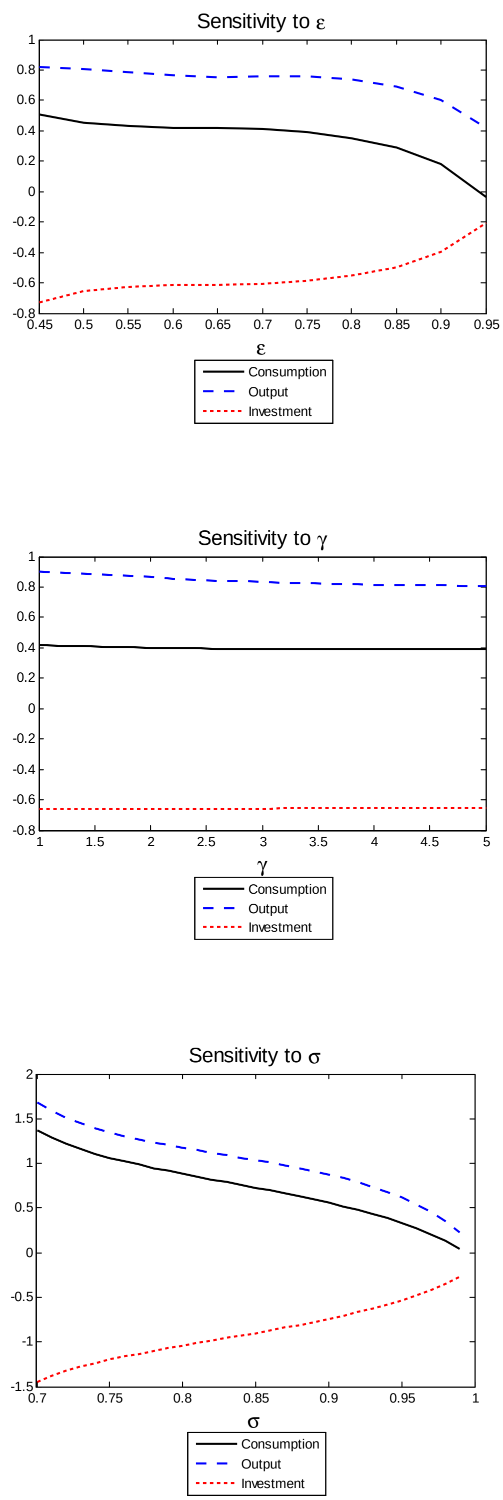
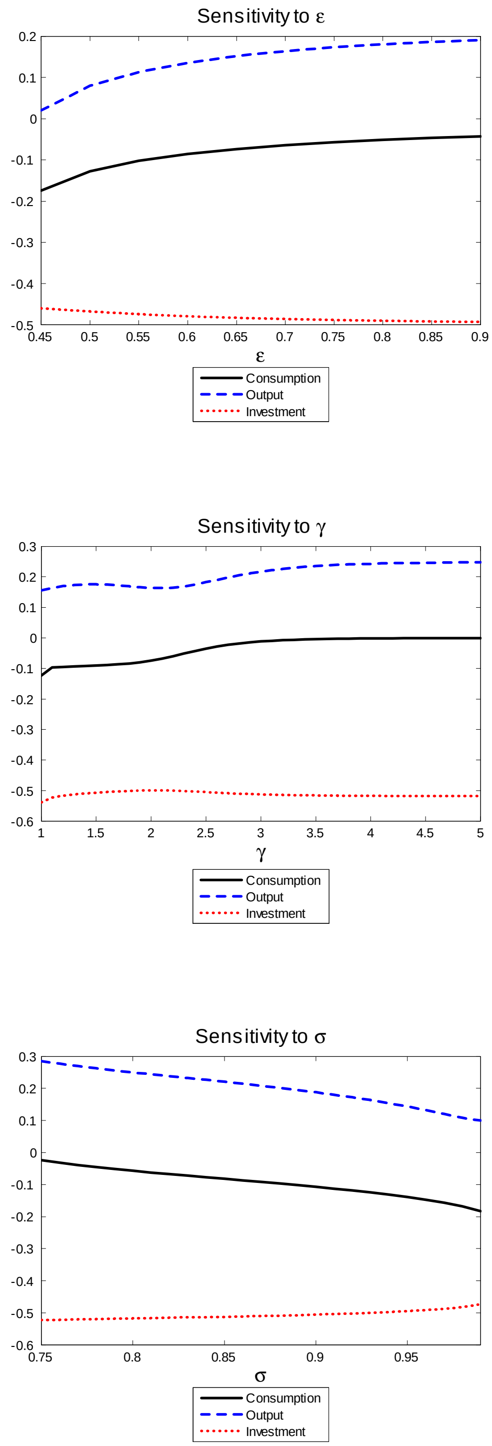


Figure 3.4: Impact Multipliers to an Exogenous Government Spending Shock



Chapter 4

An "Agnostic" Approach for Validating Competing Models

4.1 Introduction

The importance of empirically validating economic models cannot be overemphasized, both from a practical and theoretical perspective. On the one hand, policy makers need to be able to evaluate which are the best models to employ for the design and implementation of policy, in terms of matching the dynamics of the data. On the other hand, different competing theories needs to be tested against a similar empirical benchmark.

A number of technical difficulties accompany the mapping between DSGE models and structural VARs. As known from Hansen and Sargent (1991) and Lippi and Reichlin (1994), there are models which cannot be recovered when the Wold representation is used to set up a VAR, or that do not admit a finite VAR representation (Fernandez-Villaverde et al. (2007)) or that in small samples are poorly represented by VARs (Chari et al. (2006)). Even the most sophisticated state-of-the-art DSGE models represent a reduced form representation of reality and can be misspecified in various ways. Time aggregation, omission of variables and shocks, nonfundamentalness, lack of finite-order representation, etc. may distort the link between loglinearized DSGE models and their potential restricted VAR representation (Canova (2007)).

In this context, classical evaluation methods like maximum likelihood, which place a lot of confidence in the model (required to be the true DGP, up to some serially uncorrelated measurement errors), are bound to fare badly. For example, attempting to minimize the discrepancy between a "false" model and the data would result in estimates which are best exactly in the direction in which the model is misspecified, which cannot be satisfactory from an econometric perspective.

These issues have given rise to a literature aimed at designing more "agnostic" procedures for dealing with potentially misspecified models, which has become an important avenue for research in recent years. In the context in which the model is known to be a distorted representation of reality and the researcher does not have full confidence in quantitative restrictions (like the conventional short-run and long-run restrictions), Bayesian methods, combined or not with DSGE models (see e.g. Schorfheide (2000)) have been applied with considerable success, which explains why they have gained a lot of popularity in both policy and academic circles.

Bayesian estimation, however, is very time-consuming especially when the objective function is not well-behaved (as is likely to be the case with many DSGE models). A possible alternative which has been suggested is evaluating the model based on the *qualitative* features of some of the dynamic responses to the identified shocks. This more lax approach of using sign restrictions to identifying VARs thus offers a possible solution to validating incompletely specified (and possibly false) DSGE models[1]. One standard way of employing sign restrictions is to identify VARs via "robust" sign restrictions (i.e. non-sensitive to parameter or model uncertainty) and considering whether the dynamics of unconstrained variables allows one to reject subclasses or alternative models.

However, while sign restrictions are more robust than classical structural VAR methods,

[1] See, e.g Canova (2007), Canova (2001).

they are also relatively "weak" identification and are not likely to work in every situation. This paper investigates what is the power of the sign restriction methodology employed in Chapter 2 of this dissertation to separate between two fundamentally different models. This question is applied to the specific problem of discerning between two alternative theories for the positive response of consumption to government spending shocks.

We consider two models which both generate a crowding-in of private consumption to expansionary public expenditures. In Chapter 3 of this dissertation, a modified version of the Ramsey optimal fiscal policy model with no nominal rigidities has been shown to be consistent with a positive comovement between private consumption and certain types of government consumption. An alternative explanation which has receive considerable attention has been the one proposed by Galí et al. (2005), who show, in a DNKY framework with price and wage stickiness, that a similar effect on private consumption can be obtained when allowing for a certain part of the population to act as non-optimizers (i.e. rule-of-thumb).

This paper proposes a simple method for evaluating the power of relatively weak identification procedure through sign restrictions developed in Chapter 2 in distinguishing between these two competing theories. In essence, we make use of the fact that one key difference between the two explanations resides in the different transmission mechanism through the labor market, in particular in that they imply qualitatively different responses of the real wage. For a wide range of parametrizations, the RBC model would predict that a positive government spending shock reduces wages, while the DNKY model would generate a positive response of the same variable (the difference is caused, of course, by the presence of nominal rigidities combined with consumer heterogeneity versus heterogeneity in goods).

It seems thus possible to investigate whether one can one distinguish between the different explanations based on the response of wages. For this purpose we use some of the least controversial qualitative implications of both models to identify economic shocks on simulated data from the two models. The discrepancy between the two models can be examined based on the response of the real wage and private consumption. The probability of recovering the correct response for the unsigned variables offers us a way of assessing the power of the restrictions in selecting the better model.

Overall, we find that a weak identification strategy like the sign restrictions method proposed in Chapter 2 allows us to differentiate between the two theories, solely based on the behavior of the real wage. While the procedure is able to correctly recognize the qualitative features of the true DGP, this hinges on several conditions. In particular, our experiments in a controlled environment show that the procedure is more powerful the more restrictions are imposed and the higher the relative variance of the shock(s) one wishes to identify. We also find that the correlation of the responses to various shocks matters and may make it more difficult to recover the true response.

This chapter thus brings together the empirical and theoretical parts in this dissertation proposing a simulation exercise aimed at assessing the robustness of our explanation, when comparing it with an alternative theory. Together with the results in Chapter 2, which point, on real data, to a clear crowding out of real wages across various sectors in response to government spending shocks, our results seem to suggest that the data is more supportive of a neoclassical channel, than of a nominal rigidities channel, at least in order to match the response of private consumption.

This paper contributes to a growing literature on more agnostic procedures for model evaluation by proposing a simple yet easily generalizable methodology for the testing of alternative theories. It builds upon Canova (2001), with the difference that, while in that paper the testing involved nested models, in our exercise, the two models belong to different classes.

The chapter is organized as follows. Section 2 discusses the two models that we compare. Section 3 presents the methodology and the calibration we employ. In Section 4 the results from testing the models against each other are presented and a number of experiments are reported. The last section offers some conclusions.

4.2 A Tale of Two Models

We compare two models providing alternative explanations for the response of private consumption to government spending shocks. The first model is a simplified version of the RBC model with utility-yielding government spending presented in Chapter 3 (model M1). The second one is the DNKY model with rule-of-thumb consumers proposed by Galí et al. (2005) (model M2). We bring the models as close as possible in terms of the structure of the economy and the underlying shocks and frictions, so that we are able to differentiate between them on the basis of the proposed channel for the transmission of fiscal policy shock: the utility of the private agent in model M1 versus consumer heterogeneity and nominal rigidities in model M2.

4.2.1 An RBC Model with Utility-Yielding Government Spending

The model we analyze is a simplified version of the one presented in Chapter 2 of this dissertation, from which a number of frictions are eliminated in order to render the model more comparable with the DNKY model of Galí et al. (2005). In particular, in the model proposed in Chapter 2, utility-yielding government spending was optimally determined by the planner. Here, for simplicity, we consider that the utility-yielding government spending is given exogenously. Additionally, we abstract from a number of additional features, namely habits, distortionary factor taxation and government investment.

The economy is populated by a representative agent who is optimizing over a consumption aggregate of private and public goods $C_t^*(C_t, G_t)$ and leisure $1 - N_t$:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^*(C_t, G_t), 1 - N_t) \tag{4.1}$$

The representative agent supplies both labor and capital to firms and is paid their marginal products, while at the same time she pays a lump-sum tax to the government and saves via a real riskless one-period bond carried over from period $t-1$ and paying one unit of goods in period t, implying the following budget constraint:

$$C_t + I_t + R_t^{-1} B_{t+1} = W_t N_t + R_t^k K_t + B_t - T_t \tag{4.2}$$

Production is the standard Cobb-Douglas function:

$$Y_t = A_t K_t^{\alpha} N_t^{1-\alpha}$$

while capital evolves according to the rule:

$$K_{t+1} = (1-\delta) K_t + \phi \left(\frac{I_t}{K_t} \right) K_t \tag{4.3}$$

The government consists only of a fiscal side with the period-by-period budget constraint:

$$T_t + R_t^{-1} B_{t+1} = B_t + G_t \tag{4.4}$$

Unlike the optimal Ramsey model we have specified in Chapter 3, here we assume that the planner follows a simple fiscal rule, by responding to the deficit and the government spending in the following way:

$$T_t = \phi_b B_t + \phi_g G_t \tag{4.5}$$

The market clearing in the goods market implies that

$$Y_t = C_t + G_t + I_t \tag{4.6}$$

The model is completed by specifying three sources of exogenous shocks for technology, government spending and a labor supply shock.

4.2.2 A DNKY Model with Rule-of-Thumb Consumers

The model in Galí et al. (2005) is an extension of the benchmark DNKY model featuring heterogenous consumers. Part $1-\lambda$ of the households are optimizers, have access to capital markets and accumulate physical capital which they rent out to firms. The remaining λ share of households are rule-of-thumb, i.e. they do not own any financial or physical assets nor have any liabilities and just consume their current labor income. Their sole decision concerns the amount of labor they supply.

The Ricardian households aim to maximize:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^o, 1 - N_t^o) \tag{4.7}$$

subject to the budget constraint:

$$P_t(C_t^o + I_t^o) + R_t^{-1} B_{t+1}^o = W_t P_t N_t^o + R_t^k P_t K_t^o + B_t^o + D_t^o - P_t T_t^o \tag{4.8}$$

where the notation is the same as for problem of the agent in the RBC model presented in the previous section, where the superscript "o" stands for optimizers, and additionally, firms are assumed to pay dividends D_t^o and P_t represents the price level. B_t^o stands here for the quantity of nominally riskless one-period bonds carried over from period $t-1$, and paying one unit of the numéraire in period t.

Capital is accumulated by the optimizing agents in a standard fashion, subject to adjustment costs ϕ:

$$K_{t+1}^o = (1-\delta)K_t^o + \phi\left(\frac{I_t^o}{K_t^o}\right)K_t^o \tag{4.9}$$

The first order conditions for the optimizing households are standard, in that:

$$1 = R_t E_t \Lambda_{t,t+1} \tag{4.10}$$

$$\Lambda_{t,t+1} = \beta \frac{U_{C^o_{t+1}}}{U_{C^o_t}} \tag{4.11}$$

$$\frac{U_{N^o_t}}{U_{C^o_t}} = W_t P_t \tag{4.12}$$

$$P_t Q_t = E_t \left\{ \Lambda_{t,t+1} \left[R^k_{t+1} + Q_{t+1} \left((1-\delta) + \phi_{t+1} - \frac{I^o_{t+1}}{K^o_{t+1}} \phi'_{t+1} \right) \right] \right\} \tag{4.13}$$

where Q_t stands for the shadow price of capital (Tobin's Q) and is given by:

$$Q_t = \frac{1}{\phi'(\frac{I^o_t}{K^o_t})} \tag{4.14}$$

The second class of consumers are assumed to be "naive" and consume their entire labor income. Their utility is described as $U(C^r_t, 1-N^r_t)$ and their their budget constraint is given by:

$$P_t C^r_t = W_t P_t N^r_t - P_t T^r_t \tag{4.15}$$

This gives rise to a first order constraint of the form:

$$\frac{U_{N^r_t}}{U_{C^r_t}} = W_t P_t \tag{4.16}$$

A number of aggregation conditions also hold, namely:

$$C_t = (1-\lambda) C^o_t + \lambda C^r_t \tag{4.17}$$

$$N_t = (1-\lambda) N^o_t + \lambda N^r_t \tag{4.18}$$

$$I_t = (1-\lambda)I_t^o \tag{4.19}$$

$$K_t = (1-\lambda)K_t^o \tag{4.20}$$

On the production side, as standard in this literature, a continuum of monopolistically competitive firms produce differentiated intermediate goods which are used as inputs by a perfectly competitive constant returns firm producing one single final good.

The cost minimization problem of the intermediate goods firms, taking the wage and rental price of capital as given, yields a real marginal cost equal to:

$$MC_t = \frac{(R_t^k)^\alpha (W_t)^{1-\alpha}}{\alpha^\alpha (1-\alpha)^{1-\alpha}} \tag{4.21}$$

Intermediate firms are assumed to set prices in a staggered fashion à la Calvo (1983), with the probability of prices being reset given by $1-\theta$ every period.

The first order condition of the profit maximization problem with respect to price gives rise to the following first order condition:

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \Lambda_{t,t+k} Y_{t+k}(j) \left(\frac{P_t^*}{P_{t+k}} \right) - \frac{\eta}{\eta-1} MC_{t+k} \right\} = 0 \tag{4.22}$$

where P_t^* represents the optimal price chosen by the firms resetting the price at time t and η is the elasticity of substitution in production between intermediate goods.

The equation describing the evolution of the aggregate price level is given by:

$$P_t = [\theta P_{t-1}^{1-\eta} + (1-\theta)\left(P_{t-1}^*\right)^{1-\eta}]^{\frac{1}{1-\eta}} \tag{4.23}$$

Monetary policy is assumed to follow a Taylor rule (Taylor (1993)) according to which the nominal interest rate depends linearly on its own lag, the log deviations of output from its steady state value and the deviations of inflation from the inflation target:

$$\ln \frac{R_t}{R^*} = \rho_r \ln \frac{R_{t-1}}{R^*} + (1-\rho_r)\left(\gamma_\pi \ln\left(\frac{\pi_t}{\pi^*}\right) + \gamma_y \ln\left(\frac{y_t}{y^*}\right)\right) \tag{4.24}$$

Fiscal policy is specified as following the period-by-period budget constraint:

$$P_t T_t + R_t^{-1} B_{t+1} = B_t + P_t G_t \tag{4.25}$$

where taxes are aggregated over the two categories of agents:

$$T_t = (1-\lambda) T_t^o + \lambda T_t^r \tag{4.26}$$

Since there is no optimal policy set-up, we assume as Galí et al. (2005) the existence of a fiscal rule:

$$T_t = \phi_b \frac{B_t}{P_t} + \phi_g G_t \tag{4.27}$$

where the parameters ϕ_b and ϕ_g are specified in such a way that determinacy is ensured.

Finally, the model is closed by a market-clearing condition for goods:

$$Y_t = C_t + G_t + I_t \tag{4.28}$$

and by the exogenous processes for technology, government spending and the labor supply shock.

4.3 Methodology

The procedure consists in the following steps.

4.3.1 Finding Robust Sign Restrictions for Each Model

The identification of robust sign restrictions from the two theoretical models proceeds as follows. A number of uncontroversial parameters are fixed, while the rest are drawn from uniform distributions over the plausible ranges encompassing the most usual values found in the literature. For each draw, the model is simulated and the signs of the impulse responses to a number of structural shocks are considered. A criterion is then defined for what restrictions are considered robust enough which takes the form of a "confidence" band for a certain horizon.

This method can be formalized in the following way.

Let $h(y(\theta|x, M))$ be the $N_y \times 1$ vector of impulse response functions produced by the model M containing N_y endogenous variables, N_x shocks and N_θ structural parameters θ. Let Θ be the set of admissible parameter values for θ derived from the empirical literature.

The procedure involves the following steps:

Step 1. For $l = 1, ..., R$, R representing the number of replications, draw structural parameters $\theta_i^l, i = 1, ..., N_\theta$ from each Θ_i and generate the vectors $h(y(\theta^l|x, M))$ when they are well defined (when a determinate rational expectations equilibrium exists).

Step 2. Order the impulse response vectors $h(y(\theta^l|x, M))$ increasingly period-by-period.

Step 3. Define the sign criterion to be employed. For example, if one is interested in the sign for a number of T periods, let $sgn(h_t(y_j(\theta^l|x_k, M)), j = 1, ..., N_y, k = 1, ..., N_x, t = 1, ..., T$ denote the sign in period t of the response of variable j to shock k. Define also a robustness criterion α (for example $\alpha = 0.95$).

Step 4. The impulse response $h(y_j(\theta^l|x_k, M)$ is considered to be robust if $sgn(h_t^U(y_j(\theta^l|x_k, M)) = sgn(h_t^L(y_j(\theta^l|x_k, M))$ for $L \leq \frac{1-\alpha}{2}$, where L represents some lower percentile and U represents some upper percentile of the ordered impulse response functions vector $h(y(\theta^l|x, M))$.

4.3.2 Recovering the True Model on the Basis of the Imposed Restrictions

In order to be able to answer the question of whether our robust sign restrictions identified in the previous step would allow to distinguish between structurally different models, we proceed in the following way. Suppose we have two models, M1 and M2, and for each of them a set of robust restrictions has been identified, which do not entirely overlap. Assuming for example that M1 is the true data generating process, we simulate data from this model and estimate a VAR using the sign identification restrictions which are common to both models. We then assess the probability of this procedure of delivering the "correct" sign for the variable(s) which have been left unsigned. More formally we can express this procedure through the following steps.

Step 5. For each model $M_m, m = 1, ..., N_m$, derive the set of sign robust IRFs as corresponding to pairs of variables j to shocks k which are robust for t periods according to the set criterion:

$$\Upsilon_{M_m} = \{(j,k)/h_t(y_j(\theta^l|x_k, M) \text{ is robust}\} \tag{4.29}$$

Step 6. Consider two models M_1 and M_2 such that their sets of sign robust IRFs are different, none is entirely included in the other set and they are not disjoint:

$$\Upsilon_{M_1} \neq \Upsilon_{M_2}$$

$$\Upsilon_{M_1} \cap \Upsilon_{M_2} \neq \varnothing$$

$$\Upsilon_{M_1} - \Upsilon_{M_1} \cap \Upsilon_{M_2} \neq \varnothing$$

$$\Upsilon_{M_2} - \Upsilon_{M_1} \cap \Upsilon_{M_2} \neq \varnothing$$

This is equivalent to assuming that for some shock k, there exists at least a variable $j^*, 1 \leqslant j^* \leqslant N_y$ such that for t periods, the models imply strictly different signs:

$$sgn(h_t^R(y_{j^*}(\theta|x_k, M_1)) = -sgn(h_t^R(y_{j^*}(\theta|x_k, M_2))$$

where R stands for the robust sign found for model $M_{m=1,2}$.

Step 7. Simulate model M_1 and estimate a VAR on this data using the set of restrictions common to the two models , i.e. $\Upsilon_{M_1} \cap \Upsilon_{M_2}$. The implementation of the sign restrictions methodology has been described in detail in Chapter 2.

Step 8. Evaluate:

$$Prob(sgn(h_t^S(y_{j^*}(\theta|x_k, M_1) = sgn(h_t^R(y_{j^*}(\theta|x_k, M_1)) \tag{4.30}$$

$$Prob(sgn(h_t^S(y_{j^*}(\theta|x_k, M_1) = sgn(h_t^R(y_{j^*}(\theta|x_k, M_2)) = 1 - sgn(h_t^R(y_{j^*}(\theta|x_k, M_1)) \tag{4.31}$$

where the superscript S stands for the pseudo-impulse responses generated at Step 7 while R identifies the robust IRFs signs computed at Step 4.

These probabilities have a clear interpretation in terms of hypothesis testing. In the context of the artificial data being generated with model M1 and setting up the null hypothesis that the correct sign is the one produced by model M2, (4.30) can be interepreted as the power of the test (rejecting a false null), while (4.31) would correspond to the probability of a Type II error.

4.3.3 Functional Forms and Calibration

Preferences are described by a standard specification, additively separable in consumption (which can be an aggregate) and leisure, where we also specify a labor supply disturbance ε_t^{LS} affecting the marginal rate of substitution between the two, as:

$$u(C_t^*, N_t) = \frac{(C_t^*)^{1-\gamma}}{1-\gamma} + \varepsilon_t^{LS} \frac{(1-N_t)^{1-\phi}}{1-\phi}$$

While in the DNKY model C_t^* simply stands for private consumption, in the modified-RBC model, consumption is a composite of the private and public good, defined as a CES aggregator:

$$C_t^* = \begin{cases} \left(\sigma C_t^{\frac{\epsilon-1}{\epsilon}} + (1-\sigma)(G_t)^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}, \epsilon \neq 1 \\ C_t^{\sigma}(G_t)^{1-\sigma}, \epsilon = 1 \end{cases}$$

The convex investment adjustment cost function is specified as:

$$\phi(\frac{I_t}{K_t}) = \frac{\kappa}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t \tag{4.32}$$

We employ a quarterly calibration (see Table 4.1). The parameter vector θ is divided into two parts. First, some parameters, which are widely established are calibrated to their standard values used in the literature (we include here the capital share α, the depreciation rate δ and the discount factor β). The second category includes parameters for which there is considerable more dispersion in the values estimated in the literature or usually assumed in calibration exercises. In their case we allow for variation ranges which are wide enough to encompass most of the values used in other studies (the reader is also referred to the discussion on the calibration of these parameters from Chapter 3).

The risk aversion parameter γ in the benchmark is set to the standard log utility and is allowed to vary between 0.5 and 5, which covers both the lower values used in the macroeconomics literature and the generally higher numbers which are consistent with asset pricing models. At the same time, the share of private goods in the aggregate consumption bundle σ is allowed to vary between 0.7 to 1.

The the elasticity of substitution between private and public goods ϵ is key to the response of private consumption to government spending shocks in the modified RBC model. In particular, as discussed also in Chapter 3 of this dissertation, a positive comovement depends on the two types of goods being complementary in the utility function. Since here we are concerned only this type of dynamics, we restrict the elasticity of substitution between private and public goods ϵ to vary between 0.3 and 0.95, which is consistent with complementarity and covers most of the empirical estimates.

The parameter ϕ characterizing leisure smoothing is chosen such that the elasticity of labor supply varies in the interval $[0.5, 10]$, which covers both the relatively low elasticities typically estimated in micro studies and the larger elasticities which are generally used in macro models (for a steady-state labor supply of 1/3 of total time, this yields an interval for $\phi \in [0.25, 5]$).

The capital adjustment cost parameter κ is specified to also cover a very broad range, from 1 to 10, given that, especially in the DNKY model, these effects seem to be particularly important not only for the response of investment, but also indirectly, for those of the labor markets.

Moving on to the parameters characterizing the fiscal rule, we follow Gali who calibrate the benchmark values for the parameter of spending in the tax rule ϕ_g to 0.10 and for the parameter of debt in the tax tule ϕ_b to 0.30, based on VAR-estimates for the responses of government spending and the deficit. A number of long-run ratios are also calibrated from post-war US data, namely the government spending to GDP ratio is take to be 0.20, fluctuating within the range $[0.10, 0.30]$, while the debt to GDP ratio is benchmarked at 0.30, while allowed to vary in the interval $[0.20, 0.60]$.

The modified-DNKY model includes a number of additional parameters characterizing the nominal rigidities. The more standard parameters, such as the degree of price stickiness

θ, is taken to be 0.7, which is quite standard in the literature and the interval of variation is also quite wide, from 0 to 0.9. The coefficients in the Taylor rule are set to ranges of values which cover both more aggressive and weaker interest rate responses to inflation and respectively output and low and high levels of inertia. The benchmark values are quite standard for the literature and they are the ones used for example by Canova (2001).

Additionally, the modified-DNKY model includes a specific parameter, namely the share of rule-of-thumb consumers λ, which is crucial for the predictions of this model. In the benchmark version we calibrate this value to 0.5, as in Gali. However, in this model the crowding in effect of private consumption depends on the share of share of "naive" consumers being sufficiently large. For this reason, in our calibration we restrict our attention to the support for λ from 0.4 to 0.9.

The vector of shocks $S_t = [\varepsilon_t^{PROD}, \varepsilon_t^{LS}, \varepsilon_t^{G}]$ is assumed to follow an AR(1) process, as follows:

$$S_{t+1} = (I - \varrho)\overline{S} + \varrho S_t + V_t$$

where V_t is a vector of white noises with diagonal covariance matrix Σ_V,ϱ is diagonal matrix with subunitary roots and $\overline{S}$ is the mean of S. The benchmark values for these shocks come from Smets and Wouters (2003), however, they are quite standard, while the variation ranges are quite encompassing.

4.4 Results

4.4.1 Robust Signs for the Considered Models

As discussed, in the first part of the procedure we obtain robust implications of the two models. From a set of 10^5 draws for the structural parameters from the range of values described in Table 4.1, we select those in which a determinate rational expectations equilibrium exists and examine the signs of the impulse responses to the three types of shocks. For our set of variables of interest (real wage, consumption, output, investment and government spending) we report in Table 4.2 the robust signs corresponding to 95 percent bands over a 4 quarter horizon.

The effects of the productivity and labor supply shocks are identical across both models for the variables of interest. In particular, in line with a large literature[2], a positive shock to technology is expansionary for both consumption, investment and output. The real wage also rises uncontroversially regardless of the presence of nominal rigidities, as the reduction in the labor supply due to the positive wealth effect and the increase in labor demand reinforce each other. The reader may observe that we do not include hours in our system of variables, since this response is not robust, nor do we want to take a stance on this very controversial issues.

Similarly, for labor supply shocks both models generate similar predictions for a wide range of reasonable parametrizations. The channel through which these shocks operate, by affecting the elasticity of substitution between consumption and leisure and thus generating a shift in the labor supply, leads, regardless of whether nominal rigidities operate or not, to a positive comovement of output, consumption and investment, while real wages move in the opposite direction.

Turning to the only demand-side shock we consider - government spending - , both models generate an increase in private consumption for our considered parameter values. It should be noted that both models can generate a response of private consumption for government spending shocks in either direction. This depends crucially on the elasticity of substitution between private and public goods in model M1 and on the share of rule-of-thumb consumers in model M2. Since the purpose of this exercise is to compare two different theories which explain a crowding-in of consumption by government spending, our focus is naturally on values for these parameters which are consistent with this prediction.

[2] See also the discussion in Chapter 2.

While both models imply a crowding-in of private consumption, the transmission channel of the fiscal shock is different, which is reflected in the opposite response of the real wage. In particular, in the modified RBC model with utility-yielding government consumption, real wages uncontroversially decrease, due to the negative wealth effect of government spending (this is true regardless of how the latter is expended).

Unlike the neoclassical paradigm, the DNKY models generate an increase in the real wage in response to government spending shocks. The presence of price stickiness make it possible for real wages to increase (or, at least, to decline by a smaller amount) even when the marginal product of labor declines, as the price markup may adjust sufficiently downward to absorb the resulting gap.

On the basis of these summary responses, it appears that one way of distinguishing between the two explanations put forward for the response of private consumption to government spending shocks is the behavior of the real wages.

4.4.2 Testing the Two Models against each Other

We consider in turn that each model is the DGP and test whether it can be distinguished from the other model on the basis of the response of the real wage to government spending shocks only. This is done via a series of experiments in which we take one model as the DGP and impose the common sign restrictions, which allows us to assess the probability that the response of response(s) for the unsigned variable(s) is correctly signed. Then, we reverse the null and the alternative hypothesis and repeat the experiment for simulated data from the second model and assess the corresponding probabilities. If these probabilities are higher than conventional levels, we can claim that the procedure is indeed capable of differentiating between the two theoretical explanations.

In the first experiment, we take in turns models M1 and M2 to be the "true" representation of the dynamics of the data. The parameters are set to their benchmark values as described in Table 4.1. We draw 200 replications of the shocks and simulate paths for all the endogenous variables of length 1000. Samples of length $T = 250$ for our variables of interest (the last observations) are retained, in order for the results to be comparable with those estimated on post-war quarterly time series.

For each replication, we estimate a 4 lag VAR identified through imposing the common sign restrictions from the two models (the order of the lag is determined through the standard information criteria). More precisely, the 8 restrictions identifying the productivity and labor supply shocks (on real wage, consumption, output and investment) are imposed for 4 periods. Additionally, the government spending shock is assumed to generate the dynamics described in Table 4.2 on consumption, output, investment and government spending. The only unsigned response is that of wages to government spending shocks.

For each replication, we compute 95 and 68 percentile bands and the median (based on a minimum of 1000 solutions). We then average the medians across the samples and compare them with the true (population) impulse responses. We also take the average of the upper and lower 95 and 68 percentile bands across replications (alternatively, we could take the maximum and respectively the minimum, which would result in slightly larger bands).

In Figure 4.1 we plot how the sign-VAR on the artificial data compares with the true model dynamics for the modified RBC model, by plotting the average median, together with the 95 and 68 percentile bands. In Figure 4.2 we plot the same results for data generated by the modified DNKY model.

The average median responses are good estimators of the true responses, both in terms of magnitude and shape, not only for the periods in which the restrictions have been imposed (i.e. 4 quarters) but for the entire path of the impulse response functions. Moreover, the estimation seems to recover remarkably well the response of the real wage to the government spending shock, which has been left unsigned. The 95 percentile bands exclude zero for the entire number of periods for which the restrictions have been imposed and in some occasions for even longer, while the 68 percentile bands are obviously even more precise.

Overall, the procedure seems to perform very well, in that the dynamic responses of the model are well captured. However, the circumstances of this estimation are very favorable, which may not be the case in practice. In particular, we have assumed perfect knowledge of all the underlying disturbances and the model's responses to them (with only one impulse response left unsigned). In practice, one may dispose over identification restrictions over fewer variables and fewer shocks.

We now move on to probabilistically assess the outcomes of several deviations from the ideal conditions described above. As a benchmark, we report in Table 4.3 the outcomes from the first set of experiments. Out of the 10^6 rotations, we find that 2.6% of the draws satisfy all the restrictions for model M1 and 1.6% satisfy all the restrictions of model M2. The response of the real wage to the government spending shock has the correct sign on impact in 98 percent of the cases for model M1 and in 96 percent of the cases for model M2. Thus, with only one impulse response left unsigned, the sign restrictions methodology almost always pins down the correct response. Certainly, as one increases the horizon, the precision also declines, so that at a 2 year horizon, for model M1 only 68 percent of the wage responses have the right sign.

However, one may be interested how much "power" the procedure loses if fewer restrictions are used, which is likely to be the case in real estimation, where not all underlying shocks can be recovered. For this purpose we repeat the experiments in that we only identify two shocks instead of three (the government spending shock and either the productivity or the labor supply shock) and finally, we identify solely the government spending shock. Intuitively, one would expect that the variance of the identified shocks relative to the "left-out" shocks to matter. Also, identifying fewer shocks should increase the number of solutions, while possibly reducing the precision of correctly signing the "free" response(s).

This is precisely what we observe (see Table 4.3). The number of draws satisfying all the restrictions increases as fewer shock are identified, however, the proportion of correctly signed response for the real wage decreases in both models. For example, leaving the technology shock out increases the proportion of solutions by the order of 20-25 percent in both models, however, the response of the real wages crosses the zero line more often.

When a shock with a large variance is left unidentified (in our case the labor supply shock provides the strongest signal), the outcome is most heavily affected in both models. However, the results in the DNKY model suffer slightly worse. If in the estimation on data simulated from the modified-DNKY model we "omit" the labor supply shock, the probabilities of correctly signing the real wage becomes relatively low (at longer lags well under 50 percent). In this case, some of the variance-covariance matrix decompositions consistent with the restrictions would be "contaminated" by the higher signal of the labor supply shock. Thus, it may be possible that the estimation attributes to a government spending shock the effects of a labor supply shock (this may happen in up to 5 percent of the cases in which the response of investment is bordeline). However, a labor supply shock in the DNKY model drives down wages, which leads to some of these negative responses in wages being wrongly attributed to the government spending shock.

A further experiment involves imposing fewer restrictions, while of course keeping sufficient constraints in place so that the shocks are properly identified. In our case, a relevant candidate variable to be left unsigned is private consumption, since in the empirical estimation in Chapter 2 this is our main object of interest. We thus eliminate the restrictions on the response of private consumption from all identified shocks (otherwise the restrictions are as above) and again experiment with identifying a variable number of shocks.

The results (see Table 4.4) point to the fact that even if private consumption is not a "necessary" variable for the identification of the shocks, the predictions come out sharper if this response is also imposed. When all three shocks are identified (using the common restrictions lest those on consumption and the real wage), the probabilities of recovering the correct response for both consumption and the real wage to government spending shocks are still quite high for data generated by either model. Nevertheless, as we "omit" relevant shocks, while this increases the number of solutions, it also introduces more noise and the probability of borderline responses increases.

Overall, a number of conclusions can be derived from these experiments. These results point to the importance of using an adequately large number of restrictions in order to be confident that the identified response is not "blurred" by uncertainty stemming from other sources. The variance of the identified shocks plays an important role in allowing a clear extraction of the true responses: the larger the relative variance of the shock we are interested in recovering, the stronger the signal and the more precise the identification of the correct effects. On the other hand, important shocks left unidentified have the potential to affect the results.

In order to check for this implication, we conduct an experiment in which the variance of the government spending shock is multiplied by a factor of 10 (this correction is enough to make it the most important shock). As expected, the results (reported in Table 4.5) point to a dramatic increase in precision when there is a stronger variance signal (and a corresponding narrowing of the percentile bands).

4.4.3 Comparison with the Literature

The experiments pursued in this paper provide insights which are more general in nature than the specific problem to which we apply it. In particular, they highlight potential strengths and weaknesses of the sign restrictions method of which the researcher needs to be aware. We present here the main conclusions, while at the same time comparing our findings with those of the previous literature.

This paper confirms the importance of the imposing a large number of restrictions and of identifying shocks with large variance. A similar observation has been made by Canova (2001): *"Two conditions must be met for [sign restrictions] to unambiguously deliver the correct sign of the unconstrained impulse response: a sufficiently large number of restrictions must be imposed and the variance of the shock under study must be sufficiently large."* This would imply, as a matter of practical procedure in a VAR identified by signs restrictions, that the researcher attempts to identify as many as possible of the important shocks. If high variance shocks are left completely unidentified, they can potentially distort the estimation of the results to the shock of interest, in particular if the responses to the two shocks are highly correlated for a number of variables, but not for the variable(s) in which one is most interested. These observation question some of the practice in the literature, in particular, the identification of only a single shock (see, e.g. Uhlig (2005), Dedola and Neri (2004)).

Finally, one needs to acknowledge that this procedure is not suited in all circumstances and requires to be seriously checked for robustness and corroborated with results from other methodologies. In particular, trying to identify the effects of relatively small shocks, while considering a set of variables for which other shocks generate close dynamics, is likely to be problematic. The method seems to be best suited when the derived predictions are very sharp and the possibility of confusing the desired shock with others are limited. In such circumstances, the sign restriction procedure can be a useful diagnostic tool for rejecting alternative models.

4.5 Conclusions

The set of experiments conducted in this paper discusses some of the strengths and weaknesses of the sign restrictions procedure employed in Chapter 2 of the dissertation in a simulated environment, in order to infer its power in real estimation. Overall, we find that the method is quite robust in recognizing the qualitative features of the data generating process with high probability, under certain conditions. In particular, the method operates best when as many shocks as possible are identified through a sufficiently large number of restrictions and/or when the identified shocks provide the strongest signal.

In particular, we offer the example of two models with different channels for the transmission of government spending shocks, where we find that a critical distinctive element is the response of real wages. We show that the method works well in this set-up and is able to provide evidence in order to differentiate between these two models. In particular, our results suggest that the response of the real wage to government spending shocks allows us to recognize the true DGP and to reject the alternative model with sufficiently high probability.

Table 4.1: Structural Parameter Values and Ranges

Model(s)	*Parameter*	*Description*	*Benchmark*	*Support*
		Calibrated Parameters		
M1,M2	α	Share of capital	0.36	
M1,M2	δ	Depreciation rate	0.025	
M1,M2	β	Discount factor	0.99	
		Randomized Parameters		
M1,M2	γ	Risk aversion in (aggregate) consumption	1	$[0.50, 5]$
M1,M2	ϕ	Inverse of the elasticity of the labor supply	2	$[0.25, 5.00]$
M1	σ	Share of private consumption in total consumption	0.93	$[0.7, 1]$
M1	ϵ	Elast. of substitution betw. private and public goods	0.72	$[0.3, 0.95]$
M1,M2	κ	Capital adjustment cost	5	$[1, 10]$
M1,M2	ϕ_g	Parameter of spending in the tax rule	0.10	$[0.05, 0.15]$
M1,M2	ϕ_b	Parameter of debt in the tax tule	0.30	$[0.25, 0.40]$
M2	λ	Share of rule-of-thumb consumers	0.50	$[0.40, 0.90]$
M2	θ	Price stickiness	0.70	$[0, 0.90]$
M2	ρ_r	Inertia in Taylor rule	0.74	$[0.25, 0.95]$
M2	γ_π	Inflation coefficient in Taylor rule	1.08	$[1.05, 2.50]$
M2	γ_y	Output coefficient in Taylor rule	0.26	$[0, 0.50]$
M1,M2	$\frac{G}{Y}$	Steady-state gvt. spending to GDP ratio	0.20	$[0.10, 0.30]$
M1,M2	$\frac{D}{Y}$	Steady-state debt to GDP ratio	0.30	$[0.20, 0.60]$
		Shock Processes		
M1,M2	ρ_{PROD}	Persistence of the productivity shock	0.85	$[0.50, 0.95]$
M1,M2	σ_{PROD}	Standard deviation of the productivity shock	0.61	
M1,M2	ρ_{LS}	Persistence of the labor supply shock	0.89	$[0.5, 0.95]$
M1,M2	σ_{LS}	Standard deviation of the labor supply shock	1.65	
M1,M2	ρ_{GOV}	Persistence of the government spending shock	0.87	$[0.5, 0.95]$
M1,M2	σ_{GOV}	Standard deviation of the government spending shock	0.32	

Notes

M1 - modified RBC: flexible wages and prices and utility-yielding government spending

M2 - modified DNKY: sticky wages and prices, wasteful government spending and rule-of-thumb consumers

Table 4.2: Robust Signs of the Impulse Responses for the Considered Models

	Supply Shocks		**Demand Shocks**	
	Technology	**Labor Supply**	**Government Spending**	
	M1, M2	**M1, M2**	**M1**	**M2**
Real Wage	+	-	-	+
Consumption	+	+	+	+
Output	+	+	+	+
Investment	+	+	-	-
Govt. Spend.			+	+

Notes:
M1 - modified RBC: flexible wages and prices and utility-yielding government spending
M2 - modified DNKY: sticky wages and prices, wasteful government spending and rule-of-thumb consumers
The signs are robust for at least 4 periods after the shock based on 95 percentiles.

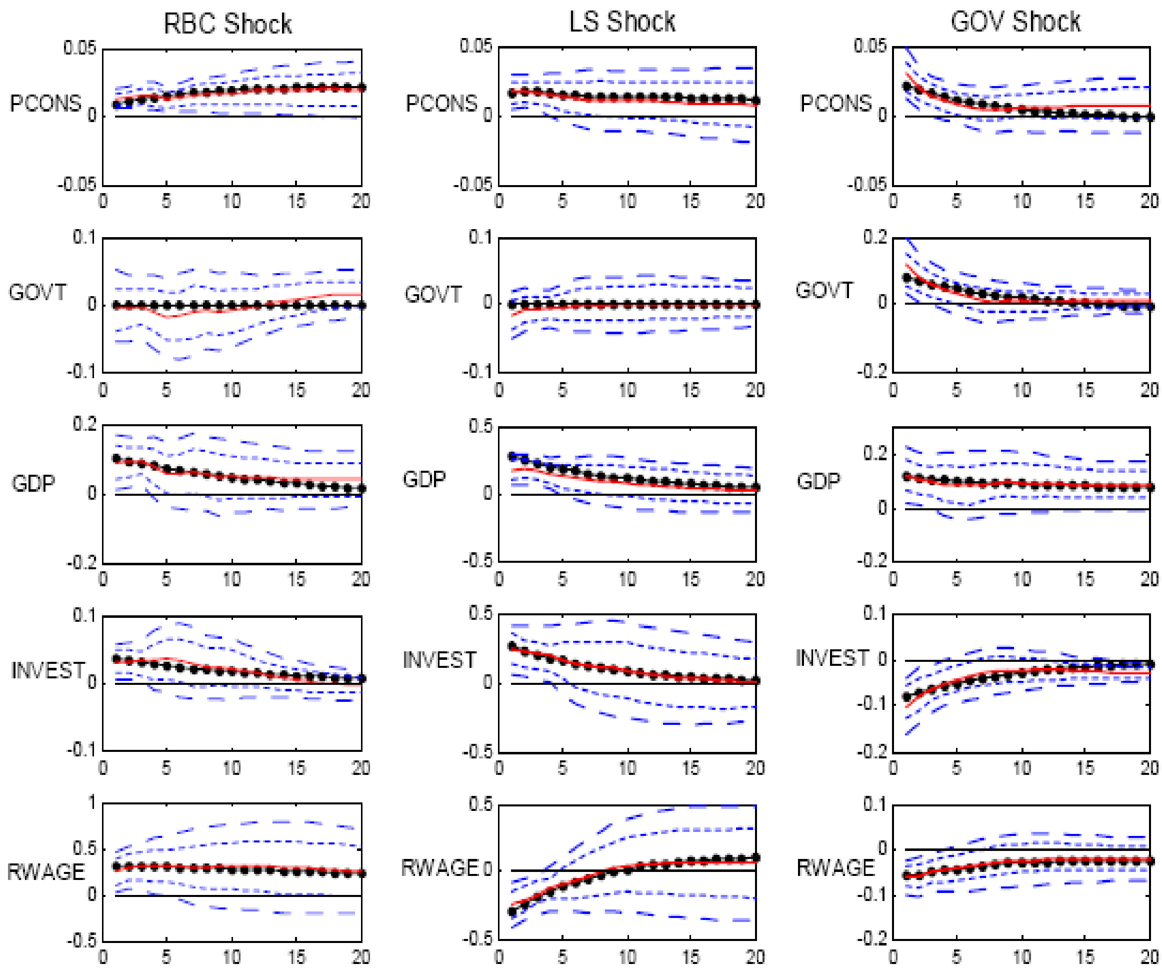


Figure 4.1: Responses to the technology, labor supply and government spending shocks in the modified RBC model

Note: This figure shows the true model response (black with round markers), estimated median (red line), the 16th and 64th percentiles (blue short dashes, the 2.5th and 97.5th percentiles (blue long dashes).

Note: This figure shows the true model response (black with round markers), estimated median (red line), the 16th and 64th percentiles (blue short dashes, the 2.5th and 97.5th percentiles (blue long dashes).

Figure 4.2: True and Estimated Impulse Responses in the Modified DNKY Model

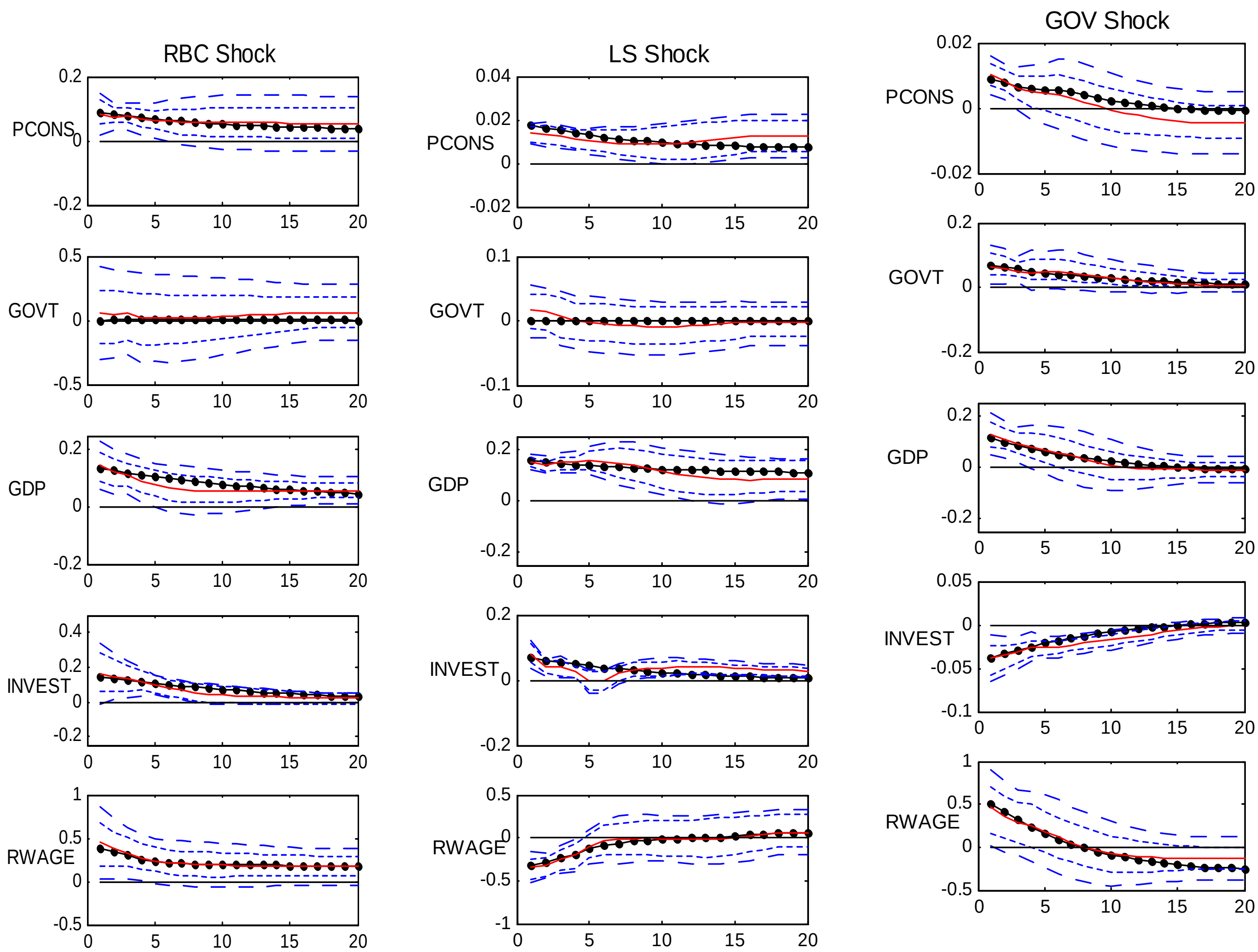


Table 4.3: Probability of Correctly Signed Impact Wage Responses to Government Spending for Various Identified Shocks and Horizons

Identified Shocks	**Model M1-RBC**				**Model M2-DNKY**			
	% sol	% wage			% sol	% wage		
		Q0	*Q4*	*Q8*		*Q0*	*Q4*	*Q8*
PROD, LS and GOV	0.026	0.98	0.84	0.68	0.016	0.96	0.70	0.53
LS and GOV	0.32	0.88	0.78	0.59	0.24	0.86	0.68	0.49
PROD and GOV	0.24	0.78	0.63	0.53	0.26	0.78	0.60	0.45
GOV	0.74	0.72	0.60	0.51	0.69	0.63	0.52	0.43

Shocks identified through the common restrictions in Table 3 imposed for 4 periods. The impact response is denoted as the response at horizon 0.

Table 4.4: Probability of Correctly Signed Impact Wage Responses to Government Spending when both Private Consumption and the Real Wage are Left Unsigned

Identified Shocks	**Model M1-RBC**				**Model M2-DNKY**			
	% cons	% wage			% cons	% wage		
	Q0	*Q0*	*Q4*	*Q8*	*Q0*	*Q0*	*Q4*	*Q8*
PROD, LS and GOV	0.94	0.94	0.74	0.67	0.97	0.96	0.70	0.49
LS and GOV	0.93	0.78	0.60	0.51	0.90	0.87	0.66	0.53
PROD and GOV	0.89	0.88	0.65	0.59	0.88	0.76	0.60	0.52

Shocks identified through the common restrictions in Table 3 imposed for 4 periods. The impact response is denoted as the response at horizon 0.

Table 4.5: Probability of Correctly Signed Impact Wage Responses to Government Spending when Changing the Variance of the Identified Shocks

Identified Shocks (Variances)	**Model M1-RBC**				**Model M2-DNKY**			
	% sol	% wage			% sol	% wage		
		Q0	*Q4*	*Q8*		*Q0*	*Q4*	*Q8*
3 ($\sigma_{PROD} = 0.61, \sigma_{LS} = 1.65, \sigma_{GOV} = 0.32$)	0.026	0.98	0.84	0.68	0.016	0.96	0.70	0.49
3 ($\sigma_{PROD} = 0.61, \sigma_{LS} = 1.65, \sigma_{GOV} = 3.2$)	0.034	0.99	0.98	0.84	0.025	0.99	0.96	0.85
2 ($\sigma_{PROD} = 0.61, \sigma_{GOV} = 3.2$)	0.34	0.97	0.96	0.73	0.26	0.96	0.88	0.76
2 ($\sigma_{LS} = 1.65, \sigma_{GOV} = 3.2$)	0.25	0.98	0.73	0.69	0.32	0.96	0.82	0.72

Shocks identified through the common restrictions in Table 3 imposed for 4 periods.
The impact response is denoted as the response at horizon 0.

Bibliography

Abreu, D., D. Pierce, and E. Stacchetti (1990). Toward a theory of discounted repeated games with imperfect monitoring. *Econometrica 58*, 1041–1063.

Ahmed, S. and B. S. Yoo (1995). Fiscal trends and real economic aggregates. *Journal of Money, Credit and Banking 27*, 985–1001.

Aiyagari, S. R., L. Christiano, and M. Eichenbaum (1992). The output, employment and interest rate effects of government consumption. *Journal of Monetary Economics 30*, 73–86.

Amano, R. A. and T. S. Wirjanto (1997). Intertemporal substitution and government spending. *The Review of Economics and Statistics 4*, 605–609.

Ambler, S. and E. Cardia (1997). Optimal public spending in a business cycle model: Should we rebuid built-in stabilizers?

Ambler, S. and A. Paquet (1996). Fiscal spending shocks, endogenous government spending and real business cycles. *Journal of Economic Dynamics and Control 20*, 237–256.

Apostol, T. M. (1974). *Mathematical Analysis* (2nd ed.). Reading, Mass.: Addison-Wesley.

Aschauer, D. (1985). Fiscal policy and aggregate demand. *American Economic Review 75*, 117–127.

Barnett, A. and R. Straub (2007). What drives US current account fluctuations ? Mimeo.

Barro, R. (1981). Output effects of government purchases. *Journal of Political Econ-*

omy 89, 1086–21.

Barro, R. J. (1979). On the determination of public debt. *Journal of Political Economy 87*(940-971).

Basu, S. and J. F. M. Kimball (1999). Are technology improvements contractionary? Mimeo.

Baxter, M. and R. G. King (1993). Fiscal policy in general equilibrium. *American Economic Review 83*(3), 315–334.

Bernanke, B. S. (1986). Alternative explanations of the money-income correlation. In *Real Business Cycles, Real Exchange Rates, and Actual Policies*, Volume No. 25 of *Carnegie-Rochester Conference Series on Public Policy*. Amsterdam: North-Holland.

Blanchard, O. and R. Perotti (2001). An empirical characterization of the dynamic effects of changes in government spending and taxes on output. Mimeo.

Blanchard, O. and D. Quah (1989, September). The dynamic effects of aggregate demand and supply disturbances. *American Economics Review 79*, 655–675.

Blanchard, O. and M. Watson (1986). Are all business cycles alike? In R. J. Gordon (Ed.), *The American Business Cycle*, pp. 123–160. Chicago: University of Chicago Press.

Bouakez, H. and N. Rebei (2003). Why does private consumption rise after a government spending shock ? Bank of Canada Working Paper 2003-43.

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

Canova, F. (2001, October). Validating monetary DSGE models through VARs. Mimeo.

Canova, F. (2007). *Methods for Applied Macroeconomic Research*. Princeton University Press.

Canova, F. and G. de Niccolo (2002). Monetary disturbances matter for business fluctuations in the G-7. *Journal of Monetary Economics 49*, 1131–59.

Canova, F. and L. Gambetti (2004). Structural changes in the US economy: Bad luck or bad policy?

Canova, F. and E. Pappa (2003). Price dispersion in monetary unions: The role of fiscal shocks. CEPR Discussion Paper Series, No. 3746.

Canzoneri, M. B., R. E. Cumby, and B. T. Diba (2002). Should the European Central Bank and the Federal Reserve be concerned about fiscal policy?

Cardia, E., N. Kozhaya, and F. Ruge-Murcia (2003). Distortionary taxation and labor supply. *Journal of Money, Credit and Banking 35*, 763–785.

Cavallo, M. (2005, September). Government employment expenditures and the effects of fiscal policy shocks. Working Paper 2005-16, Federal Reserve Bank of San Francisco.

Chamley, C. (1986). Optimal taxation of capital income in general equilibrium with infinite lives. *Econometrica 54*, 607–622.

Chari, V. V., L. J. Christiano, and P. J. Kehoe (1994). Optimal fiscal policy in a business cycle model. *The Journal of Political Economy 102*(4), 617–652.

Chari, V. V., P. Kehoe, and E. McGrattan (2006). A critique of SVAR using real business cycle theory. Federal Reserve Bank of Minneapolis Working Paper 631.

Christiano, L. and M. Eichenbaum (1982). Cyclical effects of governments' employment and good purchases. *American Economic Review 83*, 430–450.

Christiano, L. and M. Eichenbaum (1992). Current real-business cycle theories and aggregate labor-market fluctuations. *American Economic Review 82(3)*, 430–50.

Christiano, L., M. Eichenbaum, and R. Vigfusson (2004). The response of hours to a technology shock: Evidence based on direct measures of technology. *Journal of the European Economic Association 2(2-3)*, 381–395.

Christiano, L. J., M. Eichenbaum, and C. L. Evans (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy 113(1)*, 1–45.

Coenen, G. and R. Straub (2005). Does government spending crowd in private consumption? theory and empirical evidence for the Euro Area.

Correia, H. I. (1996). Should capital income be taxed in the steady-state? *Journal of Public Economics 60*, 147–151.

Dedola, L. and S. Neri (2004). Can the RBC hypothesis be rescued ? A model based VAR-analysis. Mimeo.

Devereux, M. B., A. C. Head, and M. Lapham (1996). Monopolistic competition, increasing returns and the effects of goverment spending. *Journal of Money, Credit and Banking* (28), 233–254.

Edelberg, W., M. Eichenbaum, and J. Fisher (1998). Understanding the effects of a shock to government purchases. Mimeo.

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

Fatas, A. and I. Mihov (2001). The effects of fiscal policy on consumption and employment: Theory and evidence. Mimeo, INSEAD.

Faust, J. (1998). The robustness of identified VAR conclusions about money. *Carnegie-Rochester Conference Series in Public Policy 49*, 207–44.

Favero, C. (2002). How do European monetary and fiscal authorities behave? CEPR Discussion Paper No. 3426.

Fernandez-Villaverde, J., J. F. Rubio-Ramirez, T. J. Sargent, and M. W. Watson (2007). The ABC and D of structural VARs. *American Economic Review 97*, 1021–1026.

Fleishman, C. (1999). The causes of business cycles and the cyclicality of real wages. Board of Governors of the Federal Reserve System.

Francis, N., M. Owyang, and A. Theodorou (2003). The use of long-run restrictions for the identification of technology shocks. (85(6)), 53–66.

Francis, N. and V. Ramey (2002). Is the technology-driven business cycle hypothesisn dead? shocks and aggregate fluctuations revisited. NBER Working Paper No. 8726.

Fry, R. and A. Pagan (2007, April). Some issues in using sign restrictions for identifying structural VARs. Working Paper No. 14, NCER Working Paper Series.

Galí, J. (1992). How well does the IS-LM model fit postwar US data ? *Quarterly Journal of Economics*, 709–738.

Galí, J., J. D. López-Salido, and J. Vallés (2000). Technology shocks and monetary policy: Assessing the Fed's performance. Mimeo.

Galí, J., J. D. López-Salido, and J. Vallés (2005). Understanding the effects of government spending on consumption.

Giavazzi, F. and M. Pagano (1990). Can severe fiscal contractions be expansionary? Tales of two small European countries. In O. J. Blanchard and S. Fischer (Eds.), *NBER Macroeconomics Annual*. Addison-Wesley.

Gorostiaga, A. (2003). Should fiscal policy be different in a non-competitive framework. *Journal of Monetary Economics 50*(1311-1331).

Hansen, L. and T. Sargent (1991). *Two Difficulties in Interpreting Vector Autoregressions*. Westview Press: Boulder and London.

Hassler, J., P. Krusell, K. Storesletten, and F. Zilibotti (2004). On the role of commitment for tax dynamics. Mimeo.

Jones, L. E., R. E. Manuelli, and P. E. Rossi (1993). Optimal taxation in models of endogenous growth. *The Journal of Political Economy 101*(3), 485–517.

Judd, K. (1995). Optimal taxation and spending in general competitive growth models. Working Paper Stanford University.

Judd, K. L. (1992). Optimal taxation in dynamic stochastic economis: Theory and evidence.

Karras, G. (1994). Government spending and private consumption: Some international evidence. *Journal of Money,Credit and Banking 26*, 9–22.

Klein, P. (1998, January). Using the generalized Schur form to solve a system of linear expectational difference equations. Mimeo, Institute for International Economic Studies, Stockholm University.

Klein, P., P. Krusell, and J.-V. Ríos-Rull (2003). Time-consistent public expenditures. Mimeo.

Kormendi, R. C. (1983). Government debt, government spending and private sector behaviour. *American Economic Review 73*, 994–1010.

Linnemann, L. (2002). The effect of government spending on private consumption: a puzzle? *Journal of Money, Credit and Banking*. forthcoming.

Linnemann, L. and A. Schabert (2003). Fiscal policy in the new neoclassical synthesis. *Journal of Money, Credit and Banking 35*, 911–929.

Lippi, M. and L. Reichlin (1994). VAR analysis, non-fundamental representation, Blaschke matrices. *Journal of Econometrics 63*, 307–325.

Lucas, R. E. and N. L. Stokey (1983). Optimal fiscal and monetary policy in an economy without capital. *Journal of Monetary Economics 12*, 55–93.

Marcet, A. and R. Marimon (1999). Recursive contracts. Mimeo Universitat Pompeu Fabra, Barcelona.

Mendoza, E. G., A. Razin, and L. L. Tesar (1994). Effective tax rates in macroeconomics: Cross-country estimates of tax rates on factor incomes and consumption. *Journal of Monetary Economics 34*, 297–323.

Monacelli, T. and R. Perroti (2007). The sectorial effects of government spending: Theory and evidence. Mimeo.

Mountford, A. and H. Uhlig (2002). What are the effects of fiscal policy shocks. CEPR Discussion Paper 3338.

Ni, S. (1995). An empirical analysis on the substitutability between private consumption and government purchases. *Journal of Monetary Economics 36*, 593–605.

Nieh, C.-C. and T.-W. Ho (2006). Does the expansionary government spending crowd out the private consumption? Cointegration analysis in panel data. *The Quarterly Review of Economics and Finance 46*, 133–148.

Pappa, E. (2004, July). New Keynesian or RBC transmission? The effects of fiscal policy on labor markets. IGIER Universita Bocconi Working Paper n. 293.

Peersman, G. and F. Smets (2001, December). The monetary transmission mechanism in the Euro area.

Peersman, G. and R. Straub (2004). Technology shocks and robust sign restrictions in an Euro Area SVAR. ECB Working Paper No. 373.

Peersman, G. and R. Straub (2006, March). Putting the New-Keynesian model to a test. Mimeo.

Perotti, R. (2001). What do we know about the effects of fiscal policy? In M. Bordignon and D. D. Empoli (Eds.), *Politica fiscale, flessibilita dei mercati e crescita*. Milano: Angeli.

Perotti, R. (2004). Estimating the effects of fiscal policy in OECD countries. Mimeo.

Perotti, R. (2007, June). In search of the transmission mechanism of fiscal policy. *NBER Working Paper No. 13143*.

Ramey, V. and M. Shapiro (1997). Costly capital reallocation and the effects of government spending. *Carnegie Rochester Conference on Public Policy*.

Ramey, V. A. (2007, December). Identifying government spending shocks: It's all in the timing.

Ravn, M. O., S. Schmitt-Grohe, and M. Uribe (2008, April). Explaining the effects of government spending shocks on consumption and the real exchange rate.

Riascos, A. and C. A. Vegh (2003). Procyclical government spending in developing countries: The role of capital market imperfections. *IMF Staff Papers*.

Rotemberg, J. and M. Woodford (1992). Oligopolistic pricing and the effects of aggregate demand on economic activity. *Journal of Political Economy 100*, 1153–1297.

Schmitt-Grohe, S. and M. Uribe (2004). Solving dynamic general equilibrium models using a second-order approximation to the policy function. *Journal of Economic Dynamics and Control 28*, 755–775.

Schorfheide, F. (2000). Loss function based evaluation of DSGE models. *Journal of Applied Econometrics 15*, 645–670.

Scott, A. and A. Marcet (2001). Debt and deficit fluctuations and the structure of debt market. CEPR Discussion Paper 3029.

Shea, J. (1998). What do technology shocks do? NBER Working Paper No 6632.

Smets, F. and R. Wouters (2003). An estimated stochastic dynamic general equilibrium model of the euro area. *Journal of the European Economic Association 1*.

Straub, R. and I. Tchakarov (2007, August). Assessing the impact of a change in the composition of public spending. A DSGE approach. ECB Working Paper Series, No 795.

Uhlig, H. (2004). Do technology shocks lead to a fall in total hours worked ? *Journal of the European Economic Association 2(2-3)*, 361–371.

Uhlig, H. (2005). What are the effects of monetary policy? Results from an agnostic identification procedure. *Journal of Monetary Economics*.

Yakadina, I. (2001). Optimal capital-labor taxes under uncertainty and limits on debt. Mimeo Universitat Pompeu Fabra.

Zhu, X. (1992). Optimal fiscal policy in a stochastic growth model. *Journal of Economic Theory 58*, 250–289.