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Master Thesis

rule-of-thumb consumers in the new keynesian framework: the implications for fiscal policy

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Abstrakt

Tato diplomová práce zkoumá dopady fiskálních výdajů na agregátní makroekonomické veličiny v České republice. Standardní modely reálných hospodářských cyklů a nové keynesiánské modely předpokládají pouze vpředhledící domácnosti, přestože literatura ukazuje na exitenci velkého množství domácností, které spotřebovávají celý svůj běžný důchod. Oba typy modelů předpovídají pokles spotřeby po pozitivním šoku do vládních výdajů, což není konzistentní s empirickou evidencí. Proto používáme pro analýzu modifikaci nového keynesiánského modelu, ve kterém modelujeme oba typy domácností - optimalizující i neoptimalizující.

V práci docházíme k závěru, že fiskální výdaje mají pozitivní efekt na domácí produkt, přestože multiplikátor vládních výdajů je menší než jedna. Vliv výdajů na spotřebu je také kladný během několika období po fiskálním šoku, což je konzistentní s výsledky empirických modelů.

JEL klasifikace: C32, E32, E62

Klíčová slova: fiskální politika, fiskální multiplikátory, fiskální VAR, neoptimalizující spotřebitelé

Abstract

This thesis investigates the effects of government spending on aggregate economic variables in the Czech Republic. The standard RBC and New Keynesian models assume only forward-looking households despite the evidence of a significant fraction of non-optimizing households. These models do not provide reasonable predictions for the response of consumption: both models predict its fall following a government spending shock. Therefore, a variant of the New Keynesian model, where rule-of-thumb households coexist with optimizing households, is used for the analysis.
We have found that fiscal policy has a positive impact on output, although government spending multiplier does not exceed one. Also, the impact on consumption is positive for several periods following a fiscal spending shock, which is consistent with the evidence.

JEL Classification: C32, E32, E62
Keywords: fiscal policy, fiscal multipliers, fiscal VAR, rule-of-thumb consumers

Poděkování

Rád bych poděkoval Jaromíru Baxovi za vedení této práce a za cenné rady, připomínky a podporu, které mi při psaní práce věnoval.

Master Thesis Proposal

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Proposed Topic:

Rule-of-thumb consumers in the New Keynesian framework: the implications for fiscal policy

Topic Characteristics:

My thesis will study the impacts of the presence of rule-of-thumb (non-Ricardian) consumers on the behaviour of aggregate variables in the standard New Keynesian framework. The first part of the thesis will review the literature concerning the theory and empirics of consumption function with an emphasis on liquidity constraints, rule-of-thumb consumers and fiscal policy multipliers when the former two phenomena are taken into account. The purpose of the discussion will be to make a case for a need to introduce some form of non-Ricardian households into macroeconomic models, if the models are supposed to replicate and predict the reality sufficiently well, particularly the impacts of fiscal policy on consumption and other aggregate variables.

The second part of the thesis will present a model that incorporates non-Ricardian households into the standard New Keynesian framework. I will follow a model described in Galí et al. (2004), which I will calibrate to the data of the Czech economy. Most of the parameters will be adopted from the literature. However, as the proportion of non-Ricardian households has not been estimated for the Czech economy, I will attempt to estimate it using techniques described in Campbell and Mankiw (1989) and other works.

Since the introduction of non-Ricardian households alters the determinacy conditions of the model so the well known Taylor principle is not sufficient for the uniqueness of equilibria, I will analyze the conditions that must hold in order to obtain a unique solution of the dynamical system.

Finally, I will provide sensitivity analysis in order to show how fiscal multipliers change with respect to changes in the proportion of non-Ricardian households and other parameters, such as price stickiness. The thesis will conclude by an assessment of the model and suggestions of its potential improvements.

Hypotheses

1. The presence of non-Ricardian households implies a relatively higher increase of aggregate consumption following a positive fiscal shock compared to an increase in the standard New Keynesian model
2. The effects of fiscal policy depend on the proportion of non-Ricardian households on the population – the higher the share of rule-of-thumb households, the higher the crowding in of consumption
3. The extent of the consumption crowding in is positively related to the degree of price stickiness
4. The uniqueness of the solution of the model depends on the proportion of non-Ricardian households and the solution may be indeterminate even if the Taylor rule is satisfied

Methodology:

The thesis will utilize the standard New Keynesian framework in order to assess the properties of the aggregate variables when non-Ricardian households coexist with Ricardian (intertemporally optimizing) households.

The economy will consist of the two mentioned types of households; a competitive final goods sector and an intermediate goods sector characterized by monopolistic competition and price stickiness (modeled by Calvo pricing); the government which imposes lump sum taxes on households in order to finance transfers to the households and other governmental purchases; monetary authority that pursues monetary policy by setting the nominal interest rates.

The optimality and market clearing conditions will be log-linearized around the steady state which will result in a reduced-form dynamical system consisting of 6 equations. The equations must satisfy certain determinacy conditions in order to provide a unique solution of the dynamical system. These conditions will be described and examined when parameters of the model change. Finally and most importantly, the system will be solved and its dynamics simulated using Dynare package in Matlab.

Outline:

- Introduction – a motivation
- Literature review: a review of theory and empirical studies concerning the consumption function with liquidity constraints and rule-of-thumb consumers
- The model
- Calibration
- Results, sensitivity analysis
- Conclusions

Core Bibliography:

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Chapter 1

Introduction

The recent global economic recession that followed the financial crisis has rekindled the debate on the ability of fiscal policy to stabilize output. Several countries have used fiscal measures to boost their economies because they were considered to be efficient in the aftermath of financial turmoil. Moreover, monetary policies in many countries were constrained by the zero lower bound, so fiscal policy was a natural tool to boost economies. As a response, several economists and politicians have discussed whether the costs of these policies are not greater than their benefits.

This thesis is a contribution to this discussion and to the relatively scarce literature on fiscal policy effects in the Czech Republic in that it analyses the impacts of government expenditures on aggregate variables of the Czech economy. Because the predictions of the standard real business cycles models and the New Keynesian models are not very convincing (particularly their predictions on consumption movement after a government spending shock), I will use a modification of the New Keynesian model, where the economy is populated by two types of households - one that smooths its consumption and maximizes its lifetime utility; the other one that consumes its current income, which might be caused by a restricted access to capital markets or by its unwillingness to save or borrow funds. The inclusion of the rule-of-thumb households is a sensible step because the evidence has shown that a significant fraction of households does not optimize its consumption over its lifetime as the modern macroeconomic models assume.

I come to the conclusion that fiscal expenditures have a positive impact on the economy, although government spending multiplier is not larger than one. The impact on consumption is positive in several periods after the spending shock but this increase is relatively small. This result fits the evidence better than the results by models that assume only optimizing households.

Three issues should be taken into account when one interprets the results of the thesis. First, the model assumes a closed economy, while the Czech Republic is a small open economy. However, one can expect that qualitative results would not change under an open economy specification but the impacts on consumption and output would be weaker. Next, the results of the model rely crucially on the parameters of fiscal policy. These have been estimated using a VAR model on a relatively short time series and the results are not very robust with respect to the length of the series. However, I have performed a sensitivity analysis with respect to both parameters, so one can observe how the predictions would change if the parameters were altered. Finally, the model assumes that the economy was in the steady state before the government spending shock occurs and it studies how aggregate variables deviate from their steady state values. Also, the fraction of non-optimizing households has been estimated on a time series of several years, which corresponds to an estimate of medium or long run value of this parameter. In practice, fiscal measures are taken when the economy is out of its steady state and one can expect that the share of liquidity constrained households becomes higher in times of recessions. Therefore, the effects and their magnitude can be expected to be slightly different from those predicted by the model.

The thesis is structured in the following way. In the first part, I will provide an overview of the milestones of the theory of consumption function in order to introduce some concepts regarding consumption theory and liquidity constraints that will be used subsequently. Next, I will compare how the standard neoclassical and Keynesian models have coped with the predictions of the effects of fiscal policy. I will claim that neither approach is sufficiently able to realistically describe those effects. Moreover I will show, that neither the standard New Keynesian model, which synthesizes the Neoclassical and Keynesian models, provides realistic results, most notably of the behaviour of consumption following a fiscal spending shock. As a possible resolution of the issue, I will mention several New Keynesian models which incorporate rule-of-thumb consumers, who are not forward looking and who consume their whole current income in a given time period. The literature suggests that the inclusion of rule-of-thumb households improves the predictions of he model, but the extent of this improvement is limited when the model is estimated using the data of the eurozone. Therefore, it seems that some other elements should be included in the models of fiscal policy. The second part of the literature overview discusses the findings of some empirical studies which analyse the effects of fiscal policy. The conclusion is that these effects have become weaker over time and one possible reason of this decline is the development of financial sector, which has enabled more household to participate in financial markets and smooth their consumption.

The next chapter presents the results of a VAR analysis of fiscal policy effects in the Czech economy, which are not covered sufficiently in the literature. Next, I will describe in detail a model by Galí et al. (2007), which incorporates a simple version of liquidity constraints into a relatively standard DSGE model. I will show how the model is built and solved in detail. Then, I will calibrate the model to the parameters of the Czech economy. I will use some parameters from the literature. But as the model I will calibrate is relatively innovative, some of its parameters have not been estimated for the Czech economy yet. Therefore, I will show how I have estimated the remaining parameters - the share of rule-of-thumb households and fiscal policy parameters. Then, I will present the results of the model, the behaviour of aggregate variables and the results of a sensitivity analysis with respect to several parameters. Finally, I will assess the model and provide some policy recommendations.

Chapter 2

Literature overview

2.1 A brief history of consumption theory[1]

The modern literature on consumption stems generally from two seminal works: from the life cycle model by Brumberg and Modigliani (1954) and permanent income model by Friedman (1957). Both approaches are in a sharp contrast to the theory of consumption by Keynes (1936) who claims that the level of current consumption is a function of the current disposable income only. Instead, the two more recent models assert that consumers optimize their consumption profiles intertemporally through their lifetime, taking into account their income profiles. In their optimization, consumers regard their consumption in each period as a different commodity and maximize their lifetime utility, which provides the theory of consumption with solid microfoundations. The predictions of both theories are very similar - the optimization of a concave utility function leads to consumption smoothing, i.e. one does not want her consumption to fluctuate through time.

The following is a formalization of a consumer's optimization problem. A very similar form was introduced by Hall (1978) and it has been used ever since. Let c_t denote consumption in period t, $U_0(c_0, c_1, \ldots)$ be an additive separable utility function at time 0, $u(c_t)$ an instantaneous utility function, $\beta = \frac{1}{1+\rho}$ a discount factor, where ρ is a discount rate. Next, let A_t denote assets held by a consumer at time t, y_t be her income in period t (which is not known until period t) and r a constant interest rate.

[1]This overview will by no means be exhaustive and the reader is referred to Deaton (1992) or Attanasio (1999) to obtain a more thorough exposition to the subject and further references.

The consumer solves the following dynamic programming problem:

$$\max U_0 = \max_{\{c_t\}_{t=0}^{\infty}} \mathrm{E}_0 \left[\sum_{t=0}^{\infty} \beta^t u(c_t) \right], \text{ s.t.} \tag{2.1}$$

$$A_{t+1} = (1+r)A_t + y_t - c_t, c_t \geq 0 \tag{2.2}$$

$$\lim_{t \to \infty} \left(\frac{1}{1+r} \right)^t A_t \geq 0 \tag{2.3}$$

where Equation 2.2 is the law of motion of assets held by the consumer and Equation 2.3 is a no-Ponzi-game condition which ensures that the consumer's debt does not grow infinitely.

The Bellman equation associated with this dynamic programming problem can be written as:

$$V(A) = \max_{A_t} \{u((1+r)A_t + y_t - A_{t+1}) + \beta E_t V(A_{t+1})\} \tag{2.4}$$

and its solution is characterized by the following Euler equation:

$$u'(c_t) = \frac{1+r}{1+\rho} E_t \left[u'(c_{t+1}) \right] \tag{2.5}$$

Unfortunately, we cannot further examine any other properties of the consumption function without imposing any assumptions on the parameters of the model. And even if we impose some assumptions on the instantaneous utility function, we usually do not obtain a closed-form solution for the consumption function. However, it can be easily shown that if we assume that $\rho = r$ (which holds in the steady state), the utility function quadratic in consumption and expectations are rational, then the consumption process follows a random walk: $E_t[c_{t+1}] = c_t$. This is a very strong result which means, that the only predictor of future consumption is the current level of consumption. But this result is still not enough to study the the behaviour of the consumption function. To obtain an expression for the current level of consumption, we can plug the previous result into the law of motion of assets which results in:

$$c_t = r \left[A_t + \frac{1}{1+r} \sum_{i=0}^{\infty} \left(\frac{1}{1+r} \right)^i E_t y_{t+i} \right] = r(A_t + H_t) \equiv y_t^p \tag{2.6}$$

This can be interpreted in a way that the consumption is equal to a return on the life-time or permanent income (the sum of total assets held today and income from work from now on) y_t^p. We can recognize two changes in income - a transitory change, which lasts only a limited number of periods; and a change in permanent income, which influences an income through the lifetime of an individual. The first change, e.g. a temporary tax cut which will be reversed by a tax hike in the future, will have almost no effect on consumption today. On the other hand, an inheritance increases the volume of assets of the consumer. According to the previous equation, her permanent income rises and the value of inheritance is spread evenly into consumption through the lifetime. The previous two cases imply that consumption is much less responsive to current income than the consumption predicted by the Keynesian model and this is the reason why the permanent income hypothesis has been widely embraced, because empirically, consumption responds to current income only slightly.

The permanent income hypothesis has been tested by a number of authors both on aggregate data and on panel data. References for studies of individual households data can be found for instance in Attanasio (1999). In what follows, I will highlight the most important results using the aggregate time series data.

A very important contribution to the empirics of consumption is by Hall (1978), who tests whether consumption follows a random walk, as was shown previously in this text. A rejection of the random walk would mean a rejection of the permanent income hypothesis. A random walk property of consumption means that the only predictor of consumption in period $t + 1$ is the level of consumption in period t. This means that if we regress consumption in period t on any past variables, the only variable that should be significant is the last level of consumption c_{t-1}. Hall has studied how several lagged variables influence the current consumption. For several variables including the past level of income, consumption $t - 2$ etc., he has not rejected the null hypothesis that the consumption follows a random walk. However, lagged values (most importantly, the value in period $t - 1$) of stock market index, which are an approximation of the past wealth, seem to be a significant predictor for the level of consumption in period t. This rejects the pure permanent income hypothesis. However, Hall suggests a modification of the permanent income hypothesis, which takes into account that the adjustment of a part of consumption is time consuming. His version of the permanent income hypothesis is consistent with the data.

Contrary to Hall, Flavin (1981) rejects the permanent income hypothesis. He assumes an AR(1) process for a period income and estimates how consumption changes as a result of innovations in the income. He comes to the conclusion that consumption is "excessively sensitive", i.e. it reacts more than the permanent income hypothesis predicts. This can be regarded as an evidence against the permanent income hypothesis.

Another evidence against the permanent income hypothesis is provided by Campbell and Mankiw (1989), who propose an alternative hypothesis that the consumption choices of a share of consumers do not follow a random walk. Instead, they consume their current income. This behaviour can have several reasons, as Andersson (2010) points out, and they include liquidity constraints, myopia or the use of a heuristic rule in consumption decisions (therefore, the consumers that consume their whole income are sometimes called rule-of-thumb consumers). Using an instrumental variable estimation, Campbell and Mankiw find that approximately half of the households behave in a rule-of-thumb way, which contradicts the permanent income hypothesis.

One of the mentioned reason for the rule of thumb behaviour are liquidity constraints. These mean that a consumer cannot borrow funds exceeding a given ceiling or that she cannot borrow funds at all. Deaton (1992) presents three arguments why liquidity constraints arise. First, it is perfectly consistent with theory that some people do not want to borrow or save in any time in their life (this is given by their patience, risk aversion and expectations of future income - when one anticipates that her income will decline in the future, she will most likely be hesitant to borrow now). At the same time, according to the life cycle hypothesis, there is a multitude of consumers who want to borrow early in their lives and repay these loans later when their incomes rise. But given the limited funds saved by the first group, the second group cannot borrow the amount that they want, thus they face liquidity constraints. The second argument why liquidity constraints emerge follows from Stiglitz and Weiss (1981), who claim that credit rationing is a result of long-term equilibria when interest rates do not clear a loan market. It is because banks, by charging higher interest rates, would drive out lenders who are likely to repay (because their investment projects have lower return and lower risk at the same time). Thus, by charging lower interest rates, banks decrease the risk of their loan portfolio. At the same time, as the loan market does not clear, credit rationing is an inevitable consequence. The last mentioned reason of liquidity constraint follows from the theory of permanent income hypothesis. It was shown in the previous section that under some assumptions the assets process follows a random walk. That means that after a sufficiently long time, consumer's assets will either exceed a given ceiling or fall below a given floor. In the second case, it is plausible that the consumer will not be able to borrow any amount of funds, thus the liquidity constraint emerges again.

Probably the most significant work on consumption with liquidity constraints is by Deaton (1991). The author considers the problem described by Equations 2.1 and 2.2 with one additional constraint, $A_t \geq 0$, meaning that consumers cannot borrow at all. Apart from the standard assumptions of the permanent income hypothesis model, two additional assumptions are imposed: $\rho > r$ and $u'''(c_t) > 0$. The first assumption means that consumers are impatient, which makes them borrow early in their lives. The second, convexity of marginal utility is a necessary assumption for precautionary behaviour. Deaton defines cash on hand $x_t = A_t + y_t$ as the sum of assets that the consumer holds and current income that the consumer receives. The Euler equation from the dynamic programming problem can be written as:

$$\lambda(c_t) = \max\left[\lambda(x_t), \frac{1+r}{1+\rho}\mathrm{E}_t\lambda(c_{t+1})\right] \tag{2.7}$$

According to this Euler equation, if the consumer faces a liquidity constraint in this period, she consumes all her available consumption. On the other hand, if the consumer does not currently face the liquidity constraint, she consumes such amount that equates the discounted expected marginal utility of consumption in the next period to the current marginal utility of consumption. Despite its resemblance of the second case with the solution of the permanent income hypothesis, the consumption policy function is different from that case. Apparently, the policy function depends on the expectations of future income and as the author showns, it is altered even if the liquidity constraints are not binding at a given moment. In most cases, a possibility that liquidity constraints will bind in the future lead to precautionary savings at a time when they do not bind. The author has also shown that when the income process follows a random walk, the consumers spend their whole income, i.e. they follow a rule-of-thumb behaviour.

To summarize this section, it seems that the permanent income hypothesis is a useful benchmark for the study of consumption. However, the departures from it can be shown both empirically and theoretically on several grounds, one of them being liquidity constraints. Therefore, one can argue that some form of liquidity constraints should be incorporated into macroeconomic models that study the behaviour of consumption. The problems stemming from their lack in the models of fiscal policy will be presented in the subsequent sections.

2.2 Fiscal policy multipliers

The economic literature has not found a general consensus on the predictions of fiscal policy effects. On the one hand, most of the authors agree that government spending has a positive effect on output. On the other hand, the predictions of magnitude of the increase in output differs both in the theoretical and empirical literature. The impacts on the components of GDP and the amount of labour supply have also been examined with varying results.

Before I provide an overview of some significant theoretical and empirical works on the effects of fiscal policy, it is instructive to mention some concepts and issues. First, fiscal shock means an unpredicted change in fiscal policy (Mountford and Uhlig, 2009). This definition is very broad and can include a multitude of instruments. Nevertheless, what most of the literature is interested in are the impacts on macroeconomic variables of two basic types of shocks - government spending shock and government revenue shock. Using only these two variables, one can study several types of fiscal policies - a debt-financed tax cut, balanced budget fiscal spending etc. The identification of the two shocks proves to be a relatively difficult task, since both tax receipts and government spending move not only as a response to fiscal shocks but also after automatic responses to changes in other variables embedded in laws and legal arrangements. Speaking of receipts and expenditures of the government, these are usually defined in the following way for the purposes of the analyses. Government receipts are defined as total tax and social security contributions minus transfers (including subsidies), and government expenditures are defined as the sum of government consumption plus investment.

The identification of fiscal shocks is difficult also due to the choice of the input data that one uses for the econometric analysis. There is no consensus in the literature on whether one should use fiscal data on a cash basis or an accrual basis. The receipts and expenditures on the accrual basis are recorded at a time when an obligation to transfer money is generated. On the other hand, the fiscal data on the cash basis are recorded at a time when the money is transferred. Apparently, these two types of time series are not equivalent, which might result in slightly different identification of fiscal shocks.

Another issue pertaining to the timing of fiscal policy are inside and outside lags. An outside lag is the time it takes for the policy to become effective. In this respect, fiscal policy is more efficient than monetary policy, as Blinder (2004) argues, because it works faster due to different transmission mechanisms but the lag length depends on the policy used. Generally, outside lags are considered shorter for transfers and income tax cuts than for government spendings. On the other hand, fiscal policy suffers from long inside lags. This is the time it takes from the moment that a policy maker realizes that one should act to stabilize output to the moment when a measure is taken. The reason for the long inside lags is a legislative process and administrative reasons. Therefore, in this respect, fiscal policy is less effective compared to monetary policy. In an extreme case, the original measure by the government can be modified in and passed slowly through the parliament, so the conditions of the economy can change by the time the measure is taken and as a result, its costs can largely exceed its benefits.

Another feature that influences the effectiveness of fiscal policy is the Barro-Ricardian equivalence. This proposition states that if consumers are forward-looking, then a deficit financed lump sum tax cut (a policy aimed at income stabilisation) does not have any impact on aggregate consumption. This is because the debt will have to be repaid in the future by a tax hike which covers the debt including interest payments, therefore the present value of life-time income, or permanent income, of consumers is not affected at all. Only timing of receipts is affected, which, according to the theory, does not matter. A tax cut, according to the proposition, only increases aggregate savings. However, the assumptions, which include perfect markets, no liquidity constraints of households, identical interest rate for borrowers and lenders and perfect rationality of consumers, are too strong to hold in reality. Some discussion and objections against the Barro-Ricardian equivalence are presented in Blinder (2004). One of the most famous objections against the Barro-Ricardian equivalence is the imperfect bequest motive, which means that the current generation does not treat its descendants equally as themselves. However, Blinder (2004) claims that this argument is largely irrelevant because issued bonds mature mostly during the lifetime of most of the current generation. Another argument against the equivalence is the presence of liquidity constraints, which means that current income matters more than permanent income. Thus, liquidity constrained households do not smooth their consumption perfectly, which leads to the failure of the equivalence. Another case when the equivalence does not hold is when consumers have a different discount rate (or face a different interest rate) than the government. Next, savings can have a form of spending on durables, thus tax cuts can induce an increase of aggregate demand. Also, myopia of consumers can lead to the failure of the Barro-Ricardian equivalence. Finally, Blinder (2004) claims that the budget constraint of government holds only asymptotically, thus the basic assumption of the equivalence may not hold. He also reviews empirical literature on the testing of the equivalence and comes to the conclusion that liquidity constraints are the strongest argument why the equivalence might not hold. They imply that consumption responds strongly to current cash income compared to future tax changes.

The role of uncertainty is also very important when assessing the fiscal policy. On the one hand, a deficit financed tax cut by the government means a reduction of uncertainty, in that one receives more income today and expects less in the future. Thus, precautionary motive for savings diminishes and consumption can rise today, contrary to the predictions of the Barro-Ricardian equivalence. On the other hand, interest rate premia and the loss of credibility have an opposite effect. Higher indebtedness leads to higher interest rates due to higher risk, which leads to crowding out effects of investment. This implies that a temporary debt increase is more effective than permanent expansion because it leads to a lower risk. Also, credibility of a policymaker to reverse spending is crucial in this context.

Political economy considerations are also important for the assessment of fiscal policies. As Hemming et al. (2002) points out, the governments suffer from deficit bias, which is an analogue of inflation bias in monetary policy analysis. In the long run, the government should strive to achieve debt sustainability but in the short run, the policy makers are tempted to use fiscal expansions for output stabilisation, which is an example of time consistency problem. The credibility and history of policy makers is therefore important for the policy effectiveness, because when it is low, even a short term fiscal expansion can be deemed a long-term one and this leads to lower efficiency.

Consumption smoothing described in the previous section also has significant impacts on the answer to the question of whether fiscal policy should be used for stabilisation purposes. This depends crucially on the properties of output time series process. If output follows a deterministic trend (i.e. if it is trend stationary), it means that it reverts back to its long run trend following a departure caused by a shock to productivity or some of its components. Fiscal policy could be in this case used to move the economy faster to its potential. The policy maker's role would be to decide on the speed with which the economy converges back and he or she should weigh whether long run fiscal costs are not higher than the short term benefits. On the other hand, if output has a stochastic trend (i.e. output is a process with a unit root), negative shocks to the economy do not disappear and there is no trend toward which the economy leads to. In other words, the economy is subject to hysteresis. In this case, the goal of the fiscal policy is not the output stabilization, because there is no level to which the output should be stabilized. Instead, the policy maker should, as Brusselen (2009) points out, focus on long run growth or a target level of unemployment. So, the fiscal policy would have a structural, instead of stabilizing role. As the author shows, the literature used to conclude that the output had a unit root but recently more authors have concluded that the output is mean reverting with structural breaks. One issue that is related to liquidity constraints is worth to point out - mean reversion is largely caused by consumption smoothing because the consumption is the largest component of GDP. But if households are liquidity constrained, they cannot smooth their consumption and this may cause that the output is not mean reverting.

Several recommendations for the recent economic recession can be drawn based on this informal discussion that are in line with Spilimbergo et al. (2008). First, wealth of a large number of households has decreased, which means a reduction of permanent income. This is caused by a decline in property and share prices, by losing a job and future abilities. As a result, due to a decline in permanent income, consumption has decreased. Moreover, banks and other financial institutions have become more cautious when providing credit to households - tighter liquidity constraints have been imposed on households. As a result, they cannot smooth their consumption and the consumption decreased as a result. Finally, higher uncertainty has lead to higher precautionary savings and wait and see attitude. Fiscal policy response should have the following characteristics. First, tax cuts will not be very effective because of precautionary savings. Second, the policy should be aimed at liquidity constrained households (to increase unemployment benefits etc.). Finally, the policy should be stated clearly to reduce uncertainty. This includes a plan on when the policy will be reversed. This transparency of policy should limit the extent to which interest rates increase and crowding out effects should be mitigated.

2.2.1 Theoretical models of fiscal policy

The informal results from the previous section can be shown also formally, which will be done in this part. It is natural to start the discussion on the theory of fiscal policy with the Keynesian theory, following Keynes (1936). This tradition is based on the IS-LM and Phillips curve models. The assumptions of the theory are met during times of recessions, i.e. when it makes a good sense to use fiscal policy for output stabilization and they include idle production capacities, fixed price level, and consumption being a function of disposable income. It follows that the output is a function of aggregate demand and a fiscal expansion has the following effects: the multiplier is predicted to be greater than one if the spending is deficit-financed; if the spending is financed by an increase in taxation, the balanced-budget multiplier is predicted to be exactly one. Because the disposable income rises, consumption rises as well. Due to higher output and employment, wages rise and goods prices rise too.

This theory of fiscal policy effects was widely embraced (e.g. (Blinder, 2004)) and fiscal policy was used for output stabilization in the 1960s. However, after the criticism of the Phillips curve approach by Phelps and Friedman, together with stagflation in the 1970s and the rise of the school of rational expectation, the traditional Keynesian theory was abandoned. Also, the theory was criticized for the lack of microeconomic foundations. As a result, the theory was largely succeeded by the school of real business cycles in mainstream economics, which assumes a forward looking representative household, competitive markets and flexible prices. According to this theory, effective demand does not play the role for the output determination, as in the Keynesian model, and the level of output is determined by labour supply decisions, decisions on savings by households and by the level of technological progress. Also, because the Ricardian equivalence holds in these models, consumption falls when the government debt is financed by lump sum taxes or labour supply decision are distorted when the expenditures are financed by income tax. Therefore, the government can have only a destabilizing role in the economy.

Despite the wide popularity of the RBC models, the effects of fiscal policy in these models were not studied in a deeper detail until the paper by Baxter and King (1993) was published. The authors provide an analysis of the fiscal policy effects in an RBC model, which was modified in a number of ways. First, an instantaneous utility function was extended so that it includes utility from government purchases and capital (but none of them influences marginal utility from the consumption of private goods). Second, the Cobb-Douglas production function now includes a public capital and finally the resource constraint is adjusted by the inclusion of public spending.

If the expenditures are financed by lump sum taxes, the authors show that they can have a multiplier effect (one percentage point increase in spending leads to an increase in GDP larger than one) because a wealth effect (due to the fall of after-tax income in the future) induces households to increase their labour supply. On the other hand, consumption shrinks because of a negative wealth effect. As a result, consumption and employment are negatively correlated following a positive government spending shock which, as we will see, is not supported by the data. A second conclusion is that permanent spending has larger effect than temporary spending. Also, financing decision is important. When spending is financed by taxes on labour income instead of by lump sum taxes, the spending multiplier can be even negative. This is because a higher tax rate decreases the incentive to work, which shrinks the output. Finally, the means of government spendings is important. Most notably, government investments may influence marginal product of private capital in a positive way, which brings about a more positive multiplier effect.

The fact that the RBC models cannot cope with the evidence that consumption as well as employment rise after a positive government spending shock made an incentive to the introduction of imperfect competition and sticky prices into the economy based on microeconomic foundations and gave rise to the New Keynesian economics (or the New Neoclassical synthesis). Fiscal policy was introduced into this kind of model by Linnemann and Schabert (2003). This model is a synthesis of the Keynesian and RBC-type model in that it stresses the importance of both aggregate demand and supply after a government shock. The reaction of supply side is the same as in RBC models, since a wealth effect induces a higher labour supply. On the demand side, the response of the central bank to the spending shock is important. If the reaction of nominal interest rates is only low following the shock, real interest rate diminishes, which further boosts the economy. As a result, the response of output is higher in this model than in the RBC models. Also, monopolistic competition in the intermediate sector presents an aggregate demand externality, in that an increase in government expenditures induces higher profits of capital owners. However, the simulations show that response of consumption is still negative following the shock, so the price stickiness and imperfect competition are not sufficient to explain the Keynesian effects of consumption.

For a summary of basic mechanisms behind the Neoclassical and the New Keynesian models, see for instance the paper by Woodford (2010), who presents simple forms of the models, which can be solved analytically. Also, a discussion of zero lower bound is included. This has been particularly relevant during the recent global recession, when short term interest rates of many central banks reached their effective lower bound. In this case, fiscal expansion is most effective, because the central bank does not act against the government. As expected inflation rises and interest rates are kept at their lower-bound level, real interest rates decrease which multiplies positive impact of government purchases on output.

2.2.2 Empirical evidence of fiscal policy effects

As I have shown in the previous subsection, the predictions of fiscal policy effects vary across the models. It makes little sense to discuss the validity of a model without its testing on real data, so it is relatively surprising that the empirical testing of the impacts of fiscal policies has started relatively recently, at the end of the 90s. Several reasons had led to this timing.

One of the reasons why little attention was paid to fiscal policy during the 1990s is that the focus of economics was put on monetary policy (Blinder, 2004). For example, Solow (2004) says: *"A reading of the literature on macroeconomic theory and policy would lead you to believe that there is only one policy goal - the control of inflation - and that task is assigned to monetary policy. Fiscal policy is either impossible or undesirable or both"* (p. 1). The reasons of an increased attention at the end of 90s include the rise of consumption in the United States following several budget cuts, which contradicts the predictions of Keynesian models. Also, the timing coincides with the formulation of the Stability and growth pact in the EU. Finally, econometric techniques required for a proper identification of fiscal shocks had not been used extensively before.

Fiscal policy effects have been studied using various approaches in the literature. Hemming et al. (2002) is an example of a more comprehensive overview. In the following text, I will briefly review the methods used in some of most significant papers and present their results. Most of the papers use a VAR model to identify the fiscal policy effects. I will also mention one panel study which claims that the level of financial development is crucial for the transmission of fiscal shocks.

A test of the predictions of an RBC model with a fiscal authority is performed by Fatás and Mihov (2001), who modify the model in a way that enables debt-financed tax cuts or government spending increases. Furthermore, distortionary as well as lump sum taxation is used to finance government expenditures and to repay the debt.

Their VAR analysis includes several macroeconomic variables as well as lagged forecasts of current government spendings and taxations. This should isolate the effect of unanticipated fiscal policy changes from those that are anticipated. The reason is that plans or forecasts of future tax policies influence, in theory, the behaviour of households. And forecasts and plans about future government policies are usually available a long time in advance - tax changes are announced several quarters before they become effective; government spendings forecasts are announced by the government before a new fiscal year. However, as the authors claim, the inclusion of these information to the VAR model does not qualitatively change the predictions of the model. Empirically, the authors identify the following results. First, the output increases more than government spending, i.e. the government spending multiplier is greater than one. This can be reconciled with the RBC model presented in the paper. However, the reason for a multiplier effect is a significant rise in consumption, which is predicted by the Keynesian theory and is in a contrast with the RBC model. Also, hours worked rise after a government spending shock. This implies that conditional correlation between employment and consumption after a government spending shock is positive. This is in sharp contrast with the predictions of the model. A possible reason is that real wage rises so much that income effect outweighs substitution effect from house worked to leisure. Neither the VAR nor RBC model provides a clear-cut prediction about the impact on investments. In the RBC model, this impact depends on the elasticity of labour supply.

Blanchard and Perotti (2002) study the effects of fiscal shocks on the U.S. economy using a structural VAR model on the postwar data. Some of the identification of structural shocks from the reduced-form shocks is based on the information on timing (for example, as quarterly data are used, the authors assume that government spending shocks are exogenous to contemporary shocks to GDP - fiscal measures are taken, due to implementation lags and legislative procedures, with a long delay after a productivity or demand shock takes place). The rest of the identification is based on ordering and elasticities of tax receipts with respect to GDP. The results cannot be easily reconciled solely using the Neoclassical or Keynesian theory. On the one hand, positive fiscal shocks induce higher output and consumption, which is in a sharp contrast with the neoclassical theory's predictions. On the other hand, both positive fiscal and tax (increase of taxes) shocks have a negative impact on investments. This effect, contrary to the first effect, is consistent with the predictions of the neoclassical models but cannot be reconciled with the Keynesian theory. This is because the Keynesian theory predicts opposing effects of tax and fiscal hikes on private investment. The size of output multipliers varies during studied periods and based on assumptions on GDP trend (whether it is assumed to be deterministic or stochastic) but generally it is estimated to be close to one.

A similar approach has been taken in another paper by Perotti (2005), who estimates the effects of fiscal policy in five OECD countries. These countries include Australia, Canada, West Germany, United Kingdom, United States - the countries that have available non-interpolated data on quarterly government spendings and revenues for sufficiently long periods. The analysis was extended to variables representing price level (given by GDP deflator) and interest rates (given by 10-year nominal interest rate). The data are on quarterly frequency and range from the beginning of 1960s to 2001. Also, the results are estimated for two subperiods, with the end of the first one spanning from the mid 70s to the beginning of 80s. These dates coincide with structural breaks of monetary policy identified by other VAR studies and are approximately in the middle of the studied periods. Because of the inclusion of two other variables, the author had to estimate additional elasticities - elasticity of government spending and taxes with respect to the interest rate and inflation. With this identification, two types of shocks can be studied - government spending shocks and tax shocks.

Similar qualitative results of spending and tax shocks are identified as in the previous paper - after a positive fiscal shock, government consumption and output rise. However, if the break points in the 1980s are taken into account, the quantitative results change in that the magnitude of the fiscal effect diminishes significantly. Government spending multiplier greater than one is identified only in the US in the first period. Also, the effect on real interest rate and investment changes dramatically. In the first sub-period, real interest falls after a fiscal shock. On the other hand, it rises in the second sub-period. The direction of a change in investments is opposite - investment rises slightly in the first sub-period and fall in the second one after a fiscal shock. Also, the author finds no evidence that tax cuts have a faster and higher effect on the economy than an increase in spending. The author also suggests some reasons for the decline in the efficiency of fiscal measures. The first one is the development of financial sector, which caused a decline in liquidity constraints of households. As a results, higher fraction of the economy behaves in a forward-looking way and the Keynesian effects have become weaker. A second plausible explanation of the change in the reaction of the economies to fiscal shocks is a change of monetary policies of central banks and their more aggressive stance towards expected inflation and output gap. Also, the author claims that the structural change in the response to fiscal policy might be a cause of a lower variance of GDP in the 1990s.

The results of the previous papers have been further examined using an innovative approach by Mountford and Uhlig (2009). The method is similar to the one introduced by Uhlig (2005) and it relies on a Bayesian VAR estimation and the identification of business cycle, monetary policy and fiscal shocks. The identification procedure does not require as many assumptions and restrictions as the method in Blanchard and Perotti (2002). It only imposes some sign restrictions and rules on impulse responses to shocks. For example, business cycle shocks are characterized by an increase in output, consumption, non-residential investments and government revenues for 4 subsequent quarters. Several sign restrictions are put on the two remaining shocks - fiscal and monetary shocks, one of them being that all shocks are orthogonal to each other.

Because three types of shocks have been identified, the authors are able to provide an analysis of three different policies. The first one is a deficit spending fiscal shock. This means that government spending rises unexpectedly but taxes are kept unchanged. This policy results in an increase of GDP and consumption in four quarters but this rise is very weak. On the other hand, both residential and non-residential investments fall, and price level falls as well. The second policy, deficit financed tax cut, means that tax burden is cut by 1 % and government spendings stays at the same level. This results in a rise of output, consumption and investment, with the peak impact in the thrid quarter. Price level falls firstly and then it rises. The final policy, balanced budget spending shock, means that spending is increased and taxes are increased in such a way that the change in policy does not have any impact on budget deficit or surplus in the fourth quarter following the policy change. This policy has a small effect on GDP, consumption and investments and all of these variables fall. This is because tax hike has a greater effect on GDP than tax spending.

The authors also compare their results with the results by Blanchard and Perotti (2002). These are very similar for almost all aggregate variables, except for consumption. The effect of fiscal shocks on consumption are identified to be very low and significant only on impact. This contradicts the predictions of both RBC and Keynesian models. The main policy recommendation from the paper is that the best way to stimulate the economy in times of recessions are deficit financed tax cuts. However, in the long run, the deficits have to be paid back. And the decrease of output caused by a hike in taxes might be larger than an increase after the taxes are slashed. Thus, from purely positive perspective, fiscal policy has larger costs than benefits.

To sum up, all of the mentioned papers provide a support to the hypothesis that positive fiscal shocks, in the form of higher government consumption or tax cuts, have a positive impact on output. However, this impact seems to diminish over time. A comparison of the results is provided in Table 2.1. Also, none of the papers have identified the prediction of both the Neoclassical and the new Keynesian models, that private consumption falls after a government spending shock, due to the wealth effect. On the contrary, the papers identify either a positive or an insignificant effect of government spending on consumption.

Table 2.1: Government spending multipliers identified in various papers

Paper	Country	Period	Spending shocks multipliers			Tax shock multipliers		
			Impact	Peak (Period)	LT	Impact	Peak (Period)	LT
Blanchard and Perotti (2002)	United States	1960-1997 (DT)	0.8	1.3 (15)	1	0.7	0.8 (5)	0.2
		1960-1994 (ST)	0.9	0.9 (1)	0.7	0.7	1.3 (7)	1.3
Fatás and Mihov (2001)	United States	1960-1999	0.1	0.3 (16)	0.2			
Mountford and Uhlig (2009)	United States	1955-2000	0.2	0.5 (3)	n/a	0.2	0.4 (9)	
Perotti (2005)	United States	1960-2000	0.4	1.1 (15)	1	0.3	0.8 (7)	0.5
		1960-1979	0.7	1.6 (10)	-0.6	0.4	1.1 (13)	0.8
		1980-2000	0.1	0.5 (3)	-1.3	0.2	0.2 (1)	0.1
	Germany	1960-2000	1.3	1.3 (1)	0.9	0.3	0.3 (1)	0.1
		1960-1974	1.7	1.7 (1)	1.1			
		1974-2000	0.8	0.8 (1)	-0.7			
	United Kingdom	1960-2000	0.3	0.3 (1)	0.1			
		1960-1979	0.5	0.9 (17)	0.8			
		1980-2000	-0.2	-0.1 (3)	-1.1			
	Canada	1960-2000	0.4	0.5 (2)	0.2			
		1960-1979	0.6	0.9 (17)	0.9			
		1980-2000	0.1	0.2 (3)	-2.2			
	Australia	1960-2000	0.3	0.3 (1)	0.2			
		1960-1979	0	0.5 (5)	0.3			
		1980-2000	0.6	0.8 (14)	0.6			

A different approach from the mentioned VAR analyses is used by Tagkalakis (2008), who performs an analysis of a panel dataset of annual variables of 19 OECD countries between 1970 and 2001. The author seeks to answer the question of how the effects differ when the economy is growing (good times) or is in a slump (bad times). In addition, the analysis seeks to answer what quantitative results the development of consumer credit market has on the fiscal policy effects. A higher development of consumer credit market means that less consumers are credit-constrained and it is proxied as a maximum loan to value of the house ratio of first time buyers.

The first conclusion of the paper is that Keynesian effects prevail among all economies, i.e. output and consumption rise following a spending shock. The effect of fiscal spending on consumption is higher in countries with less developed credit markets, i.e. in countries where liquidity constraints bind for a larger proportion of population. Also, the impact on consumption differs over phases of business cycles. Fiscal spending effects are higher in times of recessions because liquidity constraints bind for more households. An interesting finding is that tax policy has a greater effect only in deep recessions in countries with a higher share of liquidity constrained households.

2.3 Rule of thumb consumers in DSGE models

Based on the discussion so far, it is evident that models for fiscal policy analysis miss some elements that would account for the rise of consumption following a fiscal spending shock, a feature that is widely observed in reality. A possible resolution might be to include some form of liquidity constraints into the models. Apparently, the inclusion of liquidity constraints would cause a divergence of the economy from that predicted by the models that assume only an optimizing representative household with an unlimited access to credit markets. The simplest way to model this feature is to assume that a proportion of the population spends its current income, i.e. to assume the existence of hand-to-mouth households (these households are also called rule-of-thumb or non-Ricardian households in the literature). Mankiw (2000) summarizes the evidence of rule-of-thumb behaviour, which characterizes low-income households with their net wealth approaching zero. One cannot assume that these households smooth their consumption over their lifetime or even across generations, as some models do. Therefore, the author claims that it is wrong to assume only one, Ricardian, type of consumers and calls for the inclusion of rule-of-thumb households into macroeconomic models.

Some papers on fiscal policy effects have therefore incorporated rule-of-thumb households into their analyses. Galí et al. (2007) extend their model in (Galí et al., 2004) by an introduction of simple fiscal policy rules (the former model focused on implications of the presence of non-Ricardian households on the monetary policy). Lump sum taxes are levied on both types of consumers, so the non-Ricardian households consume their after-tax income, while optimizing households smooth their consumption in the way predicted by other macroeconomic models. The deviation of the level of taxes from its steady state responds to the deviation of the debt and government expenditures from their steady state levels. The level of government expenditures is determined by a highly persistent exogenous shock. This model will be described in detail in the following chapter but its calibration to the U.S. data imply that not only output, but also consumption rises as a response to positive government spending shock. It is because the presence of rule-of-thumb households mean a higher sensitivity to current income, which offsets negative wealth effect and the shrinkage of consumption of optimizing households after a government spending shock. Therefore, the model can be regarded as a synthesis of the Keynesian approach (predicting the sensitivity of consumption to disposable income) and the RBC approach (assuming forward-looking behaviour of the rest of households).

A similar approach to model the effects of fiscal policies was taken by Coenen and Straub (2004). They extend the DSGE model by Smets and Wouters (2002), which provides plausible results except for the decline in consumption following a government spending shock, which is not observed in reality. The authors incorporate three features into the model - fiscal policy rule of the government, distortionary and lump sum taxes and finally non-Ricardian households. Parameters of the model are estimated using Bayesian inference and the results are not as positive as the results in the model by Galí et al. (2007). On the one hand, consumption is higher on the impact after a fiscal shock, compared to the baseline model with no rule of thumb households but the response of consumption is still negative. One reason for this is a low share of non-Ricardian households, as the authors claim. The second reason is a high persistence of government spending shock, which causes a negative wealth effect. Due to the persistence of a shock, the households expect a larger rise of taxes in the future and thus they save more to the detriment of consumption. Also, consistently with Perotti (2005), the author claims that the development of financial markets has diminished the extent of liquidity constraints and this can be seen as a source of the inability of fiscal policy to boost consumption.

Neither a more complex DSGE model of the eurozone by Ratto et al. (2009) does predict a rise in consumption following a government spending shock. This model regards the eurozone as an open economy and predicts a crowding out of both investment and consumption due to a spending shock. However, this follows, according to the authors, from wage adjustment costs which are explicitly modelled. If these costs approach zero, the model predicts by and large similar qualitative results as the one in Galí et al. (2007).

More recently, Furceri and Mourougane (2010) extend the analysis even further in that they explicitly model the interest rates on government bonds. These are a function of monetary policy rate and market risk premia given by the expectations of future debt, which is a measure of the debt sustainability. Next, the share of rule-of-thumb households is assumed to be endogenous and being a function of the output gap, which is consistent with the idea that liquidity constraints are binding more in recessions than in expansions. Qualitative results are similar to the previous three papers but the crowding out effect on investments and consumptions is higher. This is because a higher interest rate on government bonds induces higher savings and lower real investments.

From the discussion in this section, one can infer that rule-of-thumb behaviour of households plays an important role for the analysis of fiscal policy. A standard New Keynesian model, which includes rule-of-thumb households predicts the behaviour of aggregate variables successfully in the U.S. This success is more limited when the model is applied to the data of the eurozone. Although the behaviour of consumption predicted by the model approaches more the one observed in reality compared to the one disregarding rule-of-thumb households, the response of consumption to a government spending shock is still negative. Therefore, it seems that some other missing feature should be included in the models assessing fiscal policies. In the subsequent chapters, I will show whether the inclusion of rule-of-thumb households is sufficient to explain the effects of fiscal policy in the Czech Republic.

Chapter 3

Fiscal policy effects in the Czech Republic

3.1 A VAR model and its identification

To estimate the effects of an increase in government spending or taxation on the Czech economy, I will use the approach by Blanchard and Perotti (2002). Assume a reduced form VAR model in the following basic specification:

$$Y_t = \mu + K(L,q)Y_{t-1} + U_t$$

where $Y_t = [G_t, Y_t, T_t]'$ is a vector of endogenous quarterly variables representing government spending on consumption and investments, GDP and the net taxes (i.e. tax receipts minus transfers to households), respectively. $K(L,q)$ is a lag polynomial vector of order q and $U_t = [g_t, y_t, t_t]'$ is a vector of reduced form error terms. The specification includes also linear trend and seasonal dummy variables, that capture the seasonality in tax receipts and spending, which is given by timing of tax receipts and spending given by the law. The dummy and trend variables are for convenience not included in the specification stated above.

The reduced form error terms have generally non-zero cross-correlations so using them to make inference from the impulse response functions is misleading. Therefore, we need to perform the following identification procedure. Assume that the reduced form error terms have the following structure:

$$t_t = a_1 y_t + a_2 e_t^g + e_t^t \tag{3.1}$$

$$g_t = b_1 y_t + b_2 e_t^t + e_t^g \tag{3.2}$$

$$y_t = c_1 t_t + c_2 g_t + e_t^y \tag{3.3}$$

where e_t^t, e_t^g, e_t^y are structural shocks to government revenues, spending and GDP, respectively. This specification can be interpreted in the following way. According to the first equation, the unexpected movements of tax receipts is a sum of a response to unexpected movements in GDP, response to the structural shock to government spending and to the structural shock to taxes. The unexpected movements of government spending and GDP are interpreted in a similar way.

As quarterly data are used for the analysis, we can set $b_1 = 0$. This is because the data on GDP for a particular period are published with a delay so the policy reacts to them with a lag of at least one quarter. Parameter a_1 represents the elasticity of net taxes to GDP, i.e. by how many percent tax receipts increase after a one percentage increase in GDP. The elasticity parameter is taken from Barrios and Fargnoli (2010, p. 23) and its value is set at 1.3.

To estimate the values of c_1 and c_2, construct first the cyclically adjusted reduced-form tax and spending residuals: $t_t' = t_t - a_1 y_t$ and $g_t' = g_t - b_1 y_t = g_t$. These residuals are correlated with t_t and g_t respectively but they are not correlated with e_t^x. Therefore, we can use them as instruments for the estimation of c_1 and c_2.

The remaining coefficients, a_2 and b_2 are estimated based on ordering. In the first one, assume that tax decisions come first. In this case, $a_2 = 0$ and b_2 is estimated. In the second case, assume that spending decision comes first. Therefore, $b_2 = 0$ and a_2 is estimated.

The relationship among reduced form and structural errors can be written in a matrix form as $AU_t = BE_t$, where $E_t = [e_t^t, e_t^g, e_t^x]$:

$$\begin{pmatrix} 1 & 0 & -a_1 \\ 0 & 1 & -b_1 \\ -c_1 & -c_2 & 1 \end{pmatrix} \begin{pmatrix} t_t \\ g_t \\ y_t \end{pmatrix} = \begin{pmatrix} 1 & a_2 & 0 \\ b_2 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Using a simple algebra, we obtain $U_t = A^{-1} B E_t$ which allows us to study impulse responses of variables to structural shocks.

In addition to the three mentioned endogenous variables in the VAR model, I have included a fourth variable (as in Blanchard and Perotti (2002)) to study the responses of other aggregate variables to fiscal shocks. The following variables were substituted as a fourth variable - consumption, private investments and hours. Structural identification of these variables was done by ordering, where I assume that the fourth variable is ordered last. Also, one should bear in mind a very strong assumption when the fourth variable is included. This assumption is that structural shocks to the fourth variable is not correlated with structural shocks in other equations. Its validity is questionable, but a solution is beyond the scope of this thesis.

3.1.1 Data and impulse responses

I have used time series spanning from 1998 to 2010 for the identification of fiscal policy effects. All variables were downloaded from the Czech Statistical Office, except for the data on government spending and revenues, which were obtained from the website of the Ministry of Finance, which provides monthly data on spending and revenues of the central government budget on a cash basis. The government spending variable includes spending on government consumption and investment. The government revenues, or net taxes, variable was computed as a difference between all tax receipts (including social and health security contributions) and transfers.

The observations are on a quarterly basis and they were transformed into logarithms of real per capita values. Moreover, all variables were seasonally adjusted using multiplicative X12 procedure. According to Augmented Dickey-Fuller test, none of the variables has a unit root, so the inclusion of a deterministic trend into the equation seems valid. Two lags of each endogenous variable were included in the estimation, based on Schwarz information criterion. Other criteria suggest to include more lags but because the time series is relatively short, a lot of degrees of freedom would be lost due to the inclusion of more lags, so only two lags were chosen. Jarque-Bera test of normality on residuals does not reject normality of individual residuals or joint normality of all residuals.

Figure 3.1.1 shows impulse response functions of the three endogenous variables to structural shocks identified using procedure stated above. The responses are normalized to percentage changes of GDP. I have assumed that spending shocks precede shocks to taxation, so $b_2 = 0$ in the estimation and a_2 is estimated. The figure shows a positive response of GDP to a positive spending shock, which has its peak in the second period after the shock. In the following periods, the response declines steadily. Tax receipts increase accordingly, due to a rise in GDP. The second column of the figure shows that a shock to GDP has a small positive effect on government expenditures. On the other hand, it has relatively high and persistent effect on both domestic product and revenues of the government. Finally, a positive government revenue shock has a negative impact on GDP, which firstly increases and then falls for several periods.

It is interesting to compare the results of the preceding identification procedure with the one based on ordering, where I assume that the government spending decisions have a contemporaneous effect on both GDP and government revenues in the current; shocks to GDP have an impact only on government revenues in the current period; and shocks to government revenues have no contemporaneous effect on GDP or government spending. The results are depicted in Figure 3.1.1. One qualitative difference is worth to stress - in this case, GDP declines immediately after a revenues shock, which is different from the previous case based on a different identification procedure.

The impacts of shocks to government spending and revenues in a four-variable model are depicted in Figure 3.1.1 and Figure 3.1.1, respectively. The figures show responses in three four-variable models, where the fourth variable represents consumption, investments and hours worked. Because the responses of other three variables (spending, GDP, revenues) differ under various specifications, their responses are included in the figures as well. Following a spending shock, consumption rises, which is a Keynesian effect identified in studies cited in the previous chapter. After a shock to government revenues, consumption firstly rises negligibly and falls after five periods. Concerning private investments, they rise slightly after a spending shock for several periods. A response of investments is insignificant after a shock to revenues. Finally, hours worked rise slightly after a for two periods and then stay stable. The response of hours worked is slightly negative after a shock to revenues.

The analysis from this chapter has been performed in order to have some evidence to which I will compare the predictions in the subsequent chapters. However, the results should be interpreted cautiously because only relatively short time series of the variables have been used for the estimation.

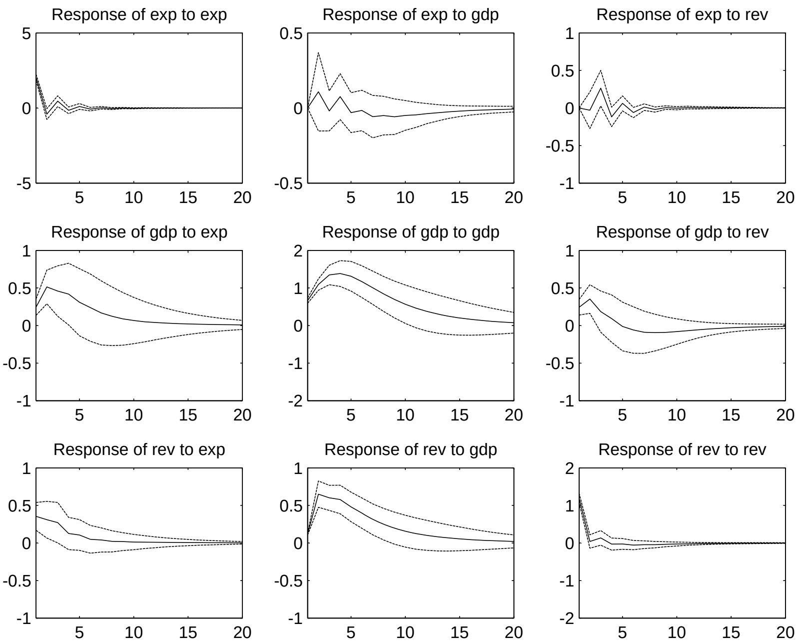

Figure 3.1: Responses of endogenous variables to structural shocks, identification using restriction on elasticity, 1 s.e. confidence bands; all responses are normalized by the component's share on GDP

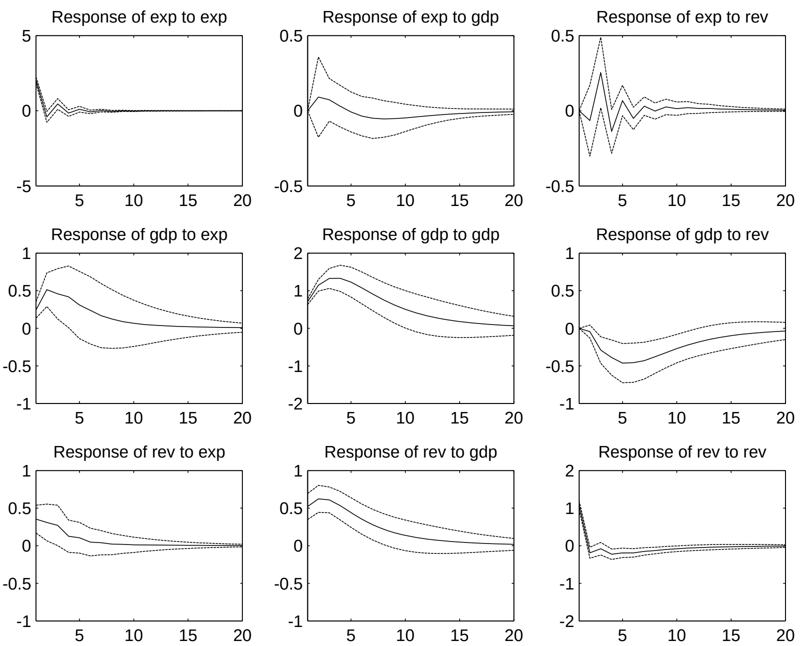

Figure 3.2: Responses of endogenous variables to structural shocks, identification based on ordering, 1 s.e. confidence bands; all responses are normalized by the component's share on GDP

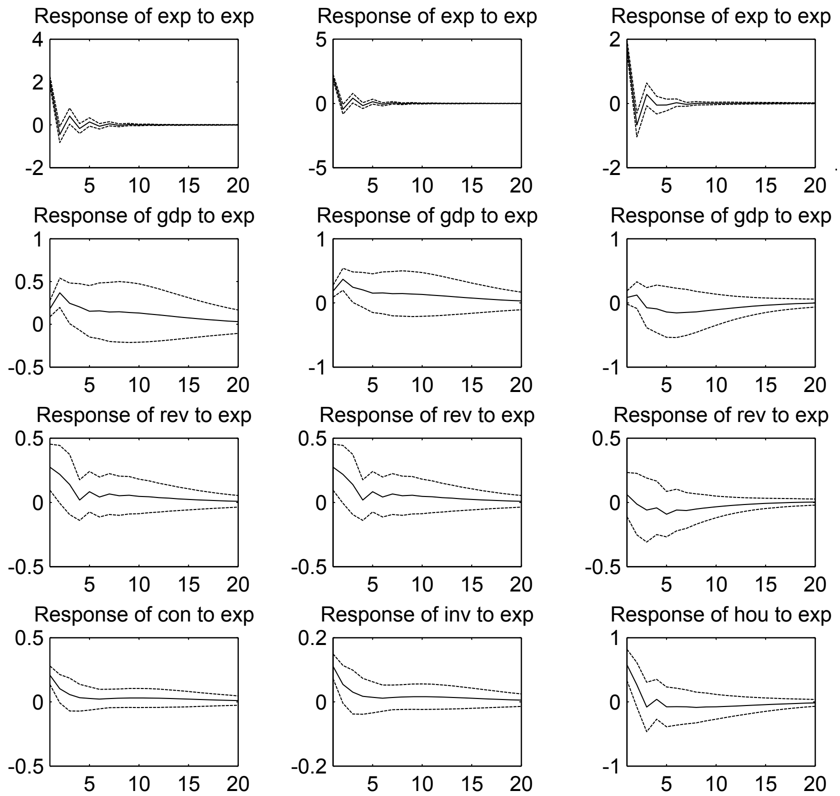

Figure 3.3: Responses of endogenous variables to government spending shock, 1 s.e. confidence bands; four different specifications

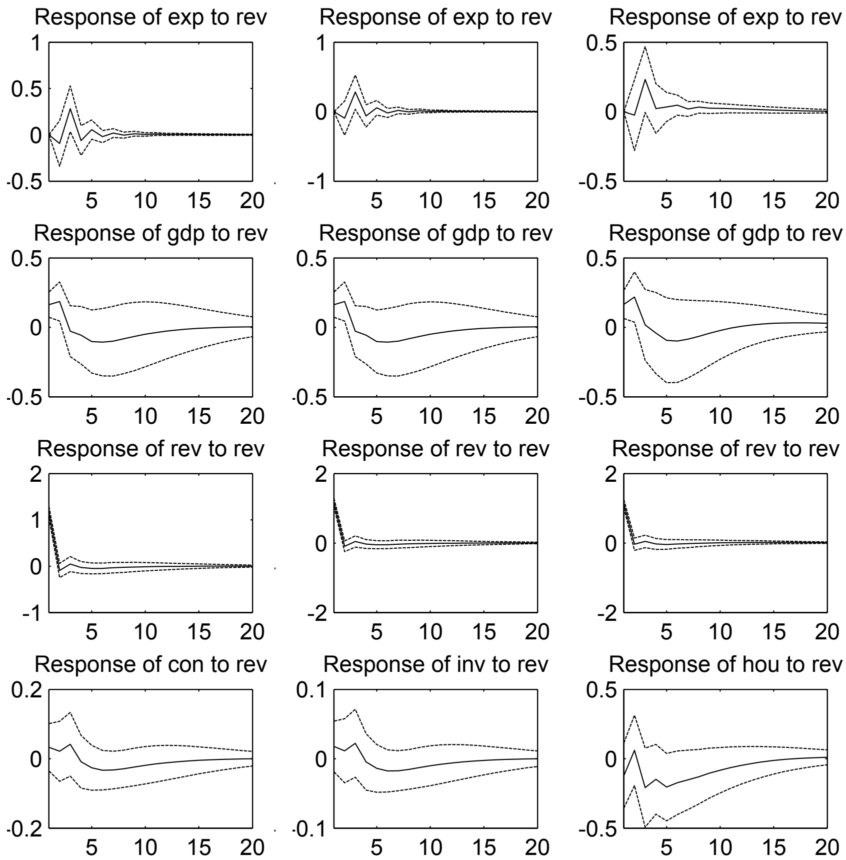

Figure 3.4: Responses of endogenous variables to government revenues shock, 1 s.e. confidence bands; four different specifications

Chapter 4

The model

Based on the discussion in the literature review, it is evident that liquidity constraints play a very important role when one studies the properties of consumption and the effects of fiscal policy. Thus, we should not disregard the fact that liquidity constraints bind the behaviour of households, which departs significantly from the one that would arise when the households had an unlimited access to credit markets. This chapter presents a model in which I will quantify how the predictions of the New Keynesian framework change under the presence of liquidity constrained households. I will follow closely the model by Galí et al. (2007), which shows the impacts of fiscal spending shocks in the presence of non-Ricardian households. The calibration, model predictions and sensitivity analyses with respect to several parameters for the Czech economy will be presented in the subsequent chapters.

The model consists of six building blocks which will be described in detail subsequently. Figure 4.1 provides an overview of real, tax and transfer flows in the model. The model assumes a closed economy, which consists of Ricardian (intertemporally optimizing) households, non-Ricardian (rule-of-thumb) households, a final goods sector, an intermediate goods sector, the government and finally the monetary authority. The households supply labour and capital (they are the only ultimate capital owners) to the continuum of intermediate goods firms. The intermediate goods sector is characterized by staggered price setting and monopolistic competition. So, each firm maximizes its expected profit subject to the demand by the final goods sector. The frequency of price setting is modelled using the approach by Calvo (1983). Unlike the intermediate goods sector, the final goods sector is characterized by perfect competition and flexible price setting, so it can be modelled using one representative firm. The product of the final goods firm is equal to the gross domestic product, which can be

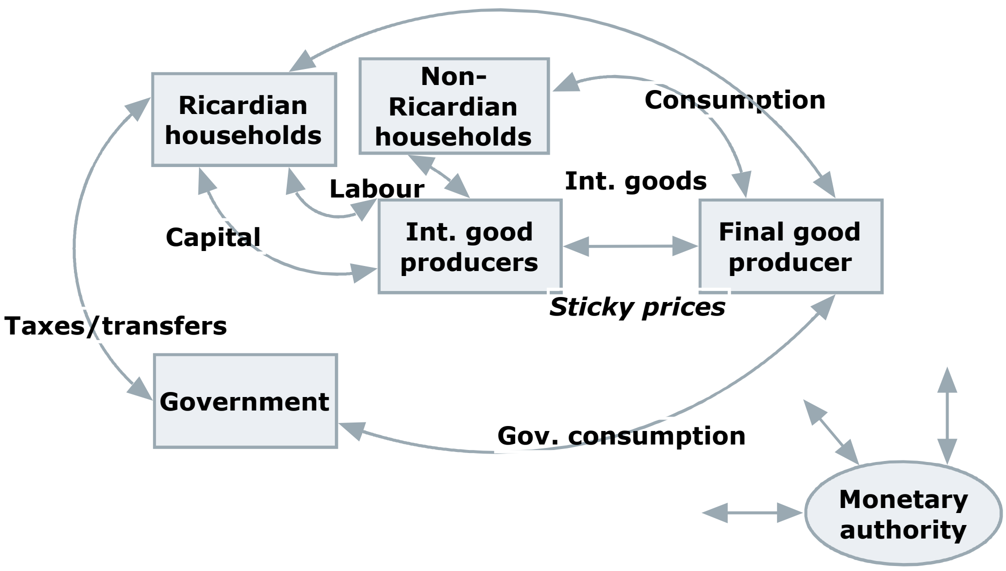

Figure 4.1: A flow diagram of the model

decomposed into the household and the government consumption and investments. Next, the government expenses, i.e. consumption, which is determined stochastically, and transfers, are financed by lump-sum taxes imposed on households. Finally, the monetary authority (the central bank) sets the nominal interest rate in order to achieve price stability. The remainder of this chapter presents the details of each sector's decision making, equilibrium conditions and their log-linear representation, which will be used for an approximate solution in the subsequent chapter.

4.1 Households

The economy of this model is assumed to be inhabited by a continuum of measure one of infinitely lived households. The households are assumed to be of two types. The first type, Ricardian or intertemporally optimizing households, is maximizing its lifetime utility subject to an intertemporal budget constraint. These households have an unlimited access to capital markets, so they can borrow or save funds without any constraints. The second type, rule-of-thumb households, cannot access capital markets (or they do not want to), and the households of this type consume their current labour income completely. It is assumed that $1 - \lambda \in [0, 1]$ of households belong to the first group, while λ households belong to the second group.

4.1.1 Ricardian households

A typical Ricardian household maximizes its lifetime utility subject to its intertemporal budget constraint. This constraint states that the expenses of the household (on consumption, investments and purchases of government bonds) cannot exceed its income given by wage, capital income, face value of bonds (with a one-year maturity) held since the previous period, dividends and net governmental transfers (the difference between transfers and lump sum taxes paid by the household). Next, the capital held by the households depreciates at a constant rate and investments are subject to adjustment costs.

The following notation will be used throughout the text. Consumption in period t by Ricardian households will be denoted by C_t^o and their labour supply by N_t^o. The period utility $U(C_t^o, N_t^o)$ will be discounted by the discount factor $\beta \in (0,1)$. The dynamic programming problem of Ricardian households is stated by the following three expressions:

$$\max_{\{C_t^o, N_t^o\}_{t=0}^{\infty}} \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t^o, N_t^o), \text{ s.t.} \tag{4.1}$$

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

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

Where 4.2 is the budget constraint and 4.3 is the law of motion of capital, which is owned by the Ricardian households. In Equation 4.2, P_t represents the price level in period t, W_t the nominal wage, R_t^k nominal rental costs of capital. B_t^o is the amount of bonds with face value equal to one unit of consumption good in period t which were purchased by the household in period $t-1$. Similarly, B_{t+1}^o denotes bonds with maturity in period $t+1$. Gross nominal return on bonds purchased in period t is denoted by R_t. Dividends to the company owners are denoted by D_t^o, taxes (or transfers) in real terms by T_t. Consumption and investments, in real terms, are denoted by C_t^o and I_t^o, respectively.

Consistently with Tobin's theory, the adjustment of the capital level requires adjustment costs, captured by the $\phi\left(\frac{I_t}{K_t}\right) K_t$ term. The function $\phi(.)$ is assumed to be increasing, concave and it is further assumed that $\phi'(\delta) = 1$ and $\phi(\delta) = \delta$.

For the calibration of the model, I will use, consistently with Galí et al. (2007), the instantaneous utility function of the form

$$U(C_t^o, N_t^o) \equiv \log C_t^o - \frac{(N_t^o)^{1+\varphi}}{1+\varphi}, \varphi \geq 0 \tag{4.4}$$

where $\varphi \geq 0$ is the inverse of Frisch labour supply elasticity (with respect to wages).

First order conditions

The first order conditions can be obtained either by the optimization of a constrained maximization problem (using the method of Lagrange multipliers) or by the optimization of a Bellman equation. I will use the second approach for obtaining the first order conditions of the household's optimization problem.

Before deriving the first order conditions, it is useful to state a result that follows from the capital accumulation equation. Since the capital adjustments costs function $\phi(.)$ is strictly increasing, its inverse function $\phi^{-1}(.)$ exists. Therefore, we can write the amount of investments in period t as:

$$I_t^o = \phi^{-1}\left(\frac{K_{t+1}^o - (1-\delta)K_t^o}{K_t^o}\right) K_t^o \tag{4.5}$$

A Bellman equation associated with Ricardian households optimization problem is defined as:

$$V(K_t^o, B_t^o) = \max_{K_{t+1}^o, N_t^o, B_{t+1}^o} \left\{ U(C_t^o, N_t^o) + \beta E_t V(K_{t+1}^o, B_{t+1}^o) \right\} \tag{4.6}$$

where we substitute for consumption from:

$$C_t^o = \frac{W_t}{P_t} N_t^o + \frac{R_t}{P_t} K_t^o + \frac{B_t^o}{P_t} + \frac{D_t^o}{P_t} - T_t^o - I_t^o - \frac{R_t^{-1}}{P_t} B_{t+1}^o \tag{4.7}$$

and for investments from Equation 4.5.

The following equations follow from the first order conditions of the Bellman equation:

$$P_t Q_t = E_t \left\{ \Lambda_{t,t+1} \left[R_{t+1}^k + P_{t+1} Q_{t+1} \left((1-\delta) + \phi_{t+1} - \left(\frac{I_{t+1}^o}{K_{t+1}^o} \right) \phi_{t+1}' \right) \right] \right\} \tag{4.8}$$

$$\frac{W_t}{P_t} = N_t^{\varphi} C_t \tag{4.9}$$

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

where Q_t denotes Tobin's Q, the real shadow value of capital and where $\Lambda_{t,t+1}$ is a one period stochastic discount factor. Its general form has the following form:

$$\Lambda_{t,t+k} \equiv \beta^k \left(\frac{C^o_{t+k}}{C^o_t}\right)\left(\frac{P_t}{P_{t+k}}\right) \tag{4.11}$$

In the basic New Keynesian models, as well as in RBC type models, labour supply is determined jointly by households and firms and the labour market is cleared through wages. It is not the case in this model. Here, it is assumed that only firms determine the amount of working hours at a given wage. It is also assumed that the wage is higher than the households' marginal rate of substitution between hours and consumption, so the households work the amount of hours demanded by the firms.

4.1.2 Non-Ricardian Households

The second type of households, non-Ricardian or rule-of-thumb households, do not take part in capital market activities. Therefore, they do not own any capital that would be rented to intermediate goods firms. Also, they do not save or borrow funds. Several reasons for their inactivity in the financial markets exist - the households might have no access to the market, their budget constraints are binding (or might be binding in the future - see the discussion on the paper by Deaton (1991) above), they are myopic regarding their future or simply they do not want to enter the financial markets.

The non-Ricardian households derive their utility from the utility function $U(C^r_t, L^r_t)$ subject to

$$P_t C^r_t = W_t N^r_t - P_t T_t \tag{4.12}$$

(again, the labour supply is determined by the firms). As the households do not optimize intertemporally, they consume their whole income:

$$C^r_t = \frac{W_t}{P_t} N^r_t - T_t \tag{4.13}$$

4.2 Final-Goods Sector

Consumption goods are produced in the final-goods sector which is characterized by perfect competition and constant returns to scale. Due to these characteristics, we can assume that there is one single representative firm selling its output at a price equal to the marginal costs.

The firm produces the consumption goods using intermediate goods (which are of continuum of measure of one) by CES technology and its profit maximization problem can be stated in the following way:

$$\max_{X_t(j)} P_t \left[\int_0^1 X_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}} - \int_0^1 P_t(j) X_t(j) dj \tag{4.14}$$

where $X_t(j)$ and $P_t(j)$ are the amount and price of the j-th intermediate good, respectively; P_t is the final good's price, which is taken as given, and ϵ is the elasticity of substitution parameter.

The demand schedules follow from the first order conditions of the maximization problem:

$$X_t(j) = \left[\frac{P_t(j)}{P_t} \right]^{-\epsilon} \tag{4.15}$$

From the zero profit condition, we have $P_t = \int_0^1 P_t(j) X_t(j) dj$ (unit price is equal to unit costs), which results in an expression of the final goods price in terms of the prices of the intermediate goods:

$$P_t = \left[\int_0^1 P_t(j)^{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}} \tag{4.16}$$

4.3 Intermediate-goods sector

A typical intermediate-goods firm j minimizes its real costs of producing the quantity $Y_t(j)$ demanded by final good sector. The firms use a Cobb-Douglass production technology:

$$Y_t(j) = K_t(j)^{\alpha} N_t(j)^{(1-\alpha)} \tag{4.17}$$

The Lagrangian associated with the j-th firm optimization problem is

$$L = -\frac{W_t}{P_t}N_t - \frac{R_t^k}{P_t}K_t + \lambda\left(K^\alpha N^{1-\alpha} - Y_t(j)\right) \tag{4.18}$$

where $Y_t(j) = X_t(j)$.

From the first order conditions, we can derive the following optimal capital/labour ratio,

$$\frac{K_t}{N_t} = \frac{\alpha}{1-\alpha}\frac{W_t}{R_t^k} \tag{4.19}$$

conditional factor demands

$$N_t = \left(\frac{\alpha}{1-\alpha}\right)^{-\alpha}\left(\frac{W_t}{R_t^k}\right)^{-\alpha} Y_t \tag{4.20}$$

$$K_t = \left(\frac{\alpha}{1-\alpha}\right)^{1-\alpha}\left(\frac{W_t}{R_t^k}\right)^{1-\alpha} Y_t \tag{4.21}$$

and the real marginal costs:

$$MC_t = \left(\frac{W_t}{P_t}\right)^{1-\alpha}\left(\frac{R_t}{P_t}\right)^{\alpha}\frac{1}{\Phi} \tag{4.22}$$

where $\Phi \equiv \alpha^\alpha(1-\alpha)^{1-\alpha}$

Price setting and dynamics

Price setting by intermediate firms is done in a staggered way, that is firms cannot change their prices optimally in every period. Instead, it is assumed that only a fraction of the firms reset their prices every period. This proportion is set stochastically in a way proposed by Calvo (1983). Intuitively, we assume that a measure $1-\theta$, where $\theta \in (0,1)$, of the firms are visited by the Calvo fairy, who allows them to change their prices for uncertain number of periods (until the Calvo fairy visits the firms again; the way the Calvo fairy visits firms is stochastically independent).

In what follows, I will show how intermediate-goods firms set their prices optimally (because the firms are symmetric, I omit the subscript at the optimal price term). First, assume that the firms which change their prices set the optimal prices at the level of P_t^*. Then the price level in period t is:

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

which follows from Equation 4.16.

The optimal price set by firms in period t is found by solving the following problem:

$$\max_{P_t^*} \sum_{k=0}^{\infty} E_t \left\{ \Lambda_{t,t+k} Y_{t+k}(j) (P_t^* - P_{t+k} MC_{t+k}) \right\} \tag{4.24}$$

subject to $Y_{t+k}(j) = X_{t+k}(j) = \left[\frac{P_t^*}{P_{t+k}}\right]^{-\epsilon} Y_{t+k}$

That is, the firms maximize their expected discounted profit with respect to two sources of uncertainty: the first one is that the firms are not sure whether they will be allowed to change their price in period $t+k$; the second is the uncertain level of prices, wages and return on capital in period $t+k$. The firms discount the stream of profits by the stochastic discounting factor from the consumer's optimization problem. The reason for this is that households are the ultimate capital owners and require the return on capital equal to $\Lambda_{t,t+k}$. Also, it is interesting to observe that Equation 4.24 is not the net expected discounted profit but instead only the part of it which accrues when the firms' prices remain constant. But the maximization problem remains equivalent to the former one because if the prices are changed in the future, they are set optimally in the same way.

The first order condition associated with Equation 4.24 is:

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \Lambda_{t,t+k} Y_{t+k}(j) \left(P_t^* - \frac{\epsilon}{\epsilon - 1} P_{t+k} MC_{t+k} \right) \right\} = 0 \tag{4.25}$$

4.4 Labour market

As I have already mentioned in the section describing the behaviour of households, labour market is not modelled explicitly in this model. Instead, it is assumed that there exists a wage schedule:

$$\frac{W_t}{P_t} = H(C_t, N_t)$$

where $H_C > 0$ and $H_N > 0$. These assumptions capture both convex marginal disutility of labour and wealth effects of wage. Firms decide how much labour to hire given the prevailing wage, which is assumed to be larger than the one demanded by households given the amount of labour, based on their first order conditions: $H(C_t, N_t) > C_t^j N_t^{\varphi}$, $i = r, o$. Therefore, the labour supply will always meet the amount of labour demanded by the firms. Also, firms do not discriminate among the types of households, so $N_t^r = N_t^o$.

4.5 The government

The government's expenditures consist of two parts - the first is the repayment of one-year bonds and the second part is the actual government consumption.

The receipts of government finance stem from lump-sum taxes and the face value of bonds, which mature in the next period. These receipts are used to repay bonds issued in the previous period and to finance the government consumption in this period. The government budget constraint can be written as:

$$P_t T_t + R_t^{-1} B_{t+1} = B_t + P_t G_t \tag{4.26}$$

A fiscal policy rule is determined in a way to close the deviations of government debt and government expenditures from the steady state values normalized by the steady state income. So, the fiscal policy rule has the following form:

$$t_t = \phi_b b_t + \phi_g g_t \tag{4.27}$$

where $g_t = \frac{G_t - G}{Y}$, $t_t = \frac{T_t - T}{Y}$, $b_t = \frac{B_t/P_{t-1} - B/P}{Y}$ are deviation of government expenditures, taxes and real bond holdings from their steady state values normalized by steady state income. In the steady state, we assume a balanced budget ($T = G$) and zero level of debt ($B = 0$). Apparently, the policy parameters ϕ_b and ϕ_g are positive constants.

The government consumption (in terms of its deviations from the steady state normalized by the steady state of output) follows an AR(1) process:

$$g_t = \rho_g g_{t-1} + \epsilon_t \tag{4.28}$$

where $0 < \rho_g < 1$ and ϵ_t is a white noise process with constant variance σ_ϵ^2 which represents a shock to the government consumption.

4.6 The monetary authority

The central bank in this model determines the nominal interesting rate by following a simple version of the Taylor rule (Taylor (1993)):

$$r_t = r + \phi_\pi \pi_t \tag{4.29}$$

where $r_t \equiv R_t - 1$ is the nominal interest rate, r is the steady state interest rate ($r = \beta^{-1} - 1$) and $\phi_\pi \geq 0$ is the parameter of the response of interest rate to inflation.

This Taylor rule is simplified in that the monetary policy seeks to stabilize the price level only, disregarding the level of output gap. A well known result, known as the Taylor principle, states that if $\phi_\pi > 1$, the solution of the model is unique. However, as we will see later, this is not the case in this model, due to the presence of rule-of-thumb households.

4.7 Equilibrium conditions

The equilibrium of the economy described by this model is characterized by the following conditions:

- Households, intermediate and final-goods firms, the government and the monetary authority maximize their optimization problems in each time period t.
- Aggregation conditions
  - Aggregate consumption: $C_t \equiv \lambda C_t^r + (1-\lambda)C_t^o$
    Total consumption is equal to the sum of consumption of optimizing and non-optimizing households.
  - Aggregate investments: $I_t \equiv (1-\lambda)I_t^o$
    Investments are made only by Ricardian households, so only a proportion $1-\lambda$ of their investments counts as total investments
  - Aggregate capital: $K_t \equiv (1-\lambda)K_t^o$
    Similarly, only a proportion of $1-\lambda$ of capital counts as total capital supplied
  - Aggregate labour supply: $N_t \equiv \lambda N_t^r + (1-\lambda)N_t^o = N_t^r = N_t^o$
    Both types of households supply the same amount of labour
- Market clearing conditions
  - Labour market clears: $N_t = \int_0^1 N_t(j)dj$
    Total labour supplied by households is equal to total labour demanded by intermediate good sector.
  - Capital market clears: $K_t = \int_0^1 K_t(j)dj$
    Total capital supplied by Ricardian households is equal to the total capital demanded by firms.

  - Intermediate goods market clears: $Y_t(j) = X_t(j), \forall j$
    Demand for each good j is equal to supply of good j in each period t

- Final good market clears: $Y_t = C_t + I_t + G_t$ in each time period t.
  Total GDP is equal to the sum of consumption, investments and government expenditures.

4.8 Log-linearized equilibrium conditions

The model described in the previous section is relatively complex and its precise solution by function iterations or similar methods would be prohibitively time-consuming. Instead, a numerical method based on the approximation of equilibrium solution around its steady-stead will be used. The principle of the method will be sketched in the following chapter and the log-linearized equations are derived in the Appendix. In this section, I will present the log-linear approximation of equilibrium conditions around their steady state values.

The following notational convention will be used. Lower-case letters will denote natural logarithm of a variable or a log-deviation of a variable from its steady state value. So, for example $y_t = \log Y_t - \log \bar{Y}$, where log is the natural logarithm of a variable and Y is the steady state value of income.

4.8.1 Households

The dynamics of Tobin's Q is described by the following log-linear approximation:

$$q_t = \beta E_t \{q_{t+1}\} + [1 - \beta(1-\delta)] E_t \left\{ r^k_{t+1} - p_{t+1} \right\} - (r_t - E_t \pi_{t+1}) \tag{4.30}$$

The relation between the dynamics of Tobin's q and investment is given by:

$$i_t - k_t = \eta q_t \tag{4.31}$$

where $\eta \equiv -\frac{1}{\phi''(\delta)\delta}$ is the elasticity of the investment-capital ratio with respect to Q in the steady state.

Capital accumulation equation is approximated by the following equation:

$$k_{t+1} = \delta i_t + (1-\delta) k_t \tag{4.32}$$

The following equations summarize the consumption decisions of households. Let $\gamma_o \equiv \frac{C^o}{C}$ be the share of consumption of optimizing households on the total consumption. Then the following equation pertains to optimizing households:

$$c_t^o = E_t\left\{c_{t+1}^o\right\} - \gamma_o(r_t - E\left\{\pi_{t+1}\right\}) \tag{4.33}$$

where $c_t^o \equiv \frac{C_t^o - C^o}{C}$.

Wage-schedule consistent with balanced growth is approximated by:

$$w_t - p^t = c_t + \psi n_t \tag{4.34}$$

where ψ is the elasticity of wages with respect to hours.

This can be used to describe the consumption decisions of non-Ricardian households. Let $c_t^r \equiv \frac{C_t^r - C^r}{C}$. Then

$$c_t^r = \left(\frac{WN}{PC}\right)\left[c_t + (1+\psi)n_t\right] - \left(\frac{Y}{C}\right)t_t \tag{4.35}$$

approximates the consumption decisions of non-Ricardian households.

Log-linear version of consumption aggregation is given by:

$$c_t = \lambda c_t^r + (1-\lambda)c_t^o \tag{4.36}$$

where $c_t^o \equiv \frac{C_t^o - C^o}{C}$. When the decisions of both types of households are plugged into the previous equation, we obtain an aggregate equilibrium condition for consumption:

$$c_t = E_t\left\{c_{t+1}\right\} - \frac{1}{\tilde{\tilde{\sigma}}}(r_t - E_t\left\{\pi_{t+1}\right\} - \rho) - \Theta_n E_t\left\{\Delta n_{t+1}\right\} + \Theta_\tau E_t\left\{\Delta t_{t+1}\right\} \tag{4.37}$$

where

$$\tilde{\sigma} \equiv \frac{\gamma_c - \lambda(1-\alpha)(1-\frac{1}{\epsilon})}{\gamma_o\gamma_c(1-\lambda)} \tag{4.38}$$

$$\Theta_n = \frac{\lambda(1-\alpha)(1+\psi)}{\gamma_c(\frac{\epsilon}{\epsilon-1}) - \lambda(1-\alpha)} \tag{4.39}$$

$$\Theta_\tau = \frac{\lambda(1+\mu_p)}{\gamma_c(\frac{\epsilon}{\epsilon-1}) - \lambda(1-\alpha)} \tag{4.40}$$

where $\gamma_c = \frac{C}{Y}$ is the steady state share of consumption on output. The last log-linear relationship is the only one dependent on the share of rule-of-thumb households λ. Also notice that as this share approaches zero, we obtain an analogue of the standard dynamic IS curve:

$$c_t = E_t \{c_{t+1}\} - (r_t - E_t \{\pi_{t+1}\} - \rho) \tag{4.41}$$

From the previous equations, one can observe that the presence of rule-of-thumb households makes the growth of aggregate consumption directly dependent on the growth of employment and also on the growth of taxes, even when they are not distortionary.

4.8.2 Firms

The dynamics of inflation as a function of the deviations of the average logarithm of markup from its steady state can be obtained from Equation 4.23 and Equation 4.25:

$$\pi_t = \beta E_t \{\pi_{t+1}\} - \lambda_p \mu_t^p \tag{4.42}$$

where

$$\lambda_p = \frac{(1-\beta\theta)(1-\theta)}{\theta} \tag{4.43}$$

and

$$\mu_t^p = (y_t - n_t) - (w_t - p_t) \tag{4.44}$$

when we ignore constant terms. This is equivalent to

$$\mu_t^p = (y_t - k_t) - (r_t^k - p_t) \tag{4.45}$$

A first order approximation of the aggregate production yields:

$$y_t = (1-\alpha)n_t + \alpha k_t \tag{4.46}$$

4.8.3 The government

Let $\rho \equiv \beta^{-1} - 1$ denote the steady state interest rate. By log-linearization of government budget constraint (Equation 4.26), we obtain:

$$b_{t+1} = (1+\rho)(b_t + g_t - t_t) \tag{4.47}$$

Plugging in the fiscal policy rule yields:

$$b_{t+1} = (1+\rho)(1-\phi_b)b_t + (1+\rho)(1-\phi_g)g_t \tag{4.48}$$

In order to obtain stationary process of the level of debt, we need to impose a condition that $(1+\rho)(1-\phi_b) < 1$. This is equivalent to $\phi_b > \frac{\rho}{1+\rho}$

4.8.4 Monetary authority

The policy function of the central bank is already in the log-linear form so there is no need to transform it further.

4.8.5 Market clearing condition

By a simple log-linearization, one obtains:

$$y_t = \gamma_c c_t + \gamma_i i_t + g_t \tag{4.49}$$

where $\gamma_i = \frac{\bar{I}}{\bar{Y}}$ denotes the steady state share of investments on total output.

Chapter 5

Solution and calibration of the model

5.1 Solution of the model

The model described so far is very complex and cannot be solved analytically, i.e. no closed-form solution of policy functions of households and firms exist. Instead, several numerical methods are used to solve such type of complex macroeconomic models. I will use a collection of numerical routines Dynare for Matlab®/Octave to solve the model. According to the reference manual, Dynare uses the methods by Klein (2000) and Sims (2002) to solve first-order approximation of stochastic models. The details of the method, which is one of a variety methods that solve linear rational expectations models, are not very important for the sake of this thesis.

The log-linearized equilibrium conditions from the previous chapter can be transforemed into a reduced form system: $\mathbf{A}E_t\left\{x_{t+1}\right\} = \mathbf{B}x_t + \epsilon_t$ where $x_t \equiv \left[n_t, c_t, \pi_t, k_t, b_t, g_{t-1}\right]^T$,

$$\mathbf{A} = \begin{pmatrix} 0 & 0 & 0 & 1 & 0 & \frac{\delta}{1-\tilde{\gamma}_c} \\ 0 & 0 & \beta & 0 & 0 & 0 \\ -\Theta_n & 1 & \frac{1}{\tilde{\sigma}} & 0 & \Theta_t\phi_b & \Theta_t(\rho_g - 1)\phi_g \\ \omega(1+\psi) + \beta(1-\alpha) & \omega - \beta\gamma_c & (1-\tilde{\gamma}_c)\eta & -\left[\omega + \beta(1-\tilde{\gamma}_c - \alpha)\right] & 0 & (1-\beta\rho_g) \\ 0 & 0 & 0 & 0 & 1 & -(1+\rho)(1-\phi_g) \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \tag{5.1}$$

and

$$\mathbf{B} = \begin{pmatrix} \frac{\delta(1-\alpha)}{1-\tilde{\gamma}_c} & -\frac{\delta\gamma_c}{1-\tilde{\gamma}_c} & 0 & 1-\delta+\frac{\delta\alpha}{1-\tilde{\gamma}_c} & 0 & 0 \\ -(\alpha+\psi)\lambda_p & -\lambda_p & 1 & \alpha\lambda_p & 0 & 0 \\ -\Theta_n & 1 & \frac{\phi_\pi}{\sigma} & 0 & \Theta_t\phi_b & 0 \\ (1-\alpha) & -\gamma_c & (1-\tilde{\gamma}_c)\eta\phi_\pi & \tilde{\gamma}_c+\alpha-1 & 0 & 0 \\ 0 & 0 & 0 & 0 & (1+\rho)(1-\phi_b) & 0 \\ 0 & 0 & 0 & 0 & 0 & \rho_g \end{pmatrix} \quad (5.2)$$

5.2 Calibration

This part of the chapter presents how the parameters of the model have been chosen. Some of them have been adopted from the literature and others have been estimated. A special attention has been paid to the estimation of fiscal policy parameters and the share of rule of thumb households, which are essential features of the model and have not been estimated using the Czech data yet. Therefore, special subsections are devoted to their estimation.

One period is assumed to represent a quarter. Discount factor of households is taken from Natalucci and Ravenna (2002) and its value is set to 0.99. This implies the steady state quarterly real interest rate $\rho = \frac{1}{\beta} - 1 = 0.01$. The yearly depreciation rate is set to 0.1, which implies the quarterly depreciation rate $\delta = 0.025$

Elasticity of labour supply is taken to be 2, implying $\phi = \psi = \frac{1}{2} = 0.5$ (according to Natalucci and Ravenna (2002)). Parameter η, the elasticity of the investment-capital ratio with respect to Tobin Q, is set to 2. Steady-state mark-up is defined as $\mu_p = \frac{\epsilon}{\epsilon-1} = 0.1$. This is consistent with the value of elasticity of substitution among intermediate goods of $\epsilon = 11$.

The literature does not provide a consensus on the estimate of parameter θ, which is the probability that a firm will not adjust its price during the next period. That is, this parameter represents the inflexibility of prices in the intermediate goods sector. For example, Natalucci and Ravenna (2002) assume this parameter to be 0.85. Similarly, Danišková and Fidrmuc (2011) estimates the parameter θ as ranging from 0.708 to 0.898 under various specifications. Vašıcek and Musil (2006) estimate the parameter to be slightly lower, 0.64. Finally, Štork et al. (2009) assume that the parameter value is 0.5. For the purposes of this model, the baseline value of parameter θ was chosen as 0.8, which is in line with the first two mentioned papers. The third paper estimates the parameter using Bayesian inference when other stickiness are present in the model, thus its value is lower. Average length of price non-adjustment can be calculated as $\frac{1}{1-\theta}$.

Parameter α from the Cobb-Douglas production function of the final goods sector represents the elasticity of output with respect to capital. Also, it represents the share of capital income when markets are competitive and factors of production are paid their marginal products. Similarly, parameter $1-\alpha$ represents the share of output that is paid to labour. Following Hájková and Hurník (2007), I have used the following formula to estimate parameter α:

$$1 - \alpha_t = \frac{TLC_t L_t}{GVA_t}$$

where TLC_t is total nominal labour cost per employee adjusted for hours worked, L_t is total employment in the economy and GVA_t is gross value added in nominal terms. The data available from the Czech Statistical Office are available for monthly averages and can be used after slight adjustment for the estimation. The resulting values of parameter α range from 0.412 to 0.418 from 2001 to 2008. Therefore, the value of 0.415 will be used for the solution of the model.

The steady-state share of government expenditures on income is computed as a share of government consumption on GDP (the data were downloaded from the website of the Czech Statistical Office). Surprisingly, the average value of this fraction is almost identical to that of the USA, assumed in Galí et al. (2007) (estimated as 0.2) and its size is $\gamma_g = 0.21$ for the Czech economy. Steady state consumption/output ratio follows from market clearing conditions:

$$\gamma_c = \frac{C}{Y} = 1 - \frac{I}{Y} - \frac{G}{Y} = 1 - \frac{\delta}{\frac{Y}{K}} - \gamma_g = (1-\gamma_g) - \frac{\delta\alpha}{(\rho+\delta)(1+\mu^p)}$$

The last identity follows from two facts. First, in the steady state, $Q = 1$ so there are no capital adjustment costs and thus the real rental rate is equal to the sum of real interest rate and depreciation rate: $\frac{R^k}{P} = \rho + \delta$ (households must be indifferent between lending their savings in the form of capital or purchase of bonds. Second, the first order condition of Equation 4.18 with respect to capital implies: $\frac{R^k}{P} = \frac{\lambda}{1+\mu^p}\frac{Y}{K}$ (Lagrange multiplier is interpreted as the marginal cost, which equals $\lambda = \frac{1}{1+\mu^p}$ in the steady state).

The previous relation for the steady state share of consumption on output implies the value $\gamma_c = 0.52$.

5.3 Share of rule-of-thumb households - parameter λ

A crucial parameter of the model presented in this thesis is the parameter λ, which quantifies the share of rule-of-thumb households in the economy. The existence of this parameter is the main component which distinguishes the model from the standard New-Keynesian models. Also, the impact of fiscal policy changes depends crucially on the magnitude of this parameter, as I will show consequently. Therefore, a separate section will be devoted to the estimation of the parameter.

Two approaches to the estimation of the parameter λ exist in the literature. The first is based on microeconomic data and requires a sizeable panel of household data. The second approach, which I will use, is based on an approximation using aggregate macroeconomic variables and follows the "lambda model" presented in the paper by Campbell and Mankiw (1989).

Assume again, that the size of the population is normalized to 1 and that the proportion $1 - \lambda$ behaves optimally, that is their behaviour complies with the permanent income hypothesis. Income of optimizing households is denoted as $Y_t^o = (1 - \lambda)Y_t$ and income of non-optimizing households is $Y_t^r = \lambda Y_t$. The total income is given as the sum of incomes of the two types of households, i.e. $Y_t = Y_t^o + Y_t^r$. Under the assumptions stated in the literature review (utility is quadratic and preference parameter β is equal to real interest rate r), the consumption of optimizing households follows a random walk: $\Delta C_t^o = (1 - \lambda)\epsilon_t$, where ϵ_t is a white noise process, which represents an innovation to permanent income. On the other hand, non-Ricardian households consume their current income, $C_t^r = \lambda Y_t$, thus $\Delta C_t^r = \lambda \Delta Y_t$. From the definition of aggregate consumption ($C_t = C_t^r + C_t^o$), one obtains:

$$\Delta C_t = \Delta C_t^r + \Delta C_t^o = \lambda \Delta Y_t + (1 - \lambda)\epsilon_t \tag{5.3}$$

This is an estimable equation and can be interpreted as an alternative hypothesis to the permanent income hypothesis. When λ is significantly larger than zero, one can conclude that the permanent income hypothesis is rejected, since the proportion λ of households does not behave optimally, i.e. these households do not consume their permanent income. Instead, they consume their current income. However, one needs to be cautions when estimating parameter λ using the previous equation. It is very likely that $cov(\epsilon_t, \Delta Y_t) \neq 0$, thus the method of ordinary least squares provides an inconsistent estimate of λ. Therefore, one needs to find valid instruments of ΔY_t and use a two stage least squares regression.

One possible set of instruments of ΔY_t is a set of all lagged variables, because they are by definition orthogonal to ϵ_t. Also, a valid instrument must be correlated with ΔY_t, so all lagged stationary variables which help to predict income growth can be used as an instrument.

Two additional problems need to be taken into account for the estimation, as Campbell and Mankiw (1989) argue. First, the variables of our interest, consumption and income, are non-stationary and their mean and variance increase with the level of innovations. Therefore, logarithms of variables are used instead of raw series. This does not cause any changes for the interpretation of parameter λ, because the estimated equation can be interpreted as a log-linear approximation to the true model. The second problem is that data at specific points in time are not available. Instead, aggregate volumes for quarterly periods are available. Therefore, as Campbell and Mankiw (1989) argue that the change in consumption is autocorrelated, instruments that are lagged at least twice from the original variable have to be used.

The quarterly data used for the estimation of the parameter λ for the Czech republic were downloaded from the OECD statistics database. They span from the first quarter of 1995 to the last quarter of 2010, i.e. 64 observations were collected. As the data on disposable income were not available, I have used quarterly data on GDP as a proxy (the same approach was taken by Campbell and Mankiw (1989) for the estimation of the parameter λ of some non-US countries). Both series on GDP and consumption were seasonally adjusted, converted into real terms and to per capita values.

Three sets of instruments were used - lagged GDP values, lagged consumption values and finally lagged interest rate, which is given by quarterly 3m interbank rate. Together 9 regressions were estimated and their results are presented in Table 5.1. The first one disregards the fact that variable ΔY_t needs to be instrumented. Not surprisingly, an OLS estimate provides a meaningless result.

As I have shown, the results of the estimation differ when various instruments are used. The most meaningful result seems to be 40.27% from regression 8. One can argue that R^2 is higher in the first stage in the first stage of regression 7. But I would claim that this result can be disregarded, since changes interest rate do not have any explanatory power for future income, as the first stage of regression 6 shows.

The last column of Table 5.1 presents the result of the Sargan test of over-identifying restrictions. The null hypothesis of the test is that none of the instruments is correlated with the residuals from the IV regression. This would imply that the instruments

Equation	Instruments	λ estimate *(s.e.)*	First stage *(R^2)*	Overidentification test *(p-value)*
1	None (OLS)	-0.0436794 (0.1084673)	-	-
2	$\Delta(L^2y_t,\ldots,L^4y_t)$	0.8132888 (0.3010564)	0.1208 (0.0178)	1.33886 (0.512)
3	$\Delta(L^2y_t,\ldots,L^6y_t)$	0.7157121 (0.2766958)	0.0997 (0.0643)	3.48998 (0.4794)
4	$\Delta(L^2c_t,\ldots,L^4c_t)$	0.2888788 (0.3820936)	0.0284 (0.2081)	4.28792 (0.1172)
5	$\Delta(L^2c_t,\ldots,L^6c_t)$	0.2859378 (0.3283623)	0.0162 (0.3299)	4.28197 (0.3692)
6	$\Delta(L^2i_t,\ldots,L^4i_t)$	0.3462353 (1.544126)	-0.0448 (0.9514)	2.0517 (0.3585)
7	$\Delta(L^2i_t,\ldots,L^6i_t)$	-0.224346 (1.101624)	-0.0736 (0.9699)	3.36314 (0.499)
8	$\Delta(L^2y_t,\ldots,L^4y_t)$, $\Delta(L^2c_t,\ldots,L^4c_t)$, $L^2c_t-L^2y_t$	0.402664 (0.1942862)	0.2083 (0.0072)	7.48463 (0.2783)
9	$\Delta(L^2y_t,\ldots,L^4y_t)$, $\Delta(L^2c_t,\ldots,L^4c_t)$, $\Delta(L^2i_t,\ldots,L^4i_t)$, $L^2c_t-L^2y_t$	0.2921848 (0.1718933)	0.2611 (0.0045)	11.3413 (0.253)

Table 5.1: Proportion of rule-of-thumb households estimates

are valid. P-values reported in the fifth column of the table indicate that none of the instruments in any estimated equation is exogenous. Therefore, instruments used in the regression were valid.

There is one further issue which should be taken into when estimating parameter λ. Recently, Andersson (2010) has argued, that parameter λ is significantly biased downwards when one uses the estimation procedure that I have used. This is because the model is designed for aggregate variables and per capita variables are used for the estimation. The correct estimation equation should be the same as the above, but instead of changes in income of the whole population, only changes in rule-of-thumb consumers' income should be used. Unfortunately, no remedy can be used in the model, as one would have to know the income of rule-of-thumb consumers, which is impossible.

However, one lesson can be learnt from the mentioned paper - the estimate that I have obtained can be considered a lower bound on the proportion of rule-of-thumb consumers. Therefore, I will provide a sensitivity analysis of the behaviour of the model, with respect to parameter λ.

5.4 Fiscal policy parameters

To estimate parameters ϕ_b and ϕ_g from the fiscal policy rule (Equation 4.27), I have performed a historical decomposition of a four-variable VAR model from Section 3.1, where government debt is used as the fourth variable. That is, I have estimated the VAR model and identified the historical structural shocks using the relation $\epsilon_t = B^{-1}Au_t$ (where ϵ_t is a vector of structural shocks and u_t is a vector of reduced-form shocks). Then, I have simulated time series that one would observe if only shocks to GDP affected the deviations from the predicted values by the estimated VAR model. That is, this time series has the following form:

$$\tilde{Y}_t = \mu + K(L,q)\tilde{Y}_{t-1} + A^{-1}B\tilde{E}_t$$

where $\tilde{E}_t$ is a vector of shocks, where the shocks pertaining to shocks other than the shocks to GDP are set to zero.

After the variation due to GDP shocks was identified, I have computed exogenous variation due to these shocks (i.e. $\tilde{Y}_t - Y_t$) and regressed those of debt on those of government spending and taxes. The source code of the procedure written in EViews is listed in Appendix.

Unfortunately, the results of this method are not robust when it is applied on the Czech data and they differ when the estimation is performed using various time periods of the data. Also, the results are sensitive with respect to the method of seasonal adjustment that is used to adjust the data.

Table 5.2 presents the estimates using 16 various specifications. The time series were seasonally adjusted using X12 and TRAMO procedures. The estimations were performed using the whole sample (1998:1 to 2010:4) and three sub-samples. Also, the identification of structural errors was performed in two ways - based on structural decomposition described in Section 3.1 and based on ordering.

The estimates are most meaningful (i.e., they are relatively similar to those estimated for the US and the eurozone) when they are estimated using the whole sample. When the time series ends before 2010, the results are sensible until the first quarter of 2009 and then they are similar to those estimated in the second rows (1998:1 - 2008:1). Also, the estimates are sensible in the third rows (2000:1 - 2010:4). Also, it should be noted that the results are statistically insignificant. The reason for this is that time series is relatively short and the fiscal rule might have been manifested only in the last periods (the government had not been bound much by the level of deficits and debt before the recent economic slowdown). Therefore, for the calibration purposes, I will use the longest possible time period.

Table 5.2 also present two possibilities of the VAR model specification - with one lag and two lags of endogenous variables included in the model. The parameters do not change dramatically under the two specifications but still their values vary.

For the solution of the model, I will use two sets of parameters: 1) $\phi_g = 0.11$ and $\phi_b = 0.24$; 2) $\phi_g = 0.06$ and $\phi_b = 0.19$. These parameters are consistent with those estimated using a similar method by Galí et al. (2007) using the same procedure for the U.S. - $\phi_g = 0.12$, $\phi_b = 0.3$ and also those estimated by Coenen and Straub (2004) using Bayesian inference for the eurozone (under the specification of lump-sum and distortionary taxes, which approximates the reality better than the specification under the lump-sum taxes only): $\phi_g = 0.123$, $\phi_b = 0.292$.

The parameter ρ_g was set as $\rho_g = 0.9$, which is consistent with the two papers cited above. Also, a sensitivity analysis with respect to this parameter will be performed.

Table 5.2: Estimates of fiscal policy rule parameters under various specifications and seasonal adjustments

	X12				TRAMO			
2 lags								
period	structural		ordering		structural		ordering	
	ϕ_g	ϕ_b	ϕ_g	ϕ_b	ϕ_g	ϕ_b	ϕ_g	ϕ_b
1998:1 2010:4	0.14	0.17	0.09	0.16	0.11	0.24	0.03	0.24
1998:1 2008:1	0.02	-0.25	-0.03	-0.29	-0.05	-0.14	-0.09	-0.19
2000:1 2010:4	0.11	0.07	0.04	0.02	0.08	0.1	-0.02	0.06
2000:1 2008:1	0.01	-0.41	-0.04	-0.44	-0.07	-0.21	-0.11	-0.27
1 lag								
period	structural		ordering		structural		ordering	
	ϕ_g	ϕ_b	ϕ_g	ϕ_b	ϕ_g	ϕ_b	ϕ_g	ϕ_b
1998:1 2010:4	0.12	0.12	0.06	0.1	0.06	0.19	-0.005	0.17
1998:1 2008:1	0.03	-0.21	0.01	-0.24	-0.05	-0.11	-0.06	-0.14
2000:1 2010:4	0.12	0.12	0.06	0.1	-0.04	0.05	-0.1	0.03
2000:1 2008:1	0.03	-0.21	0.01	-0.24	-0.07	-0.24	-0.1	-0.3

Chapter 6

Results and sensitivity analysis

This chapter analyses the results of the model presented in the previous chapters and presents sensitivity analyses with respect to several parameters. Because the estimation of fiscal policy parameters has proved not to be robust, I will show two sets of results and sensitivity analyses with respect to each parameter. Throughout this chapter, Fiscal rule 1 refers to the rule, where $\phi_g = 0.11$ and $\phi_b = 0.24$ and Fiscal rule 2 refers to the set of fiscal policy parameters, where $\phi_g = 0.06$ and $\phi_b = 0.19$. The reason for the choice of these parameters were given in the previous chapter.

Figure 6.1 presents the results of the two scenarios - responses of all variables of the model to a five percentage shock to governmental expenditures normalized by the level of output (i.e. the log-deviations of variables are measured in terms of percentage GDP deviations)[1]. We can observe that the government spending multiplier is very close to one in the first case, while it is smaller than one in the second case. The response of aggregate consumption is determined by the response of each type of households and the proportion of each type of households. The response of Ricardian households is by and large similar - due to a negative wealth effect of governmental consumption, which is caused by a higher tax burden in the future, these households cut back on their consumption and increase their labour supply. The extent of the wealth effect depends on the fiscal rule, i.e. how the tax profile changes over time. Because the value of both parameters is higher under Fiscal rule 1, the debt of the government is repaid faster and consumption reverts back faster as well under this rule. The total level of consumption is a convex combination of its two components.

[1]Figure B.1 in the Appendix presents the impulse responses to a fiscal shock when the fiscal rule estimated for the eurozone is assumed ($\phi_g = 0.123$, $\phi_b = 0.292$). The results are qualitatively similar to those under Fiscal rule 1, however, the impulse profiles slightly differ quantitatively.

Therefore, if the proportion of the rule-of-thumb households was higher, we would observe more periods where total consumption increases with respect to its steady state after a government spending shock.

Aggregate hours worked increase in both cases and it is because of a higher demand by firms, that need to produce more in order to meet an increased demand by the government. This increase in labour demand is met by the labour supply because of the negative wealth effect of the increased government consumption. In contrast with RBC models, an increase in hours worked is accompanied by an increase in real wages.

Sensitivity analysis

As Galí et al. (2007) point out, the conditions for the unique solution are altered under the presence of rule-of-thumb households compared to the standard New Keynesian model. In the latter model, it is sufficient to have $\phi_\pi > 1$ in order to achieve a unique solution (this result is known as the Taylor principle). However, the Taylor principle does not hold in this model any more. Figure 6.2 shows the combinations of parameters λ (the proportion of rule-of-thumb households) and θ (price stickiness) under which the determinacy is achieved, given that other parameters are fixed at their baseline values (recall that ϕ_π = 1.5). The white space denotes the combinations that achieve an indeterminate solution. Also, we can observe that the combination of our parameters ($\lambda = 0.4$ and $\theta = 0.8$) still achieves a unique solution.

As I have stated in this section, the aggregate consumption is a convex combination of the consumption of each type of households. Therefore, it is not surprising that the aggregate consumption rises as a result of an increase in the proportion of rule-of-thumb households. This is depicted in Figure B.2. This figure and all that follow show results only for those parameter values for which the unique solution exists. Therefore, for example, the parameter λ ranges from zero to 0.45, approximately.

Figure B.3 shows that output, consumption and investment are increasing in the degree of price stickiness. All variables rise more rapidly for extremely high values of θ. Costs of investment (captured by parameter η) have obviously the largest impact on investments (Figure B.4). When the costs are prohibitively large ($\eta = 0$), the investment does not react to government spending shock at all. Furthermore, as expected, the response of investment is larger the higher the parameter η. Similarly but to a smaller degree, both output and consumption are decreasing in parameter η.

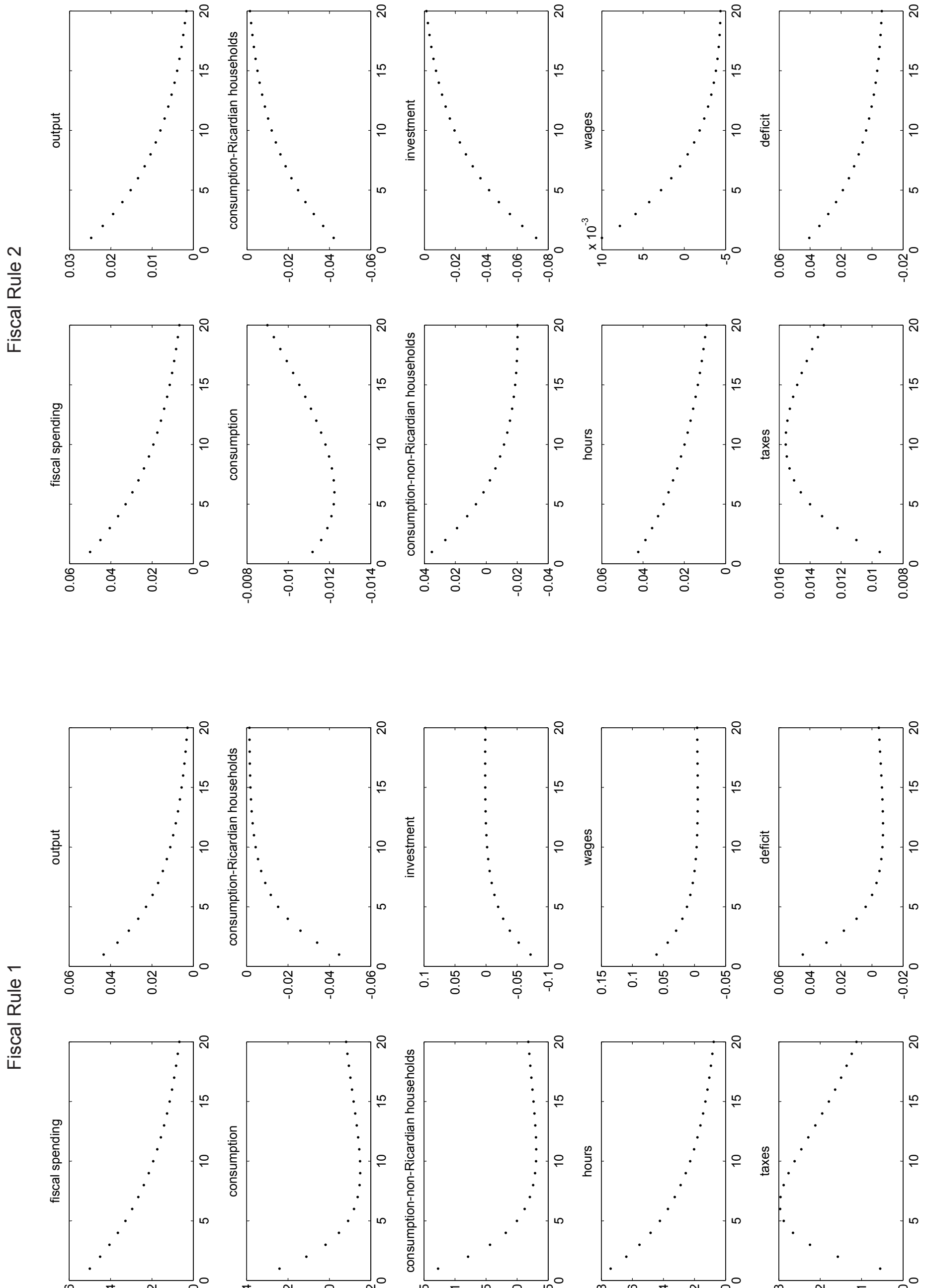

Figure 6.1: Model impulse responses

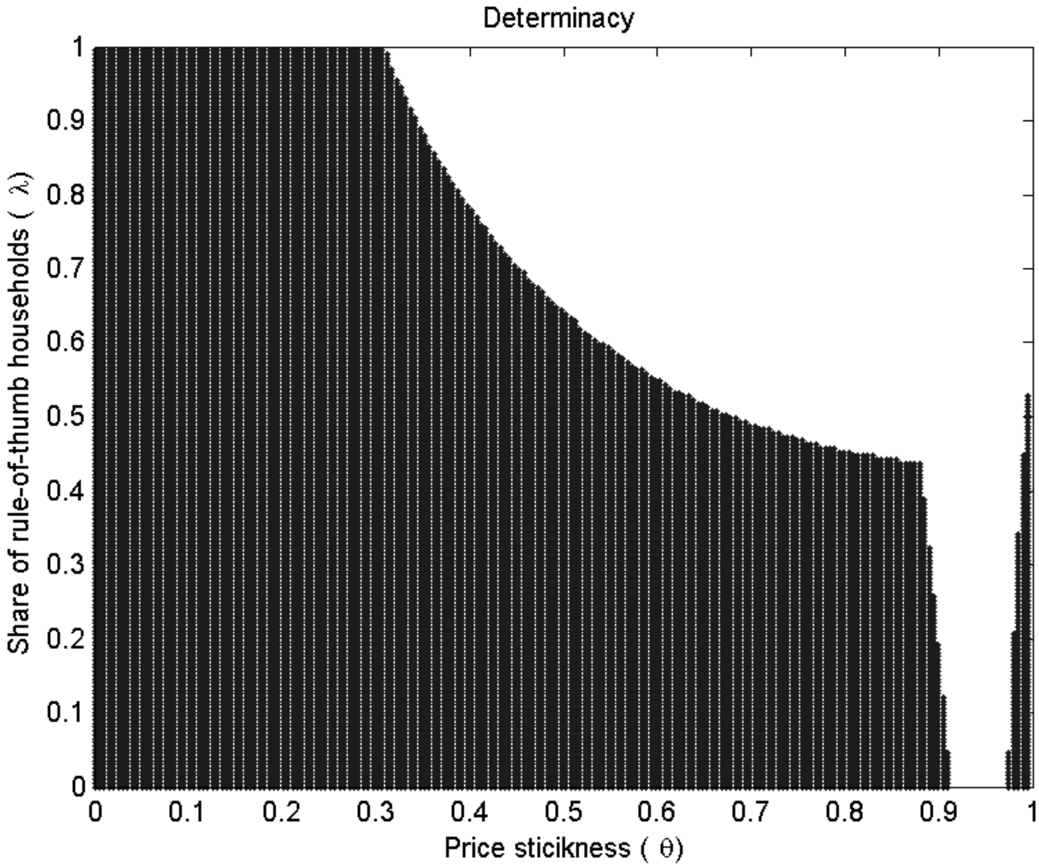

Figure 6.2: Combinations of θ (price stickiness) and λ (share of rule-of-thumb households) parameters that assure a unique solution of the model

The response of aggregate variables to a change in θ is similar as for parameter η - the relation among them is negative, but the three variables do not respond so much.

Policy parameters remain to complete the sensitivity analysis. As Galí et al. (2007) argue, the graph of impact responses with respect to ϕ_π (Figure B.6) is an inverse one to the one where θ is on the x axis. This is because the monetary authority can achieve the responses of variables by varying parameter ϕ_π that would arise under various parameters of price stickiness. The impact response of output and consumption is decreasing in parameter ρ_g, the persistence of government spending shocks (Figure B.7). This is because a higher persistence means higher spending in the future, which implies a larger negative wealth effect. Therefore, the Ricardian households save more to the detriment of consumption.

The two fiscal policy parameters have an opposite effect - crowding in of consumption is decreasing in parameter ϕ_g, as one can observe in Figure B.8, (deficit will increase more on impact, thus higher disposable income remains to households) and increasing in ϕ_b (the debt will be repaid sooner but in later periods), which is depicted in Figure B.9.

Chapter 7

Conclusion

This thesis has analysed the effects of fiscal spending shocks on the Czech economy. The study of the literature has suggested that the standard RBC and New Keynesian models have difficulties in predicting the effects of fiscal policy on the economy, particularly in predicting the response of private consumption. A possible reason of this problem is that they ignore the fact that a significant fraction of population does not behave in a forward-looking manner, i.e. they consume their whole current income instead of their permanent income, as these models assume. Therefore, I have used a variant of the New Keynesian model, where rule-of-thumb households, which consume their current income, coexist with the standard Ricardian households.

The results of the model suggest that output increases following a government spending shock but the response is less than proportional, so the government spending multiplier does not exceed one. The response of consumption depends on the share of Ricardian households in the economy. These households increase their labour supply following a government spending shock and decrease their consumption due to a negative wealth effect. The reaction of the rule-of-thumb households is different - their consumption increases due to higher income, which stems from higher wages. The aggregate consumption rises more when the share of rule-of-thumb households is higher. The response of other aggregate variables is similar as in other models - investments are crowded out and total hours worked increase.

These results imply several policy recommendations. Because the responses of output and consumption to a government spending spending shock do not seem to be large (based on both empirical and theoretical analyses), the long-term costs of fiscal stabilization seem to be relatively larger compared to its benefits. Therefore, a fiscal stimulus should be used only in deeper economic downturns to stabilize output. In deeper recessions, the share of rule-of-thumb households is higher due to the difficulties of low-income households in accessing credit markets to smooth their consumption. Therefore, the response of output and consumption is stronger, which provides a case for fiscal policy action. Also, fiscal spending should be aimed at liquidity constrained households, which would spend their additional income instead of saving it for even worse times. Finally, the stance of the government to its debt is important. When the government reacts to the level of debt in a stronger way, i.e. when taxes are increased more when the debt rises in order to repay it, the effectiveness of fiscal policy is expected to be higher. This is because forward-looking households expect an increase in taxation soon, thus they increase their labour supply more, which boosts the output.

The sensitivity analysis has shown that the magnitude of the response of each variable depends crucially on the expectations of future behaviour of the government, which is summarized in the fiscal rule. This rule has been estimated on relatively short time series and there is a large uncertainty about its parameters. Also, the model used for the analysis assumes a closed economy, but the Czech Republic is a small open economy. Therefore, future research of fiscal policy effects should focus on open economy models which incorporate rule of-thumb-consumers. I expect that the response of output and consumption to fiscal spending shocks would be weaker in those models than in the model presented in this thesis. Nonetheless, this does not alter the recommendations stated above.

Appendix A

Baseline model parameters

Parameter	Description of the parameter	Value
Preference, technology parameters		
β	Discount factor	0.99
ϵ	Elasticity of substitution among intermediate goods	11
δ	Depreciation rate	0.025
η	Elasticity of investment w.r.t. Tobin's Q	2
α	Capital share on output	0.41
ψ	Wage elasticity w.r.t. hours	0.5
General parameters (for which sensitivity analysis will be performed)		
λ	Proportion of rule-of-thumb consumers	0.4
θ	Price stickiness - fraction of firms that leave their prices unchanged	0.8
Policy parameters		
ϕ_π	Response of the monetary authority to inflation	1.5
ϕ_g	Response of taxes to gov. expenditures	0.11 / 0.06
ϕ_b	Response of taxes to debt	0.24 / 0.19
γ_g	Average government spending share on GDP	0.21
ρ_g	AR(1) parameter in the government spending shock	0.9

Table A.1: Baseline model parameters

Appendix B

Sensitivity analysis

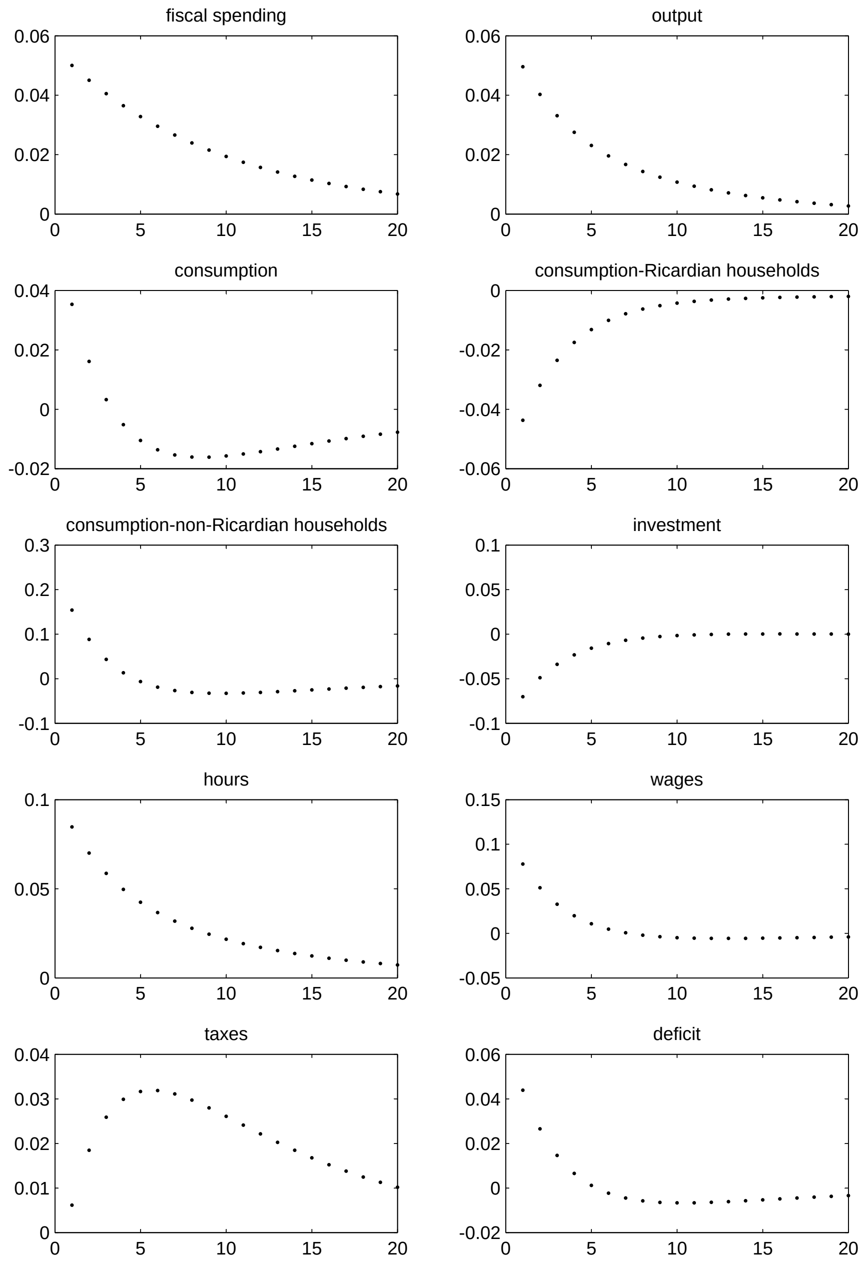

Figure B.1: Impulse response functions - EU fiscal rule

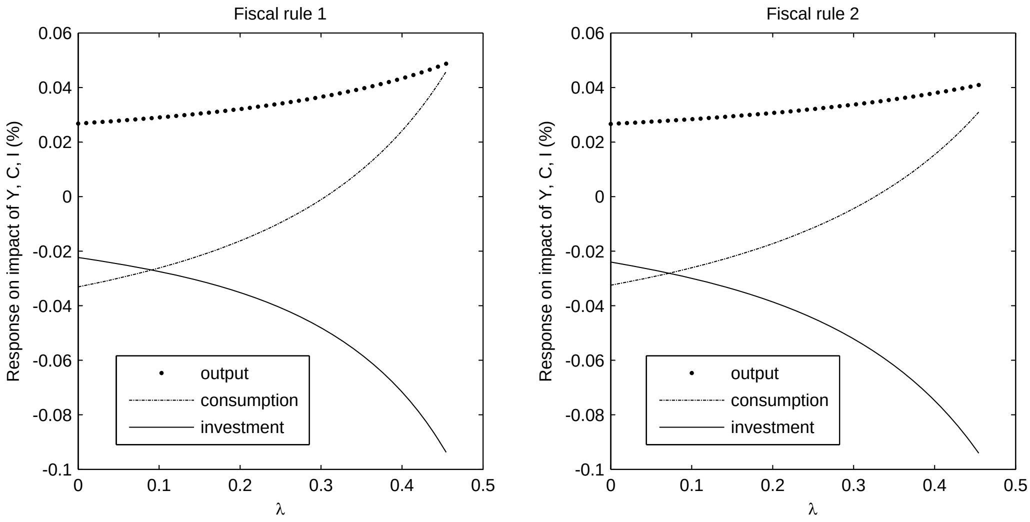

Figure B.2: Impact multipliers: sensitivity with respect to parameter λ (share of rule-of thumb households) under two fiscal policy rule scenarios

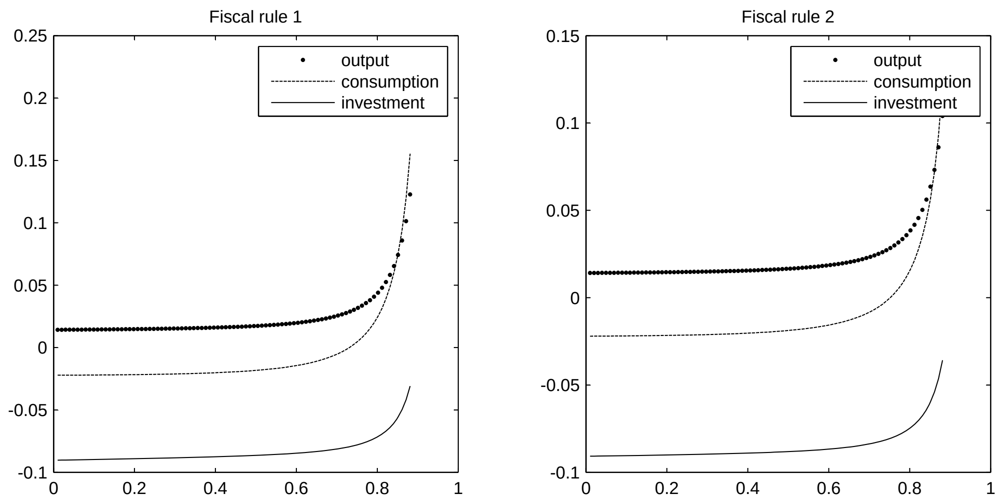

Figure B.3: Impact multipliers: sensitivity with respect to parameter θ (price stickiness) under two fiscal policy rule scenarios

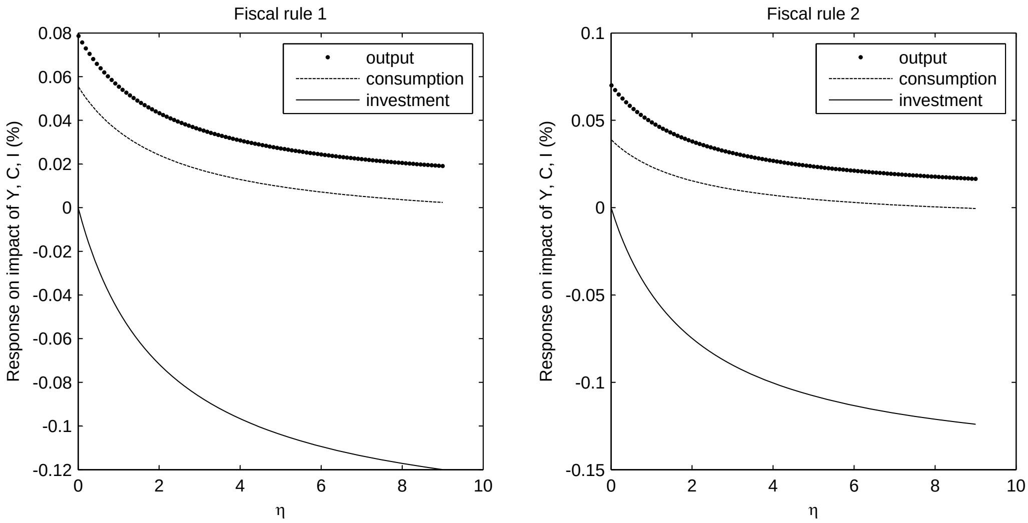

Figure B.4: Impact multipliers: sensitivity with respect to parameter η (elasticity of investment w.r.t. Tobin's Q) under two fiscal policy rule scenarios

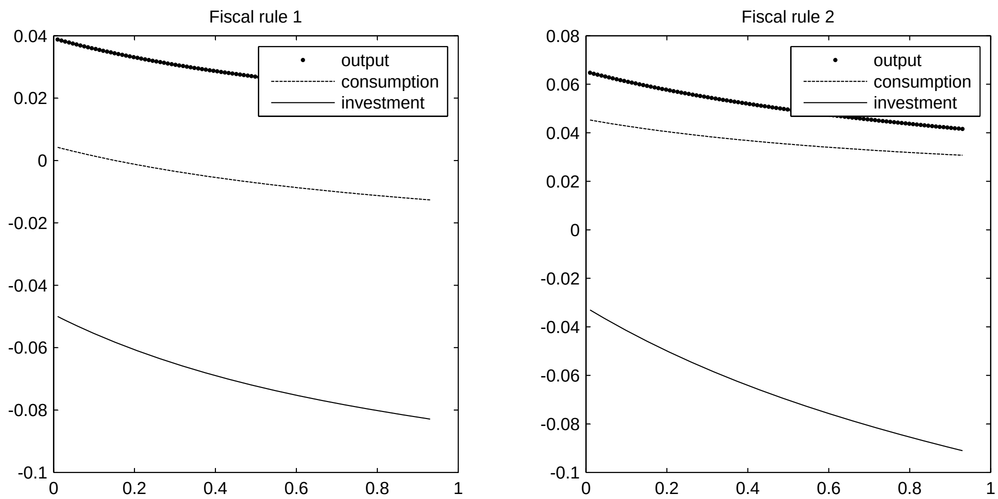

Figure B.5: Impact multipliers: sensitivity with respect to parameter ψ (elasticity of wages w.r.t. labour supply) under two fiscal policy rule scenarios

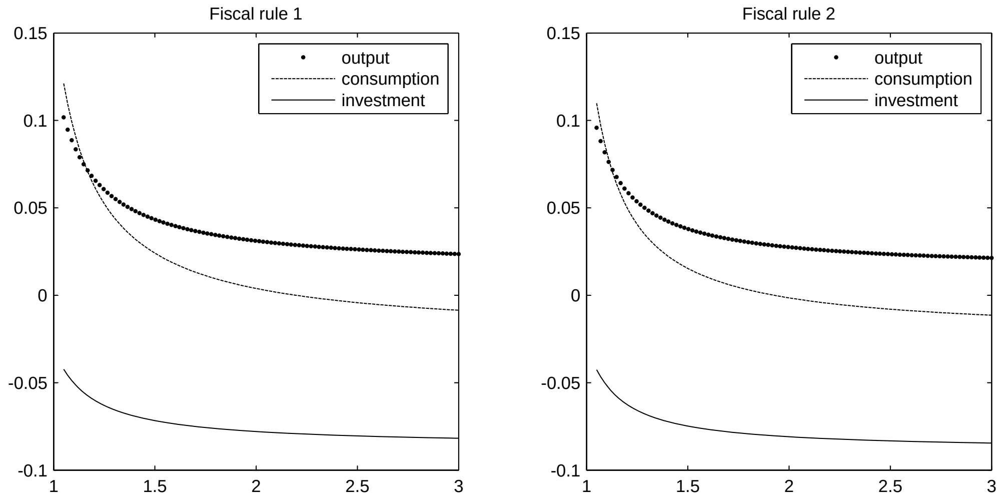

Figure B.6: Impact multipliers: sensitivity with respect to parameter ϕ_π (response of monetary policy to inflation) under two fiscal policy rule scenarios

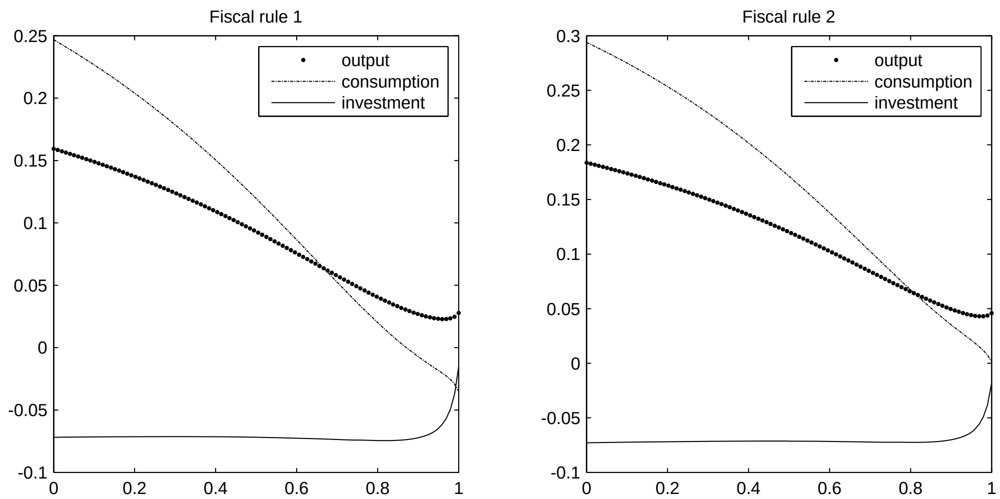

Figure B.7: Impact multipliers: sensitivity with respect to parameter ρ_g (persistence of government spending shocks) under two fiscal policy rule scenarios

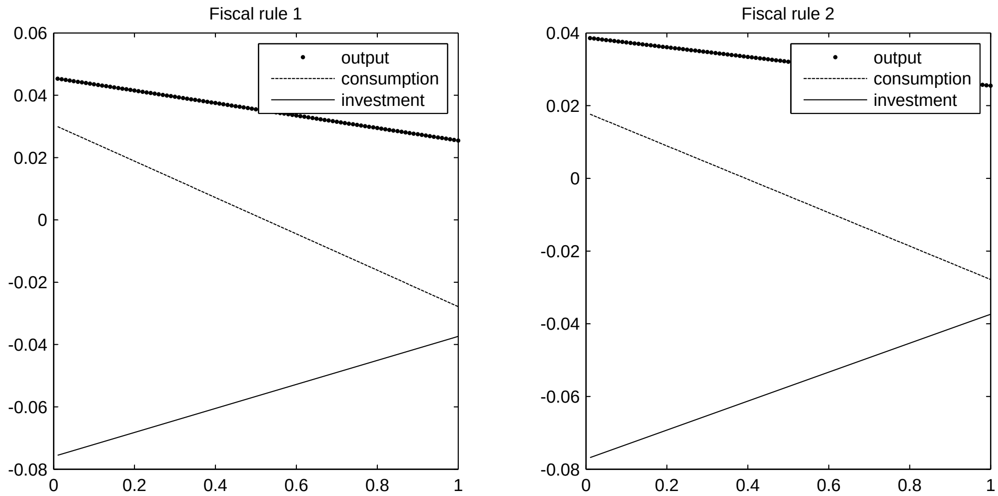

Figure B.8: Impact multipliers: sensitivity with respect to parameter ϕ_g (response of taxes to spending) under two fiscal policy rule scenarios

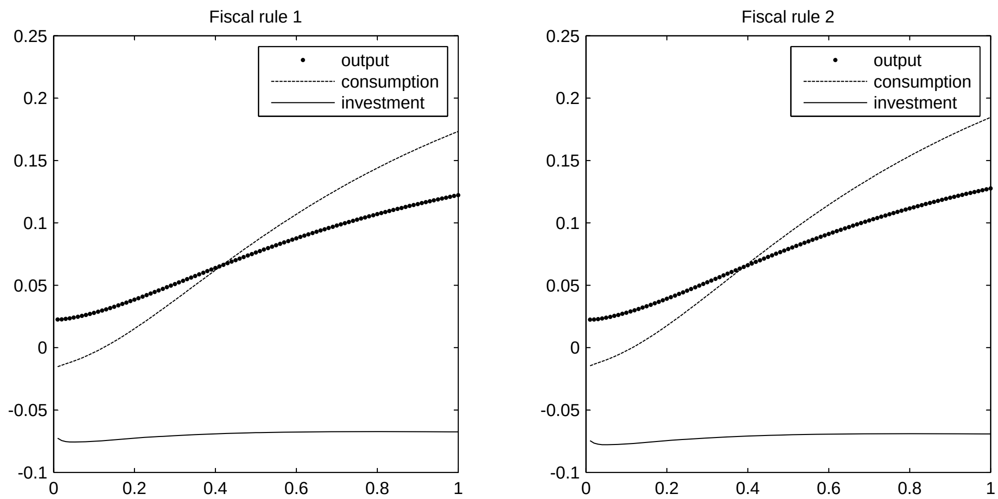

Figure B.9: Impact multipliers: sensitivity with respect to parameter ϕ_b (response of taxes to debt) under two fiscal policy rule scenarios

Appendix C

Log-linear approximation around steady state

In the main body of the thesis, I have omitted the derivation of equations representing log-linearized equilibrium conditions. This was done in order to make the text as lucid and brief as possible. As the log-linearization is a technical procedure, I have postponed it into this section of the Appendix. I will use the method by Uhlig (1999) for log-linearization, which will be summarized in the following text.

Log-linear deviation of a positive variable x_t from its positive steady state value X is defined as $\tilde{x}_t = \log x_t - \log X$. It is approximately equal to its percentage deviation from the steady state value: $\log x_t - \log X = \log(\frac{X_t - X}{X} + 1) \cong \frac{X_t - X}{X}$, where the approximation $\log(1+a) \cong a$ can be used for small values of a. By a simple transformation, we can write $x_t = Xe^{\tilde{x}_t}$, which is a precise identity. Using the fact that for small values of $\tilde{x}_t$, we can use approximation $e^{\tilde{x}_t} \cong 1 + \tilde{x}_t$, we arrive at the Rule 1:

Rule 1: $x_t \cong X(1 + \tilde{x}_t)$.

The second rule of log-linearization enables us to simplify most of expressions:

Rule 2: $\tilde{x}_t \tilde{y}_t \cong 0$. Because we assume that variables characterizing the economy are very close to their steady state values, we can approximate products of their log-deviations from the steady state values as zero.

Rule 3: $f(x_t) \cong f(X)(1 + \epsilon \tilde{x}_t)$, where $\epsilon = \frac{\partial f(X)}{\partial X} \frac{X}{f(X)}$.

This rule is used to approximate a function of a variable using its steady state value and log-linear deviation from its steady state value. This rule follows from the first order Taylor expansion and Rule 1:

$$f(x_t) \cong f(X) + f'(X)(x_t - X) = f(X) + \epsilon \frac{f(X)}{X} (X(1 + \tilde{x}_t) - X) = f(X)(1 + \epsilon \tilde{x}_t)$$

Equation 4.30

First, we need to obtain an approximation of ϕ_{t+1} term using Rule 3. Start with the elasticity of function ϕ with respect to $\frac{I}{K}$ in its steady state:

$$\epsilon^{\phi}_{\frac{I}{K}} = \phi'\left(\frac{I}{K}\right)\frac{I}{K}\frac{1}{\phi(\frac{I}{K})} = \phi'(\frac{I}{K})\delta\frac{1}{\phi(\delta)} = 1$$

where the fact that $\frac{I}{K} = \delta$ holds in the steady state and the properties of function ϕ are used.

Now, using Rule 3, arrive at the approximation:

$$\phi(\frac{I_t}{K_t}) \cong \phi(\frac{I}{K})(1 + \tilde{i}_t - \tilde{k}_t) = \delta(1 + \tilde{i}_t - \tilde{k}_t).$$

To log-linearize Equation 4.8, rewrite it into the following form (using Equation 4.10 and the fact that $\phi'_{t+1} = \frac{1}{Q_{t+1}}$):

$$P_t Q_t R_t = E_t\left\{R_{t+1} + P_{t+1}Q_{t+1}\left((1-\delta) + \phi_{t+1} - \frac{I_{t+1}}{K_{t+1}}\frac{1}{Q_{t+1}}\right)\right\}$$

Using a straightforward application of Rule 1, obtain:

$$\begin{aligned} PQR(1 + \tilde{p}_t + \tilde{q}_t + \tilde{r}_t) =& E_t\{R(1+\tilde{r}_t) + PQ(1-\delta)(1 + \tilde{p}_{t+1} + \tilde{q}_{t+1}) + \\ &+ PQ(1 + \tilde{p}_{t+1} + \tilde{q}_{t+1})\delta(1 + \tilde{i}_{t+1} - \tilde{k}_{t+1}) - \\ &- \frac{PI}{K}(1 + \tilde{p}_{t+1} + \tilde{i}_{t+1} - \tilde{k}_{t+1})\Big\} \end{aligned}$$

Now, use the fact that the steady state values of price level and Tobin's Q are $P = 1$ and $Q = 1$, respectively. The steady state value of interest rate is $R = \frac{1}{\beta}$ and the steady state fraction $\frac{I}{K} = \delta$. Finally, $\pi_{t+1} = \tilde{p}_{t+1} - \tilde{p}_t$. Using these facts and some tedious algebra, we obtain Equation 4.30.

Equation 4.35

First, subtract the steady state identity $\bar{C}^r = \frac{\bar{W}}{\bar{P}}\bar{N}^r - \bar{T}$ from Equation 4.13 and divide the equation by $\bar{C}$. Obtain

$$c^r_t = \frac{W_t N_t}{P_t \bar{C}} - \frac{\bar{W}\bar{N}^r}{\bar{P}\bar{C}} - t_t\frac{\bar{Y}}{C}$$

Now apply Rule 2: $\frac{W_t N_t}{P_t} \cong \frac{WN}{P}[1 + \tilde{w}_t + \tilde{n}_t - \tilde{p}_t]$. Plugging from Equation 4.34 into the previous equation, results in Equation 4.35.

Equation 4.34

To log-linearize the condition $\frac{W_t}{P_t} = C_t N_t^{\phi}$, first take logarithm of this equality, subtract the logarithm of steady-state value and obtain Equation 4.34.

Equation 4.36

The equation holds also in the steady state: $\bar{C} = \lambda \bar{C}^r + (1-\lambda)\bar{C}^o$. When we subtract this identity from and divide by the steady state value of consumption $\bar{C}$, we obtain Equation 4.36 (here we employ the fact that a percentage deviation of a variable from its steady state is approximately equal to the log-deviation of a variable from the steady state).

Equation 4.42

First, divide Equation 4.25 by P_{t-1} and rewrite it as

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

In the log-linearization, I will use several approximations (which follow from simple applications of the stated rules and steady state identities):

$$Y_{t+k}(j) = \left(\frac{P_t^*}{P_{t+k}} \right)^{-\epsilon} Y_t \cong \frac{P}{P} Y (1 - \epsilon(p_t^* - p_{t+k}))$$

$$\frac{P_t^*}{P_{t-1}} \cong (1 + p_t^* - p_{t-1})$$

$$\frac{P_{t+k}}{P_{t-1}} \cong (1 + p_{t+k} - p_{t-1})$$

$$MC_{t+k} \cong \frac{1}{M}(1 + \hat{mc}_{t+k}(j))$$

$$\Lambda_{t,t+k} = \beta^k \left(\frac{C_{t+k}}{C_t} \right)^{-1} \left(\frac{P_t}{P_{t+k}} \right) \cong \beta^k (1 - (c_{t+k} - c_t) + p_t - p_{t+k})$$

Now approximate the left hand side using the stated approximations and using the fact that the product of two variables in log-deviations can be approximated as zero and arrive at the following equation:

$$p_t^* - p_{t-1} = (1-\beta\theta)\sum_{k=0}^{\infty} E_t\,(\theta\beta)^k\left\{\hat{mc}_{t+k} + p_{t+k} - p_{t-1}\right\}$$

where individual firm marginal costs $\hat{mc}_{t+k}(j)$ were replaced by economy-wide marginal costs $\hat{mc}_{t+k}$ due to constant returns to scale.

Now realize the following identity:

$$\begin{aligned}\sum_{k=0}^{\infty}(\theta\beta)^k(p_{t+k}-p_{t-1}) &= p_t - p_{t-1} + \theta\beta(p_{t+1}-p_t+p_t-p_{t-1})+\\ &+\theta^2\beta^2(p_{t+2}-p_{t+1}+p_{t+1}-p_t+p_t-p_{t-1})+\ldots=\\ &=\pi_t+\theta\beta(\pi_{t+1}+\pi_t)+\theta^2\beta^2(\pi_{t+2}+\pi_{t+1}+\pi_t)+\ldots=\\ &=\pi_t\frac{1}{1-\theta\beta}+\theta\beta\pi_{t+1}\frac{1}{1-\beta\theta}+\ldots=\\ &=\frac{1}{1-\beta\theta}\left(\sum_{k=0}^{\infty}(\theta\beta)^k E_t\pi_{t+k}\right)\end{aligned}$$

Therefore, we can write

$$p_t^* - p_{t-1} = (1-\beta\theta)\sum_{k=0}^{\infty} E_t\,(\theta\beta)^k\left\{\hat{mc}_{t+k}\right\} + \sum_{k=0}^{\infty}(\theta\beta)^k E_t\pi_{t+k}$$

This can be rewritten as the following difference equation:

$$p_t^* - p_{t-1} = \theta\beta E_t\left\{p_{t+1}^* - p_t\right\} + (1-\theta\beta)\hat{mc}_t + \pi_t$$

Now log-linearize Equation 4.23: $\pi_t = (1-\theta)(p_t^* - p_{t-1})$.
and combine the two previous equations:

$$\pi_t = \beta E_t\pi_{t+1} + \lambda_p\hat{mc}_t$$

where $\lambda = \frac{(1-\theta)(1-\theta\beta)}{\theta}$
Finally, define $\mu_t^p \equiv -\hat{mc}_t$

Equation 4.44, 4.45 and 4.46

All of the equations can be log-linearized by taking logarithms and subtracting the logarithms of their steady-state values. Next, constant terms in Equations 4.44 and 4.45 are omitted.

Equation 4.49

Using the method described above, we can rewrite the market clearing condition as: $\bar{Y}(1+\tilde{y}_t) = \bar{C}(1+\tilde{c}_t) + \bar{I}(1+\tilde{i}_t) + \bar{G}(1+\tilde{g}_t)$. Now subtract the steady state identity $\bar{Y} = \bar{C} + \bar{I} + \bar{G}$, divide by $\bar{Y}$ and rewrite $\frac{\bar{G}}{\bar{Y}}\tilde{g}_t = \frac{G_t - \bar{G}}{\bar{G}}\frac{\bar{G}}{\bar{Y}} = g_t$

Equation 4.31

First, rewrite Equation 4.31 as $Q_t\phi'\left(\frac{I_t}{K_t}\right) = 1$. Using Rule 1 (on Q_t)and Rule 3 (on $\phi'\left(\frac{I_t}{K_t}\right)$), obtain

$$Q(1+\tilde{q}_t)\phi'\left(\frac{I}{K}\right)\left[1+\phi''\left(\frac{I}{K}\right)\frac{I}{K}\frac{1}{\phi'\left(\frac{I}{K}\right)}(\tilde{i}_t - \tilde{k}_t)\right] = 1 \tag{C.1}$$

Divide by the steady-state values and use the fact that $\frac{I}{K} = \delta$ and $\phi'\left(\frac{I}{K}\right) = 1$ and obtain

$$(1+\tilde{q}_t)(1-\frac{1}{\eta}(\tilde{i}_t - \tilde{k}_t)) = 1 \tag{C.2}$$

By an application of Rule 2, obtain Equation 4.31.

Equation 4.32

First, rewrite Equation 4.32 as $\frac{K_{t+1}}{K_t} = (1-\delta) + \phi\left(\frac{I_t}{K_t}\right)$

Using Rule 2 and 3, obtain:

$$\frac{K}{K}\left(1+\tilde{k}_{t+1} - \tilde{k}_t\right) = 1 - \delta + \phi\left(\frac{I}{K}\right)\left[1 + \frac{\phi'(\frac{I}{K})\frac{I}{K}}{\phi(\frac{I}{K})}(\tilde{i}_t - \tilde{k}_t)\right] \tag{C.3}$$

Now, using the fact that the steady state investment - capital ratio $\frac{I}{K} = \delta$ and the assumptions on the capital adjustment costs, we obtain Equation 4.32.

Equation 4.33

Rewrite the equation that we want to log-linearize:

$$1 = R_t E_t\left\{\beta\frac{C_t^o}{C_{t+1}^o}\frac{P_t}{P_{1+1}}\right\}$$

By an application of the log-linearization method described above, we obtain: $1 \cong \bar{R}\beta\bar{\pi}(1+\tilde{r}_t + \tilde{c}_t^o - \tilde{c}_{t+1}^o - \tilde{\pi}_{t+1})$

Dividing by the steady state identity $1 = R\beta\bar{\pi}$, subtracting 1 and rearranging results in $\tilde{c}_t^o = E_t\{\tilde{c}_{t+1}\} + \pi_{t+1} - r_t$. Now multiply both sides of the equation by $\frac{\bar{C}^o}{\bar{C}}$, use the definitions of c_t and c_{t+1} and obtain Equation 4.33.

Equation 4.47

First, express variables in terms of their log-deviations (which are defined in the text):

$$G_t = g_t Y + G; \;\; T_t = t_t Y + T; \;\; B_t = P_{t-1}(b_t Y + \frac{B}{P}); \;\; B_{t+1} = P_t(b_{t+1} Y + \frac{B}{P})$$

Also, these log-linear approximation will be used:

$$R_t^{-1} = \frac{1}{1+\rho}(1 - \tilde{r}_t)$$

$$\frac{P_{t-1}}{P_t} = 1 - \pi_t$$

Plug these expressions into the government budget constraint (Equation 4.26):

$$P_t(t_t Y + T) + \frac{1 - \tilde{r}_t}{1+\rho} P_t(b_{t+1} Y + \frac{B}{P}) = P_{t-1}(b_t Y + \frac{B}{P}) + P_t(g_t Y + G)$$

Now divide by P_{t-1}, use the fact that the budget is balanced in the steady state ($T = G$), the government has zero debt ($B = 0$) and use Rule 2. Then we obtain $t_t + \frac{b_{t+1}}{1+\rho} = b_t + g_t$ which can be easily rewritten as Equation 4.47.

C.0.1 Steady state values of γ_c and γ_o

Parameter $\gamma^o = \frac{C^o}{C}$ is the proportion of the consumption of optimizing households on total consumption. The steady state values of consumption of rule-of-thumb households implies:

$$C^r = \frac{W\lambda N}{P} - \lambda T$$

This can be rewritten using the steady state relation $T = G$ (budget is balanced in the steady state) as

$$(1 - \gamma^o) = \lambda\left(\frac{WN}{PC} - \frac{G}{C}\right)$$

Using $\frac{WN}{PC} = \frac{1-\alpha}{(1+\mu_p)\gamma_c}$, we can express γ^o from the previous equation as

$$\gamma^o = 1 - \lambda\left(\frac{1-\alpha}{(1+\mu_p)\gamma_c} - \frac{\gamma_g}{\gamma_c}\right)$$

Appendix D

Dynare and EViews codes

D.1 Dynare solution of the model

```
var n, c, infl, k, b, g;
varexo e;

parameters alpha, beta, delta, eps, eta, gamma_c, gamma_c_tilde, gamma_g,
    gamma_o, lambda, lambda_p, mu_p, omega, phi_b, phi_g, phi_pi, psi, rho,
    rho_g, sigma_tilde, theta, theta_n, theta_t;

alpha = 0.415;
beta = 0.99;
rho = 1/beta-1;
delta = 0.025;
psi = 0.5;
eta = 2;
lambda = 0.4;
eps = 11;
theta = 0.8;
gamma_g = 0.21;
mu_p = eps/(eps-1)-1;
gamma_c = 1-gamma_g-alpha*delta/((rho+delta)*(1+mu_p));
gamma_o = 1-lambda*((1-alpha)/(1+mu_p)/gamma_c-gamma_g/gamma_c);
gamma_c_tilde = gamma_c + gamma_g;

phi_pi = 1.5;
```

```
rho_g = 0.9;
phi_g = 0.11;
phi_b = 0.24;


lambda_p = (1-beta*theta)*(1-theta)/theta;
omega = eta*(1-beta*(1-delta))*(1-gamma_c_tilde);
theta_n = lambda*(1-alpha)*(1+psi)/(gamma_c*(1+mu_p)-lambda*(1-alpha));
theta_t = lambda*(1+mu_p)/(gamma_c*(1+mu_p)-lambda*(1-alpha));
sigma_tilde = (gamma_c*(1+mu_p)-lambda*(1-alpha))/(gamma_o*gamma_c*
    (1-lambda)*(1+mu_p));

model(linear) ;

k=(1-delta+delta*alpha/(1-gamma_c_tilde))*k(-1)+
    delta*(1-alpha)/(1-gamma_c_tilde)*n(-1)-
    delta*gamma_c/(1-gamma_c_tilde)*c(-1)-delta/(1-gamma_c_tilde)*g(-1);

infl=beta*infl(+1)+lambda_p*c-alpha*lambda_p*k+(alpha+psi)*lambda_p*n;

(1-alpha)*n-gamma_c*c-(1-gamma_c_tilde-alpha)*k+
    (1-gamma_c_tilde)*eta*phi_pi*infl=(omega*(1+psi)+beta*(1-alpha))*n(+1)+
    (omega-beta*gamma_c)*c(+1)-(omega+beta*(1-gamma_c_tilde-alpha))*k(+1)+
    (1-gamma_c_tilde)*eta*infl(+1)+(1-beta*rho_g)*g;

b=(1+rho)*(1-phi_b)*b(-1)+(1+rho)*(1-phi_g)*g(-1);

g=rho_g*g(-1)+e;

c-theta_n*n+phi_pi/sigma_tilde*infl=c(+1)+1/sigma_tilde*infl(+1)-
    theta_n*n(+1)+theta_t*phi_b*(b(+1)-b)+theta*phi_g*(rho_g-1)*g;
end;

initval;
    n = 0;
    c = 0;
    infl = 0;
    k = 0;
```

```
    b = 0;
    g = 0;
end;

check;

shocks;
var e; stderr 0.05;
end;

steady;
check;

stoch_simul(nograph);
figure;
impulses;

phi_b = 0.19;
phi_g = 0.06;
steady;
check;
stoch_simul(nograph);
figure;
impulses;
```

D.2 EViews code for historical decomposition

```
' structural decomposition or ordering?
' 1: structural
' 2: ordering
open "fisvar.wf1"
scalar decomp = 2
!l = 0
' generate dummy variable
series dum = 0
dum(35) = 1
genr d1=@seas(1)
```

```
genr d2=@seas(2)
genr d3=@seas(3)
genr time = @trend+1
'=====  generate per capita real seasonally adjusted series =====
' GDP
series lgdp = log(gdp/deflator/pop*1000)
lgdp.tramoseats(save=sa)
' Government revenue
series lgrev = log(grev/deflator/pop*1000)
lgrev.tramoseats(save=sa)
' Government expenditures
series lgexp = log(gexp/deflator/pop*1000)
lgexp.tramoseats(save=sa)
' Government debt
series lgdebt = log(gdebt/deflator/pop*1000)
' 4 VAR
matrix(4,4) M
matrix(4,4) N
if decomp == 1 then
M.fill(b=r) 1, 0, 0, 0, NA, 1, NA, 0, 0, -1.3, 1, 0, 0, 0, 0, 1
N.fill(b=r) NA, 0, 0, 0, 0, NA, 0, 0, NA, 0, NA, 0, NA, NA, NA, NA
endif
if decomp == 2 then
M.fill(b=r) 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1
N.fill(b=r) NA, 0, 0, 0, 0, NA, 0, 0, NA, NA, NA, 0, NA, NA, NA, NA
endif
'============ var: exp, gdp, rev, debt =================
pagestruct(start=1998:1, end=2010:4)
time = @trend+1
group gvar5 lgexp_sa lgdp_sa lgrev_sa lgdebt
var vardebt.ls 1 2 gvar5 @ c dum d1 d2 d3 time
vardebt.svar(rtype=patsr,namea=M,nameb=N)
' save matrices from structural factorization: Au = Be
matrix mata = vardebt.@svaramat
matrix matb = vardebt.@svarbmat
' save residuals into matrix merr
vardebt.makeresids r1 r2 r3 r4
group err r1 r2 r3 r4
```

```
' merr: matrix with structural errors
stomna(err, merr)
'================ structural errors ====================
vector(4) aux ' auxiliary vector
' matrix with structural errors: mserr
matrix(@obs(time),4) mserr
for !j = 1 to @obs(time)
aux =@transpose(@rowextract(merr,!j))
aux =  @inverse(matb)*mata*aux
rowplace(mserr,@transpose(aux),!j)
next
' matrix with structural government errors only
matrix(@obs(time),4) mgovshock
colplace(mgovshock,@columnextract(mserr,2),2)
' matrix with reduced shocks only
for !j = 1 to @obs(time)
aux=@transpose(@rowextract(mgovshock,!j))
aux =  @inverse(mata)*matb*aux
rowplace(mgovshock,@transpose(aux),!j)
next
'===============  historical decomposition ===============
vardebt.makemodel(debtmod)
series b1 = lgexp_sa
series b2 = lgdp_sa
series b3 = lgrev_sa
series b4 = lgdebt
for !j = 3+!l to @obs(time)
debtmod.solve
lgexp_sa(!j) = lgexp_sa_0(!j)+mgovshock(!j,1)
lgdp_sa(!j) = lgdp_sa_0(!j)+mgovshock(!j,2)
lgrev_sa(!j) = lgrev_sa_0(!j)+mgovshock(!j,3)
lgdebt(!j) = lgdebt_0(!j)+mgovshock(!j,4)
next
'================  Fiscal rule - Regression ====================
series exo_debt = b4-lgdebt
series exo_exp = b1-lgexp_sa
series exo_rev = b3-lgrev_sa
equation fisrule.ls exo_rev exo_exp exo_debt
```

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