Essays on Fiscal Policy: Trade Balance Deficits, Private Debt Deleveraging, and Heterogeneous Agents

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Contents

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1. Introduction

Over the last decades, a number of factors have led to an increased importance of employing fiscal policy measures in times of economic crisis. First of all, the foundation of the Monetary Union in Europe prevented a country-specific stabilizing role of monetary policy. While the determination of monetary policy in a currency union may help to provide the basis for stable economic conditions and could even play an economy stabilizing role in case of union-wide shocks, the monetary authority – most likely – cannot involve in dampening the effects of idiosyncratic shocks affecting single countries. This is a task which must be taken by the national governments. Second, the recent financial crisis resulted in nominal interest rates being almost at the zero lower bound. In this situation, regardless of monetary policy being exploit on a national or a union-wide level, the monetary authority does not have much room for policy interventions counteracting economic fluctuations. Finally, the recent economic developments stated a situation featuring the pressing need for economy stabilizing measures. Starting with the foundation of the monetary union and related economic adjustment processes, peaking in the financial crisis in 2008, and resulting in serious government solvency concerns, exploring fiscal policy measures being able to soften negative crisis impacts as well as investigating how to prevent future crises seems to be an urgent task.

In this thesis, I explore three issues of (optimal) fiscal policy related to recent economic developments. First, I refer to the case of a monetary union featuring intra-union trade balance imbalances. As became apparent during the recent years, being member of a monetary union may state serious problems related to trade and trade imbalances as nominal exchange rates are no longer able to adjust. Second, I turn to the event of a financial shock via a private debt deleveraging process as could be observed following the financial crisis since 2009 in the Euro area as well as in the US. And finally, I explore national distributive effects of these fiscal policy measures by regarding heterogeneous agents within a single country and raising the question of an appropriate social welfare measure.

The first essay, presented in Chapter 2, refers to the situation of countries forming a monetary union featuring intra-union trade balance imbalances. It is explored if and how a unilateral fiscal devaluation by means of a budget-neutral tax shift from direct to indirect taxation may decrease these imbalances. Methodologically, a two-country DSGE model is used where both countries belong to a monetary union. Within this framework, a devaluation is implemented as a decrease in the social security contributions and an increase in the value added tax.

In the first part of the chapter, different ways of implementing a fiscal devaluation and their respective effectiveness in eliminating trade balance deficits are examined. Regarding the revenue generating side, the effects of increasing the value added tax on tradables is compared to the effects of an increase in the tax on non-tradables. It is shown that increasing the tax on tradables is a more effective measure in raising the trade balance – a result which is at odds with propositions frequently found in literature to abolish reduced rates of VAT. Regarding the social security contributions, a decrease in the employers' share versus the employees' share is investigated and it is shown that the common view of assuming a decrease in the employers' share to be more effective does not hold to be true. In the second part of the chapter, I use these insights to simulate a fiscal devaluation implemented in Euro area countries featuring trade balance deficits in 2015 by using a more elaborate New-Keynesian 2-country model and find that a fiscal devaluation may lead to a substantial trade balance improvement if conducted as an increase in the standard rate of value added tax and a decrease in the employees' share of social security contributions.

Chapter 3 refers to the occurrence of a financial crisis and the role of fiscal policy in this context. A closed-economy DSGE model is used to simulate a private debt deleveraging shock in a situation where monetary policy is constrained by the zero lower bound. In a first step, it is shown that monetary policy being constrained by the zero lower bound implies huge welfare losses. Building on this insight, the possibility of fiscal policy taking over the economy-stabilizing role is explored by investigating fiscal measures implemented to counteract the negative deleveraging effects. And here, the essay differs methodologically from the first essay. Constrained-optimal policy reactions to a deleveraging shock are investigated while in the first essay the policy reaction consists in an exogenously given one-time tax adjustment. In the second essay, in contrast, the Ramsey-optimal policy reaction is computed, meaning a Ramsey planner maximizes economy-wide welfare but is subject to the private sector's behavior. Consequently, on the one hand, fiscal measures are no longer exogenously given but set constrained-optimal, and, on the other hand, fiscal instruments may be adjusted in each period instead of consisting in a one-time shift. Furthermore, while the Ramsey-optimal policy regarded in this chapter is defined to maximize economy-wide welfare, the devaluation scenario regarded in the first essay does not necessarily imply a welfare gain but is set to reduce trade balance deficits.

The results obtained in the second essay indicate that applying a constrained-optimal fiscal policy in a period of zero nominal interest rates may be highly effective by eliminating roughly one quarter of the total welfare loss of monetary policy being constrained by the zero lower bound. Interestingly, following the optimal fiscal policy implies a prolonged stay at the zero lower bound. Moreover, the essay explores the effectiveness of different fiscal instruments and it is found that the relative effectiveness of consumption versus wage taxes depends on the presence of government spending as well as on the specific monetary policy conducted. Furthermore, welfare gains of having government spending as an additional instrument are small compared to the total welfare gains of applying a Ramsey-optimal instead of an exogenous policy. Finally, it is shown that if fiscal policy is set optimally, conducting a simple inflation-targeting policy instead of an optimal monetary policy need not necessarily imply welfare losses.

Chapter 4 focuses on the agent-specific effects of optimal fiscal policy. While methodologically similar to Chapter 3, the distributive effects of constrained-optimal fiscal policy measures are central to the essay. The essay builds on a closed-economy DSGE model populated by two types of households: patient and impatient households. Within this framework, a financial shock is simulated via an interest spread shock. As in Chapter 3, Ramsey-optimal fiscal policy reactions to this spread shock are computed. While in the main part of the paper the Ramsey planner is modeled in a utilitarian fashion by maximizing economy-wide welfare defined as the sum of individual utilities, this does not coincide with maximizing the individual welfare of a patient or an impatient household. Consequently, the results are compared to the case of a Ramsey planner maximizing a social welfare function in the spirit of Rawls where the weight the planner sets on a group of agents increases with a decreasing utility level of the respective group.

The analysis is twofold: For one thing, the role of taxing different sources of income in mitigating the spread shock implied welfare losses is investigated. Here, two different kinds of income taxes – namely wage taxes and interest taxes – are regarded and their relative effectiveness as well as the gain from being able to levy different tax rates on the two different sources of income are analyzed. It is found that, first, taxing interest income is a more effective measure in reducing the welfare losses of an interest spread shock than using wage taxes. And second, applying only one general income tax instead of using different rates for both kinds of income implies huge welfare losses. For another thing, distributional issues are investigated. As a central point, it is found that maximizing economy-wide welfare may involve enlarging the disparity between agents if using a utilitarian definition of a social welfare function. This result depends on the tax base used as well as on the relation between the degrees of price and wage rigidity. In case of using wage taxes as an instrument, a larger degree of wage stickiness than of price stickiness involves decreasing the disparity between groups while prices being sufficiently more sticky than wages means that conducting a Ramsey-optimal policy enlarges the wedge between savers and borrowers. Using a social welfare function in the spirit of Rawls – meaning the weight the planner sets on the utility of one of the two groups of agents adjusts endogenously and is decreasing in the utility level of the respective group – can completely offset the disparity between groups but implies a significant decrease in the savers' welfare as well as sizable output fluctuations.

To summarize, this thesis shows that conducting a purposefully set fiscal policy in times of economic imbalances or in the aftermath of economic shocks is an important issue and, at the same time, may be quite effective in reducing imbalances and mitigating welfare losses. On an agent-specific level, however, distributive effects of these policy measures should receive attention.

2. Fiscal Devaluation in the Euro Area: The Role of Rigidities, Non-Tradables, and Social Security Contributions[3]

2.1 Introduction

The lasting divergence in intra-EU trade balances between member states of the European Union gives rise to a continuous policy debate as to whether European governments should aim at reducing their external deficits. Jaumotte and Sodsriwiboon (2010) and Eichengreen (2010) argue that external deficits could reflect domestic distortions (as e.g. asset price bubbles due to transitory booms or a too optimistic view of future growth rates). In this case, the accumulated high levels of foreign debt could not be paid back through high productivity growth but could resolve in serious liquidity problems. Related to this, high deficits may pose a potential danger as the occurrence of a sudden stop of foreign financial inflows would force the deficit countries to implement strong austerity measures. Furthermore, external imbalances could reflect competitiveness problems which would require a painful period of diminished growth to allow a gradual adjustment. Jaumotte and Sodsriwiboon (2010) find that the deficits in southern European Union countries are too large to be explained by fundamentals and that these deficits tend to remain high in the medium-run. Holinski et al. (2010) and Holinski et al. (2012) confirm this view by stressing that the increasing imbalances in the Euro zone could be seen as an indicator of economic divergence and Arghyrou and Chortareas (2006) find the real exchange rate to be a prominent determinant of current account imbalances indicating that underlying the external imbalances could be competitiveness losses. Based on these insights of recent studies, policy actions seem to be in place at

[3]A slightly different version of the chapter has been published in the "Journal of International Money and Finance" Vol. 87 (2018), https://doi.org/10.1016/j.jimonfin.2018.05.004

least for some Euro zone countries to reduce their substantial external deficits.

This paper builds on the huge strand of literature examining the possible trade-balance-improving effects of a fiscal devaluation, meaning a budget-neutral tax shift from direct to indirect taxation. In a first step, the study focuses on a stylized monetary union model with two symmetric countries. The analysis differs from existing devaluation literature in three ways: First, the role of the employees' share in social security contributions (SSC) is explored and compared to the effects of a decrease in the employers' share. Second, the model does not only include non-tradable goods but allows for a different taxation of tradable and non-tradable consumption goods and explores their effects on the trade balance. Third, the paper explicitly explores the role of nominal rigidities for the effectiveness of a fiscal devaluation in raising the trade balance. In a second step, these insights are used to simulate a fiscal devaluation in a more elaborate 2-country model calibrated to Euro Area 2015 data.

There is a large body of studies exploring the effects of a fiscal devaluation on trade-balance- or current-account-deficits. While almost all studies[4] find a positive short-run effect on the trade balance or the current account, the long-run effect is more controversial. The European Commission (2011a) uses a 3-country QUEST model to investigate the effects of a fiscal devaluation shifting revenues equal to 1% of GDP from employers' SSC to VAT and finds that the trade balance improves, but only in the short-run. Engler et al. (2014) perform the same simulation in a 2-country New-Keynesian model where the countries are calibrated to represent central-northern and southern European countries and find a short-run improvement in the trade balance of 0.2 percentage points of GDP. Gomes et al. (2016) simulate the tax shift using the EAGLE model and find that it results in an improvement in the Spanish trade balance by 0.5 percentage points of GDP after two years while there is no long-run effect. Studies finding a long-run effect contain e.g. the European Commission (2014) who use the QUEST model for Spain to simulate a fiscal devaluation implemented as a reduction in income taxation and an increase in the VAT and obtain a long-run improvement in the trade balance by 0.5 percentage points of GDP. Furthermore, the results of the Bank of Portugal (2011) indicate a positive long-run effect on the Portugese trade balance by using the PESSOA model.

This paper is related to various issues of devaluation literature: First, it is

[4]Studies finding a small worsening of the trade balance are the European Commission (2008) simulating a 4-regions QUEST model and the CPB et al. (2013) by using the NiGEM-model for different countries.

common sentiment that the effectiveness of a devaluation requires some degree of rigidity in nominal wages (e.g. International Monetary Fund (2011), Calmfors (1998), De Mooij and Keen (2012)). It is typically argued that flexible wages would impede a devaluation by offsetting the imposed competitiveness-enhancing effect as workers would aim at increasing their nominal wages both due to the reduction in the employers' SSC and due to the increase in the VAT. The reduction in the employers' share reduces labor costs and, consequently, offers a good bargaining position for workers while the increase in the VAT increases consumer prices and, hence, reduces real wages such that in both cases workers would aim at being compensated by higher nominal wages. This could result in a real producer wage being the same as before the tax-shift which would render the devaluation ineffective in affecting real variables. There are only very few studies explicitly exploring the effect of the degree of nominal rigidity on the effectiveness of a devaluation: Engler et al. (2014) simulate a fiscal devaluation in a New-Keynesian 2-country model and find that the trade balance effect decreases with decreasing wage rigidity. The CPB et al. (2013) explore the sensitivity of trade balance effects of a fiscal devaluation to the degree of wage rigidity and find that the effect varies over time as well as between models. Both focus, however, on the employers' share in SSC and do not regard the effect of price rigidity.

Second, related to the assumption of the effectiveness of a fiscal devaluation requiring some degree of rigidity, literature frequently assumes a decrease in the employers' share in SSC to be a more effective measure in raising the trade balance than a reduction in the employees' share (see e.g. European Commission (2006)). As far as I know, there is no paper explicitly exploring the differences between the effects of reducing the employers' share in SSC versus the employees' share. A paper at least regarding a decrease in the employees' share is Langot et al. (2012) who use a small open economy model with labor market search frictions and find that a reduction in the employees' share in SSC mainly induces the same effects as a decrease in the employers' share.

Finally, there is a small strand of literature exploring the practical implementation of the VAT increase, meaning which rate to increase. The VAT, after all, is not only the VAT rate but consists of at least two or three different rates applied to different categories of goods and services. In the European Union, the application of value added taxes is restricted by the VAT directive given by the council of the European Union defining that each country may raise a standard rate of VAT as well as one or two reduced rates. In the Euro zone, currently all countries make use of at least one reduced rate.[5] Concerning a fiscal devaluation, this should not matter at all if the reduced rates were distributed equally between sectors. This, however, is not the case. In fact, tradable goods are taxed more heavily than non-tradable goods as the majority of categories on which reduced rates may be applied can be classified as non-tradables.[6] Consequently, if considering an increase in the VAT, it should be contemplated which rate or rates of VAT should be increased.

There is a quite small range of literature discussing briefly the different rates of VAT in the light of a fiscal devaluation. Most of them propose to rise or eliminate reduced rates of VAT as e.g. Franco (2013), International Monetary Fund (2011), and International Monetary Fund (2012). De Mooij and Keen (2012) propose that a higher standard rate may limit the positive trade balance effects of a devaluation depending on the labor share of tradables and non-tradables. On the contrary, Koske (2013) argues that as reduced rates apply mostly to non-tradable goods, an abolition of reduced rates may lead to a substitution of tradables for non-tradables which would limit the effectiveness of a fiscal devaluation. None of these studies, however, theoretically explores the effect of non-tradables or, as a consequence thereof, the importance of considering different VAT rates. To the best of my knowledge, there is only one paper differentiating between VAT rates on tradables and non-tradables: Petroulakis (2017) explores the role of trade costs and the VAT on tradables in a small open economy model calibrated to Greece if the country is hit by a negative debt shock and finds that hikes in the VAT rate on tradables limit the tendency for an increase in exports. While this is the paper most closely related to the current paper insofar as it explicitly distinguishes between a VAT rate applied on tradables and a VAT rate applied on non-tradables, the current paper differs in several aspects. First, Petroulakis (2017) does not regard a fiscal devaluation but limits his exploration on the export-effects of increases in VAT rates while he completely abstracts from wage taxes or social security contributions. Second, he models a small open economy thus assuming that the home country is to small to affect the rest of the world. The current paper, on the contrary, explicitly allows for and analyzes spill-over effects to the foreign country. Furthermore, Petroulakis (2017) focuses on the case of Greece while the current

[5]See European Commission (2017): VAT rates applied in the member states of the European Union.

[6]Using the calculations by IAS et al. (2013b) of average VAT rates for each COICOP category and following the definition of goods and services as tradable or non-tradable of Piton (2017).

paper regards the overall intra-EU dynamics. Finally, while Petroulakis (2017) does regard the role of nominal rigidities, he explores both effects (an increase in the VAT rate and a reduction in nominal rigidity) separately. The current paper, in contrast, examines the influence of nominal rigidities on VAT increases and SSC decreases, respectively.

This paper contrasts with previous devaluation literature in three ways: First, a decrease in the employees' share of SSC is found to be a more effective measure in raising the trade balance than a reduction in the employers' share due to different effects on the tax base. Second, despite the proposition to abolish reduced rates of VAT often found in literature, the results indicate that an increase in the standard rate of VAT implies a larger trade balance improvement than an abolition of reduced rates as the latter implies a substitution of tradables for non-tradables. And third, it is found that a fiscal devaluation can have substantial effects on the trade balance even if wages and prices are fully flexible. The simulation of a devaluation implemented in EU-member states featuring trade balance deficits gives incidence that such a tax shift may lead to a substantial trade balance improvement of the respective countries if conducted as a reduction in the employees' share of SSC and an increase in the standard rate of VAT. A reduction in the employers' share in SSC financed by an abolition of reduced rates, on the contrary, is all but effectless in raising the trade balance.

The rest of the paper is organized as follows: The next section presents a simple model and explores the basic mechanisms of a fiscal devaluation. In Section 2.3, this simple model is extended and used to trace the different effects of a decrease in the employers' versus the employees' share in SSC, the effects of an increase in non-tradable VAT versus tradable VAT, and the influence of nominal rigidities. Section 2.4 presents a more elaborated model for the Euro area calibrated to 2015 data and includes the simulation of two different fiscal devaluation scenarios. Section 2.5 contains a robustness analysis while Section 2.6 concludes.

2.2 A Simple Model

2.2.1 The Model

In this section, I consider a very simple two-country model to trace the effects of a fiscal devaluation and explore the different mechanisms of various policy measures. Both countries are symmetric and belong to a monetary union whose population size is normalized to one. In each country, households derive utility from consumption and leisure, supply homogenous labor, and participate in complete asset markets. Governments in each country levy social security contributions for employers' and employees' and a value added tax. The associated revenues are rebated to the economy via lump-sum transfers. In the following, only the home economy is described in detail since the equations for the foreign country can be derived analogously.[7]

Households

In the home country (H), there exists a continuum of identical households of size n, each seeking to maximize its intertemporal utility which is given by

$$U = \sum_{t=0}^{\infty} \sum_{s^t} \pi(s^t) \beta^t \left\{ \frac{C_t^{1-\rho}}{1-\rho} - \frac{L_t^{1+\eta}}{1+\eta} \right\}, \tag{2.1}$$

where $\pi(s^t)$ is the probability of the event history s^t. C_t denotes the per capita consumption bundle and L_t is the quantity of labor supplied by an individual household. $\eta > 0$ denotes the inverse of the Frisch elasticity of labor supply and $\rho > 0$ holds. Each household has access to a complete set of Arrow-Debreu securities such that the per capita budget constraint is given by

$$\begin{aligned} &(1+\tau_t^C)P_t C_t + \sum_{s^{t+1}} Q(s^t, s_{t+1}) B(s^t, s_{t+1}) \\ \leq &(1-\tau_t^{EE}) W_t L_t + B(s^{t-1}, s_t) + T_t \end{aligned} \tag{2.2}$$

with $Q(s^t, s_{t+1})$ the price in state s^t of an Arrow-Debreu security $B(s^t, s_{t+1})$ that pays one unit of the numeraire in state s^{t+1}. τ_t^{EE} denotes social security contributions paid by employees (denoted EESSC in the following) and τ_t^c is a consumption tax. T_t denotes per capita lump-sum transfers and W_t is nominal wage. Maximizing (2.1) subject to (2.2) delivers the following first order

[7] An overview about the equilibrium conditions can be found in Appendix A.

conditions:

$$C_t^{-\rho} = \lambda_t(1+\tau_t^c)P_t$$

$$\lambda_t Q(s^t, s_{t+1}) = \beta\pi(s^{t+1})\lambda_{t+1}$$

and the labor supply equation:

$$L_t^{\eta} = \frac{1}{(1+\tau_t^C)P_t} C_t^{-\rho} W_t(1-\tau_t^{EE}).$$

Countries are assumed to be ex-ante symmetric such that the assumption of complete asset markets implies $\lambda_t = \lambda_t^*$ which delivers the following risk-sharing condition:

$$\left(\frac{C_t}{C_t^*}\right)^{-\rho} = \frac{P_t}{P_t^*}\frac{1+\tau_t^c}{1+\tau_t^{c*}}.$$

Defining

$$RS_t = \frac{P_t^*}{P_t}$$

this can be written as

$$RS_t = \left(\frac{C_t^*}{C_t}\right)^{-\rho} \frac{(1+\tau_t^C)}{(1+\tau_t^{C*})}.$$

Total consumption consists of consumption of home-produced and foreign-produced goods, which are combined according to

$$C_t = \left[\nu^{\frac{1}{\phi}} C_{Ht}^{\frac{\phi-1}{\phi}} + (1-\nu)^{\frac{1}{\phi}} C_{Ft}^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}},$$

where $\phi > 0$ denotes the elasticity of substitution between home and foreign goods and ν gives the home bias with $0 \leq \nu \leq 1$. The corresponding expenditure minimization problem is

$$P_t C_t \equiv \min\left(P_{Ht}C_{Ht} + P_{Ft}C_{Ft}\right),$$

where the law of one price is assumed to hold for goods produced in both countries. Minimization delivers the demand relationships for home- and foreign produced goods

$$C_{Ht} = \nu\left(\frac{P_{Ht}}{P_t}\right)^{-\phi} C_t$$

$$C_{Ft} = (1-\nu)\left(\frac{P_{Ft}}{P_t}\right)^{-\phi} C_t$$

as well as the home price index

$$P_t = \left[\nu P_{Ht}^{1-\phi} + (1-\nu) P_{Ft}^{1-\phi}\right]^{\frac{1}{1-\phi}}.$$

Firms

There is a continuum of identical firms indexed by j whose size is normalized to one operating under perfect competition and producing output using labor supplied by households subject to the production function

$$Y_t(j) = L_t(j).$$

Each firm chooses its output and labor demand to maximize its profits which gives

$$P_{Ht} = W_t(1 + \tau_t^{ER}),$$

where τ_t^{ER} denotes the employers' share in SSC (denoted ERSSC).

Governments

Governments raise social security contributions paid by employers and employees and a value added tax on consumption goods. I abstract from government spending to hold the model simple and instead assume that the tax revenues are redistributed to households via lump-sum transfers such that the government budget simply arises as

$$(\tau_t^{ER} + \tau_t^{EE}) W_t L_t + \tau_t^C P_t C_t = T_t.$$

Market clearing

Market clearing requires

$$Y_t = C_{Ht} + \frac{1-n}{n} C_{Ht}^*$$

and

$$Y_t^* = C_{Ft}^* + \frac{n}{1-n} C_{Ft}.$$

Parameter choice

I assume that both countries are symmetric and of equal size ($n = 0.5$). The chosen parameter values can be seen in Table 2.1. Furthermore, I set the initial tax rates to match the GDP-weighted Euro area average of 2015 which gives a rate of SCC for employers of 26% ($\tau_0^{ER} = 0.26$) and for employees of 14% ($\tau_0^{EE} = 0.14$) as well as a VAT rate of 21% ($\tau_0^C = 0.21$).

n	0.5	Size of home country
η	2	Inverse of labor supply elasticity
ρ	2	Inverse of intertemporal elasticity of substitution
ν	0.5	Home bias in consumption
ϕ	1.5	Elasticity of substitution between home and foreign goods
β	0.99	Discount factor

Table 2.1: Parameter values for the simple model

2.2.2 Tracing the Mechanisms of a Fiscal Devaluation

In a first step, I trace the mechanisms of a fiscal devaluation by considering a devaluation consisting of a decrease in the employers' share of SSC and an increase in the VAT rate as this is the scenario mostly found in literature. I consider a devaluation in the home country while the foreign fiscal policy is assumed to be constant. As is common, I calibrate the devaluation to induce a revenue-neutral change from direct to indirect taxes shifting revenues in the amount of 1% of initial steady-state GDP. As regards the revenue generating side, this means that the VAT rate has to be increased by one percentage point. ERSSC, on the other hand, must be decreased by 1.26 percentage points. Since the simple model described above does not feature any rigidities, all real variables adjust instantaneously. Table 2.2 gives the reaction of main variables to three different policy measures: the first column shows the effects of the decrease in the ERSSC, the second column gives the effects of the increase in the VAT, and the last column shows the combined devaluation effect meaning a shift from ERSSC to VAT.

Starting with the decrease in the ERSSC, this induces marginal labor costs to decline such that prices of home produced goods drop relative to foreign prices as can be seen in the first column. This raises the demand of home-produced relative to foreign goods such that home production increases while foreign production declines. This, in turn, causes labor demand to rise in the home country and to fall abroad. Ultimately, the trade-balance-to-GDP-ratio raises due to the shift from foreign-produced goods to home-produced goods.

As regards the increase in the VAT rate, this induces the home after-tax price to incline. The second column shows that, consequently, consumption declines. Furthermore, labor supply decreases as a consequence of the substitution of

	Decrease in ERSSC	Increase in VAT	Devaluation
		Home country	
Y	0.3145	-0.1027	0.2115
C	0.1257	-0.3083	-0.1829
C_H	0.3145	-0.3083	0.0053
C_F	-0.0628	-0.3083	-0.3709
W	0.8833	0.00	0.8833
L	0.3145	-0.1027	0.2115
$Loss$	-0.0525	-0.2512	-0.3032
$\Delta\tau^{SSC}$	-1.26	0.00	-1.26
$\Delta\tau^{C}$	0.00	1.00	1.00
		Foreign country	
Y^*	-0.0628	-0.1027	-0.1655
C^*	0.1257	0.1028	0.2287
C_H^*	0.3145	0.1028	0.4177
C_F^*	-0.0628	0.1028	0.0399
W^*	0.1257	0.00	0.1257
L^*	-0.0628	-0.1027	-0.1655
$Loss^*$	0.1609	0.1605	0.3211
		International	
P_H	-0.1255	0.00	-0.1255
P_F	0.1257	0.00	0.1257
TB/Y	0.1881	0.2058	0.3935

Table 2.2: Fiscal devaluation in the simple model. For all variables percentage deviations from the initial steady state are given with the exception of the trade-balance-to-GDP ratio and the tax rates where the change is given in percentage points. Prices and wages are measured relative to the aggregate consumer price index. 'Loss' denotes the consumption-equivalent utility loss in percent of initial consumption.

consumption for leisure outweighing the negative income effect. Since the VAT rate is applied to home-produced goods as well as on imports, both measures decrease to the same extent – due to the absence of any degree of home bias in both countries – meaning that relative prices remain constant. The risk-sharing condition implies a spill-over effect on the foreign country such that foreign consumption increases due to the fact that the foreign VAT rate stays constant. This increase is distributed equally between home- and foreign-produced goods since relative prices stay constant in each country. Furthermore, the decrease in home imports outweighs the increase in foreign consumption of foreign-produced goods such that foreign output decreases. Overall, the decrease in home imports as well as the increase in foreign imports induces the trade-balance-to-GDP-ratio to incline by about 0.21 percentage points.

If both measures are applied jointly – meaning a revenue-neutral fiscal devaluation is implemented – home output as well as the trade-balance-to-GDP-ratio increase as can be seen in the last column. Households in the home country, however, experience a utility loss in the amount of about 0.30% of initial steady-state consumption while the foreign country gains in the amount of 0.32%.

It should be noted that the result of a tax shift from direct to indirect taxation influencing real variables even in the long-run stems from the mechanisms of open economies. In a closed economy, nominal wages and prices would adjust in consequence of a tax shift such that real wages would remain constant ruling out any long-run effects on real variables. Even in a small open economy where foreign variables are fixed from the perspective of the home country, this insight does not hold to be true: while the price of home-produced goods may adjust, prices of foreign-produced goods are constant such that the real-exchange rate changes in response to a tax shift (at least under the assumption of the law of one price). Since imports as well as exports depend on the real exchange rate, this affects real variables even in the long-run. In the simple two-country model considered in the current paper, home as well as foreign prices may adjust. Since the law of one price is assumed to hold for pre-tax prices, however, there is no possibility of a perfect adjustment of (after-tax) consumer prices in both countries to hold real after-tax wages constant. Consequently, imports or export or both must adjust such inducing long-run real effects.

As the results show that a devaluation may quite effectively increase the trade balance, the next sections explore which factors determine this result.

2.3 Determinants of a Fiscal Devaluation

2.3.1 The Role of the Employees' Share in SSC

To explore the role of the group of tax payers which is subject to the decrease in SSC, the results obtained above are compared to the case of decreasing the employees' share in SSC instead of the employers' share. Again, I compute the decrease to reduce government revenues in the amount of 1% of the initial steady-state GDP. This means that the EESSC rate permanently decreases by 1.28 percentage points. Table 2.3 compares the effects of this measure with the case described above of decreasing the employers' share in SSC. Surprisingly, while a decrease in the ERSSC intuitively seems to be the more direct instrument to reduce marginal labor costs (which, ultimately, raises the trade balance by boosting exports), the results indicate that home marginal labor costs (measured as $W_t(1+\tau_t^{ER})$) decrease more in case of a reduction in the EESSC. The underlying mechanism is the following: By regarding the labor supply equation

$$L_t^{\eta} = C_t^{-\rho} \frac{W_t}{P_t} \frac{1-\tau_t^{EE}}{1+\tau_t^{c}}$$

it can be seen that a reduction in the employees' share of SSC means that labor or consumption must rise or real wages decrease or both. Table 2.3 shows that all three effects arise. In contrast, the price setting equation

$$P_{Ht} = W_t(1+\tau_t^{ER})$$

shows that a decrease in the ERSSC implies that wages have to increase or prices to decrease or both. Again, it can be seen that both holds true. While the decrease in prices leads to an increase in labor and consumption, the wage increase limits the effect of the tax decrease on marginal labor costs. Due to these diverging wage responses, marginal labor costs decrease more in the EESSC-scenario than in case of a ERSSC-reduction. Going one step further, this means that the price of home-produced goods decreases more in the EESSC-case such that the consumption shift from foreign-produced to home-produced goods is more pronounced in the EESSC-case. Additionally, total consumption increases more by decreasing the EESSC as a consequence of a stronger income effect evoked by the larger increase in net wages. Both effects ultimately imply a stronger response of all real variables and, as a consequence thereof, a larger increase in the home trade-balance-to-GDP-ratio in the EESSC-case.

While these simulation scenarios illustrate the different mechanisms of the

	Decrease in EESSC	Decrease in ERSSC	
	1% of GDP	1% of GDP	1.4% of GDP
		Home country	
Y	0.4555	0.3145	0.4555
C	0.1821	0.1257	0.1821
C_H	0.4555	0.3145	0.4555
C_F	-0.0909	-0.0628	-0.0909
W	-0.1816	0.8833	1.2809
$W(1-\tau^{EE})$	1.2809	0.8833	1.2809
$W(1+\tau^{ER})$	-0.1816	-0.1255	-0.1816
L	0.4555	0.3145	0.4555
$Loss$	-0.0766	-0.0525	-0.0766
$\Delta\tau^{SSC}$	-1.2600	-1.2600	-1.8200
		Foreign country	
Y^*	-0.0909	-0.0628	-0.0909
C^*	0.1821	0.1257	0.1821
C_H^*	0.4555	0.3145	0.4555
C_F^*	-0.0909	-0.0628	-0.0909
W^*	0.1821	0.1257	0.1821
L^*	-0.0909	-0.0628	-0.0909
$Loss^*$	0.2328	0.1609	0.2328
		International	
P_H	-0.1816	-0.1255	-0.1816
P_F	0.1821	0.1257	0.1821
TB/Y	0.2720	0.1881	0.2720

Table 2.3: Fiscal devaluation in the simple model: EESSC versus ERSSC. For all variables percentage deviations from the initial steady state are given with the exception of the trade-balance-to-GDP ratio and the tax rates where the change is given in percentage points.

two possible SSC decreases, it should be regarded that equivalence between these two scenarios could be obtained by considering a larger decrease in the ERSSC rate as can be seen in the last column of Table 2.3. In this case, the ERSSC rate has to be decreased by 1.82 percentage points which means government revenues are decreased by 1.4% of GDP. This way, the effects on real wages differ while the effects on net wages received by workers as well as on labor costs paid by employers are the same in both scenarios. Consequently, both measures have the same effects on prices and, hence, real variables.

These results show that the assumption of a decrease in the ERSSC being more effective than a decline in the EESSC cannot be confirmed. On the contrary, a decrease in the EESSC is found to be more effective in raising the trade balance and affecting real variables than a decrease in the ERSSC. This result differs with the assumption frequently found in literature of the distribution between the employers' and the employees' share in SSC being irrelevant for the real allocation (invariance of incidence proposition). The reason is that the current paper implicitly regards the financing side of the cut in the SSC rates: The decrease in the ERSSC is computed to give rise to the same reduction in tax revenues as the decrease in the EESSC. The decrease in the ERSSC induces wages to decline while the decrease in the EESSC increases wages. Both measures have different effects on the tax base. As a result, the EESSC can be lowered to a larger extent than the ERSSC. This can be seen as a short-cut to modeling a government having no access to lump-sum taxes but being forced to finance the SSC-cut by increasing another distortionary tax measure. More precisely, if a government may raise lump-sum taxes or issue bonds unboundedly under Ricardian equivalence to obtain the additional revenues to compensate the cut in SSC, the invariance of incidence proposition is retrieved. A fiscal devaluation, however, is defined as a revenue-neutral tax shift meaning the effect of the SSC-cut on the tax base matters since it determines the extent to which VAT rates must be increased. The results show that in the case of a revenue-neutral tax shift, the choice of the agent being subject to the SSC-cut (employers or employees) does make quite a difference in affecting real variables.

2.3.2 The Role of Non-Tradables

After considering the revenue loss generating side, in this section, I explore two possibilities of increasing the VAT to offset these losses. The VAT, after all, is not levied equally on tradables and non-tradables but is composed of a standard and a reduced rate which are applied to different groups of goods and services such that, in fact, tradable goods are taxed more heavily than non-tradable goods. For this reason, I allow for a different taxation of tradables and non-tradables. Consequently, the simple model is extended to include a non-tradable sector.

Households

Utility is now given by

$$U = \sum_{t=0}^{\infty} \sum_{s^t} \pi(s^t) \beta^t \left\{ \frac{C_t^{1-\rho}}{1-\rho} - \sum_j \frac{(L_t^j)^{1+\eta}}{1+\eta} \right\},$$

with $j = \{H, N\}$. Households supply labor to both sectors, tradable and non-tradable, and receive wages paid in the respective sector such that the labor supply equations are now given by

$$L_{Ht}^{\eta} = \frac{1}{(1+\tau_t^C)P_t} C_t^{-\rho} W_{Ht}(1-\tau_t^{EE})$$

$$L_{Nt}^{\eta} = \frac{1}{(1+\tau_t^C)P_t} C_t^{-\rho} W_{Nt}(1-\tau_t^{EE}),$$

where the consumption tax index τ_t^C is the composite of the VAT rates applied to tradables and to non-tradables. Furthermore, total consumption is now a composite of tradable and non-tradable consumption defined by the following CES aggregator:

$$C_t = \left[\omega^{\frac{1}{\epsilon}} C_{Tt}^{\frac{\epsilon-1}{\epsilon}} + (1-\omega)^{\frac{1}{\epsilon}} C_{Nt}^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}},$$

where the elasticity of substitution between tradable and non-tradable goods is set to be the same as between home and foreign tradable goods ($\epsilon = 1.5$) and the two sectors are assumed to be of equal size ($\omega = 0.5$). Since tradables and non-tradables are taxed differently, households incorporate the different taxation into their decision making by minimizing their after-tax consumption expenditures, which are defined by

$$(1+\tau_t^C)P_t C_t \equiv \min \left((1+\tau_t^{C_T}) P_{Tt} C_{Tt} + (1+\tau_t^{C_N}) P_{Nt} C_{Nt} \right).$$

Minimization yields the following demand relationships for tradable and non-tradable goods:

$$C_{Nt} = (1-\omega) \left(\frac{P_{Nt}(1+\tau_t^{C_N})}{P_t(1+\tau_t^C)} \right)^{-\epsilon} C_t$$

$$C_{Tt} = \omega \left(\frac{P_{Tt}(1+\tau_t^{C_T})}{P_t(1+\tau_t^C)} \right)^{-\epsilon} C_t$$

and the corresponding aggregate after-tax consumption price index is given by

$$(1+\tau_t^C)P_t = \left[\omega \left(\left(1+\tau^{C_T}\right) P_{Tt} \right)^{1-\epsilon} + (1-\omega) \left(\left(1+\tau_t^{C_N}\right) P_{Nt} \right)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}.$$

As before, consumption of tradables includes consumption of home-produced and foreign-produced tradable goods which are combined according to

$$C_{Tt} = \left[\nu^{\frac{1}{\phi}} C_{Ht}^{\frac{\phi-1}{\phi}} + (1-\nu)^{\frac{1}{\phi}} C_{Ft}^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}}.$$

Since the same VAT rate is levied on imports and on home-produced tradable goods, the VAT does not affect the consumption decision regarding home and foreign tradable goods such that the corresponding expenditure minimization problem is given by

$$P_{Tt}C_{Tt} \equiv \min P_{Ht}C_{Ht} + P_{Ft}C_{Ft},$$

where the law of one price is assumed to hold for tradable goods produced in both countries. Minimization delivers the demand relationships as well as the corresponding price index for tradable goods as

$$C_{Ht} = \nu \left(\frac{P_{Ht}}{P_{Tt}} \right)^{-\phi} C_{Tt}$$

$$C_{Ft} = (1-\nu) \left(\frac{P_{Ft}}{P_{Tt}} \right)^{-\phi} C_{Tt}$$

$$P_{Tt} = \left[\nu P_{Ht}^{1-\phi} + (1-\nu) P_{Ft}^{1-\phi} \right]^{\frac{1}{1-\phi}}.$$

Firms

The production side is extended by a non-tradable sector where firms in the two sectors produce goods subject to the production functions

$$Y_{Ht}(j) = L_{Ht}(j)$$

$$Y_{Nt}(j) = L_{Nt}(j)$$

which gives the following labor demand equations

$$P_{Ht} = W_{Ht}(1 + \tau^{ER})$$

$$P_{Nt} = W_{Nt}(1 + \tau^{ER}).$$

Finally, market clearing requires[8]

$$Y_{Ht} = C_{Ht} + \frac{1-n}{n} C^*_{Ht}$$

$$Y^*_{Ft} = C^*_{Ft} + \frac{n}{1-n} C_{Ft}$$

$$Y_{Nt} = C_{Nt}$$

$$Y^*_{Nt} = C^*_{Nt}.$$

Simulation

Using this extended version of the simple model, I simulate a permanent increase in the VAT on non-tradables and tradables, respectively, generating additional government revenues in the amount of 1% of initial steady-state GDP.[9] Table 2.4 gives the changes in home real variables and prices for both measures. Starting with the effects of an increase in the VAT on tradables given in the first column, the higher tax rate induces a substitution effect such that total consumption declines. The allocation of this consumption drop between home tradable, foreign tradable, and home non-tradable goods depends on the effect on prices. Here, the home after-tax price of tradables increases due to the higher tax rate which means that the relative price of non-tradables declines. Consequently, the home demand for home-produced and foreign-produced goods decreases while non-tradable consumption increases.[10] As a consequence, output of non-tradables increases somewhat while output of home-produced tradables decreases.

As regards the spill-over effects for the foreign country given in Table 2.5, the foreign price of home-produced goods decreases due to the decrease in wages while the foreign tax rate remains constant. Furthermore, the price of foreign tradable goods decreases due to diminished demand of home imports and, consequently, decreasing output and labor demand in the foreign tradable sector.

[8] An overview about the equilibrium conditions can be found in Appendix B.

[9] Starting from an initial VAT rate on both tradables and non-tradables in the amount of 21%.

[10] In this model, the effects on home and foreign tradable goods as well as on the respective prices are of equal size due to the assumption of no home bias.

	VAT on tradables	VAT on non-tradables
Y_H	-0.2551	0.0512
Y_N	0.1882	-0.5280
C	-0.3753	-0.1705
C_H	-0.9366	0.1878
C_F	-0.9366	0.1878
C_N	0.1882	-0.5280
W_H	-1.2548	-0.2386
W_N	-0.3753	-1.3905
P_H	-1.2548	-0.2386
P_F	-1.2548	-0.2386
P_N	-0.3753	-1.3905
$P_H(1+\tau^{C_H})$	0.3774	-0.2386
$P_F(1+\tau^{C_F})$	0.3774	-0.2386
$P_N(1+\tau^{C_N})$	-0.3753	0.2395
$Loss$	0.2999	-0.3643
$\Delta\tau^{C_T}$	2.0000	0.0000
$\Delta\tau^{C_N}$	0.0000	2.0000
TB/Y	0.3409	-0.0685
RS	-1.0866	-0.2727

Table 2.4: Effects of a fiscal devaluation in the simple model with non-tradables on the home country. For all variables percentage deviations from the initial steady state are given with the exception of the trade-balance-to-GDP ratio and the tax rates where the change is given in percentage points. Prices are measured relative to the aggregate after-tax consumer price index of the home country.

Overall, the real exchange rate decreases, which induces a positive wealth effect abroad such that total foreign consumption increases. Due to the rise in the relative price of non-tradables, the demand for non-tradables declines while the demand for tradable goods increases. As a consequence, the trade balance increases.

A quite different picture emerges if considering an increase in the VAT on non-tradables as can be seen in the second column of Tables 2.4 and 2.5. As before, this induces a negative wealth effect such that total home consumption decreases. Considering the allocation between tradable and non-tradable consumption, however, it becomes apparent that here consumption of tradable

	VAT on tradables	VAT on non-tradables
Y_F^*	-0.2551	0.0512
Y_N^*	-0.0851	0.0171
C^*	0.1704	-0.0341
C_H^*	0.4265	-0.0853
C_F^*	0.4265	-0.0853
C_N^*	-0.0851	0.0171
W_F^*	-0.1700	0.0342
W_N^*	0.1704	-0.0341
P_H^*	-0.1700	0.0342
P_F^*	-0.1700	0.0342
P_N^*	0.1704	-0.0341
$Loss^*$	-0.5514	-0.1113

Table 2.5: Effects of a fiscal devaluation in the simple model with non-tradables on the foreign country. For all variables percentage deviations from the initial steady state are given. Prices are measured relative to the aggregate consumer price index of the foreign country.

goods increases while consumption of non-tradables decreases. This is due to the increase in the tax rate on non-tradables making non-tradables relatively more expensive than tradables. This means that the tradable sector increases while non-tradable output drops. There are only minor effects on the foreign country since the increase in the tax on non-tradables exclusively affects the home non-tradable sector. Foreign non-tradable consumption increases slightly due to the smaller relative price of non-tradables while the consumption of tradable goods decreases. Both the increase in home imports and the decrease in foreign imports induces the trade balance to decline.

Overall, it can be stated that an increase in the tax on non-tradables triggers a substitution of non-tradables for tradables which limits the tendency of an improved trade balance. In this sense, an increase in the VAT on tradables is more effective in reducing external imbalances than an increase in the VAT on non-tradables. And – as a practical issue – this means that if a fiscal devaluation is aimed at reducing external imbalances, it should rather contain an increase in the standard rate of VAT than an abolition of reduced rates as the latter affects non-tradables more than tradables.

2.3.3 The Role of Nominal Rigidities

While it is frequently stated (see e.g. Engler et al. (2014)) that the effectiveness of a fiscal devaluation requires some degree of nominal stickiness, the results presented in the last two sections indicated that a devaluation may also be effective in a model with flexible prices and wages. To explore the relevance of nominal rigidities further, the simple model described in Section 2.2.1 is extended by nominal price and wage staggering a la Calvo.[11]

Production Sector

To introduce staggered price setting, the production sector is extended in the following way: There is a continuum of monopolistically competitive intermediate goods producers indexed by j whose size is normalized to one and a representative final goods producer operating under perfect competition. Each intermediate firm chooses its labor input to minimize its costs which gives

$$MC_t = W_t(1 + \tau_t^{ER}).$$

The final goods producer combines differentiated intermediate goods $y_t(j)$ purchased from firms to a homogenous aggregate good Y_t subject to the technology

$$Y_t = \left[\int_0^1 y_t(j)^{\frac{\sigma-1}{\sigma}} dj \right]^{\frac{\sigma}{\sigma-1}}, \tag{2.3}$$

where $\sigma > 1$ is the elasticity of substitution between differentiated goods. The associated cost minimization problem is given by

$$\min_{y_t(j)} P_{Ht} Y_t \equiv \int_0^1 p_{Ht}(j) y_t(j) dj$$

subject to the technology (2.3) such that the per capita demand for an individual good of firm j is

$$y_t(j) = \left(\frac{p_{Ht}(j)}{P_{Ht}} \right)^{-\sigma} Y_t. \tag{2.4}$$

Consequently, the zero profit condition gives the aggregate price index as

$$P_{Ht} = \left[\int_0^1 p_{Ht}(j)^{1-\sigma} dj \right]^{\frac{1}{1-\sigma}}.$$

[11] An overview about the equilibrium conditions can be seen in Appendix C.

With staggered price setting this implies

$$P_{Ht} = \left[\xi_p P_{Ht-1}^{1-\sigma} + (1-\xi_p)\widetilde{p}_{Ht}^{1-\sigma}(j)dj\right]^{\frac{1}{1-\sigma}},$$

where (1-ξ_p) denotes the fraction of firms which is able to reset its price in each period. This can be transformed to give

$$\frac{\widetilde{p}_{Ht}}{P_{Ht}} = \left(\frac{1-\xi_p\left(\frac{P_{Ht-1}}{P_{Ht}}\right)^{1-\sigma}}{1-\xi_p}\right)^{\frac{1}{1-\sigma}}.$$

If a firm is able to reset its price, it faces the optimal price setting problem

$$\max_{\widetilde{p}_{Ht}(j)} E_t \sum_{s=0}^{\infty} \xi_p^s Q_{t,t+s}\left[\widetilde{p}_{Ht}(j) - MC_{t+s}\right] y_{t,t+s}(j)$$

subject to the demand for the specific good (2.4), where the discount factor $Q_{t,t+s}$ is defined by

$$Q_{t,t+s} = \beta^s \left(\frac{C_{t+s}}{C_t}\right)^{-\rho} \frac{P_t(1+\tau_t^C)}{P_{t+s}(1+\tau_{t+s}^C)}.$$

After some manipulations, the first order condition can be written as

$$1 = \frac{\sigma}{\sigma-1}\frac{E_t\sum_{s=0}^{\infty}(\xi_p\beta)^s C_{t+s}^{-\rho}\frac{MC_{t+s}}{P_{t+s}(1+\tau_{t+s}^C)}Y_{t+s}P_{Ht+s}^{\sigma}(\widetilde{p}_{Ht}(j))^{-\sigma-1}}{E_t\sum_{s=0}^{\infty}(\xi_p\beta)^s C_{t+s}^{-\rho}\frac{1}{P_{t+s}(1+\tau_{t+s}^C)}Y_{t+s}P_{Ht+s}^{\sigma}(\widetilde{p}_{Ht}(j))^{-\sigma}}.$$

Using a recursive formulation, the price Philips curve can be expressed as

$$\left(\frac{1-\xi_p\left(\frac{P_{Ht-1}}{P_{Ht}}\right)^{1-\sigma}}{1-\xi_p}\right) = \frac{f_{1t}}{f_{2t}}$$

$$f_{1t} = \frac{\sigma}{\sigma-1}C_t^{-\rho}\frac{MC_t}{P_t(1+\tau_t^C)}Y_t + \beta\xi_p E_t\left\{\left(\frac{P_{Ht+1}}{P_{Ht}}\right)^{\sigma} f_{1t+1}\right\}$$

$$f_{2t} = C_t^{-\rho}\frac{1}{1+\tau_t^C}Y_t\frac{P_{Ht}}{P_t} + \beta\xi_p E_t\left\{\left(\frac{P_{Ht+1}}{P_{Ht}}\right)^{\sigma-1} f_{2t+1}\right\}.$$

Due to price dispersion, the aggregate production function is now given by

$$Y_t\Delta_t = L_t$$

where

$$\Delta_t = \int_0^n \frac{1}{n} \left(\frac{p_{Ht}(j)}{P_{Ht}} \right)^{-\sigma} dj.$$

Following Schmitt-Grohe and Uribe (2006), this index of price dispersion can be rewritten as

$$\Delta_t = (1 - \xi_p) \left(\frac{\widetilde{p}_{Ht}(j)}{P_{Ht}} \right)^{-\sigma} + \xi_p \left(\frac{P_{Ht}}{P_{Ht-1}} \right)^{\sigma} \Delta_{t-1}.$$

Households

To introduce some degree of wage rigidity, the labor market is assumed to be monopolistically competitive where labor services are imperfect substitutes implying that each household has some market power in setting its nominal wage. A representative labor agency buys differentiated labor from households by paying individual wages and produces a homogenous labor aggregate subject to the technology

$$L_t = \left[\frac{1}{n} \int_0^n L_t(i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}},$$

where $L_t(i)$ denotes differentiated labor supply of household i. The cost minimization problem can be expressed as

$$\min_{L_t(i)} W_t L_t \equiv \int_0^n W_t(i) L_t(i) di,$$

where $W_t(i)$ denotes the wage set by household i for its labor supply $L_t(i)$ and W_t denotes the aggregate wage index. Minimization gives the following demand for differentiated labor supplied by household i

$$L_t(i) = \frac{1}{n} \left(\frac{W_t(i)}{W_t} \right)^{-\sigma} L_t \tag{2.5}$$

and the assumption of zero profits implies that the aggregate wage index is given by

$$W_t = \left[\frac{1}{n} \int_0^n W_t(i)^{1-\sigma} di \right]^{\frac{1}{1-\sigma}}.$$

With staggered wage setting this gives

$$\frac{\widetilde{W}_t}{W_t} = \left(\frac{1 - \xi_w \left(\frac{W_{t-1}}{W_t} \right)^{1-\sigma}}{1 - \xi_w} \right)^{\frac{1}{1-\sigma}},$$

where (1-ξ_w) denotes the fraction of households which is able to reset their wages. In case of adjustment, household i sets its wage $\widetilde{W}_t(i)$ to maximize

$$E_t \sum_{s=0}^{\infty} (\beta\xi_w)^s \left[(1-\tau_{t+s}^{EE})\widetilde{W}_t(i) L_{t+s}(i) \frac{C_{t+s}^{-\rho}(i)}{P_{t+s}(1+\tau_{t+s}^{c})} - \frac{(L_{t+s}(i))^{1+\eta}}{1+\eta} \right]$$

subject to the demand for differentiated labor (2.5). After some manipulations, the first order condition can be expressed as

$$\left(\frac{\widetilde{W}_t(i)}{W_t} \right)^{1+\sigma\eta} = \frac{\frac{\sigma}{\sigma-1} E_t \sum_{s=0}^{\infty} (\beta\xi_w)^s \left(\frac{1}{n} L_{t+s}\right)^{1+\eta} \left(\frac{W_{t+s}}{W_t}\right)^{\sigma(1+\eta)}}{E_t \sum_{s=0}^{\infty} (1-\tau_{t+s}^{EE})(\beta\xi_w)^s L_{t+s} \frac{1}{n} \frac{C_{t+s}^{-\rho}}{1+\tau_{t+s}^{c}} \frac{W_{t+s}}{P_{t+s}} \left(\frac{W_{t+s}}{W_t}\right)^{\sigma-1}}.$$

Using a recursive formulation, the wage Philips curve can be expressed as

$$\left(\frac{1-\xi_w \left(\frac{W_{t-1}}{W_t}\right)^{1-\sigma}}{1-\xi_w} \right)^{\frac{1+\eta\sigma}{1-\sigma}} = \frac{g_{1t}}{g_{2t}}$$

$$g_{1t} = \frac{\sigma}{\sigma-1} \frac{1}{n} L_t^{1+\eta} + \beta\xi_w E_t \left\{ \left(\frac{W_{t+1}}{W_t} \right)^{\sigma(1+\eta)} g_{1t+1} \right\}$$

$$g_{2t} = C_t^{-\rho} \frac{1-\tau_t^{EE}}{1+\tau_t^{C}} \frac{W_t}{P_t} \frac{1}{n} L_t + \beta\xi_w E_t \left\{ \left(\frac{W_{t+1}}{W_t} \right)^{\sigma-1} g_{2t+1} \right\}.$$

Furthermore, the Euler equation is now given by

$$C_t^{-\rho} = \beta C_{t+1}^{-\rho} (1+i_t) \frac{P_t}{P_{t+1}} \frac{1+\tau_t^c}{1+\tau_{t+1}^c}$$

where i_t is defined as

$$1+i_t = \frac{\pi(s^{t+1})}{Q(s^t, s_{t+1})}.$$

Monetary Policy

There is a common central bank following a monetary policy rule responding to the aggregate union-wide consumer-price inflation:

$$1+i_t = \left(\frac{P_{ut}}{P_{ut-1}} \right)^{\mu} (1+\bar{i}),$$

where $\bar{i} = 1/\beta - 1$ denotes the steady-state nominal interest rate, $\mu \geq 1$ is a scaling parameter determining the responsiveness of the interest rate on inflation,[12] and P_{ut} is given by

$$P_{ut} \equiv s_{ct} P_t (1 + \tau_t^C) + (1 - s_{ct}) P_t^* (1 + \tau_t^{C*})$$

with

$$s_{ct} \equiv \frac{n P_t (1 + \tau_t^C) C_t}{n P_t (1 + \tau_t^C) C_t + (1 - n) P_t^* (1 + \tau_t^{C*}) C_t^*}.$$

Simulation

Using this extended version of the simple model, I simulate a permanent decrease in the employers' share of SSC, a decrease in the employees' share of SSC, and an increase in the VAT, respectively, each implemented in the home country for varying values of the degrees of price and wage stickiness.

As regards the increase in the VAT, all transition effects as well as long-run effects are independent of both the degree of price and the degree of wage stickiness. As was shown in Table 2.2, an increase in the VAT rate does neither influence pre-tax prices nor wages. Consequently, nominal rigidities are of no relevance in raising the trade balance through VAT increases.

This is different in case of a decrease in the SSC. Starting with the degree of wage rigidity, Figure 2.1 shows the effects of a decrease in the EESSC versus the ERSSC on the trade balance for different degrees of wage stickiness in the range from $\xi_w = 0$ to $\xi_w = 0.9$ while the degree of price rigidity is held constant at $\xi_p = 0.6$. It can be seen that in case of a decrease in the ERSSC the results confirm the propositions frequently found in literature: A higher degree of wage stickiness induces a larger trade balance increase. Regarding a decrease in the EESSC, however, the results indicate just the opposite. This can be explained through the following mechanism: The decrease in the ERSSC raises labor demand and, consequently, tends to increase nominal wages which would limit the intended decrease in producer costs. Some degree of wage stickiness decelerates the wage adjustment and, as a consequence, induces a larger decrease in marginal costs which results in the fiscal devaluation being more effective in increasing the trade balance. A decrease in the EESSC, on the contrary, decreases net wages such that nominal wages tend to decline which, ultimately, lowers marginal costs. A high degree of wage stickiness, however, means that wages decrease only sluggishly which diminishes the intended effect on marginal costs.

Turning to the importance of the degree of price stickiness, Figure 2.2 shows

[12] For simulation exercises, μ is chosen to be 2.

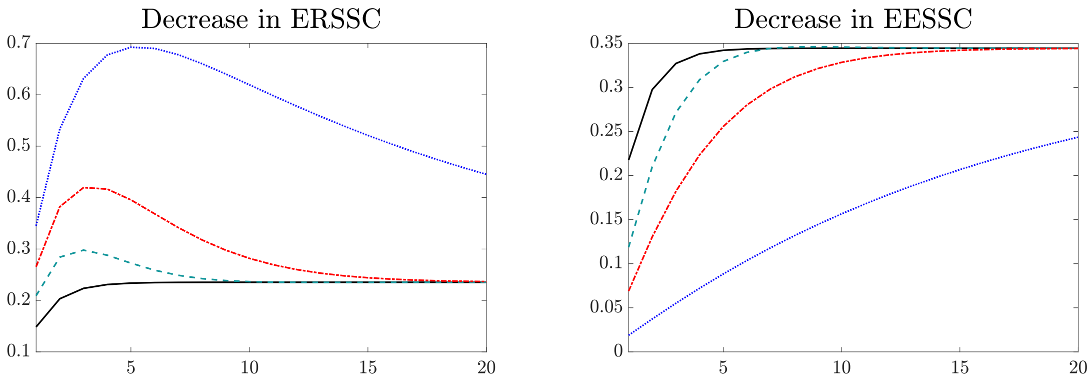

Figure 2.1: Trade balance effects to a decrease in ERSSC vs. the EESSC for different degrees of wage rigidity. The change in the trade-balance-to-GDP ratio is given in percentage points. The price rigidity is held constant at $\xi_p = 0.6$. **Black solid line:** $\xi_w = 0$. **Green dashed line:** $\xi_w = 0.3$. **Red dash-dotted line:** $\xi_w = 0.6$. **Blue dotted line:** $\xi_w = 0.9$

the trade balance effects of a decrease in the EESSC vs. the ERSSC as before but for varying degrees of price rigidity while the degree of wage rigidity is fixed at $\xi_w = 0.6$. It can be seen that with an increasing degree of price rigidity both a decrease in the ERSSC and a decrease in the EESSC become less effective in raising the trade balance. This is due to the fact that the decrease in SSC induces home marginal costs to decrease which means that the relative price of home-produced goods drops. This, ultimately, evokes a substitution of home-produced for foreign-produced goods which raises the trade balance. If prices adjust only sluggishly, however, the drop in marginal costs will only partly be reflected in a price decrease which results in smaller trade balance effects.

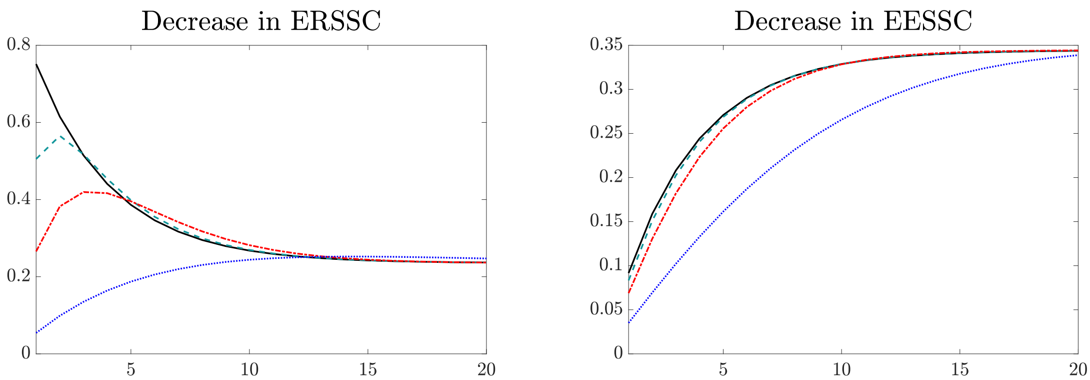

Figure 2.2: Trade balance effects to a decrease in ERSSC vs. the EESSC for different degrees of price rigidity. The change in the trade-balance-to-GDP ratio is given in percentage points. The wage rigidity is held constant at $\xi_w = 0.6$. **Black solid line:** $\xi_p = 0$. **Green dashed line:** $\xi_p = 0.3$. **Red dash-dotted line:** $\xi_p = 0.6$. **Blue dotted line:** $\xi_p = 0.9$

2.4 Fiscal Devaluation in the Euro Area

2.4.1 The Model

After exploring the particular mechanisms of the components of a fiscal devaluation in the last section, I apply these insights to simulate a fiscal devaluation constructed to reduce external deficits as effectively as possible in a more complex model calibrated to match Euro area data. For this purpose, I extend the simple model by both non-tradables and nominal rigidities as described above as well as by capital accumulation. Since the model is based on the simple model, I will only describe the changes evoked by these extensions.[13]

Intertemporal allocation

Households own the capital stock K_t, buy investment goods I_t at price P_t^I subject to quadratic capital adjustment costs, and rent capital to firms at renting rate R_t^c. Moreover, households receive dividends from firms in each sector Div_{kt} and pay lump-sum taxes T_t such that the per capita budget constraint is given by

$$\begin{aligned}&(1+\tau_t^C)P_tC_t + \sum_{s^{t+1}} Q(s^t, s_{t+1})B(s^t, s_{t+1}) + P_t^I I_t + \frac{\kappa}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t P_t^I \\ =&(1-\tau_t^{EE})W_{kt}L_{kt} + \frac{1}{n}\int_0^{ns_k} Div_{kt}(j)dj + B(s^{t-1}, s_t) + R_t^c K_t + T_t\end{aligned}$$

for $k \in \{H, N\}$ and j denoting an individual firm. Here, $\kappa > 1$ is a scaling parameter of capital adjustment costs. Dividends in each sector are given as

$$Div_{kt} = P_{kt}Y_{kt} - (1+\tau_t^{ER})W_{kt}L_{kt} - R_t^c K_{kt}$$

and the capital stock evolves as

$$K_{t+1} = (1-\delta)K_t + I_t$$

where $0 < \delta < 1$ is the depreciation rate of capital. Utility maximization and defining

$$R_t = \frac{\pi(s^{t+1})}{Q(s^t, s_{t+1})}$$

[13] The equilibrium conditions of the complete model can be seen in Appendix D.

delivers the following Euler equations for bond holdings and capital, respectively:

$$R_t = \frac{1}{\beta}\left(\frac{C_t}{C_{t+1}}\right)^{-\rho}\frac{1+\tau^C_{t+1}}{1+\tau^C_t}\frac{P_{t+1}}{P_t}$$

$$\left(\frac{C_t}{C_{t+1}}\right)^{-\rho}\frac{P_{t+1}(1+\tau^c_{t+1})}{P_t(1+\tau^c_t)}\frac{P^I_t}{P^I_{t+1}}\frac{1}{\beta}\left(1+\kappa\left(\frac{I_t}{Kt}-\delta\right)\right)-\frac{R^c_{t+1}}{P^I_{t+1}}$$
$$=\left(1+\kappa\left(\frac{I_{t+1}}{K_{t+1}}-\delta\right)\right)(1-\delta)-\frac{\kappa}{2}\left(\frac{I_{t+1}}{K_{t+1}}-\delta\right)^2+\kappa\left(\frac{I_{t+1}}{K_{t+1}}-\delta\right)\frac{I_{t+1}}{K_{t+1}}.$$

Investment decision

The allocation of total investment between tradable and non-tradable investment goods as well as the allocation of tradable investment between home and foreign investment goods take place analogously to the allocation of consumption goods. The exception is the assumption that there are no VAT on investment goods since VAT – while in practice paid and rebated at each production level – ultimately are only levied on final consumption. The share of tradables in total investment and the share of home-produced goods in tradable investment as well as the corresponding elasticities are assumed to be the same as for consumption goods.

Labor supply

As in the last section, the labor market is monopolistically competitive but now there is a representative labor agency in each sector. Consequently, in each sector, the labor agency buys differentiated labor from households by paying individual wages and produces a sector-specific homogenous labor aggregate subject to the technology

$$L_{kt} = \frac{1}{n}\left[\left(\frac{1}{ns_k}\right)^{\frac{1}{\sigma^w_k}}\int_0^{ns_k} L_{kt}(i)^{\frac{\sigma^w_k-1}{\sigma^w_k}}di\right]^{\frac{\sigma^w_k}{\sigma^w_k-1}},$$

where $L_{kt}(i)$ denotes differentiated labor supply of household i in sector k and L_{kt} is per capita aggregate labor supplied in sector k. $\sigma^w_k > 0$ is the elasticity of labor-production between differentiated labor inputs in sector k. Cost minimization and the labor choice take place just as in the last section such that the wage Philips curves can be expressed as

$$\frac{g1_{kt}}{g2_{kt}} = \left(\frac{1 - \xi_k^w \left(\frac{W_{kt}}{W_{kt-1}} \right)^{\sigma_k^w - 1}}{1 - \xi_k^w} \right)^{\frac{1+\eta\sigma_k^w}{1-\sigma_k^w}}$$

$$g1_{kt} = \frac{\sigma_k^w}{\sigma_k^w - 1} \left(L_{kt} \right)^{1+\eta} n^{-\eta} + \beta \xi_k^w E_t \left\{ \left(\frac{W_{kt+1}}{W_{kt}} \right)^{\sigma_k^w} g1_{kt+1} \right\}$$

$$g2_{kt} = (1 - \tau_t^{EE}) C_t^{-\rho} \frac{W_{kt}}{P_t} L_{kt} + \beta \xi_k^w E_t \left\{ \left(\frac{W_{kt+1}}{W_{kt}} \right)^{\sigma_k^w - 1} g2_{kt+1} \right\}.$$

Production and aggregation

Intermediate goods firms now produce output using capital services and labor supplied by households subject to the production function

$$Y_{kt}(j) = L_{kt}(j)^{\alpha_k} K_{kt}(j)^{1-\alpha_k},$$

where $0 \leq \alpha_k \leq 1$ is the labor share in sector k. Each firm chooses its capital and labor inputs to solve the cost minimization problem

$$\min_{L_{kt}, K_{kt}} (1 + \tau_t^{ER}) W_{kt} L_{kt}(j) + R_t^c K_{kt}(j)$$

subject to the production function. Minimization leads to the first order conditions

$$\frac{L_{kt}}{K_{kt}} = \frac{\alpha_k}{1 - \alpha_k} \frac{R_t^c}{(1 + \tau_t^{ER}) W_{kt}}$$

and

$$MC_{kt} = \frac{(1 + \tau_t^{ER}) W_{kt}}{\alpha_k} \left(\frac{L_{kt}}{K_{kt}} \right)^{1-\alpha_k},$$

where MC_{kt} denotes marginal costs of production in sector k. Price setting takes place as before such that the price Philips curves can be expressed as

$$\frac{f1_{kt}}{f2_{kt}} = \left(\frac{1 - \xi_k^p \left(\frac{P_{kt-1}}{P_{kt}} \right)^{1-\sigma_k^p}}{1 - \xi_k^p} \right)^{\frac{1}{1-\sigma_k^p}}$$

$$f1_{kt} = \frac{\sigma_k^p}{\sigma_k^p - 1} C_t^{-\rho} Y_{kt} \frac{MC_{kt}}{P_t} \frac{1}{1 + \tau_t^c} + \beta \xi_k^p E_t \left\{ \left(\frac{P_{kt+1}}{P_{kt}} \right)^{\sigma_k^p} f1_{kt+1} \right\}$$

$$f2_{kt} = C_t^{-\rho} Y_{kt} \frac{P_{kt}}{P_t} \frac{1}{1+\tau_t^c} + \beta \xi_k^p E_t \left\{ \left(\frac{P_{kt+1}}{P_{kt}} \right)^{\sigma_k^p - 1} f2_{kt+1} \right\}.$$

Aggregation now gives

$$Y_{Ht} = C_{Ht} + \frac{1-n}{n} C_{Ht}^* + I_{Ht} + \frac{1-n}{n} I_{Ht}^*$$

$$Y_{Nt} = C_{Nt} + I_{Nt}$$

$$K_t = K_{Ht} + K_{Nt}$$

$$Y_{kt} \Delta_{kt} = L_{kt}^{\alpha_k} K_{kt}^{1-\alpha_k},$$

where

$$\Delta_{kt} = (1 - \xi_k^p) \left(\frac{1 - \xi_k^p \left(\frac{P_{kt-1}}{P_{kt}} \right)^{1-\sigma_k^p}}{1 - \xi_k^p} \right)^{\frac{\sigma_k^p}{\sigma_k^p - 1}} + \xi_k^p \left(\frac{P_{kt}}{P_{kt-1}} \right)^{\sigma_k^p} \Delta_{kt-1}.$$

2.4.2 Calibration

The model is calibrated to match 2015 Euro area characteristics where only countries are regarded which are members of the Euro zone at least since 2002 (EA-12 countries).[14] Table 2.6 shows the intra-EA-12 trade-balance-to-GDP ratios for each country for the period from 2008 to 2015.[15] It can be seen that there are 4 countries featuring trade balance surpluses throughout the whole period from 2008 to 2015, namely Belgium, Germany, Ireland, and the Netherlands. All other countries had permanent trade balance deficits.[16] Such being the case, I define the home country as the group of the eight deficit countries, namely Austria, Spain, Finland, France, Greece, Italy, Luxembourg, and Portugal while the foreign country consists of Belgium, Germany, Ireland, and the Netherlands.

Given this baseline classification, the share of the home countries' GDP in the total EA-12 GDP was about 57% in 2015 such that the size of the home country, n, is set to be 0.57. The average trade-balance-to-GDP-ratio was -2.61% in 2015 in the home country-group and 4.00% in the foreign country-group.[17] Since the

[14] A detailed description of the data sources and construction can be found in Appendix E.

[15] Data source: Eurostat. As the model describes a monetary union consisting of two countries but abstracts from any non-monetary-union member states, extra-EA-12 trade was excluded from the calculation of trade-balance-to-GDP ratios.

[16] With the single exception of Spain in 2013.

[17] While calibrating the trade balances based on 2015 data implies assuming 2015 to be a steady-state situation which may be questionable, the data shows that the intra-EA12 trade

	2008	2009	2010	2011	2012	2013	2014	2015
AT	-6.37	-5.66	-5.81	-6.64	-6.48	-6.18	-5.73	-5.97
BE	4.26	3.80	3.22	3.04	0.71	2.44	3.03	5.97
FI	-1.14	-1.28	-2.00	-2.26	-2.66	-2.42	-2.25	-2.17
FR	-3.55	-3.32	-3.59	-4.03	-4.27	-4.15	-4.00	-4.09
DE	2.10	1.51	1.24	0.71	0.23	0.06	0.05	0.23
GR	-9.13	-7.66	-6.73	-5.93	-5.62	-5.41	-5.86	-5.22
IE	10.64	14.11	13.24	12.59	12.26	9.80	7.83	6.89
IT	-0.58	-0.71	-1.18	-1.03	-0.48	-0.47	-0.26	-0.60
LU	-7.89	-5.27	-12.52	-14.58	-13.96	-11.41	-9.96	-6.96
NL	19.29	16.41	20.70	22.83	23.99	22.26	21.47	19.35
PT	-10.42	-9.26	-9.10	-6.94	-5.54	-5.40	-6.57	-6.30
ES	-3.22	-1.41	-1.03	-0.96	-0.32	0.04	-0.41	-0.93

Table 2.6: Intra-EA-12 trade-balance-to-GDP-ratios from 2008 to 2015 (in percent)

initial wealth distribution determines the initial steady-state trade-balance-to-GDP-ratio of the home country, I use u to obtain a trade-balance-to-GDP-ratio of -2.61%. Furthermore, the relation between the home and foreign degree of openness, $\frac{\nu}{\nu^*}$, is set to obtain a foreign trade-balance-to-GDP ratio of 4.00% where ν is adjusted to guarantee that the degree of trade openness lies in the range between 0 and 1 for both countries. Here, I choose $\nu = 0.9$ which implies that there is some degree of home bias in consumption.[18]

The definition of goods and services as tradables or non-tradables follows Allington et al. (2006). Based on this definition, the weight of tradables in total consumption, ω, and the degree of price stickiness, ξ^p, can be computed for the two sectors separately.

Starting with the weight of tradables in total consumption, the cross-country expenditure-weighted average share of final consumption expenditures of house-

balance surpluses and -deficits were quite stable at least between 2001 and 2015. The average intra-EA12 trade-balance-to-GDP-ratio for the chosen home country-group is -2.66% between 2001 and 2015 and amounts to 4.92% for the foreign country group. 10 of the 12 countries regarded featured either intra-EA12 trade balance surpluses or deficits during the whole period from 2001 to 2015. This shows that the situation in 2015 was no one-time event but represented a stable economic situation at least for a given period thus making the calibration based on the data reasonable.

[18]While the specific value of ν is chosen somewhat arbitrarily, I check the robustness of the results to variations in this parameter as can be seen in the next section.

holds on tradables in total final consumption expenditures was 0.52 in the home country group and 0.51 in the foreign country group in 2015.[19] This way, ω is set to be 0.22 and ω^* to be 0.39.

To calibrate the degree of price stickiness, I use seven OECD studies, each estimating the frequency of price changes for each COICOP category in an individual country, namely Austria, Belgium, Finland, France, Italy, Netherlands, and Portugal.[20] I use these estimates to compute the cross-country expenditure-weighted aggregates for the tradable and non-tradable sector, respectively. This gives the following degrees of price stickiness in each sector: $\xi_H = 0.83$, $\xi_N = 0.76$, $\xi_F^* = 0.74$, and $\xi_N^* = 0.75$.

Regarding the production side, I use the definition proposed by Piton (2017). Given this definition, the size of the tradable sector, s_k, is calibrated as the GDP-weighted cross-country average of the share of GDP originated in the tradable sectors to total GDP.[21] Accordingly, s_H is set to be 0.59 and s_F^* to be 0.62.

The elasticity of substitution in each sector is calibrated by considering the steady-state expression for the aggregate price index which gives the price as mark-up over marginal costs and enables to pin down σ_k^p by calibrating the price mark-up in each sector. The calibration is based on Christopoulou and Vermeulen (2008). The corresponding calibrated elasticities are $\sigma_H^p = 5.43$, $\sigma_N^p = 4.69$, $\sigma_F^{p*} = 7.05$, and $\sigma_N^{p*} = 5.42$ which shows that mark-ups are larger in the home than in the foreign country-group as well as larger in the non-tradable than in the tradable sectors.

The elasticity of substitution between differentiated labor inputs is assumed to be the same as the elasticity of substitution between differentiated intermediate goods, meaning $\sigma_H^w = 5.43$, $\sigma_N^w = 4.69$, $\sigma_F^{w*} = 7.05$, and $\sigma_N^{w*} = 5.42$.

The labor share in production is computed as the weighted sum of the country-specific shares of labor compensation in total (labor plus capital) compensation for both sectors.[22] This gives $\alpha_T = 0.68$, $\alpha_{NT} = 0.77$, $\alpha_T^* = 0.64$, and $\alpha_{NT}^* = 0.77$.

I assume the degree of wage rigidity to be the same across sectors and rely on the estimates of Knoppik and Beissinger (2009) such that computing the GDP-weighted cross-country averages gives $\xi_H^w = \xi_N^w = 0.35$ and $\xi_F^{w*} = \xi_N^{w*} = 0.29$.

The remaining parameters are relatively standard. The discount factor is

[19] Data Source: Eurostat: Final consumption expenditures of households in 2015.

[20] Baumgartner et al. (2005), Aucremanne and Dhyne (2004), Vilmunen and Laakkonen (2004), Beaudry et al. (2004), Veronese and et al. (2005), Jonker et al. (2004), and Dias et al. (2004).

[21] Data Source: EU KLEMS, Release September 2017.

[22] Source: EU KLEMS, September 2017 release.

set to be $\beta = 0.995$ to match a nominal interest rate of 2%. The inverse of the labor supply elasticity, η, is calibrated to be 2 for both countries following Farhi et al. (2014), who simulate a fiscal devaluation in a model calibrated to Spain, and Eggertsson et al. (2014), who calibrate a two-country model with a tradable and a non-tradable sector to match characteristics of the European Monetary Union. The inverse of the intertemporal elasticity of substitution, ρ, is set to be 2, which lies in the range of values used in related literature (e.g. Eggertsson et al. (2014) calibrate $\rho = 0.5$, Franco (2013), who simulates a fiscal devaluation in a model calibrated to Portugal, uses $\rho = 1$, and Farhi et al. (2014) set $\rho = 5$.). Following Franco (2013) and Eggertsson et al. (2014), the elasticity of substitution between home and foreign tradable goods in both countries is calibrated to $\phi = 1.5$. The same elasticity between tradable and non-tradable goods is assumed as between home and foreign goods such that ϵ is set to be 1.5 in both countries. As regards the monetary policy rule, I follow Lipinska and von Thadden (2013) and set the response parameter of monetary policy to union-wide inflation, μ, to be 2. The depreciation rate of capital is set to $\delta = 0.025$ and the adjustment cost parameter is defined to be $\kappa = 10$.

First, the model is solved for a given set of tax instruments which are calibrated to match 2015 Euro zone data. This is used as starting point for the devaluation simulation. As the calibration is meant to capture structural differences between the home and foreign country-group explaining the differences in the trade balances, it should be excluded that the EA-12 countries already implemented fiscal devaluations such shifting the economical conditions. As there is some evidence of a fiscal devaluation between 2012 and 2015 in France, Greece, Finland, and the Netherlands whose share in total EA-12 GDP amounts to at least 32%, I will check the robustness of the results to calibrating the model to 2012 data as a sensitivity analysis but otherwise include all 12 countries into the analysis. The SSC rates are set to match the GDP-weighted cross-country average of SSC rates on the average wage,[23] which gives $\tau_0^{ER} = 0.3156$, $\tau_0^{EE} = 0.1139$, $\tau_0^{ER*} = 0.1841$, and $\tau_0^{EE*} = 0.1776$.

Regarding the VAT rates, the VAT Directive (2006) allows the application of reduced tax rates in EU member states on certain goods and services while all remaining goods and services have to be taxed with the standard rate applied in the individual country. To calibrate the respective VAT rates on tradable and non-tradable goods, I build on the IAS et al. (2013b) who calculate an average

[23]Data source: OECD Tax Statistics.

VAT rate for each of the COICOP categories of goods and services in each of the EU member states. This gives $\tau^{C_T} = 0.1397$, $\tau^{C_N} = 0.0708$, $\tau_0^{C_T^*} = 0.1458$, and $\tau_0^{C_N^*} = 0.0839$ which shows that tradables are taxed much more heavily than non-tradables.

2.4.3 Simulation

Regarding the specific form of a fiscal devaluation, literature mostly suggests an abolishing of reduced rates combined with a decrease in the ERSSC. Franco (2013) and the International Monetary Fund (2011) both argue that reduced VAT rates should – at least partly – be abolished to obtain the additional government revenues necessary to compensate the decrease in SSC. Beyond that, the European Commission (2011b) proposes to abolish at least those reduced rates applied on goods and services for which other EU policies try to reduce their consumption. With regard to the COICOP classification, the IAS et al. (2013a) outlines that this was the case for Water, Energy products, Street cleaning, Refuse collection, and Waste treatment and Housing. Interestingly, all of these categories can be classified as non-tradable consumption. Results obtained in this paper, in contrast, indicate that raising the VAT on non-tradables may in fact worsen the trade balance while an incline in the VAT on tradables tends to increase the trade-balance-to-GDP ratio.

In this section, I compare the effects of both scenarios considered, implemented in the Euro Area model: In the first scenario (named NER in the following), I take up the proposal of the IAS et al. (2013a) by simulating a fiscal devaluation in the home country where the revenue-generating side consists in an abolition of reduced rates in the categories outlined above. In the model, this means that the home VAT on non-tradables increases in the amount of 2.39 percentage points which implies additional tax revenues in the amount of 1.39% of GDP. I assume that the additional tax revenues are used to reduce the ERSSC. This implies a reduction in the ERSSC of 3.13 percentage points on impact. In the second scenario (named NTEE), I build on the results obtained in this paper and simulate an increase in the standard rate of VAT. I compute the increase in the standard rate to generate the same amount of government revenues as in the first scenario.[24] Consequently, the VAT rate on non-tradables inclines by 1.39 percentage points while the VAT rate on tradables increases by 2.50 percentage points. The additional government revenues are assumed to be compensated by

[24]A detailed description can be found in Appendix E.

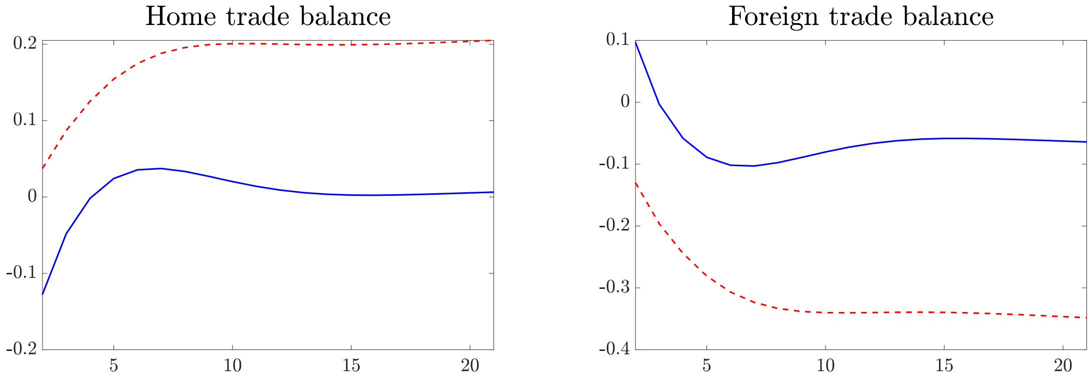

Figure 2.3: Impulse responses of the trade balance to both scenarios of a fiscal devaluation. Given are changes in the trade-balance-to-GDP ratios in percentage points. **Blue solid line:** NER-scenario. **Red dashed line:** NTEE-scenario.

a decrease in the EESSC which amounts to 3.18 percentage points on impact. Figure 2.3 shows impulse responses of the trade balances for both scenarios. It can be seen that in the NTEE-scenario the home trade-balance-to-GDP ratio increases by 0.2 percentage points in the long-run and, thus, shows that this measure may be highly effective in reducing trade balance imbalances. In contrast, it can be seen that a devaluation implemented as the NER-scenario in fact decreases the home trade balance on impact while being almost ineffective in the long-run. The foreign country features a long-run trade balance decrease in both scenarios but this being much more pronounced in the NTEE-scenario.

The difference between the trade balance effects in the NER- versus the NTEE-scenario can be divided into effects evoked by the decrease in EESSC versus ERSSC and the effects evoked by the increase in tradable versus non-tradable VAT. The SSC-effect works through marginal labor costs and influences the foreign demand for imports. The VAT-effect regards home after-tax prices and determines the home demand for imports.

Starting with the SSC-effect on marginal costs, Figure 2.4 shows that gross wages decrease only slightly (or even increase) in the NER-case whereas they decrease to a large extent in the NTEE-case. As described in Section 2.3.1, lower EESSC rates tend to decrease wages due to higher net wages. In contrast, the decrease in the ERSSC implies increasing wages. Here, however, the wage increase is mitigated through the decrease in ERSSC. In the NTEE-case, on the contrary, the change in gross labor costs is the same as in gross wages. As an overall effect it can be seen that, in the non-tradable sector, gross labor costs decrease more in the NER-scenario than in the NTEE-scenario. In the tradable sector the opposite holds true. Gross labor costs, however, are the crucial factor determining prices and, thus, (foreign) demand.

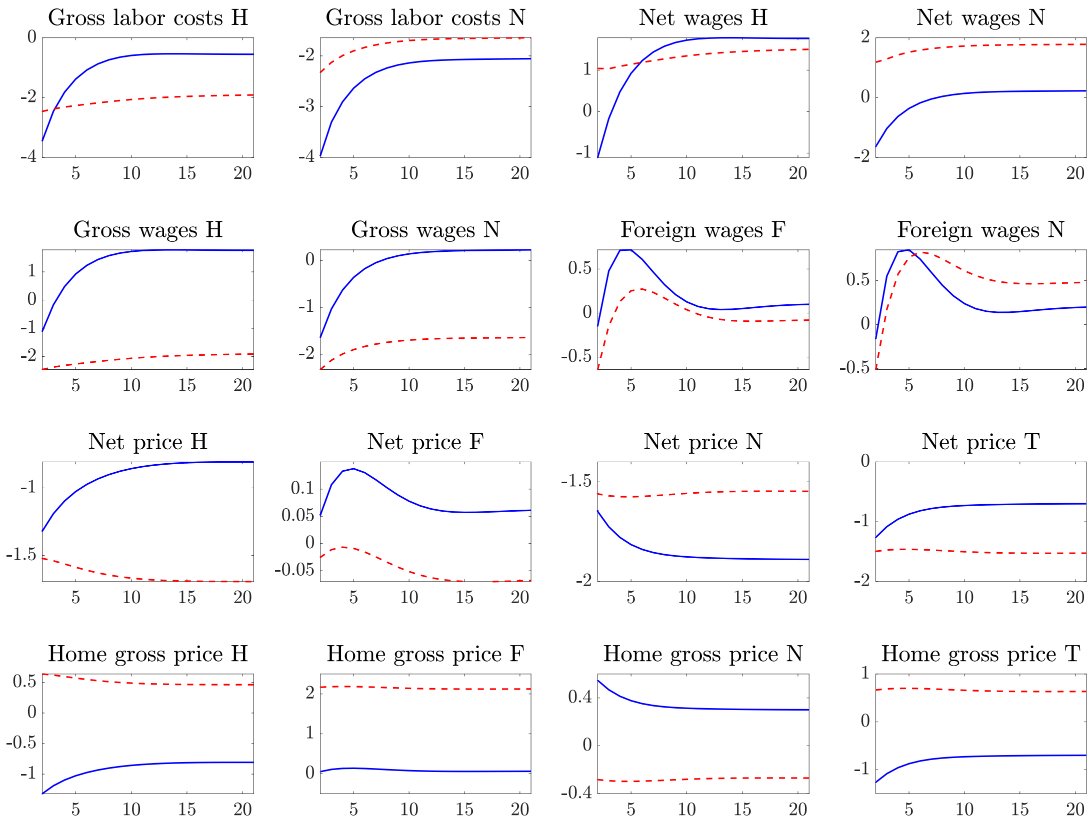

Figure 2.4: Impulse responses of prices and wages to both scenarios of a fiscal devaluation. For all variables percentage changes are given. All prices and wages are measured relative to the after-tax consumer price index of the respective country. **Blue solid line:** NER-scenario. **Red dashed line:** NTEE-scenario.

Regarding the VAT-effects on home after-tax prices, in the NER-case, the VAT on non-tradables and, consequently, their after-tax price inclines. This means a substitution of non-tradables for tradables takes place as can be seen in Figure 2.5: Consumption of non-tradables decreases while the import demand increases which limits the effectiveness of a fiscal devaluation. In contrast, in the NTEE-case, the after-tax price for tradable goods increases due to higher VAT rates while the relative after-tax price of non-tradables declines. Consequently, a shift from tradable to non-tradable consumption takes place.

Taking both effects together, a fiscal devaluation conducted as a reduction in the EESSC and an increase in the VAT on tradables is found to be much more effective in reducing trade balance differences than the case of a reduction in the ERSSC and an abolition of reduced rates.

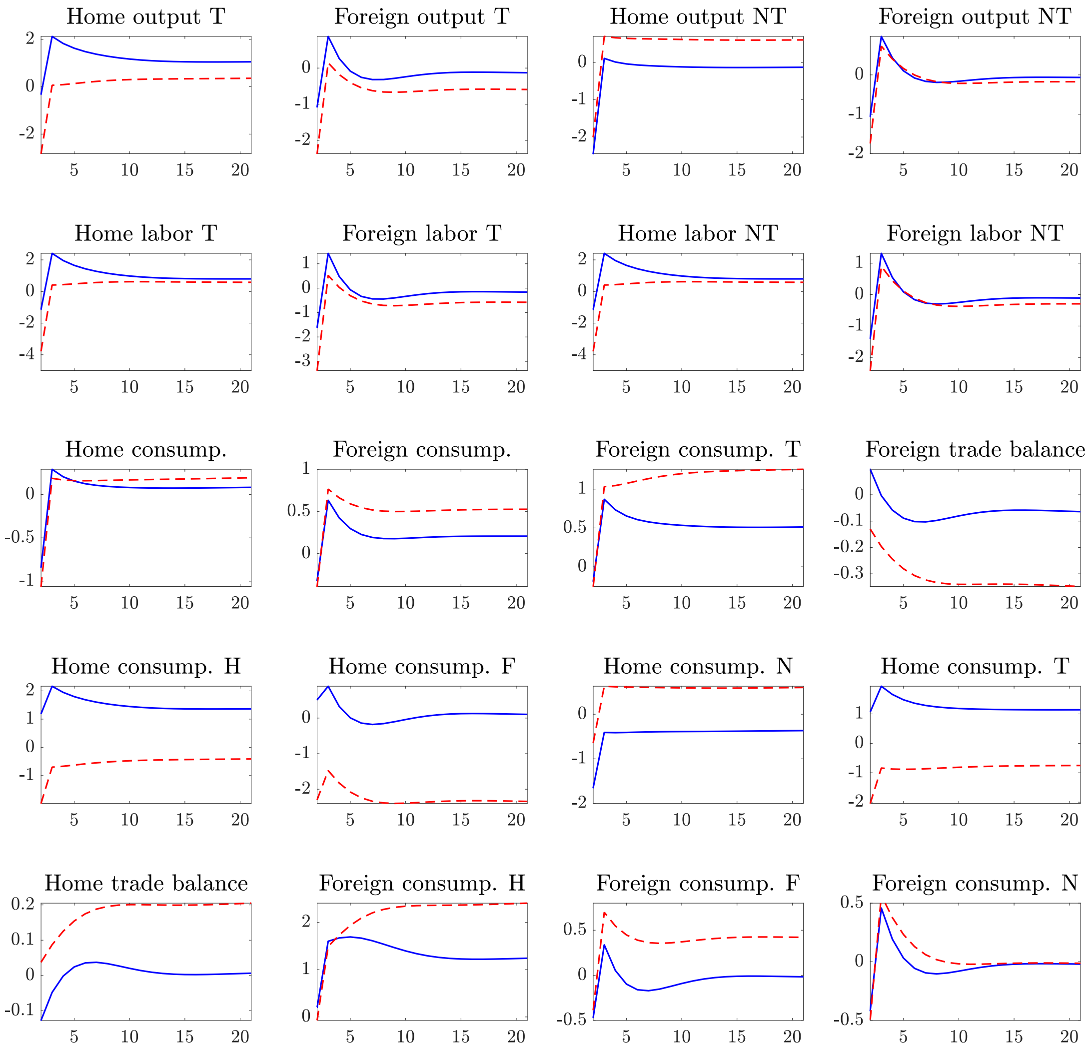

Figure 2.5: Impulse responses of real variables to both scenarios of a fiscal devaluation. For all variables percentage changes are given with the exception of the trade balance where the change in the trade-balance-to-GDP ratio in percentage points is plotted. **Blue solid line:** NER-scenario. **Red dashed line:** NTEE-scenario.

2.5 Robustness

I check the robustness of the results regarding three categories: First, a sensitivity analysis is conducted by varying the values of the parameters which could not be calibrated but were chosen somewhat arbitrarily, namely ν, η, ρ, ϵ, and ϕ. Second, the model is calibrated to 2012 data as there is evidence that mainly Greece and France could have implemented a fiscal devaluation in 2012. And finally, the effect of the country size is explored by simulating a devaluation conducted by France only.

First, choosing different values of ν or setting ρ to smaller values does not change the results. Setting η to smaller values implies larger trade balance effects. With η=0.5, a shift from EESSC to tradable VAT can eliminate almost 14% of the initial trade balance differences (foreign minus home trade-balance-to-GDP ratio). On the contrary, choosing smaller values for ϵ implies trade balance effects being somewhat smaller than under the baseline calibration: ϵ=0.5 implies that about 6% of the initial trade balance differences can be eliminated. Similarly, choosing a smaller value of ϕ limits the effectiveness of a fiscal devaluation. By setting ϕ to 0.5, only 1.3% of the initial trade balance differences can be eliminated whereas by setting ϕ to 2 the trade balance effect amounts to almost 10%. The results regarding the most effective form of a fiscal devaluation are robust to each of these variations.

Second, the results are robust to calibrating the model to 2012 data. Here, the home country features a trade-balance-to-GDP ratio of -2.59% while the foreign trade-balance-to-GDP ratio amounts to 4.07%. An abolition of reduced rates in the categories outlined before induces a revenue shift in the amount of 1.51% of GDP which eliminates 8.9% of the total initial trade balance differences in the NTEE-scenario whereas it amounts to 1.7% only in the NER-case.

Finally, I check the robustness of the results to varying the size of the home country by simulating a fiscal devaluation implemented in France while all other countries are defined to be foreign countries. Here, the size of the home country is 0.21 featuring a trade-balance-to-GDP ratio of -4.09% while the trade-balance-to-GDP ratio of the foreign country amounts to 1.4%. The results are even more pronounced. While in the NER-scenario the home trade balance even decreases and the foreign trade balance increases, in the NTEE-scenario 15% of the total initial trade balance differences can be eliminated where the home trade-balance-to-GDP ratio is improved by 0.62 percentage points.

2.6 Conclusions

This paper breaks with conventional wisdom concerning fiscal devaluations in three ways: First, while a decrease in the employers' share in SSC usually is assumed to be a more effective measure than a decrease in the employees' share, I use a simple two-country model to show that this view does not hold to be true.

Second, in contrast to the common assumption of the effectiveness of a fiscal devaluation in raising the trade balance requiring some degree of wage rigidity, I show that a devaluation implemented in a simple model with flexible prices and wages has noticeable real effects. Furthermore, I explicitly explore the role of the degree of wage and price rigidity and find that while the effectiveness of the VAT increase is independent of both the degree of wage and of price stickiness, rigidities do matter with respect to the decrease in the SSC. Contrary to conventional wisdom, however, the degree of wage stickiness is negatively related with the effectiveness of a decrease in the employees' share in SSC. A decrease in the employers' share is more effective the more rigid the wages. Regarding price stickiness, a higher degree of rigidity induces a smaller effect on the trade balance.

And third, contrary to propositions found in literature to abolish reduced rates of VAT to generate the additional government revenues necessary to implement a revenue neutral devaluation, I show that increasing the VAT in a way which affects tradables more than non-tradables – like increasing the standard rate of VAT – is a more effective measure in eliminating trade balance differences as this induces a substitution of tradables for non-tradables.

I use these insights to simulate a fiscal devaluation implemented in Euro area countries featuring trade balance deficits in 2015 for two different scenarios and find that while a shift from EESSC to tradable VAT is highly effective in eliminating trade balance differences, a shift from ERSSC to non-tradable VAT is all but effectless in raising the trade balance.

While this paper gives some indication of the crucial choice of tax instruments to be used in the context of a fiscal devaluation and shows that it may be effective in reducing external imbalances, it refrains from regarding counteracting reforms undertaken by the remaining countries. It would be interesting in future research to go beyond a unilateral devaluation and further develop a framework allowing for optimal policy reactions.

2.7 Appendices

2.7.A Equilibrium Conditions for the Simple Model

Prices are expressed relative to the consumer price level (e.g. $p_{Ht} \equiv P_{Ht}/P_t$). Real wages are defined as $W_t^r \equiv W_t/P_t$. $P_t = P_t^*$ holds implying that the real exchange rate is one ($RS_t = 1$).

International risk sharing:

$$(C_t)^{-\rho} = (C_t^*)^{-\rho} \frac{1+\tau_t^c}{1+\tau_t^{c*}}$$

Labor supply:

$$L_t^\eta = C_t^{-\rho} W_t^r \frac{1-\tau_t^{EE}}{1+\tau_t^C}$$

$$(L_t^*)^\eta = (C_t^*)^{-\rho} W_t^{r*} \frac{1-\tau_t^{EE*}}{1+\tau_t^{C*}}$$

Consumption demand relationships:

$$C_{Ht} = \nu p_{Ht}^{-\phi} C_t$$

$$C_{Ft} = (1-\nu) p_{Ft}^{-\phi} C_t$$

$$C_{Ht}^* = \nu p_{Ht}^{-\phi} C_t^*$$

$$C_{Ft}^* = (1-\nu) p_{Ft}^{-\phi} C_t^*$$

Price setting:

$$W_t^r = p_{Ht} \frac{1}{1+\tau^{ER}}$$

$$W_t^{r*} = p_{Ft} \frac{1}{1+\tau^{ER*}}$$

$$1 = \nu p_{Ht}^{1-\phi} + (1-\nu) p_{Ft}^{1-\phi}$$

Production functions:

$$Y_t = L_t$$

$$Y_t^* = L_t^*$$

Resource constraints:

$$Y_t = C_{Ht} + \frac{1-n}{n} C_{Ht}^*$$

$$Y_t^* = C_{Ft}^* + \frac{n}{1-n} C_{Ft}$$

2.7.B Equilibrium Conditions with Non-tradables

All prices are expressed relative to the after-tax consumer price level of the respective country (e.g. $p_{Ht} \equiv P_{Ht}/((1+\tau_t^C)P_t)$ and $p_{Ft} \equiv P_{Ft}/((1+\tau_t^{C*})P_t^*)$). Real wages are defined as $W_t^r \equiv W_t/((1+\tau_t^C)P_t)$ and $W_t^{r*} \equiv W_t^*/((1+\tau_t^{C*})P_t^*)$. The real exchange-rate is defined as $RS_t \equiv P_t^*(1+\tau_t^{C*})/(P_t(1+\tau_t^C))$.

Complete asset markets:

$$RS_t = u \left(\frac{C_t^*}{C_t} \right)^{-\rho}$$

Labor supply:

$$L_{Ht}^{\eta} = C_t^{-\rho} W_{Ht}^r (1 - \tau_t^{EE})$$

$$L_{Nt}^{\eta} = C_t^{-\rho} W_{Nt}^r (1 - \tau_t^{EE})$$

$$(L_{Ft}^*)^{\eta} = (C_t^*)^{-\rho} W_{Ft}^{r*} (1 - \tau_t^{EE*})$$

$$(L_{Nt}^*)^{\eta} = (C_t^*)^{-\rho} W_{Nt}^{r*} (1 - \tau_t^{EE*})$$

Consumption demand relationships:

$$C_{Ht} = \nu \left(\frac{p_{Ht}}{p_{Tt}} \right)^{-\phi} C_{Tt}$$

$$C_{Ft} = (1-\nu) \left(\frac{p_{Ft}}{p_{Tt}} RS_t \right)^{-\phi} C_{Tt}$$

$$C^*_{Ht} = \nu \left(\frac{p_{Ht}}{p^*_{Tt}} \frac{1}{RS_t} \right)^{-\phi} C^*_{Tt}$$

$$C^*_{Ft} = (1-\nu) \left(\frac{p_{Ft}}{p^*_{Tt}} \right)^{-\phi} C^*_{Tt}$$

$$C_{Nt} = (1-\omega) \left(p_{Nt} \left(1 + \tau_t^{C_N} \right) \right)^{-\epsilon} C_t$$

$$C^*_{Nt} = (1-\omega) \left(p^*_{Nt} \left(1 + \tau_t^{C^*_N} \right) \right)^{-\epsilon} C^*_t$$

$$C_{Tt} = \omega \left(p_{Tt} \left(1 + \tau_t^{C_T} \right) \right)^{-\epsilon} C_t$$

$$C^*_{Tt} = \omega \left(p^*_{Tt} \left(1 + \tau_t^{C^*_T} \right) \right)^{-\epsilon} C^*_t$$

Price indexes:

$$1 = \omega \left(p_{Tt} \left(1 + \tau_t^{C_T} \right) \right)^{1-\epsilon} + (1-\omega) \left(p_{Nt} \left(1 + \tau_t^{C_N} \right) \right)^{1-\epsilon}$$

$$1 = \omega \left(p^*_{Tt} \left(1 + \tau_t^{C^*_T} \right) \right)^{1-\epsilon} + (1-\omega) \left(p^*_{Nt} \left(1 + \tau_t^{C^*_N} \right) \right)^{1-\epsilon}$$

$$p_{Tt} = \left[\nu p_{Ht}^{1-\phi} + (1-\nu)(p_{Ft} RS_t)^{1-\phi} \right]^{\frac{1}{1-\phi}}$$

$$p^*_{Tt} = \left[\nu \left(\frac{p_{Ht}}{RS_t} \right)^{1-\phi} + (1-\nu) p_{Ft}^{1-\phi} \right]^{\frac{1}{1-\phi}}$$

Production functions:

$$Y_{Ht} = L_{Ht}^{1-\alpha}$$

$$Y_{Nt} = L_{Nt}^{1-\alpha}$$

$$Y_{Ft}^{*} = (L_{Ft}^{*})^{1-\alpha}$$

$$Y_{Nt}^{*} = (L_{Nt}^{*})^{1-\alpha}$$

Price setting:

$$W_{Ht}^{r} = (1-\alpha)p_{Ht}L_{Ht}^{-\alpha}\frac{1}{1+\tau^{ER}}$$

$$W_{Nt}^{r} = (1-\alpha)p_{Nt}L_{Nt}^{-\alpha}\frac{1}{1+\tau^{ER}}$$

$$W_{Ft}^{r*} = (1-\alpha)p_{Ft}(L_{Ft}^{*})^{-\alpha}\frac{1}{1+\tau^{ER*}}$$

$$W_{Nt}^{r*} = (1-\alpha)p_{Nt}^{*}(L_{Nt}^{*})^{-\alpha}\frac{1}{1+\tau^{ER*}}$$

Resource constraints:

$$Y_{Ht} = C_{Ht} + \frac{1-n}{n}C_{Ht}^{*}$$

$$Y_{Ft}^{*} = C_{Ft}^{*} + \frac{n}{1-n}C_{Ft}$$

$$Y_{Nt} = C_{Nt}$$

$$Y_{Nt}^{*} = C_{Nt}^{*}$$

2.7.C Equilibrium Conditions with Rigidities

Prices are expressed relative to the consumer price level (e.g. $p_{Ht} \equiv P_{Ht}/P_t$). Real wages are defined as $W_t^r \equiv W_t/P_t$ and $\Pi_t = P_t/P_{t-1}$ holds. The real interest rate on bond holdings is defined as $R_t^r \equiv R_t P_t/P_{t+1}$. Since $P_t = P_t^*$ holds, the same transformation is applied to foreign prices and wages. The real exchange rate is one ($RS_t = 1$).

Euler equation:

$$C_t^{-\rho} = \beta C_{t+1}^{-\rho} R_t^r \frac{1+\tau_t^C}{1+\tau_{t+1}^C}$$

Complete asset markets:

$$(C_t)^{-\rho} = (C_t^*)^{-\rho} \frac{1+\tau_t^c}{1+\tau_t^{c*}}$$

Wage Phillips curves:

$$\left(\frac{1-\xi_w \left(\frac{W_{t-1}^r}{W_t^r} \frac{1}{\Pi_t} \right)^{1-\sigma}}{1-\xi_w} \right)^{\frac{1+\eta\sigma}{1-\sigma}} = \frac{g_{1t}}{g_{2t}}$$

$$g_{1t} = \frac{\sigma}{\sigma-1} \frac{1}{n} L_t^{1+\eta} + \beta \xi_w E_t \left[\left(\frac{W_{t+1}^r}{W_t^r} \Pi_{t+1} \right)^{\sigma(1+\eta)} g_{1t+1} \right]$$

$$g_{2t} = C_t^{-\rho} \frac{1-\tau_t^{EE}}{1+\tau_t^C} W_t^r \frac{1}{n} L_t + \beta \xi_w E_t \left[\left(\frac{W_{t+1}^r}{W_t^r} \Pi_{t+1} \right)^{\sigma-1} g_{2t+1} \right]$$

$$\left(\frac{1-\xi_w \left(\frac{W_{t-1}^{r*}}{W_t^{r*}} \frac{1}{\Pi_t} \right)^{1-\sigma}}{1-\xi_w} \right)^{\frac{1+\eta\sigma}{1-\sigma}} = \frac{g_{1t}^*}{g_{2t}^*}$$

$$g_{1t}^* = \frac{\sigma}{\sigma-1} \frac{1}{1-n} (L_t^*)^{1+\eta} + \beta \xi_w E_t \left[\left(\frac{W_{t+1}^{r*}}{W_t^{r*}} \Pi_{t+1} \right)^{\sigma(1+\eta)} g_{1t+1}^* \right]$$

$$g^*_{2t} = (C^*_t)^{-\rho} \frac{1 - \tau^{EE*}_t}{1 + \tau^{c*}_t} \frac{W^{r*}_t L^*_t}{1-n} + \beta \xi_w E_t \left[\left(\frac{W^{r*}_{t+1}}{W^{r*}_t} \Pi_{t+1} \right)^{\sigma-1} g^*_{2t+1} \right]$$

Consumption demand relationships:

$$C_{Ht} = \nu p_{Ht}^{-\phi} C_t$$

$$C_{Ft} = (1-\nu) p_{Ft}^{-\phi} C_t$$

$$C^*_{Ht} = \nu p_{Ht}^{-\phi} C^*_t$$

$$C^*_{Ft} = (1-\nu) p_{Ft}^{-\phi} C^*_t$$

Consumer price index:

$$1 = \nu p_{Ht}^{1-\phi} + (1-\nu) p_{Ft}^{1-\phi}$$

Production functions:

$$Y_t \Delta_t = L_t^{1-\alpha}$$

$$Y^*_t \Delta^*_t = (L^*_t)^{1-\alpha}$$

Real marginal costs:

$$MC^r_t = \frac{1}{1-\alpha} W^r_t L^\alpha_t (1 + \tau^{ER}_t)$$

$$MC^{r*}_t = \frac{1}{1-\alpha} W^{r*}_t L^{*\alpha}_t (1 + \tau^{ER*}_t)$$

Evolution of price dispersion:

$$\Delta_t = (1-\xi_p) \left(\frac{1 - \xi_p \left(\frac{p_{Ht-1}}{p_{Ht}} \frac{1}{\Pi_t} \right)^{1-\sigma}}{1-\xi_p} \right)^{\frac{\sigma}{\sigma-1}} + \xi_p \left(\frac{p_{Ht}}{p_{Ht-1}} \Pi_t \right)^{\sigma} \Delta_{t-1}$$

$$\Delta_t^* = (1-\xi_p)\left(\frac{1-\xi_p\left(\frac{p_{Ft-1}}{p_{Ft}}\frac{1}{\Pi_t}\right)^{1-\sigma}}{1-\xi_p}\right)^{\frac{\sigma}{\sigma-1}} + \xi_p\left(\frac{p_{Ft}}{p_{Ft-1}}\Pi_t\right)^{\sigma}\Delta_{t-1}^*$$

Price Phillips curves:

$$\left(\frac{1-\xi_p\left(\frac{p_{Ht-1}}{p_{Ht}}\frac{1}{\Pi_t}\right)^{1-\sigma}}{1-\xi_p}\right) = \frac{f_{1t}}{f_{2t}}$$

$$f_{1t} = \frac{\sigma}{\sigma-1}C_t^{-\rho}\frac{MC_t^r}{(1+\tau_t^C)}Y_t + \beta\xi_p E_t\left[\left(\frac{p_{Ht+1}}{p_{Ht}}\Pi_{t+1}\right)^{\sigma} f_{1t+1}\right]$$

$$f_{2t} = C_t^{-\rho}\frac{1}{1+\tau_t^C}Y_t p_{Ht} + \beta\xi_p E_t\left[\left(\frac{p_{Ht+1}}{p_{Ht}}\Pi_{t+1}\right)^{\sigma-1} f_{2t+1}\right]$$

$$\left(\frac{1-\xi_p\left(\frac{p_{Ft-1}}{p_{Ft}}\frac{1}{\Pi_t}\right)^{1-\sigma}}{1-\xi_p}\right) = \frac{f_{1t}^*}{f_{2t}^*}$$

$$f_{1t}^* = \frac{\sigma}{\sigma-1}\frac{MC_t^{r*}}{(1+\tau_t^{C^*})}\frac{Y_t^*}{(C_t^*)^{\rho}} + \beta\xi_p E_t\left[\left(\frac{p_{Ft+1}}{p_{Ft}}\Pi_{t+1}\right)^{\sigma} f_{1t+1}^*\right]$$

$$f_{2t}^* = \frac{1}{1+\tau_t^{C^*}}\frac{Y_t^*}{(C_t^*)^{\rho}}p_{Ft} + \beta\xi_p E_t\left[\left(\frac{p_{Ft+1}}{p_{Ft}}\Pi_{t+1}\right)^{\sigma-1} f_{2t+1}^*\right]$$

Monetary policy rule:

$$R_t^r = \Pi_t^{\mu} R\frac{1}{\Pi_{1+1}}$$

Resource constraints:

$$Y_t = C_{Ht} + \frac{1-n}{n}C_{Ht}^*$$

$$Y_t^* = C_{Ft}^* + \frac{n}{1-n}C_{Ft}$$

2.7.D Equilibrium Conditions of the Complete Model

Prices are expressed relative to the after-tax consumer price level of the respective country (e.g. $p_{Ht} \equiv P_{Ht}/(P_t(1+\tau_t^C)))$ and the union-wide price index is expressed as $p_{ut} \equiv P_{ut}/((1+\tau_t^c)P_t)$. Real marginal costs and real wages are defined as $MC_{kt}^r \equiv MC_{kt}/(P_t(1+\tau_t^C))$ and $W_{kt}^r \equiv W_{kt}/(P_t(1+\tau_t^C))$. The real interest factor on bond holdings and the real renting rate of capital are defined as $R_t^r \equiv R_t P_t(1+\tau_t^C)/(P_{t+1}(1+\tau_{t+1}^C))$ and $R_t^{cr} \equiv R_t^c/(P_t(1+\tau_t^C))$. The respective variables for the foreign country are defined analogously. The real after-tax exchange rate is defined as $RS_t \equiv P_t^*(1+\tau_t^{C*})/(P_t(1+\tau_t^C)$ and the after-tax home consumer price inflation reads $\Pi_t \equiv P_t(1+\tau_t^C)/(P_{t-1}(1+\tau_{t-1}^C))$.

Demand for consumption goods:

$$C_{Ht} = \nu \left(\frac{p_{Ht}}{p_{Tt}}\right)^{-\phi} C_{Tt}$$

$$C_{Ft} = (1-\nu)\left(\frac{p_{Ft}}{p_{Tt}} RS_t\right)^{-\phi} C_{Tt}$$

$$C_{Ht}^* = \nu^* \left(\frac{p_{Ht}}{p_{Tt}^*}\frac{1}{RS_t}\right)^{-\phi} C_{Tt}^*$$

$$C_{Ft}^* = (1-\nu^*)\left(\frac{p_{Ft}}{p_{Tt}^*}\right)^{-\phi} C_{Tt}^*$$

$$C_{Nt} = (1-\omega)\left(p_{Nt}\left(1+\tau_t^{C_N}\right)\right)^{-\epsilon} C_t$$

$$C_{Nt}^* = (1-\omega^*)\left(p_{Nt}^*\left(1+\tau_t^{C_N^*}\right)\right)^{-\epsilon} C_t^*$$

$$C_{Tt} = \omega\left(p_{Tt}\left(1+\tau_t^{C_T}\right)\right)^{-\epsilon} C_t$$

$$C_{Tt}^* = \omega^*\left(p_{Tt}^*\left(1+\tau_t^{C_T^*}\right)\right)^{-\epsilon} C_t^*$$

Demand for investment goods:

$$I_{Ht} = \nu \left(\frac{p_{Ht}}{p_{Tt}} \right)^{-\phi} I_{Tt}$$

$$I_{Ft} = (1-\nu) \left(\frac{p_{Ft}}{p_{Tt}} RS_t \right)^{-\phi} I_{Tt}$$

$$I^*_{Ht} = \nu^* \left(\frac{p_{Ht}}{p^*_{Tt}} \frac{1}{RS_t} \right)^{-\phi} I^*_{Tt}$$

$$I^*_{Ft} = (1-\nu^*) \left(\frac{p_{Ft}}{p^*_{Tt}} \right)^{-\phi} I^*_{Tt}$$

$$I_{Nt} = (1-\omega) \left(\frac{p_{Nt}}{p^I_t} \right)^{-\epsilon} I_t$$

$$I^*_{Nt} = (1-\omega^*) \left(\frac{p^*_{Nt}}{p^{I*}_t} \right)^{-\epsilon} I^*_t$$

$$I_{Tt} = \omega \left(\frac{p_{Tt}}{p^I_t} \right)^{-\epsilon} I_t$$

$$I^*_{Tt} = \omega^* \left(\frac{p^*_{Tt}}{p^{I*}_t} \right)^{-\epsilon} I^*_t$$

Price index for investment goods:

$$p^I_t = \left[\omega p_{Tt}^{1-\epsilon} + (1-\omega) p_{Nt}^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}$$

$$p^{I*}_t = \left[\omega^* (p^*_{Tt})^{1-\epsilon} + (1-\omega^*)(p^*_{Nt})^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}$$

Euler equation for consumption:

$$R_t^r = \frac{1}{\beta}\left(\frac{C_t}{C_{t+1}}\right)^{-\rho}$$

Euler equations for capital:

$$\left(\frac{C_t}{C_{t+1}}\right)^{-\rho} \frac{p_t^I}{p_{t+1}^I}\frac{1}{\beta}\left(1+\kappa\left(\frac{I_t}{Kt}-\delta\right)\right) - \frac{R_{t+1}^{cr}}{p_{t+1}^I}$$
$$= \left(1+\kappa\left(\frac{I_{t+1}}{K_{t+1}}-\delta\right)\right)(1-\delta) - \frac{\kappa}{2}\left(\frac{I_{t+1}}{K_{t+1}}-\delta\right)^2 + \kappa\left(\frac{I_{t+1}}{K_{t+1}}-\delta\right)\frac{I_{t+1}}{K_{t+1}}$$

$$\left(\frac{C_t^*}{C_{t+1}^*}\right)^{-\rho} \frac{p_t^{I*}}{p_{t+1}^{I*}}\frac{1}{\beta}\left(1+\kappa\left(\frac{I_t^*}{K_t^*}-\delta\right)\right) - \frac{R_{t+1}^{cr*}}{p_{t+1}^{I*}}$$
$$= \left(1+\kappa\left(\frac{I_{t+1}^*}{K_{t+1}^*}-\delta\right)\right)(1-\delta) - \frac{\kappa}{2}\left(\frac{I_{t+1}^*}{K_{t+1}^*}-\delta\right)^2 + \kappa\left(\frac{I_{t+1}^*}{K_{t+1}^*}-\delta\right)\frac{I_{t+1}^*}{K_{t+1}^*}$$

Perfect risk sharing:

$$RS_t = u\left(\frac{C_t^*}{C_t}\right)^{-\rho}$$

Wage Phillips curves:

$$\frac{g1_{Ht}}{g2_{Ht}} = \left(\frac{1-\xi_H^w\left(\frac{W_{Ht}^r}{W_{Ht-1}^r}\Pi_t\right)^{\sigma_H^w-1}}{1-\xi_H^w}\right)^{\frac{1+\eta\sigma_H^w}{1-\sigma_H^w}}$$

$$g1_{Ht} = \frac{\sigma_H^w}{\sigma_H^w-1}\frac{(L_{Ht})^{1+\eta}}{n^\eta} + \beta\xi_H^w E_t\left[\left(\frac{W_{Ht+1}^r}{W_{Ht}^r}\Pi_{t+1}\right)^{\sigma_H^w} g1_{Ht+1}\right]$$

$$g2_{Ht} = (1-\tau_t^{EE})\frac{W_{Ht}^r L_{Ht}}{C_t^\rho} + \beta\xi_H^w E_t\left[\left(\frac{W_{Ht+1}^r}{W_{Ht}^r}\Pi_{t+1}\right)^{\sigma_H^w-1} g2_{Ht+1}\right]$$

$$\frac{g1_{Nt}}{g2_{Nt}} = \left(\frac{1-\xi_N^w\left(\frac{W_{Nt}}{W_{Nt-1}}\Pi_t\right)^{\sigma_N^w-1}}{1-\xi_N^w}\right)^{\frac{1+\eta\sigma_N^w}{1-\sigma_N^w}}$$

$$g1_{Nt} = \frac{\sigma_N^w}{\sigma_N^w - 1}\frac{(L_{Nt})^{1+\eta}}{n^\eta} + \beta\xi_N^w E_t\left[\left(\frac{W^r_{Nt+1}}{W^r_{Nt}}\Pi_{t+1}\right)^{\sigma_N^w} g1_{Nt+1}\right]$$

$$g2_{Nt} = (1-\tau_t^{EE})\frac{W^r_{Nt}L_{Nt}}{C_t^\rho} + \beta\xi_N^w E_t\left[\left(\frac{W^r_{Nt+1}}{W^r_{Nt}}\Pi_{t+1}\right)^{\sigma_N^w - 1} g2_{Nt+1}\right]$$

$$\frac{g1^*_{Ft}}{g2^*_{Ft}} = \left(\frac{1-\xi_F^{w*}\left(\frac{W^*_{Ft}}{W^*_{Ft-1}}\frac{RS_{t-1}}{RS_t}\frac{1}{\Pi_t}\right)^{\sigma_F^{w*}-1}}{1-\xi_F^{w*}}\right)^{\frac{1+\eta\sigma_F^{w*}}{1-\sigma_F^{w*}}}$$

$$g1^*_{Ft} = \frac{\sigma_F^{w*}}{\sigma_F^{w*}-1}\frac{(L^*_{Ft})^{1+\eta}}{(1-n)^\eta} + \beta\xi_F^{w*} E_t\left[\left(\frac{W^{r*}_{Ft+1}}{W^{r*}_{Ft}}\frac{RS_t}{RS_{t+1}}\frac{1}{\Pi_{t+1}}\right)^{\sigma_F^{w*}} g1^*_{Ft+1}\right]$$

$$g2^*_{Ft} = (1-\tau_t^{EE*})\frac{W^{r*}_{Ft}L^*_{Ft}}{(C^*_t)^\rho} + \beta\xi_F^{w*} E_t\left[\left(\frac{W^{r*}_{Ft+1}}{W^{r*}_{Ft}}\frac{RS_t}{RS_{t+1}}\frac{1}{\Pi_{t+1}}\right)^{\sigma_F^{w*}-1} g2^*_{Ft+1}\right]$$

$$\frac{g1^*_{Nt}}{g2^*_{Nt}} = \left(\frac{1-\xi_N^{w*}\left(\frac{W^*_{Nt}}{W^*_{Nt-1}}\frac{RS_{t-1}}{RS_t}\frac{1}{\Pi_t}\right)^{\sigma_N^{w*}-1}}{1-\xi_N^{w*}}\right)^{\frac{1+\eta\sigma_N^{w*}}{1-\sigma_N^{w*}}}$$

$$g1^*_{Nt} = \frac{\sigma_N^{w*}}{\sigma_N^{w*}-1}\frac{(L^*_{Nt})^{1+\eta}}{(1-n)^\eta} + \beta\xi_N^{w*} E_t\left[\left(\frac{W^{r*}_{Nt+1}}{W^{r*}_{Nt}}\frac{RS_t}{RS_{t+1}}\frac{1}{\Pi_{t+1}}\right)^{\sigma_N^{w*}} g1^*_{Nt+1}\right]$$

$$g2^*_{Nt} = (1-\tau_t^{EE*})\frac{W^{r*}_{Nt}L^*_{Nt}}{(C^*_t)^\rho} + \beta\xi_N^{w*} E_t\left[\left(\frac{W^{r*}_{Nt+1}}{W^{r*}_{Nt}}\frac{RS_t}{RS_{t+1}}\frac{1}{\Pi_{t+1}}\right)^{\sigma_N^{w*}-1} g2^*_{Nt+1}\right]$$

Consumer price indexes:

$$1 = \omega\left(p_{Tt}\left(1+\tau_t^{C_T}\right)\right)^{1-\epsilon} + (1-\omega)\left(p_{Nt}\left(1+\tau_t^{C_N}\right)\right)^{1-\epsilon}$$

$$1 = \omega^*\left(p^*_{Tt}\left(1+\tau_t^{C^*_T}\right)\right)^{1-\epsilon} + (1-\omega^*)\left(p^*_{Nt}\left(1+\tau_t^{C^*_N}\right)\right)^{1-\epsilon}$$

Price index of tradable goods:

$$p_{Tt} = \left[\nu p_{Ht}^{1-\phi} + (1-\nu)(p_{Ft}RS_t)^{1-\phi}\right]^{\frac{1}{1-\phi}}$$

$$p_{Tt}^* = \left[\nu^* \left(\frac{p_{Ht}}{RS_t}\right)^{1-\phi} + (1-\nu^*)p_{Ft}^{1-\phi}\right]^{\frac{1}{1-\phi}}$$

Real marginal costs:

$$MC_{Ht}^r = W_{Ht}^r \frac{1+\tau_t^{ER}}{\alpha_T}\left(\frac{L_{Ht}}{K_{Ht}}\right)^{1-\alpha_T}$$

$$MC_{Nt}^r = W_{Nt}^r \frac{1+\tau_t^{ER}}{\alpha_{NT}}\left(\frac{L_{Nt}}{K_{Nt}}\right)^{1-\alpha_{NT}}$$

$$MC_{Nt}^{r*} = W_{Nt}^{r*} \frac{1+\tau_t^{ER*}}{\alpha_{NT}}\left(\frac{L_{Nt}^*}{K_{Nt}^*}\right)^{1-\alpha_{NT}}$$

$$MC_{Ft}^{r*} = W_{Ft}^{r*} \frac{1+\tau_t^{ER*}}{\alpha_T}\left(\frac{L_{Ft}^*}{K_{Ft}^*}\right)^{1-\alpha_T}$$

Labor cost minimization:

$$\frac{L_{Ht}}{K_{Ht}} = \frac{\alpha_T}{1-\alpha_T}\frac{R_t^{cr}}{(1+\tau_t^{ER})W_{Ht}^r}$$

$$\frac{L_{Nt}}{K_{Nt}} = \frac{\alpha_{NT}}{1-\alpha_{NT}}\frac{R_t^{cr}}{(1+\tau_t^{ER})W_{Nt}^r}$$

$$\frac{L_{Nt}^*}{K_{Nt}^*} = \frac{\alpha_{NT}}{1-\alpha_{NT}}\frac{R_t^{cr*}}{(1+\tau_t^{ER*})W_{Nt}^{r*}}$$

$$\frac{L_{Ft}^*}{K_{Ft}^*} = \frac{\alpha_T}{1-\alpha_T}\frac{R_t^{cr*}}{(1+\tau_t^{ER*})W_{Ft}^{r*}}$$

Aggregate production function:

$$Y_{Ht}\Delta_{Ht} = L_{Ht}^{\alpha_T} K_{Ht}^{1-\alpha_T}$$

$$Y_{Nt}\Delta_{Nt} = L_{Nt}^{\alpha_{NT}} K_{Nt}^{1-\alpha_{NT}}$$

$$Y_{Ft}^{*}\Delta_{Ft}^{*} = L_{Ft}^{\alpha_T} (K_{Ft}^{*})^{1-\alpha_T}$$

$$Y_{Nt}^{*}\Delta_{Nt}^{*} = L_{Nt}^{\alpha_{NT}} (K_{Nt}^{*})^{1-\alpha_{NT}}$$

Evolution of price dispersion:

$$\Delta_{Ht} = (1-\xi_H^p)\left(\frac{1-\xi_H^p\left(\frac{p_{Ht-1}}{p_{Ht}}\frac{1}{\Pi_t}\right)^{1-\sigma_H^p}}{1-\xi_H^p}\right)^{\frac{\sigma_H^p}{\sigma_H^p-1}} + \xi_H^p\left(\frac{p_{Ht}}{p_{Ht-1}}\Pi_t\right)^{\sigma_H^p}\Delta_{Ht-1}$$

$$\Delta_{Nt} = (1-\xi_N^p)\left(\frac{1-\xi_N^p\left(\frac{p_{Nt-1}}{p_{Nt}}\frac{1}{\Pi_t}\right)^{1-\sigma_N^p}}{1-\xi_N^p}\right)^{\frac{\sigma_N^p}{\sigma_N^p-1}} + \xi_N^p\left(\frac{p_{Nt}}{p_{Nt-1}}\Pi_t\right)^{\sigma_N^p}\Delta_{Nt-1}$$

$$\Delta_{Ft}^{*} = (1-\xi_F^{p*})\left(\frac{1-\xi_F^{p*}\left(\frac{p_{Ft-1}^{*}}{p_{Ft}^{*}}\frac{RS_{t-1}}{RS_t}\frac{1}{\Pi_t}\right)^{1-\sigma_F^{p*}}}{1-\xi_F^{p*}}\right)^{\frac{\sigma_F^{p*}}{\sigma_F^{p*}-1}}$$
$$+\xi_F^{p*}\left(\frac{p_{Ft}^{*}}{p_{Ft-1}^{*}}\frac{RS_t}{RS_{t-1}}\Pi_t\right)^{\sigma_F^{p*}}\Delta_{Ft-1}^{*}$$

$$\Delta_{Nt}^{*} = (1-\xi_N^{p*})\left(\frac{1-\xi_N^{p*}\left(\frac{p_{Nt-1}^{*}}{p_{Nt}^{*}}\frac{RS_{t-1}}{RS_t}\frac{1}{\Pi_t}\right)^{1-\sigma_N^{p*}}}{1-\xi_N^{p*}}\right)^{\frac{\sigma_N^{p*}}{\sigma_N^{p*}-1}}$$
$$+\xi_N^{p*}\left(\frac{p_{Nt}^{*}}{p_{Nt-1}^{*}}\frac{RS_t}{RS_{t-1}}\Pi_t\right)^{\sigma_N^{p*}}\Delta_{Nt-1}^{*}$$

Price Phillips curves:

$$\frac{f1_{Ht}}{f2_{Ht}} = \left(\frac{1 - \xi_H^p \left(\frac{p_{Ht-1}}{p_{Ht}} \frac{1}{\Pi_t} \right)^{1-\sigma_H^p}}{1 - \xi_H^p} \right)^{\frac{1}{1-\sigma_H^p}}$$

$$f1_{Ht} = \frac{\sigma_H^p}{\sigma_H^p - 1} C_t^{-\rho} Y_{Ht} MC_{Ht}^r + \beta \xi_H^p E_t \left\{ \left(\frac{p_{Ht+1}}{p_{Ht}} \Pi_{t+1} \right)^{\sigma_H^p} f1_{Ht+1} \right\}$$

$$f2_{Ht} = C_t^{-\rho} Y_{Ht} p_{Ht} + \beta \xi_H^p E_t \left\{ \left(\frac{p_{Ht+1}}{p_{Ht}} \Pi_{t+1} \right)^{\sigma_H^p - 1} f2_{Ht+1} \right\}$$

$$\frac{f1_{Nt}}{f2_{Nt}} = \left(\frac{1 - \xi_N^p \left(\frac{p_{Nt-1}}{p_{Nt}} \frac{1}{\Pi_t} \right)^{1-\sigma_N^p}}{1 - \xi_N^p} \right)^{\frac{1}{1-\sigma_N^p}}$$

$$f1_{Nt} = \frac{\sigma_N^p}{\sigma_N^p - 1} C_t^{-\rho} Y_{Nt} MC_{Nt}^r + \beta \xi_N^p E_t \left\{ \left(\frac{p_{Nt+1}}{p_{Nt}} \Pi_{t+1} \right)^{\sigma_N^p} f1_{Nt+1} \right\}$$

$$f2_{Nt} = C_t^{-\rho} Y_{Nt} p_{Nt} + \beta \xi_N^p E_t \left\{ \left(\frac{p_{Nt+1}}{p_{Nt}} \Pi_{t+1} \right)^{\sigma_N^p - 1} f2_{Nt+1} \right\}$$

$$\frac{f1_{Nt}^*}{f2_{Nt}^*} = \left(\frac{1 - \xi_N^{p*} \left(\frac{p_{Nt-1}^*}{p_{Nt}^*} \frac{RS_{t-1}}{RS_t} \frac{1}{\Pi_t} \right)^{1-\sigma_N^{p*}}}{1 - \xi_N^{p*}} \right)^{\frac{1}{1-\sigma_N^{p*}}}$$

$$f1_{Nt}^* = \frac{\sigma_N^{p*}}{\sigma_N^{p*} - 1} (C_t^*)^{-\rho} Y_{Nt}^* MC_{Nt}^{r*} + \beta \xi_N^{p*} E_t \left\{ \left(\frac{p_{Nt+1}^*}{p_{Nt}^*} \frac{RS_{t+1}}{RS_t} \Pi_{t+1} \right)^{\sigma_N^{p*}} f1_{Nt+1}^* \right\}$$

$$f2_{Nt}^* = (C_t^*)^{-\rho} Y_{Nt}^* p_{Nt}^* + \beta \xi_N^{p*} E_t \left\{ \left(\frac{p_{Nt+1}^*}{p_{Nt}^*} \frac{RS_{t+1}}{RS_t} \Pi_{t+1} \right)^{\sigma_N^{p*} - 1} f2_{Nt+1}^* \right\}$$

$$\frac{f1^*_{Ft}}{f2^*_{Ft}} = \left(\frac{1-\xi^{p*}_F \left(\frac{p^*_{Ft-1}}{p^*_{Ft}} \frac{RS_{t-1}}{RS_t} \frac{1}{\Pi_t} \right)^{1-\sigma^{p*}_F}}{1-\xi^{p*}_F} \right)^{\frac{1}{1-\sigma^{p*}_F}}$$

$$f1^*_{Ft} = \frac{\sigma^{p*}_F}{\sigma^{p*}_F - 1} (C^*_t)^{-\rho} Y^*_{Ft} MC^{r*}_{Ft} + \beta \xi^{p*}_F E_t \left\{ \left(\frac{p^*_{Ft+1}}{p^*_{Ft}} \frac{RS_{t+1}}{RS_t} \Pi_{t+1} \right)^{\sigma^{p*}_F} f1^*_{Ft+1} \right\}$$

$$f2^*_{Ft} = (C^*_t)^{-\rho} Y^*_{Ft} p^*_{Ft} + \beta \xi^{p*}_F E_t \left\{ \left(\frac{p^*_{Ft+1}}{p^*_{Ft}} \frac{RS_{t+1}}{RS_t} \Pi_{t+1} \right)^{\sigma^{p*}_F - 1} f2^*_{Ft+1} \right\}$$

Monetary policy:

$$1 + i_t = \left(\frac{p_{ut}}{p_{ut-1}} \Pi_t \right)^{\mu} (1 + \bar{i})$$

$$p_{ut} = s_{ct} + (1 - s_{ct}) RS_t$$

$$s_{ct} = \frac{nC_t}{nC_t + (1-n) RS_t C^*_t}$$

$$R^r_t = (1 + i_t) \frac{1}{\Pi_{t+1}}$$

Resource constraints:

$$Y_{Ht} = C_{Ht} + \frac{1-n}{n} C^*_{Ht} + I_{Ht} + \frac{1-n}{n} I^*_{Ht}$$

$$Y_{Nt} = C_{Nt} + I_{Nt}$$

$$Y^*_{Ft} = \frac{n}{1-n} C_{Ft} + C^*_{Ft} + \frac{n}{1-n} I_{Ft} + I^*_{Ft}$$

$$Y^*_{Nt} = C^*_{Nt} + I^*_{Nt}$$

$$K_t = K_{Ht} + K_{Nt}$$

$$K_t^* = K_{Ft}^* + K_{Nt}^*$$

Law of motion for capital:

$$K_{t+1} = (1 - \delta)K_t + I_t$$

$$K_{t+1}^* = (1 - \delta)K_t^* + I_t^*$$

2.7.D.1 Calibrated Parameters

n	0.57	Size of home country
β	0.995	Discount factor of home country
η	2	Inverse of labor supply elasticity
ρ	2	Inverse of intertemporal elasticity of substitution
ϕ	1.5	Elasticity of substitution between home and foreign tradables
ϵ	1.5	Elasticity of substitution between tradables and non-tradables
θ	0.95	Smoothing parameter of nominal interest rate
μ	2	Response parameter of monetary policy to union-wide inflation
δ	0.025	Depreciation rate of capital
κ	10	Capital adjustment cost parameter
ν	0.9	Weight of home-produced goods in home tradable consumption
ν^*	0.48	Weight of foreign-produced goods in foreign tradable cons.
u	0.46	Initial wealth distribution
ω	0.22	Weight of tradables in total consumption in home country
ω^*	0.39	Weight of tradables in total consumption in foreign country
s_H	0.59	Size of tradable sector in home country
s_F	0.62	Size of tradable sector in foreign country
σ_H^p	5.43	Elasticity of substitution between home tradable goods
σ_N^p	4.69	Elasticity of substitution between home non-tradable goods
σ_F^{p*}	7.05	Elasticity of substitution between foreign tradable goods
σ_N^{p*}	5.42	Elasticity of substitution between foreign non-tradable goods
σ_H^w	5.43	Elasticity of substitution in labor: home tradable sector
σ_N^w	4.69	Elasticity of substitution in labor: home non-tradable sector
σ_F^{w*}	7.05	Elasticity of substitution in labor: foreign tradable sector
σ_N^{w*}	5.42	Elasticity of substitution in labor: foreign non-tradable sector

Table 2.7: Calibrated parameters for the Euro area model (Part 1)

α_T	0.68	Labor share in tradable sector home country
α_{NT}	0.77	Labor share in non-tradable sector home country
α_T^*	0.64	Labor share in tradable sector foreign country
α_{NT}^*	0.77	Labor share in non-tradable sector foreign country
ξ_H^w	0.35	Degree of wage stickiness in home tradable sector
ξ_N^w	0.35	Degree of wage stickiness in home non-tradable sector
ξ_F^{w*}	0.29	Degree of wage stickiness in foreign tradable sector
ξ_N^{w*}	0.29	Degree of wage stickiness in foreign non-tradable sector
ξ_H^p	0.83	Degree of price stickiness in home tradable sector
ξ_N^p	0.76	Degree of price stickiness in home non-tradable sector
ξ_F^{p*}	0.74	Degree of price stickiness in foreign tradable sector
ξ_N^{p*}	0.75	Degree of price stickiness in foreign non-tradable sector

Table 2.8: Calibrated parameters for the Euro area model (Part 2)

τ^{EE}	0.1139	SSC paid by employees in home country
τ^{EE*}	0.1776	SSC paid by employees in foreign country
τ^{ER}	0.3156	SSC paid by employers in home country
τ^{ER*}	0.1841	SSC paid by employers in foreign country
τ^{C_T}	0.1397	VAT on tradable goods in home country
τ^{C_N}	0.0708	VAT on non-tradable goods in home country
$\tau^{C_T^*}$	0.1458	VAT on tradable goods in foreign country
$\tau^{C_N^*}$	0.0839	VAT on non-tradable goods in foreign country

Table 2.9: Baseline tax instruments for the Euro area model

2.7.E Data Sources and Construction

Intra-EU trade balance

For each country, the trade-balance-to-GDP ratios with respect to each of the remaining eleven countries are computed. This means the ratio of the difference between exports and imports between the two countries and the gross domestic product of the country under consideration is calculated. The intra-EA-12-trade-balance of an individual country is then defined as the sum of its trade-balance-to-GDP-ratios with each of the countries.

Tradable and non-tradable consumption

In defining goods and services as tradable or non-tradable, I build on Allington et al. (2006) who classify each COICOP (3 digit) category of goods and services as tradable or non-tradable. However, I exclude "Accommodation and food service activities" since the definition as tradable or non-tradable seems to be controversial: Christopoulou and Vermeulen (2008) classify this sector as tradable while Allington et al. (2006) define it to be non-tradable. Furthermore, "Education" is excluded as there is no fiscal sector modeled in the present paper. Finally, "Miscellaneous goods and services" are excluded as, on the one hand, averagely 56% of this category consist of financial services which are not modeled here and, on the other hand, it is a relatively broad definition while the share in total GDP is less then 3% on average. This way, the categories considered amount to 79% of total consumption on country-average. Table 2.10 shows the resulting classification.

Tradable and non-tradable production

I follow Piton (2017) in defining the GDP components as tradable or non-tradable. Piton (2017) computes degrees of tradability using data of 24 European countries for the period from 1995 to 2014 for 19 production sectors of the NACE classification. "Financial and insurance activities" is excluded since the model does not feature a financial sector as well as "Real Estate, Renting, Business Activities". Furthermore, "Community social and personal services" is excluded since Christopoulou and Vermeulen (2008) claim the absence of true markets to be problematic for estimating the respective mark-ups for these sectors and "Arts, entertainment, recreation and other service activities" are excluded since this is a relatively broad definition while their share in total GDP is averagely 2.6% only. Finally, "Accommodation and food service activities" is excluded since the definition as tradable or non-tradable seems to be contro-

COICOP	Definition	Class.
011	Food	T
012	Non-alcoholic beverages	T
021	Alcoholic beverages	T
022	Tobacco	T
023	Narcotics	T
031	Clothing	T
032	Footwear	T
041	Actual rentals for housing	NT
042	Imputed rentals for housing	NT
043	Maintenance and repair of the dwelling	NT
044	Water supply and miscellaneous services	NT
045	Electricity, gas and other fuels	NT
051	Furniture, furnishings, carpets, other floor coverings	T
052	Household textiles	T
053	Household appliances	T
054	Glassware, tableware and household utensils	T
055	Tools and equipment for house and garden	T
056	Goods and services for routine household maintenance	NT
061	Medical products, appliances and equipment	T
062	Out-patient services	NT
063	Hospital services	NT
071	Purchase of vehicles	T
072	Operation of personal transport equipment	T
073	Transport services	NT
081	Postal services	NT
082	Telephone and telefax equipment	T
083	Telephone and telefax services	NT
091	Audio-visual, photographic, information equipment	T
092	Other major durables for recreation and culture	T
093	Other recreational items, equipment, gardens, pets	T
094	Recreational and cultural services	NT
095	Newspapers, books and stationery	NT
096	Package holidays	NT

Table 2.10: Classification of tradable and non-tradable consumption

Definition	Class.
Agriculture, forestry and fishing	T
Mining and quarrying	T
Manufacturing	T
Electricity, gas, stream and air conditioning supply	NT
Water supply and waste management	NT
Construction	NT
Wholesale and retail trade	NT
Transportation and storage	T
Accommodation and food service activities	—
Information and communication	T
Financial and insurance activities	—
Real estate and social work activities	—
Professional, scientific and technical activities	T
Community social and personal services	—
Arts, entertainment, recreation and other service activities	—

Table 2.11: Classification of tradable and non-tradable production

versial as is explained above. This way, the sectors regarded amount to 85% of total GDP on average. Table 2.11 shows the respective classification of tradable and non-tradable production sectors.

Elasticity of substitution

Christopoulou and Vermeulen (2008) estimate price mark-ups for 50 categories of goods and services for eight EU-member countries using data from 1981 to 2004. Christopoulou and Vermeulen (2008) do not find a systematic change in mark-ups between the periods from 1981 to 1992 and 1993 to 2004 and, hence, give rise to the assumption that mark-ups do not change much over time. Consequently, it seems to be justifiable to use 2004 estimates to calibrate the model which is otherwise calibrated to 2015 data. For both country-groups, I construct the mark-up in the tradable and non-tradable sector, respectively, as a GDP-weighted cross-country average of these estimated mark-ups. Here, I use data from 2004 as in Christopoulou and Vermeulen (2008) since they used the NACE1 classification of industries to compute the respective mark-ups while the KLEMS data base uses the NACE1 classification only up to the 2009 release and switches to the NACE2 classification from the 2011 release on. Consequently, the mark-ups given by Christopoulou and Vermeulen (2008) could not be matched with 2015 production data. Furthermore, “Agriculture, hunting, forestry and fishing” as well as “Mining and Quarrying” are excluded since Christopoulou and Vermeulen (2008) do not calculate mark-ups for these categories. Data Source: EU KLEMS 2009 Release, updated March 2011.

Degree of wage rigidity

There is only few evidence on the degree of wage rigidity. Lunnemann and Wintr (2010) find that while there are large differences in wage rigidities between countries, there are only insignificant differences between sectors and Druant and Fabiani (2009) confirm this by stating that sectoral differences in wage rigidities are relatively small compared to prices but that there are large differences between countries. Hence, I assume the degree of wage stickiness to be the same across sectors for an individual country. Behr and Pötter (2010) and Knoppik and Beissinger (2009) both estimate the degree of wage rigidity in EU countries. While their results differ quantitatively, they obtain the same order of wage rigidities for the countries regarded in both studies (with the exception of Belgium), meaning that e.g. in both studies Spain has the lowest degree of wage rigidity. Here, I rely on the estimates of Knoppik and Beissinger (2009) since they regard 10 Euro zone countries while Behr and Pötter (2010) regard 7 only.

Social security contributions in the EA-12 countries

Tables 2.12 and 2.13 give the SSC rates for employers and employees, respectively, for the EA-12 countries from 2008 to 2016.[25] Regarding the employees' share in SSC, it can be seen that exclusively the Netherlands implemented a significant cut in the EESCC rate in 2014 amounting to 3.8 percentage points. In Ireland and Luxembourg the EESSC rate was increased by 0.8 percentage points in 2013 and 0.5 percentage points in 2015, respectively, while in Finland and France the EESSC has inclined steadily from 2008 to 2012 by 2.6 and 0.6 percentage points, respectively. In all other countries the EESSC rate stayed constant or fluctuated in the small range between 0.1 and 0.5 percentage points.

Regarding the employers' share in SSC, Table 2.13 shows that Belgium, France, and Greece featured a continuous decrease in the ERSSC rates while in Luxembourg the ERSSC rate was increased by 0.8 percentage points in 2011. In all other countries the ERSSC rates stayed constant or fluctuated in the small range

[25] Data source: OECD Tax Statistics (database).

	2008	2009	2010	2011	2012	2013	2014	2015	2016
AT	18.1	18.1	18.1	18.1	18.1	18.1	18.1	18.1	18.0
BE	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
FI	6.2	6.3	7.1	7.1	7.6	7.6	8.0	8.3	8.8
FR	13.7	13.7	13.7	13.7	13.7	13.8	14.1	14.2	14.3
DE	20.7	20.6	20.5	20.9	20.7	20.4	20.4	20.5	20.7
EL	16.0	16.0	16.0	16.2	16.5	16.5	16.0	15.5	15.8
IE	3.2	3.2	3.2	3.2	3.2	4.0	4.0	4.0	4.0
IT	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
LU	12.1	12.2	12.2	13.1	12.3	12.3	12.3	12.8	12.8
NL	17.4	15.2	15.5	15.3	15.2	18.9	17.3	13.1	13.5
PT	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
ES	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4

Table 2.12: Employees' SSC rates in EA-12 countries from 2008 to 2016 (in percent)

between 0.1 and 0.2 percentage points. France and Greece, however, decreased the ERSSC rate significantly from 2012 up to 2016 in the amount of 7.4 and 3.7 percentage points, respectively.

Overall, there are 4 countries which systematically decreased either their EESSC or ERSSC rate or both: the Netherlands, Finland, France, and Greece. Table 2.14 shows, however, that only the Netherlands, at the same time, significantly increased their VAT rate. In the reaming three countries the VAT rate was raised by 1 percentage point at the most. Consequently, there might be some indication of fiscal devaluations in France, Greece, and Finland, but only regarding the Netherlands there is substantial evidence of a fiscal devaluation which is, however, relatively small compared to the remaining EA-12 countries.

The VAT rate applied on tradable and non-tradable goods

The IAS et al. (2013b) calculated for each of the COICOP (3 digit) categories of goods and services an average VAT rate for private households in each of the EU member states in 2011. To check if these results may be applicable to the model otherwise calibrated to 2015 data, Table 2.14 shows changes in the reduced as well as the standard rate of VAT between 2011 and 2015 for each country regarded. It can be seen that while in Belgium, Germany, Austria, and Portugal the VAT rates stayed constant, Ireland, Greece, France, Italy, and the Netherlands increased the standard rate of VAT, but only to a relatively small

	2008	2009	2010	2011	2012	2013	2014	2015	2016
AT	29.0	29.1	29.1	29.1	29.1	29.1	29.1	28.9	28.9
BE	30.4	30.1	30.0	30.2	30.2	29.9	29.8	29.7	28.7
FI	24.0	23.0	22.3	22.5	22.8	22.8	23.1	22.4	23.1
FR	43.8	43.8	44.0	44.0	44.0	40.2	38.3	37.9	36.6
DE	19.5	19.5	19.3	19.7	19.6	19.3	19.3	19.3	19.3
EL	28.1	28.1	28.1	28.6	28.6	27.5	26.0	24.6	24.9
IE	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8
IT	32.1	32.1	32.1	32.1	32.1	32.1	32.1	32.1	31.9
LU	11.1	11.5	11.5	12.3	12.3	12.3	12.3	12.3	12.2
NL	10.5	10.0	10.4	10.2	10.8	9.8	10.7	10.6	11.2
PT	23.8	23.8	23.8	23.8	23.8	23.8	23.8	23.8	23.8
ES	30.2	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9

Table 2.13: Employers' SSC rates in EA-12 countries from 2008 to 2016 (in percent)

	Reduced rates		Standard rate
AT	0	0	0
BE	0	0	0
FI	1	1	1
FR	0	0	0.4
DE	0	0	0
EL	0	0	1
IE	0	0	2
IT	0	0	1
LU	0	2	2
NL	0	0	2
PT	0	0	0
ES	0	2	3

Table 2.14: Changes in VAT rates between 2011 and 2015 (in percentage points)

extent in the range between 0.4 and 2 percentage points which should not bias the results. Finland increased all three rates by one percentage point meaning that there will be no bias by using 2011 instead of 2015 data as all rates inclined by the same amount. Spain and Luxembourg, however, changed two of the rates in the amount of between 2 and 3 percentage points. For this reason, these two countries are excluded in computing the average VAT rates of the home country.

Scenario 1: The abolition of reduced VAT rates

The categories of goods and services for which reduced rates are assumed to be abolished and replaced by the standard rate are the following:
CP0432 – Services for the maintenance and repair of the dwelling
CP0441 – Water supply
CP0442 – Refuse collection
CP0444 – Other services relating to the dwelling
CP0451 – Electricity
CP0452 – Gas
CP0454 – Solid fuels
CP0455 – Heat energy
It can be seen that all subcategories belong to the 2-digit category "Housing, water, electricity, gas and other fuels". Average tax rates on all other categories are assumed to stay constant at their initial values calculated by the IAS et al. (2013a) as described above. Since data on consumption expenditure is available at a 3-digit COICOP classification only, however, I assume that each of the 4-digit subcategories belonging to a 3-digit category has the same size.

Scenario 2: The increase in the standard rate of VAT

I assume that the standard rate of VAT is raised by 3.1 percentage points while reduced rates remain unchanged. This means that in each category only goods and services subject to the standard rate are affected by the VAT increase while for goods and services to which reduced rates may be applied there is no change in taxation. As consumption data is only available for the COICOP 3-digit classification while the Council of the European Union allows the application of reduced rates referring to more specific categories, I approximate the share of goods and services subject to the standard rate in each category. Here, I use the relation of the average VAT rate for each COICOP 3-digit category to the initial (2011) standard rate of VAT as weight for each category.

3. Optimal Fiscal Policy under Private Debt Deleveraging[26]

3.1 Introduction

The impact of the global financial crisis has highlighted the importance of searching for novel policy measures as it has both disabled conventional monetary policy by driving interest rates almost to the zero lower bound (ZLB) and, at the same time, stated a situation featuring the pressing need for economy-stabilizing interventions. Beyond that, the foundation of the European currency union restrains monetary policy from taking a country-specific stabilization-role. Mainly two alternative measures possibly able to assume this role have been considered so far: Macroprudential tools aimed at financial stability – such as countercyclical capital requirements – and an optimal fiscal policy. While the former has been investigated in a rich set of different frameworks (see e.g. Schwanebeck and Palek (2006b), Levine and Lima (2015), and Quint and Rabanal (2013)), there is a surprisingly small literature on evaluating optimal fiscal policy measures in times of financial crises. And, more particularly, there is a even smaller literature regarding a crisis in the private debt sector. This seems to be of special interest, however, as private-debt-to-GDP ratios increased substantially between 1999 and 2009 in the US as well as in the Euro Area while a pronounced private debt deleveraging process can be observed ever since 2009.

This paper closes this gap by investigating and comparing constrained optimal fiscal policy reactions to a private debt deleveraging shock in a model with heterogeneous agents where monetary policy is constrained by the ZLB. Instead of modeling the financial sector explicitly, I use the shortcut proposed by Benigno et al. (2014) who define a private debt deleveraging shock as a decrease in the perceived risk-free debt level between savers and borrowers. This decline increases the spread between the interest rate savers obtain and the interest rate borrowers pay and, consequently, makes borrowing more costly. This way,

[26] A slightly different version of the chapter has been published in the “Journal of Economic Dynamics and Control” Vol. 97 (2018), https://doi.org/10.1016/j.jedc.2018.09.003

a private debt deleveraging process is simulated which allows to examine the success a constrained-optimal fiscal policy may have in eliminating the related welfare losses. Several issues are explored in this context: First, the effects of a deleveraging shock in the private sector are examined. Second, the effectiveness of optimal fiscal policy in reducing deleveraging-related welfare losses in a situation where monetary policy is constrained by the ZLB is investigated. Finally, the role of government spending as well as of the specific monetary policy conducted is examined.

The paper is related to various strands of literature: First, there is a literature on optimal fiscal policy during a financial crisis. Niemann and Pichler (2016) explore optimal fiscal policy in a small open economy in times of a belief-driven sovereign debt crisis with endogenous default. In contrast to the present paper, they abstract from private debt but regard a sovereign bond crisis. Eggertson (2001) explores optimal monetary and fiscal policy in a liquidity trap in a New-Keynesian model and Bilbiie et al. (2014) explore optimal government spending at the ZLB in a closed model. The current paper differs from these approaches by regarding distortionary taxes and allowing for heterogeneous agents.[27]

Second, the present paper is related to the strand of literature exploring optimal fiscal policy in models featuring some kind of heterogeneity as e.g. Evans (2014), Shourideh (2012), and Panousi and Reis (2014) who explore optimal capital taxation under idiosyncratic risk. Bilbiie et al. (2012) compare the effects of a debt-financed tax cut with a tax-financed increase in government spending in a model with savers and borrowers as in the present paper but focus on exogenous tax cuts. Furthermore, the current paper builds on Benigno et al. (2014) as it uses a model with savers and borrowers where the debt level decreases endogenously due to an increase in the risk-free debt level. The focus differs, however, as Benigno et al. (2014) regard optimal monetary policy while the present paper explores fiscal policy in a situation where the monetary policy is constrained by a zero lower bound. Moreover, there are a few papers modeling agents to be heterogeneous regarding productivity in the context of optimal fiscal policy as e.g. Bassetto (2014), Bhandari et al. (2016), Bhandari et al. (2017), and Werning (2007). All of these papers do, however, consider lump-sum or debt-financed income taxation as single instrument.

[27] Beyond that, there is a strand of literature exploring the effects of exogenous tax cuts or increases in government spending at zero interest rates as for example Eggertson (2009), Christiano et al. (2010), and Eggertson (2006). None of these papers does, however, consider the optimal fiscal policy but they investigate the effects of exogenously given policy actions.

Finally, the paper contributes to the small strand of literature regarding consumption taxes in addition to income taxation. While the distinction between capital and labor income taxes is examined in a wide range of different frameworks (see e.g. Werning (2007), Fasolo (2014), Chari and Kehoe (1998), and Le Grand and Ragot (2017)), consumption taxes have been considered quite infrequently. One of the few exceptions is Vasilev (2016) who finds that consumption taxes may play an important role in determining optimal fiscal policy but, in contrast to the present paper, focuses on steady-state results and regards homogenous agents.

The main contributions of the present paper are the following: First, it is shown that a private debt deleveraging shock implies economy-wide welfare losses. Second, while monetary policy being constrained by the ZLB implies a sizable welfare loss if the economy is hit by a deleveraging shock, optimal fiscal policy can be highly effective in this setup. Third, following the optimal fiscal policy implies a prolonged stay at the ZLB. Moreover, the welfare gains of having government spending as an additional instrument are found to be small compared to the total welfare gains of applying an optimal instead of an exogenous fiscal policy. Finally, if fiscal policy is set optimally, conducting an optimal monetary policy need not necessarily imply welfare gains relative to following a simple inflation-targeting policy depending on the fiscal instruments used.

The remainder of the paper is organized as follows: In the next section, the model as well as both the Ramsey and the Social planner's maximization problem is described. Section 3.3 contains the simulation results, first, for the simple case of flexible prices and, following, for the case with price rigidity and the presence of the ZLB. Sections 3.4 and 3.5 explore the role of government spending and monetary policy. A sensitivity analysis can be found in Section 3.6 while Section 3.7 concludes.

3.2 The Model

3.2.1 Decentralized Equilibrium

The model consists of a closed economy populated by two types of households – savers and borrowers. There is a mass s of savers and $1-s$ of borrowers. Monopolistically competitive firms produce a single good and the fiscal authority has access to two types of distortionary taxes: a consumption tax and a wage tax.

Households

Households seek to maximize the following increasing and concave utility function which is twice continuously differentiable

$$U_0^h = E_0 \sum_{t=0}^{\infty} (\beta^h)^t \left\{ \left[1 - \exp(-zC_t^h)\right] - \frac{(L_t^h)^{1+\eta}}{1+\eta} \right\}, \tag{3.1}$$

with $h = s, b$ denoting savers and borrowers, respectively, and $0 < \beta^h < 1$. C_t^h and L_t^h are consumption and labor per saver or borrower, respectively. Here, $\eta > 0$ denotes the inverse of the Frisch elasticity of labor supply and $z > 0$ holds.

Borrowers have to pay a risk premium on debt, $\Phi(D_t^b)$, which takes the following form

$$\Phi(D_t^b) = 1 + \phi \exp\left(\frac{D_t^b}{\bar{D}_t^b} - 1\right) - \phi, \tag{3.2}$$

where D_t^b denotes per borrower debt given in real terms (meaning nominal debt divided by the price level) and ϕ is a scaling factor determining the extent to which the interest spread reacts to relative changes in the debt levels. Following Benigno et al. (2014), $\bar{D}_t^b$ can be interpreted as the perceived risk-free debt level meaning that if debt of borrowers is equal to this risk-free level ($D_t^b = \bar{D}_t^b$) there is no risk premium at all. For each $D_t^b > \bar{D}_t^b$ borrowers will pay a positive risk premium increasing in the level of debt. A deleveraging shock is defined as an exogenous and permanent decrease in this risk-free debt level. This approach differs from studies on deleveraging as e.g. Eggertson and Krugman (2012) since it implies that the debt level decreases endogenously and, thus, adjusts over time in response to a decrease in the risk-free debt level. Consequently, during the transition process, the debt level can (and will) be different from the risk-free debt level while the modeling assumption of Eggertson and Krugman (2012) implies that the debt level always is equivalent to the borrowing constraint.

The risk premium can be seen as charged by a financial intermediary which is owned by the savers and implies that the interest rate paid by borrowers is given by

$$1 + i_t^b = (1 + i_t)\Phi(D_t^b), \tag{3.3}$$

where i_t denotes the nominal interest rate of savers.

Savers consume the consumption good C_t^s, supply labor L_t^s, and have access to non-state-contingent private bonds. They have to pay a consumption tax τ_t^c on goods and a wage tax τ_t^w on their labor income. Furthermore, savers receive lump-sum transfers T_t^s, yield dividends from firms Div_t, and collect the risk premium RP_t paid by private borrowers (all written in real terms).[28] Consequently, the per saver budget constraint for savers can be written in real terms as

$$\frac{B_{t-1}^s}{\Pi_t} + (1 - \tau_t^w)W_t^s L_t^s = \frac{B_t^s}{1 + i_t} + (1 + \tau_t^c)C_t^s - Div_t - RP_t - T_t^s, \tag{3.4}$$

with

$$RP_t = \left(\frac{1}{1 + i_t} - \frac{1}{1 + i_t^b}\right) B_t^s,$$

where B_t^s are nominal bonds per saver divided by the price level and $\Pi_t \equiv \frac{P_t}{P_{t-1}}$.

Maximizing (3.1) subject to (3.3) and (3.4) delivers the following Euler equation for bond holdings and labor supply equation for savers:

$$\exp(-zC_t^s) = \beta^s E_t \left\{ \exp(-zC_{t+1}^s)(1 + i_t)\frac{1}{\Pi_{t+1}}\frac{1 + \tau_t^c}{1 + \tau_{t+1}^c} \right\} \tag{3.5}$$

and

$$(L_t^s)^\eta = W_t^s z \exp(-zC_t^s)\frac{1 - \tau_t^w}{1 + \tau_t^c}. \tag{3.6}$$

For borrowers, the per borrower budget constraint reads

$$\frac{D_t^b}{1 + i_t^b} + (1 - \tau_t^w)W_t^b L_t^b = (1 + \tau_t^c)C_t^b + \frac{D_{t-1}^b}{\Pi_t} - Div_t - T_t^b. \tag{3.7}$$

Maximizing (3.1) subject to (3.7) gives the Euler equation and labor supply for borrowers as

$$\exp(-zC_t^b) = \beta^b E_t \left\{ \exp(-zC_{t+1}^b)\frac{1 + i_t^b}{\Pi_{t+1}}\frac{1 + \tau_t^c}{1 + \tau_{t+1}^c}\left[1 - D_t^b \frac{\Phi_t'}{\Phi_t}\right]^{-1} \right\} \tag{3.8}$$

[28] Div_t and RP_t are assumed to depend on the average per capita levels of dividends and risk premia, respectively, such that agents do not internalize the fact that their dividend and risk premium income depends on their own levels of consumption and bond holdings.

and

$$(L_t^b)^\eta = W_t^b z \exp(-zC_t^b) \frac{1-\tau_t^w}{1+\tau_t^c}. \tag{3.9}$$

Production

There is a continuum of monopolistically competitive firms of unit mass each producing a differentiated good facing Rotemberg-type adjustment costs and being subject to the production function

$$Y_t(j) = (L_t^s(j))^s (L_t^b(j))^{1-s},$$

with $Y_t(j)$ being per capita output of firm j where it is assumed that output is a Cobb-Douglas aggregate of the two types of labor. The demand for the individual good produced by firm j is given by

$$Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\theta} Y_t,$$

where $P_t(j)$ is the price chosen by firm j and $\theta > 0$ is the elasticity of substitution between differentiated goods. It is assumed that firms pay a quadratic price adjustment cost following Rotemberg (1982) which is given by

$$PAC_t(j) = \frac{\kappa}{2}\left(\frac{P_t(j)}{P_{t-1}(j)}\right)^2 Y_t$$

with $\kappa > 0$. The respective Lagrangian for the firms' optimization problem reads

$$\begin{aligned}\Lambda = E_0 \sum_{t=0}^{\infty} \beta^t u_{ct} \Bigg\{ & \frac{P_t(j)}{P_t} Y_t(j) - sW_t^s L_t^s - (1-s) W_t^b L_t^b - PAC_t(j) \\ & - MC_t(j) \left[Y_t(j) - (L_t^s(j))^s \left(L_t^b(j)\right)^{1-s} \right] \Bigg\},\end{aligned}$$

where $u_{ct} = s\exp(-zC_t^s) + (1-s)\exp(-zC_t^b)$. The respective first order conditions with respect to $P_t(j)$, $L_t^s(j)$, and $L_t^b(j)$ can be obtained to read

$$\begin{aligned} & u_{ct}(1-\theta) Y_t(j) \frac{1}{P_t} - \kappa \left(\frac{P_t(j)}{P_{t-1}(j)} - 1\right) \frac{1}{P_{t-1}(j)} u_{ct} Y_t \\ & + \beta u_{ct+1} \kappa \left(\frac{P_{t+1}(j)}{P_t(j)} - 1\right) \frac{P_{t+1}(j)}{(P_t(j))^2} Y_{t+1} + MC_t(j) u_{ct} \theta \frac{1}{P_t} Y_t = 0, \end{aligned}$$

$$W_t^s = MC_t(j) \left(\frac{L_t^b(j)}{L_t^s(j)}\right)^{1-s},$$

and

$$W_t^b = MC_t(j)\left(\frac{L_t^s(j)}{L_t^b(j)}\right)^s.$$

Rearranging the first order conditions and using that in equilibrium all firms choose the same price and labor inputs delivers

$$L_t^s W_t^s = L_t^b W_t^b, \tag{3.10}$$

$$W_t^s = MC_t\left(\frac{L_t^b}{L_t^s}\right)^{1-s}, \tag{3.11}$$

and

$$1-\kappa(\Pi_t-1)\Pi_t+\beta\kappa\frac{u_{ct+1}}{u_{ct}}\left(\Pi_{t+1}-1\right)\Pi_{t+1}\frac{Y_{t+1}}{Y_t}=\theta\left(1-MC_t\right). \tag{3.12}$$

The aggregate production function is given by

$$Y_t = (L_t^s)^s (L_t^b)^{1-s} \tag{3.13}$$

and dividends are given by

$$Div_t = Y_t - sW_t^s L_t^s - (1-s)W_t^b L_t^b - PAC_t. \tag{3.14}$$

Monetary policy

The monetary authority is assumed to follow an inflation-targeting policy but is constrained by the ZLB such that

$$\Pi_t = \bar{\Pi} \tag{3.15}$$

if $i_t > 0$ and $i_t = 0$ otherwise applies, where $\bar{\Pi}$ is the target inflation rate.

Government

The government levies consumption and wage taxes and transfers lump-sum payments to households such that the government budget reads

$$T_t = \tau_t^c(sC_t^s + (1-s)C_t^b) + \tau_t^w W_t L_t, \tag{3.16}$$

where $T_t \equiv T_t^s = T_t^b$ and $W_t L_t \equiv W_t^s L_t^s = W_t^b L_t^b$ holds.

Equilibrium

The resource constraint for the consumption good gives

$$Y_t = sC_t^s + (1-s)C_t^b + \frac{\kappa}{2}(\Pi_t - 1)^2 Y_t \tag{3.17}$$

and equilibrium in the asset market requires

$$sB_t^s = (1-s)D_t^b.$$

By combining the budget constraint of borrowers (3.7), with equations (3.14), (3.16), and (3.17), the evolution of debt can be expressed as

$$\frac{D_t^b}{1+i_{t-1}^b} - \frac{D_{t-1}^b}{\Pi_t} = (1+\tau_t^c)s(C_t^b - C_t^s). \tag{3.18}$$

An exogenous policy equilibrium of the model is defined by a set of the 12 equations (3.3), (3.5), (3.6), (3.8), (3.9), (3.10), (3.11), (3.12), (3.13), (3.15), (3.17), and (3.18) determining the 12 variables C_t^s, C_t^b, L_t^s, L_t^b, Y_t, W_t^s, W_t^b, MC_t, D_t^b, Π_t, i_t^b, i_t, given the fiscal instruments τ_t^c and τ_t^w and equation (3.2) defining the risk premium.

3.2.2 Ramsey Planner and Social Planner

In this section, the constrained-optimal fiscal policy by means of a Ramsey planner's problem is considered. The Ramsey planner maximizes the discounted weighted sum of the borrowers' and savers' utilities but is constrained by the private sector's behavior. Consequently, the Ramsey policy is defined as a sequence of policies maximizing $E_0 \sum_{t=0}^{\infty} \beta^t U_t$ with $\beta \equiv s\beta^s + (1-s)\beta^b$ and

$$U_t \equiv \widetilde{s}\left[1 - \exp(-zC_t^s) - \frac{(L_t^s)^{1+\eta}}{1+\eta}\right] + (1-\widetilde{s})\left[1 - \exp(-zC_t^b) - \frac{(L_t^b)^{1+\eta}}{1+\eta}\right] \tag{3.19}$$

subject to (3.2), (3.3), (3.5), (3.6), (3.8), (3.9), (3.10), (3.11), (3.12), (3.13), (3.15), (3.17), and (3.18) with respect to C_t^s, C_t^b, L_t^s, L_t^b, Y_t, W_t^s, W_t^b, MC_t, D_t^b, Π_t, i_t^b, i_t, Φ_t as well as one or two of the fiscal instruments τ_t^c and τ_t^w. Here, $\widetilde{s}$ is a parameter determining the relative weight of the savers' utility in the objective function. It is set to ensure that the initial steady state is constrained-efficient as outlined in the following. Due to the complexity of the model, I refrain from solving the Ramsey problem using the primal approach but formulate the Ramsey planner to choose policy variables and allocation simultaneously. A detailed description of the Ramsey problem as well as the solution method can be seen in Appendix A. The Ramsey planner's problem will be solved from a timeless perspective following Woodford (2003). Due to this feature, the initial steady state must be regarded carefully. Welfare analysis will only be meaningful if starting in the efficient steady state since any other starting point implies the government having an incentive to deviate from its initial policy. For this reason, the three different equilibria – exogenous policy, Ramsey planner, and Social planner – will be considered in greater detail and conditions will be obtained under which all three will start in the efficient steady state.

The Social planner maximizes the weighted sum of utilities of savers and borrowers given in equation (3.19) subject to the resource constraint (3.17) and the aggregate production function (3.13) with respect to C_t^s, C_t^b, L_t^s, L_t^b, Y_t, and Π_t. Rearranging the first order conditions gives the Social planner's equilibrium as[29]

$$C_t^s = C_t^b - \ln\left(\frac{1-\widetilde{s}}{1-s}\frac{s}{\widetilde{s}}\right)\frac{1}{z} \tag{3.20}$$

$$L_t^s = L_t^b\left(\frac{1-\widetilde{s}}{1-s}\frac{s}{\widetilde{s}}\right)^{\frac{1}{1+\eta}} \tag{3.21}$$

$$\left(L_t^b\right)^\eta = z\exp(-zC_t^b)\left(\frac{s}{\widetilde{s}}\frac{1-\widetilde{s}}{1-s}\right)^{\frac{s}{\eta(1+\eta)}} \tag{3.22}$$

$$\Pi_t = 1 \tag{3.23}$$

together with (3.13) and (3.17). This shows that if $\widetilde{s} = s$ is set, consumption and labor will be distributed equally between savers and borrowers ($C_t^s = C_t^b$ and $L_t^s = L_t^b$) such that both groups would have the same utility level.

The Ramsey allocation is given by the same equations as the exogenous policy equilibrium but extended by the Ramsey-FOC. The Ramsey allocation will be equivalent to the exogenous policy equilibrium if the latter is efficient since in this case fiscal authorities have no incentive to deviate from this allocation. A comparison of the exogenous policy equilibrium defined in the last section with the Social planner's equilibrium conditions obtained above shows that three conditions have to be fulfilled to ensure efficiency of the exogenous policy equilibrium:[30]

$$\frac{1}{(1+\tau_t^c)s}\left(\frac{D_t^b}{1+i_t^b} - D_{t-1}^b\right) = \ln\left(\frac{1-\widetilde{s}}{1-s}\frac{s}{\widetilde{s}}\right)\frac{1}{z}, \tag{3.24}$$

[29]The derivation of the Social planner's equilibrium conditions can be found in Appendix B.
[30]A description of the derivation of the efficiency-conditions can be seen in Appendix C.

$$\tau_t^w = 1 - \frac{\theta}{\theta - 1}(1 + \tau_t^c), \tag{3.25}$$

and

$$\Pi_t = 1. \tag{3.26}$$

Concerning steady states, equation (3.24) shows that if $\widetilde{s} = s$ held, the Ramsey steady state could only be efficient if assets are in net zero supply. In the Ramsey steady state, however, equation (3.15) determines steady-state inflation to be $\bar{\Pi}$ and (3.5) determines the nominal interest rate to be $i = 1/\beta^s\bar{\Pi} - 1$ such that the steady-state version of (3.8) combined with (3.3) and the definition of the risk premium (3.2) determine the steady-state level of debt to be equal to the risk-free debt level ($D^b = \bar{D}^b$) which is calibrated to be non-zero.[31]

To ensure that the initial steady state, nevertheless, is constrained-efficient even if $D^b = \bar{D}^b \neq 0$ holds, I follow Benigno and Nistico (2013) and assume that the weight used in the social welfare function are biased in that $\widetilde{s} \neq s$ holds. This means that the Social planner does not use the share of savers as weight in the social welfare function. More precisely, $\widetilde{s}$ is set to be 0.3931 as this exactly ensures that the initial steady state is constrained-efficient. This leads to a political bias in the amount of $\widetilde{s} - s = 0.0031$. This bias is taken as given during all simulation scenarios, such that each policy reaction to a deleveraging shock explored in the following is computed using $\widetilde{s} = 0.3931$ as weight in the social welfare function.

In contrast, by setting $\widetilde{s} = s$, efficiency would (by means of equations (3.20) and (3.21)) require that $C^b = C^s$ and $L^b = L^s$ hold. This, however, states an allocation which cannot be reached by the Ramsey planner as he is subject to the individuals' decision making – who differ their in discount factors ($\beta^s \neq \beta^b$) – and cannot transfer funds between agents.

Furthermore, I choose the inflation target to be one ($\bar{\Pi} = 1$) to eliminate steady-state price-setting inefficiencies and ensure that the third efficiency condition (3.26) is fulfilled in steady state. In each exogenous policy scenario, I set the consumption tax rate to be zero ($\tau^c = 0$), the wage tax to match (3.25) and use $\widetilde{s} = 0.3931$. This way, it is ensured that all policies start in the same (constrained-efficient) steady state.

[31] I set $\beta^s/\beta^b = 1/(1 - \phi)$ to ensure that $D^b = \bar{D}^b$ holds in steady state.

3.3 Simulation

3.3.1 The Case of Flexible Prices

To explore the mechanisms of a deleveraging shock as well as of the Ramsey-optimal policy reactions, I will start by considering the case with flexible prices and without the existence of the ZLB as an illustrative example, meaning κ is set to be zero. The assumption of output being a Cobb-Douglas aggregate of the two labor types implies that combining equations (3.6), (3.9), (3.10), (3.11), (3.13), and (3.17), with flexible prices, output can be written as

$$Y_t^{\eta} \exp(zY_t) = z\frac{\theta - 1}{\theta}\frac{1-\tau_t^w}{1+\tau_t^c}. \tag{3.27}$$

This shows that under flexible prices (for each $\tau_t^c \neq -1$) output is uniquely defined as a function of the two tax rates and otherwise independent of financial variables as well as of consumption.

β^s	0.996	Discount factor of savers
β^b	0.95	Discount factor of borrowers
$\bar{D}^b/Y$	1	Initial debt-to-GDP ratio
s	0.39	Share of savers
ϕ	0.025	Debt elastic risk-premium parameter
η	0.5	Inverse of labor supply elasticity
z	2.5	Weight of consumption in utility
$\bar{\Pi}$	1	Inflation target

Table 3.1: Parametrization

As the paper builds on a simple model and focuses on a qualitative evaluation, I abstract from calibrating the parameters but choose a parametrization roughly in line with related literature. Here, I set ϕ to be 0.025 where ϕ determines the impact of a variation in the relative debt level on the interest spread. Furthermore, I set $\beta^s = 0.996$ and $\beta^b = (1-\phi)\beta^s = 0.95$ to ensure that $D^b = \bar{D}^b$ holds in steady state which implies an annual interest rate of roughly 1.6%. I follow Justiano et al. (2015) and define the share of savers, s, to be 0.39. The inflation target $\bar{\Pi}$ is set to be one implying that there is no monopolistic distortion as long as the ZLB does not bind such that inflation equals the target inflation. The inverse of the labor supply elasticity, η, is set to be 0.5 and the weight of

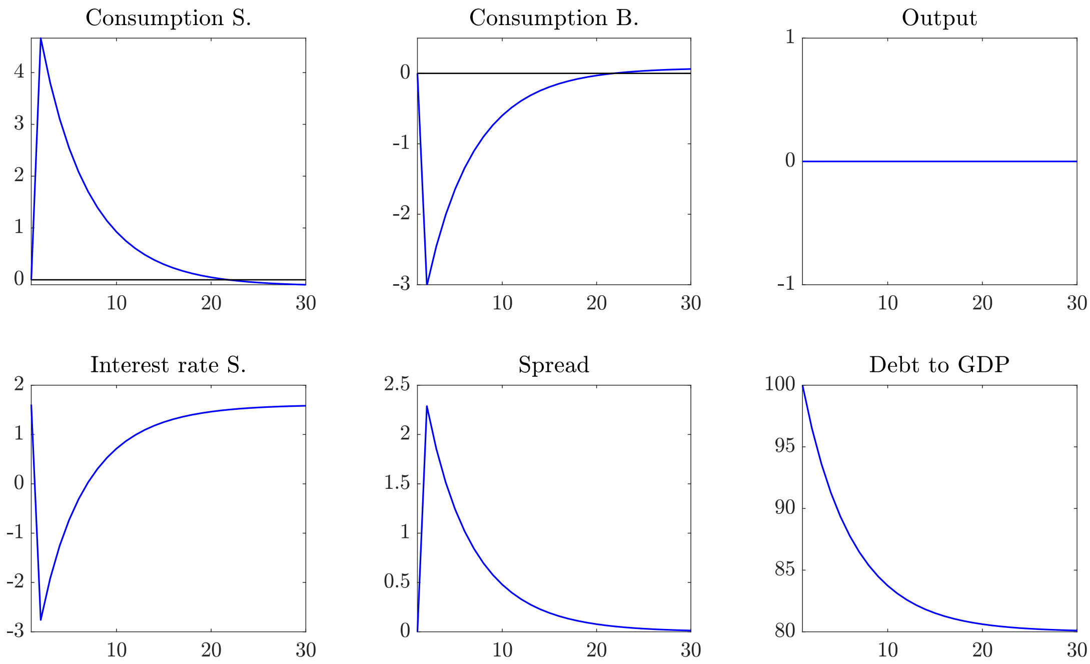

Figure 3.1: Deleveraging under an exogenous fiscal policy. For consumption and output percentage changes are given. The interest rate is measured in percent. “Spread” is defined as the difference between the interest rates of borrowers and savers in percentage points. For debt, the debt-to-GDP ratio (D_t/Y_t) is given in percent.

consumption in utility, z, is set to be 2.5. Regarding the initial risk-free debt level as well as the size of the deleveraging shock, I set $\bar{D}^b$ to match an initial steady-state debt-to-GDP ratio of 100% and calibrate the deleveraging shock to reduce the debt-to-GDP ratio by 20 percentage points. Table 3.1 gives an overview about the parameter values.

Exogenous policy

As a starting point, Figure 3.1 gives the effects of a deleveraging shock on consumption, output, interest rates, and the debt level under an exogenous policy which means that both tax instruments are held constant at their initial steady-state values ($\tau_t^w = -0.2$ and $\tau_t^c = 0$).[32] Starting with the effects on the borrowers' behavior, the reduction in the perceived risk-free debt level induces the interest spread to rise. As a consequence, borrowers reduce consumption and start to pay down their debt. This, in turn, reduces the savers' nominal interest rate such that savers have an incentive to both reduce their bond holdings and increase consumption. Over time, the reduction in the debt level induces the

[32] The model is solved by applying a Newton-type method via Dynare which solves the nonlinear system of simultaneous equations containing the equilibrium conditions including, in case of the constrained-optimal policy, the Ramsey FOCs.

spread to decline and return to zero as the debt level reaches the new risk-free debt level. Output remains constant since equation (3.27) showed that it exclusively depends on the two tax instruments which are fixed in this scenario.

In the long-run, consumption of borrowers remains slightly higher and consumption of savers is somewhat smaller than in the initial steady state (more precisely, consumption of savers is decreased by 0.12% in the long-run and consumption of borrowers increases by 0.08%). This is due to the fact that the steady-state version of the evolution of debt (3.18) determines the borrowers' consumption as a function of interest payments on outstanding debt and output. As outlined above, output remains constant and interest rates convert to their initial steady-state level, but the debt level declines permanently. Consequently, consumption of borrowers is higher in the low-debt-level steady state than in the high-debt-level steady state. Starting from an initially efficient steady state, this implies that the new consumption levels are inefficient (since the efficient allocation is independent of the debt level). For this reason, in the following, utility losses will be considered in greater detail.

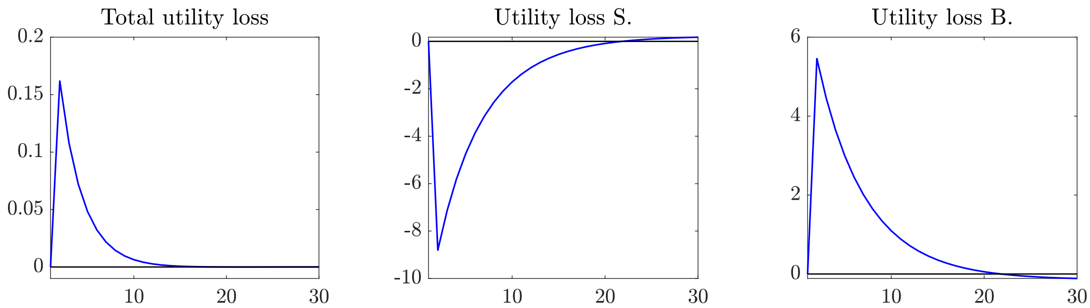

Figure 3.2: Period-by-period consumption-equivalent utility losses (in percent) of a deleveraging shock under an exogenous policy in the simple model with flexible prices.

Figure 3.2 gives period-by-period consumption-equivalent utility losses of being exposed to a deleveraging shock relative to staying in the steady state for both groups of agents separately as well as on an aggregate.[33] It can be seen that during the deleveraging process savers feature a utility gain of about 8.80% of initial steady-state consumption at its peak while borrowers loose in the amount of about 5.46%. On an economy-wide level, the utility loss amounts to about 0.16% at the maximum. In the long-run, however, the effects are reversed: Savers feature a small utility loss of about 0.23% while borrowers are slightly better off than in the initial steady state with a permanent utility gain of about

[33]Regarding aggregate utility losses, the social welfare measure given in equation (3.19) is used. The definition of all utility measures can be seen in detail in Appendix D.

0.15%. Again, this is due to the fact that with a lower debt level, steady-state payments on outstanding debt will be lower than with a high debt level which results in a higher consumption level of borrowers.

Regarding cumulative effects, lifetime utility losses can be computed defined as the percentage share of initial steady-state consumption an agent would be willing to give up in the initial period in order to be indifferent between the corresponding constant steady-state-level stream of consumption and labor and the stream of consumption and labor that will result if a deleveraging shock hits the economy. It can be observed that both agents loose from being exposed to a deleveraging shock in the amount of 7.68% in the case of savers and 20.49% of initial steady-state consumption in the case of borrowers. Even on an aggregate level, the economy as a whole features a utility loss in the amount of 0.46%. These results state the benchmark for a comparison with outcomes of optimal fiscal policy measures as is explored in the following.

Ramsey-optimal policy

I start with considering a Ramsey-optimal policy where the Ramsey planner has access to both wage and consumption taxes. In the baseline case of flexible prices and without the existence of the ZLB, the efficiency conditions (3.24), (3.25), and (3.26) obtained in the last section can be fulfilled simultaneously which means that the Ramsey-optimal policy is equivalent to the efficient policy. To obtain the optimal policy reaction of the Ramsey planner to a deleveraging shock, it should be regarded that the efficient allocation given by equations (3.20) to (3.23) is independent of the debt level as well as of interest rates. This means that the efficient allocation will not be affected by the deleveraging shock. Consumption and labor will remain constant. Under the Ramsey policy, this implies that the Euler equations of borrowers and savers collapse to

$$\frac{1}{\beta^b} = \frac{(1+i_t)\Phi_t}{\Pi_{t+1}} \frac{1+\tau_t^c}{1+\tau_{t+1}^c} \left(1 - D_t^b \frac{\Phi_t'}{\Phi_t}\right)^{-1} \tag{3.28}$$

and

$$\frac{1}{\beta^s} = \frac{1+i_t}{\Pi_{t+1}} \frac{1+\tau_t^c}{1+\tau_{t+1}^c}. \tag{3.29}$$

Combining both conditions and recalling the interest spread function (3.2) shows that the debt level must be equal to the risk-free debt level in each period. This means that the debt level has to adjust immediately in response to a decrease in the risk-free debt level. Applying this condition and plugging in equations (3.26) and (3.29), the efficiency condition (3.24) can be rewritten to give the optimal fiscal policy rule for consumption taxes as

$$1+\tau_t^c = \frac{\beta^s \bar{D}_t^b}{\frac{\bar{D}_{t-1}^b}{1+\tau_{t-1}^c} + \frac{s}{z}\ln\left(\frac{1-\tilde{s}}{1-s}\frac{s}{\tilde{s}}\right)} \tag{3.30}$$

and equation (3.25) gives the optimal wage tax as

$$\tau_t^w = 1 - \frac{\theta}{\theta-1}(1+\tau_t^c). \tag{3.31}$$

In Figures 3.3 and 3.4, the effects of a deleveraging shock under the Ramsey-optimal policy with wage and consumption taxes in comparison with the case of an exogenously given policy considered before are depicted.

It can be observed that following the optimal rules given by (3.30) and (3.31) implies raising wage taxes and decreasing consumption taxes. The intuition behind this reaction becomes clear by considering after-tax inflation dynamics: While the pre-tax inflation rate is assumed to stay at its target value, the decrease in consumption taxes implies that in the period in which the deleveraging shock materializes, consumption tomorrow will be expected to be less expensive than consumption today. Or, put differently, after-tax inflation is expected to

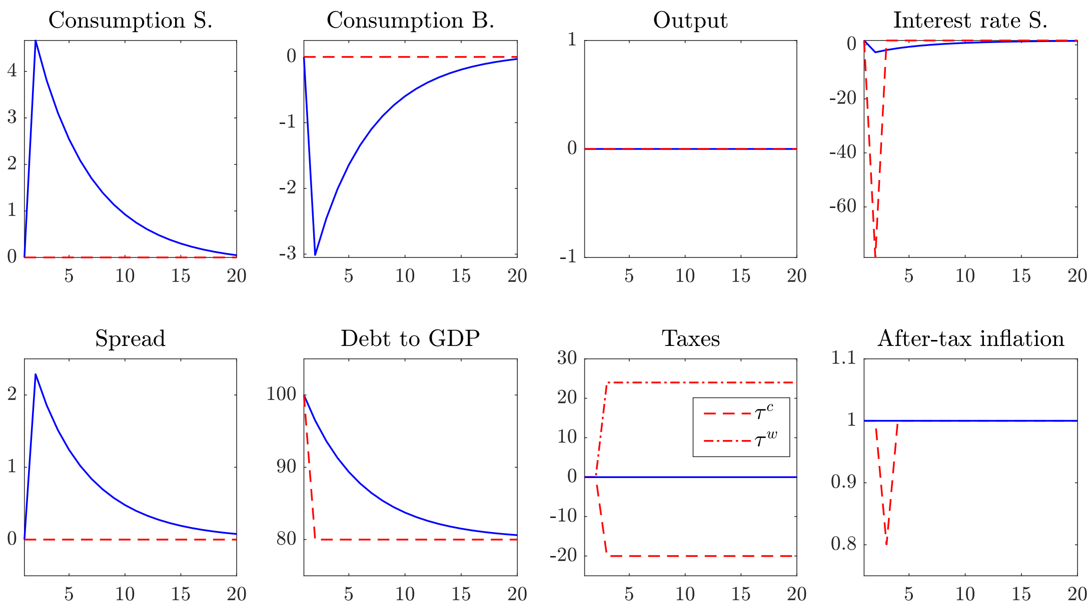

Figure 3.3: Deleveraging under the optimal fiscal policy with wage and consumption taxes in the simple model with flexible prices. For consumption and output percentage changes are given. Interest rates and taxes are measured in percent. “Spread” is defined as the difference between the interest rates of borrowers and savers in percentage points. For debt, the debt-to-GDP ratio (D_t/Y_t) is given in percent. **Solid line:** Exogenous policy. **Dashed line:** Ramsey policy.

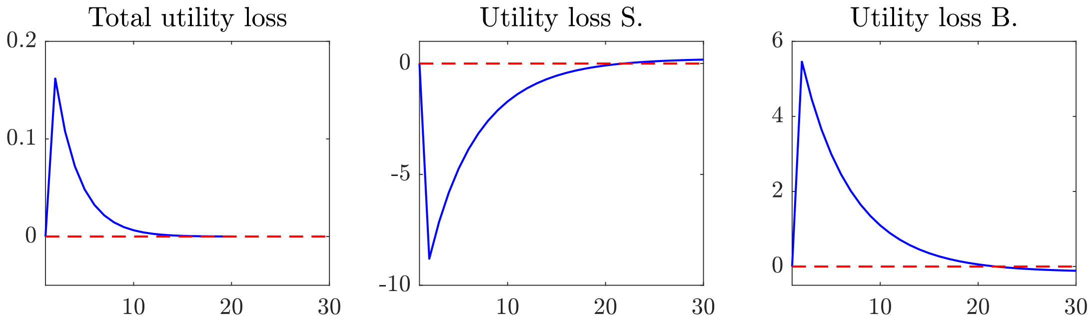

Figure 3.4: Period-by-period consumption-equivalent utility losses of a deleveraging shock under a Ramsey policy with wage and consumption taxes as well as under the exogenous policy. **Solid line:** Exogenous policy. **Dashed line:** Ramsey policy.

decrease which implies that repaying debt tomorrow will be more costly than repaying debt today. Consequently, borrowers will decrease bond holdings today. The Ramsey planner sets the decrease in consumption taxes to ensure that the reduction in bond holdings will be the same as the reduction in the risk-free debt level. Consequently, there is a one-time shift from the high debt level to the low debt level implying that the spread remains zero. Figure 3.3 shows that this deleveraging mechanism implies that borrowers are willing to pay less for borrowing such that the interest rate decreases. From the savers' perspective, lending becomes more attractive since lending one consumption unit today will result in a payoff of more than one consumption unit tomorrow such that savers will request lower interest rates. Consequently, the decrease in consumption taxes induces a reduction in the nominal interest rate while consumption remains constant.

This mechanism is comparable with the results obtained in Eggertson and Krugman (2012) in that the effects of a deleveraging shock crucially depend on the reaction of inflation or, more precisely, inflation expectations. It differs, however, in that in the current paper expected (after-tax) deflation is required to obtain an immediate adjustment of the debt level as described above. Eggertson and Krugman (2012), in contrast, find an increase in inflation reducing the burden of deleveraging due to the fact that the debt-limit is given in real terms. This difference is due to the difference in the modeling of deleveraging: In Eggertson and Krugman (2012), the debt level (plus interest payments) is assumed to adjust within a single period implying that, per construction, it always is equal to the debt limit. In the current paper, in contrast, the debt level adjusts endogenously and over time and, as a result, may differ from the risk-free debt level during the transition process.

Equation (3.27) shows that setting wage taxes as given in (3.25) ensures that

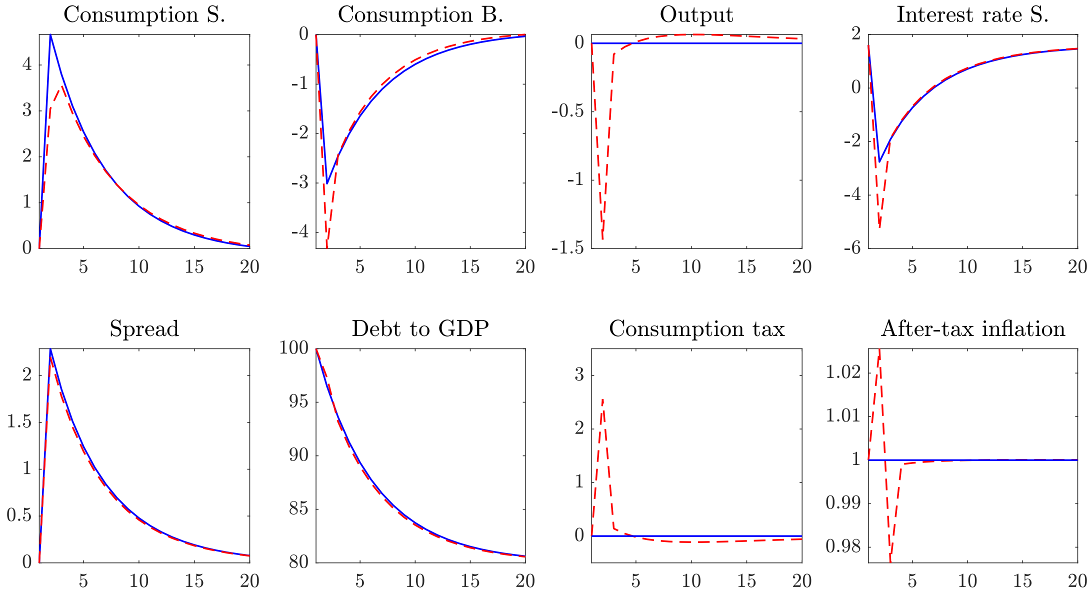

Figure 3.5: Deleveraging under the optimal fiscal policy with consumption taxes in the simple model with flexible prices. For consumption and output percentage changes are given. Interest rates and taxes are measured in percent. "Spread" is defined as the difference between the interest rates of borrowers and savers in percentage points. For debt, the debt-to-GDP ratio (D_t/Y_t) is given in percent. **Solid line:** Exogenous policy. **Dashed line:** Ramsey policy.

production – and, thus, labor – is held constant as required to obtain efficiency. Overall, it can be stated that if the Ramsey planner has access to both wage and consumption taxes, he can completely offset the real effects of a deleveraging shock such eliminating any welfare losses. This is different in case of a Ramsey planner relying on one single distortionary tax instrument as is shown in the following.

Regarding the case of consumption taxes being the only distortionary tax instrument available – implying that tax revenues will be rebated via lump-sum transfers – Figure 3.5 gives the effects of a deleveraging shock as considered before. Here, considering the two efficiency conditions it becomes apparent that the low-debt-level steady state cannot be efficient. As before, condition (3.24) determines the optimal level of consumption taxes. Condition (3.25), however, shows that choosing this optimal level of consumption taxes implies an inefficiently low level of wage taxes. This, by means of equation (3.27), implies that production decreases which cannot be efficient. Consequently, the Ramsey planner refrains from decreasing the consumption tax by 20 percentage points but chooses a much higher level in the amount of 2.6% on impact and -0.11% at its minimum after 9 periods. Again considering (after-tax) inflation reactions shows that the effects can be separated in two steps: On impact, expected higher

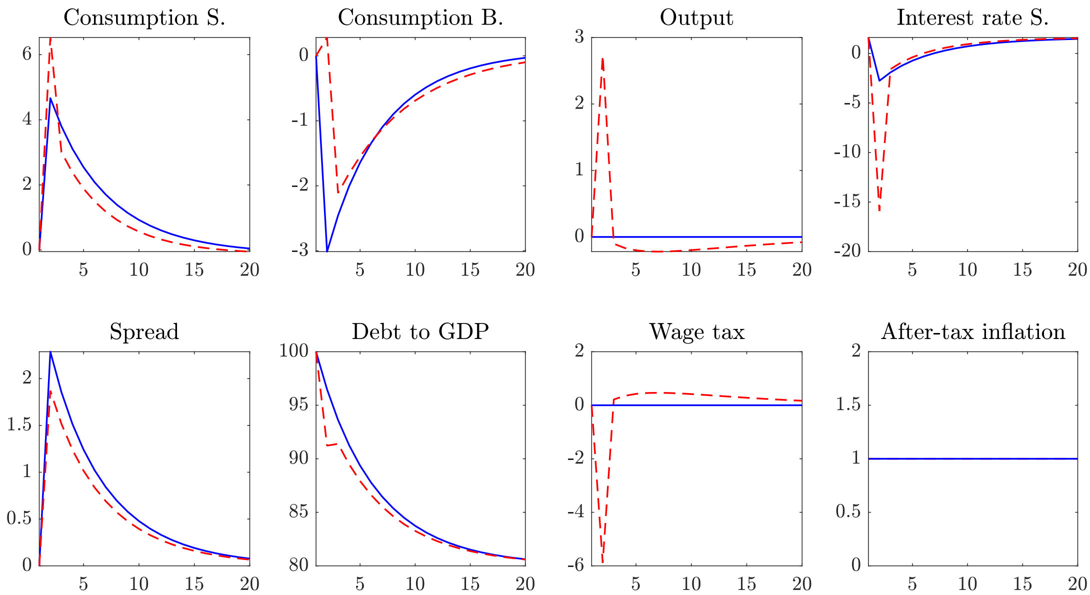

Figure 3.6: Deleveraging under the optimal fiscal policy with wage taxes in the simple model with flexible prices. For consumption and output percentage changes are given. Interest rates and taxes are measured in percent. "Spread" is defined as the difference between the interest rates of borrowers and savers in percentage points. For debt, the debt-to-GDP ratio (D_t/Y_t) is given in percent. **Solid line:** Exogenous policy. **Dashed line:** Ramsey policy.

consumption taxes cause borrowers to decrease their bond holdings slightly more slowly since they expect after-tax inflation – which is just the opposite of the mechanism described above in case of two tax instruments being available. Ever since the second period, on the contrary, the expected decrease in consumption taxes implies just the opposite behavior. Borrowers deleverage somewhat faster due to an expected decrease in after-tax inflation.

In case of a Ramsey planner having access to wage taxes as single distortionary instrument, condition (3.24) cannot be fulfilled in the low-debt-level steady state as consumption taxes cannot be adjusted in response to the decrease in the risk-free debt level. Figure 3.6 shows that the Ramsey-optimal policy implies decreasing wage taxes on impact in the amount of about 5.9 percentage points and choosing a slightly positive tax rate in the subsequent periods in the amount of 0.47% at the maximum after 7 periods. Since after-tax inflation is equivalent to pre-tax inflation – which is constant – the mechanism works through the income-channel. Wage taxes are reduced such that borrowers decrease their debt level somewhat faster than in the case of an exogenous policy meaning that the interest spread increases to a lesser extent.

Utility effects

Table 3.2 gives the lifetime utility losses defined as the percentage share of initial steady-state consumption an agent would be willing to give up in order to be indifferent between the corresponding constant steady-state-level stream of consumption and labor and the stream of consumption and labor that will result if a deleveraging shock hits the economy. It can be seen that a Ramsey-optimal policy with wage and consumption taxes is able to completely offset the effects of a deleveraging shock. Even if a Ramsey planner has access to only one tax instrument, the economy-wide utility loss can be reduced noticeably. It can be observed, however, that this has the drawback of increasing the savers' losses. Finally, it can be observed that, in this simple setup, using wage taxes is more effective than relying on consumption taxes: With wage taxes, the economy-wide utility loss can be reduced from about 0.46% to 0.38% while with consumption taxes it still amounts to about 0.44%.

	Exogenous	τ^w and τ^c	τ^c	τ^w
Total	0.4611	0.0000	0.4423	0.3780
Savers	7.68	0.00	9.34	14.54
Borrowers	20.49	0.00	19.65	16.80

Table 3.2: Lifetime consumption-equivalent utility losses (in percent) of a deleveraging shock under an exogenous and different Ramsey-optimal policies in the simple model with flexible prices.

3.3.2 Sticky Prices and the Zero Lower Bound

After exploring the mechanisms of a deleveraging shock, this section investigates optimal fiscal policy with sticky prices in the presence of a ZLB on the nominal interest rate. For this purpose, the elasticity of substitution between differentiated intermediate goods, θ, is set to be 6 and the price adjustment cost parameter, κ, is set to be 54 which is equivalent to a degree of Calvo-price-stickiness of 75%.

Impulse responses

Figure 3.7 shows the effects of a deleveraging shock for the case of a Ramsey planner having access to wage as well as consumption taxes in comparison to an exogenous policy for the model with sticky prices and the existence of the ZLB. The effects under an exogenous policy are very similar to the case of flexible prices. The main difference consists in the fact that the nominal interest rate cannot become negative any more but instead remains at the ZLB for 7 periods.

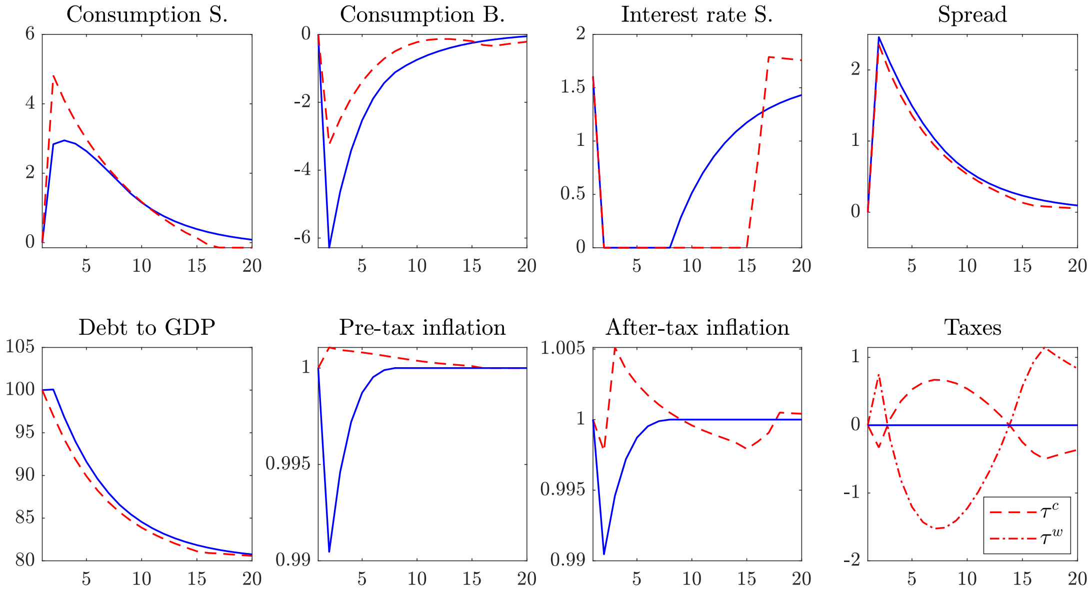

Figure 3.7: Deleveraging under the optimal fiscal policy with wage and consumption taxes in the model with sticky prices and the ZLB. For consumption percentage changes are given. Interest rates and taxes are measured in percent. "Spread" is defined as the difference between the interest rates of borrowers and savers in percentage points. For debt, the debt-to-GDP ratio (D_t/Y_t) is given in percent. **Solid line:** Exogenous policy. **Dashed line:** Ramsey policy.

The Ramsey-optimal reaction, in contrast, differs from the simple example considered before.[34] Now, the Ramsey planner pursues two goals: On the one hand, the Ramsey planner – as before – tries to eliminate the inefficiency induced by the rise in the interest spread and seeks to accelerate the deleveraging process. On the other hand, the Ramsey planner now aims at holding inflation at its target value to eliminate the inefficiency implied by the wedge between output and consumption. In contrast to the simple case considered before, the inflation rate will not necessarily stay at its target value – as was ensured by the inflation-targeting policy in the simple model without the ZLB – but will deviate from its target value if the ZLB becomes binding. The Ramsey planner chooses the optimal mix of consumption and wage taxes such that output increases (instead of decreasing under an exogenous policy) which prevents inflation from falling and, at the same time, accelerates the deleveraging process by causing (after-tax) deflationary tendencies in the initial period. The optimal policy reaction here

[34]To prevent explosive dynamics of the two tax rates, in this case of both distortionary taxes being available at the same time, a small tax collection cost is assumed for the wage tax such that in this case the government budget reads $T_t = \tau_t^c(sC_t^s + (1-s)C_t^b) + \tau_t^w W_t L_t - \phi_w^\tau(\tau_t^w - \tau^{w,eff})$. This value is small enough ($\phi_w^\tau = 0.1$) to ensure that the results regarding utility losses are not affected by this assumption.

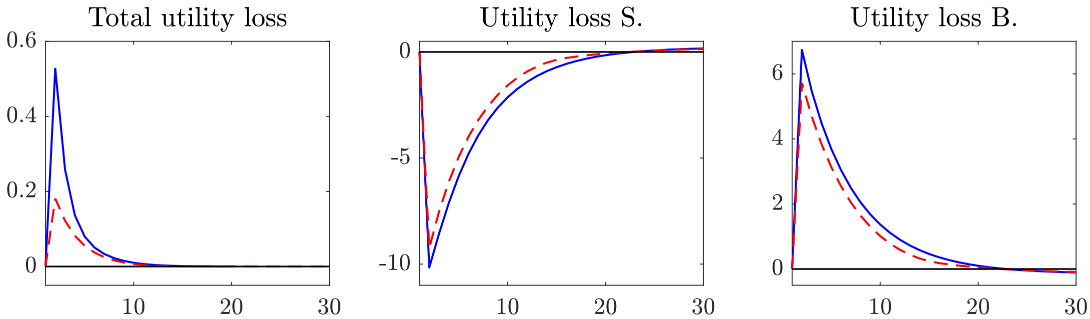

Figure 3.8: Period-by-period consumption-equivalent utility losses (in percent) of a deleveraging shock under the Ramsey-optimal policy with wage and consumption taxes in the model with sticky prices and the ZLB. **Solid line:** Exogenous policy. **Dashed line:** Ramsey policy.

consists in decreasing consumption taxes if the ZLB is not binding and increasing consumption taxes while the ZLB binds. The opposite can be observed for the optimal wage tax. It should be noted that this policy implies staying at the ZLB for a longer period than under the exogenously given policy.

Figure 3.8 shows that this optimal policy reaction is highly effective in eliminating economy-wide utility losses. The total utility loss is reduced from 0.53% under an exogenous policy to 0.18% at its peak under the Ramsey-optimal policy. Regarding agent-specific utility effects, the same effects can be observed as in the simple model: Savers gain during the deleveraging process but feature a small loss in the long-run while for borrowers the opposite holds true. As before, this long-run effect is due to a lower level of outstanding debt and, as a consequence thereof, a lower steady-state level of interest rate payments.

In the cases of a Ramsey planner relying on one distortionary tax instrument only – as depicted in Figures 3.9 and 3.10 – the mechanism is similar to the case of two tax instruments being available. Again, the consumption tax is negative if the ZLB is not binding and positive during the period in which the ZLB binds (and vice versa for the wage tax). Both optimal policy reactions prevent inflation from falling and, such, reduce the inefficiency wedge between consumption and output. Furthermore, both policies imply a faster deleveraging process. A difference consists in the duration of a binding ZLB: with consumption taxes, the interest rate leaves the ZLB after 10 periods, while with wage taxes the ZLB binds for 11 periods and with both instrument the ZLB lasts for 15 periods.

Utility effects

Considering lifetime utility losses – as given in Table 3.3 – shows that the difference between wage and consumption taxes is much smaller than in the

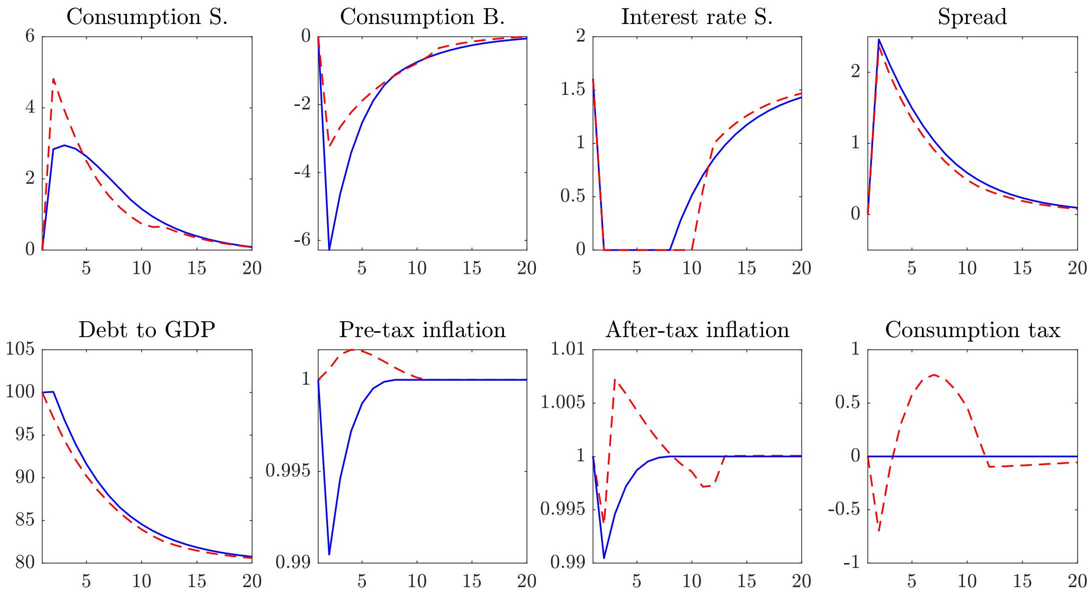

Figure 3.9: Deleveraging under the optimal fiscal policy with consumption taxes in the model with sticky prices and the ZLB. For consumption percentage changes are given. Interest rates and taxes are measured in percent. “Spread” is defined as the difference between the interest rates of borrowers and savers in percentage points. For debt, the debt-to-GDP ratio (D_t/Y_t) is given in percent. **Solid line:** Exogenous policy. **Dashed line:** Ramsey policy.

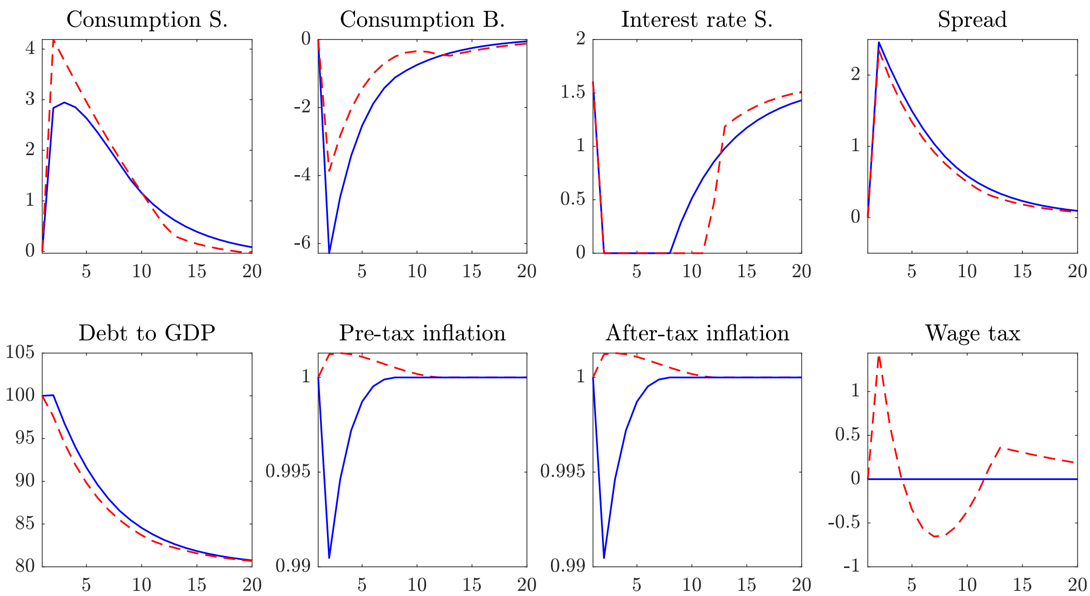

Figure 3.10: Deleveraging under the optimal fiscal policy with wage taxes in the model with sticky prices and the ZLB. For consumption percentage changes are given. Interest rates and taxes are measured in percent. “Spread” is defined as the difference between the interest rates of borrowers and savers in percentage points. For debt, the debt-to-GDP ratio (D_t/Y_t) is given in percent. **Solid line:** Exogenous policy. **Dashed line:** Ramsey policy.

simple model. A Ramsey policy including consumption taxes reduces the total economy-wide utility loss from 1.0971% to 0.5339% while the optimal policy using wage taxes implies a utility loss of 0.5370%. The ranking of the two tax instruments, however, is reversed: with sticky prices and the existence of the ZLB, consumption taxes are slightly more effective in reducing economy-wide utility losses than wage taxes. The distributive effects, in contrast, remain unchanged. Each Ramsey-optimal policy implies larger utility losses for savers while the utility loss of borrowers is decreased. Remarkably, in this set-up, savers actually gain from being exposed to a deleveraging shock under the exogenously given policy.

	Exogenous	τ^w and τ^c	τ^c	τ^w
Total	1.0971	0.5205	0.5339	0.5370
Savers	-1.69	7.13	6.26	6.12
Borrowers	25.33	20.83	21.29	21.34

Table 3.3: Lifetime consumption-equivalent utility losses (in percent) of a deleveraging shock under an exogenous and different Ramsey-optimal policies in the model with sticky prices and the ZLB.

It should be noted that all utility effects considered so far are found to be agent-specific, meaning that each policy action implies a utility gain for one group of agents and at the same time a utility loss for the other group of agents. This would be different in case of a Ramsey planner choosing the level of (utility-enhancing) government spending in addition to taxes. In this case, there will be two types of policy actions: actions which have the same utility effect on both savers and borrowers (via changes in government spending) and actions which will favor one of the two groups while adversely affecting the other group (via changes in the interest rates). In the next section, it is examined in which way this additional feature influences the constrained-optimal fiscal policy reaction by allowing for endogenous utility-enhancing government spending in addition to choosing the optimal tax rates.

3.4 The Role of Government Spending

The model is now extended by utility-enhancing government spending which is chosen endogenously as one of the fiscal instruments of the Ramsey planner. Utility is now given by

$$U_t^h = E_t \sum_{t=0}^{\infty} (\beta^h)^t \left\{ \left[1 - \exp(-zC_t^h)\right] - \frac{(L_t^h)^{1+\eta}}{1+\eta} \right\} + v\frac{(G_t)^{1-\gamma}}{1-\gamma}$$

where G_t denotes government spending per capita, $v > 0$ is a parameter determining the weight of government spending in utility, and $\gamma > 0$ is the respective elasticity.[35] The government budget is now given by

$$G_t = \tau_t^c(sC_t^s + (1-s)C_t^b) + \tau_t^w W_t L_t - T_t \tag{3.32}$$

and the aggregate resource constraint reads

$$Y_t = sC_t^s + (1-s)C_t^b + G_t + \frac{\kappa}{2}\left(\Pi_t - 1\right) Y_t. \tag{3.33}$$

The Ramsey policy is defined as a sequence of policies maximizing $E_t \sum_{t=0}^{\infty} \beta^t U_t$ with

$$U_t \equiv \widetilde{s}\left[1 - \exp(-zC_t^s) - \frac{(L_t^s)^{1+\eta}}{1+\eta}\right]$$
$$+(1-\widetilde{s})\left[1 - \exp(-zC_t^b) - \frac{(L_t^b)^{1+\eta}}{1+\eta}\right] + v\frac{(G_t)^{1-\gamma}}{1-\gamma}$$

subject to (3.2), (3.3), (3.5), (3.6), (3.8), (3.9), (3.10), (3.11), (3.12), (3.13), (3.15), (3.18), (3.32), and (3.33) with respect to C_t^s, C_t^b, L_t^s, L_t^b, Y_t, W_t^s, W_t^b, MC_t, D_t^b, Π_t, i_t^b, i_t, Φ_t, and G_t as well as one or several of the fiscal instruments τ_t^c, τ_t^w, and T_t.

The Social planner's equilibrium is now given by equations (3.20) to (3.23) as before but extended by

$$v(G_t)^{-\gamma} = \frac{\widetilde{s}}{s} z \exp\left(-zC_t^s\right). \tag{3.34}$$

Figure 3.11 shows the effects of a deleveraging shock if lump-sum financed government spending is the only instrument available to the Ramsey planner in

[35] For simulation exercises both parameters are set to be 0.5 which implies a government-spending-to-GDP ratio of 44%.

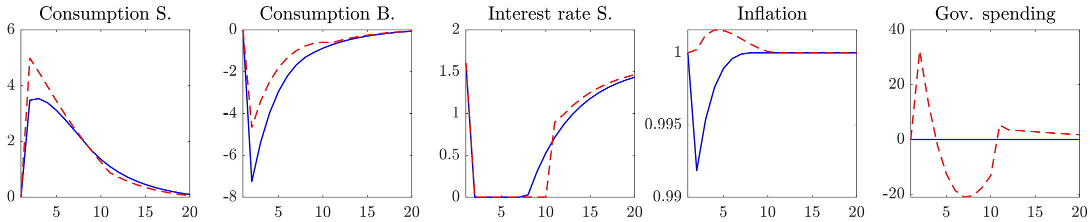

Figure 3.11: Deleveraging under the optimal fiscal policy with lump-sum-financed government spending. For consumption percentage changes are given. Interest rates are measured in percent. For government spending, the government-spending-to-GDP ratio measured as deviation from steady state in percentage points is plotted. **Solid line:** Exogenous policy. **Dashed line:** Ramsey policy.

comparison to the exogenously given policy.[36] Here, the key mechanism behind the Ramsey planner's reaction is the increase in government spending boosting output which prevents inflation from falling. As a consequence, inflation diverts only slightly from its target value which means that the inefficiency wedge between consumption and output is diminished to a large extent. Consequently, output, consumption, and government spending are higher than under an exogenous policy where the relative increase in consumption is amplified by the prolonged stay at the ZLB.

Figure 3.12 shows the implied effects of a deleveraging shock for the scenario with two distortionary taxes being available in addition to government spending. It can be observed that, on impact, the Ramsey-optimal policy consists in increasing consumption taxes and reducing wage taxes in combination with increasing government spending. In the long-run, tax rates convert to their initial values. This behavior reflects the trade-off between accelerating the deleveraging process, holding inflation constant, and obtaining an optimal level of government spending. Again, the ZLB binds much longer than under an exogenous policy featuring a zero nominal interest rate for 17 periods.

To consider utility effects of the different policies for the case with government spending, Table 3.4 gives lifetime consumption-equivalent utility losses as defined before. First, it can be seen that with government spending a deleveraging shock implies much larger utility losses under an exogenous policy. This is due to the fact that the increase in saver's consumption implies that the optimal government spending level increases – as shown by equation (3.34). Under an exogenous policy, however, government spending is fixed such implying utility

[36] To allow for a welfare comparison, as explained before, lump-sum taxes are set to ensure efficiency of the initial steady state in all cases which, now, includes setting government spending at its efficient level.

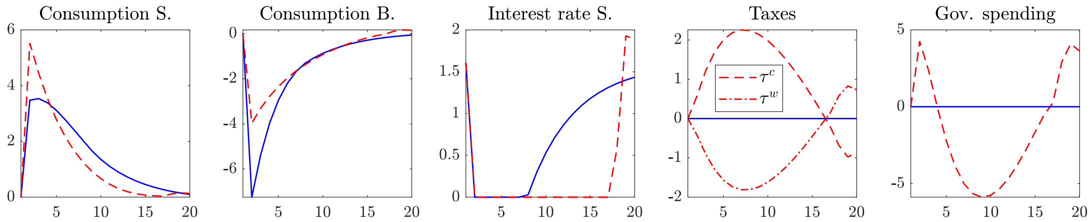

Figure 3.12: Deleveraging under the optimal fiscal policy with consumption and wage taxes and government spending. For consumption percentage changes are given. Interest rates and taxes are measured in percent. For government spending, the government-spending-to-GDP ratio measured as deviation from steady state in percentage points is plotted. **Solid line:** Exogenous policy. **Dashed line:** Ramsey policy.

losses during the transition process as well as in the final steady state. Second, it can be seen that the existence of government spending changes the ranking of the two distortionary taxes: while in the model without government spending setting consumption taxes optimally implied smaller utility losses than relying on wage taxes, in the extended model with government spending the opposite holds true. Here, the difference between the effectiveness of the two tax instruments is much more pronounced with wage taxes reducing the total utility loss from 1.48% to 0.79% while with consumption taxes the utility loss still amounts to 1.31%.

		Lump-sum taxes			No lump-sum taxes		
	Exog.	τ^c	τ^w	no τ	both	τ^c	τ^w
T	1.4803	0.7866	0.7829	0.7992	0.7440	1.3110	0.7904
S	-1.33	8.73	8.70	8.51	13.28	1.40	8.64
B	35.34	30.47	30.45	30.58	28.49	34.10	30.50

Table 3.4: Lifetime consumption-equivalent utility losses (in percent) of a deleveraging shock under different policies with government spending

Finally, Table 3.5 gives the percentage share of the utility effect evoked by endogenously choosing the level of government spending in the total utility effect of applying a Ramsey-optimal instead of an exogenously given policy in the face of a deleveraging shock. It can be seen that the effect of government spending is negligible small. Less than 0.9% of the total utility gain of applying a Ramsey-optimal policy are due to variations in government spending.

	τ^c	τ^w
Total	0.2162	0.1434
Savers	0.8946	0.6979
Borrowers	0.8214	0.6135

Table 3.5: Share of government-spending-induced utility gains in total utility effects of Ramsey-optimal fiscal policies (in percent)

3.5 The Role of Monetary Policy

As outlined before, considering sticky prices via Rotemberg-costs implies that inflation dynamics state an important inefficiency by enlarging the wedge between consumption and output and are crucial in determining utility losses of a deleveraging shock. For this reason, in this section the role of monetary policy for the effectiveness of optimal fiscal policy is explored more in detail. As a starting point, Table 3.6 gives economy-wide consumption-equivalent utility losses of a deleveraging shock under an exogenously given fiscal policy but for four different cases of monetary policy:[37] The case of a simple inflation-targeting monetary policy under the existence of a ZLB as before and the case of inflation-targeting without the existence of a ZLB, on the one hand, and a scenario of monetary policy being set optimally, again with and without the existence of a ZLB, on the other hand.

	Inflation targeting		Optimal monetary policy	
	ZLB	no ZLB	ZLB	no ZLB
No G_t	1.0971	0.4611	0.5451	0.3957
G_t	1.4803	0.6737	0.8006	0.5624

Table 3.6: Total lifetime consumption-equivalent utility losses of a deleveraging shock under an exogenously given fiscal policy for different monetary policies in the full model with sticky prices (in percent).

It can be seen that monetary policy being constrained by the ZLB implies sizable utility losses. While in consequence of a deleveraging shock the economy as a whole features a utility loss of 0.5624% under an optimal monetary policy without the existence of a (binding) ZLB, the loss amounts to 0.8006% if the

[37] A description of the implementation of the different scenarios can be found in Appendix E.

monetary authority is constrained by the ZLB. Moreover, it can be observed – as was to be expected – that following an inflation-targeting policy implies larger utility losses than following an optimal monetary policy.

To examine the difference between applying the optimal fiscal policy in an inflation-targeting set-up as before and the case of conducting optimal fiscal and monetary policy at the same time, Table 3.7 gives utility losses for a wide set of different fiscal polices for the case of conducting optimal monetary policy. Here, three observations stand out: First, it can be seen that applying the optimal fiscal policy with wage and consumption taxes as well as government spending implies reducing the utility loss of a deleveraging shock in the face of the ZLB from 0.8006% to 0.7379%. This means that conducting optimal fiscal policy in a situation where the monetary policy is set optimally but constrained by the ZLB can eliminate 26.32% of the utility loss of being at the ZLB. Second, a comparison with the results obtained in the last sections shows that applying an inflation-targeting policy instead of optimal monetary policy need not necessarily imply utility losses depending on the fiscal instruments available. It can be seen that in case of a Ramsey planner having access to wage taxes, the utility losses are independent of the specific monetary policy conducted. Third, it can be seen that the main results remain otherwise unchanged. Irrespective of the monetary policy conducted, applying the optimal fiscal policy implies increasing the loss of savers where the optimal policy reaction implies a prolonged stay at the ZLB.

	With T_t		With G_t			With G_t and T_t		
	τ^c	τ^w	both	τ^c	τ^w	τ^c	τ^w	no τ
T	0.5323	0.5370	0.7379	0.7973	0.7890	0.7844	0.7829	0.7977
S	6.31	6.12	14.51	8.45	8.66	8.79	8.70	8.52
B	21.26	21.34	27.97	30.59	30.49	30.44	30.45	30.56

Table 3.7: Lifetime consumption-equivalent utility losses of a deleveraging shock for different fiscal policies under optimal monetary policy in the model with sticky prices and the ZLB (in percent). "With T_t" refers to the model without government spending but with lump-sum financed distortionary taxes. "With G_t" refers to the model with government spending but without lump-sum taxes being available while "With G_t and T_t" relates to the model with government spending where a distortionary tax and lump-sum taxes are available.

3.6 Robustness

In this section, the robustness of the results to altering the parametrization is checked. If the elasticity of the risk premium to the debt level, ϕ, is set to larger (smaller) values, the utility losses of a deleveraging shock under an exogenously given policy as well as under Ramsey-optimal policies are larger (smaller). Otherwise, the results are robust to variations in ϕ. Furthermore, the results are robust to setting the discount factors (β^s and β^b) to smaller values but this implies that the ZLB binds for a shorter period since a smaller discount factor implies starting at a higher nominal interest rate. Varying the weight of consumption in utility, z, as well as the inverse of the labor supply elasticity, η, implies utility losses being quantitatively different while all results remain qualitatively unchanged. Finally, utility losses decrease with an increasing share of savers as debt is measured per borrower which means that if debt per borrower decreases, this has a smaller effect on savers if there are relatively more savers. For the same reason, a larger share of savers implies a shorter period at the ZLB. Robustness can be obtained, however, by recalibrating the decrease in debt adequately. The only parameter influencing the results regarding the distributive effects of Ramsey-optimal policy is the Rotemberg price-adjustment cost parameter κ. Here, for low values of κ ($\kappa \approx< 10$), applying a Ramsey-optimal policy instead of an exogenous policy implies reducing savers' losses while increasing the losses of borrowers. All other results, however, remain unchanged.

3.7 Conclusions

In the course of this paper, Ramsey-optimal policy reactions to a private debt deleveraging shock were examined in a closed economy populated by savers and borrowers in a situation where monetary policy is constrained by the ZLB on the nominal interest rate. The results show that a deleveraging shock has large effects on economic variables and implies economy-wide utility losses. Furthermore, monetary policy being constrained by the ZLB implies sizable utility losses if the economy is hit by a deleveraging shock. Here, applying an optimal fiscal policy can eliminate roughly one quarter of these utility losses of being at the ZLB where the optimal policy reaction features a prolonged stay at the ZLB. Furthermore, conducting a Ramsey-optimal policy implies enlarging the utility loss of savers. Whether consumption or wage taxes are more effective in reducing utility losses of a deleveraging shock depends on the presence of government spending as well as of the specific monetary policy conducted. Moreover, it is shown that having government spending as an additional instrument implies only small welfare gains relative to applying an optimal instead of an exogenous fiscal policy. Finally, the results indicate that if fiscal policy is set optimally, setting monetary policy optimally instead of following a simple inflation-targeting policy need not necessarily imply welfare gains depending on the fiscal instruments available.

While this paper is an attempt to investigate optimal fiscal policy reactions to a private debt deleveraging shock in the face of a ZLB on the nominal interest rate, it would be interesting for further research to expand the model to an open economy or even monetary-union framework which enables to study the difficulties of being a small member of a monetary union as well as the gains and losses of cooperation between countries. Furthermore, the introduction of wage rigidities may be a realistic feature and especially interesting in the presence of wage taxes. Finally, while this paper uses a shortcut to model a financial crisis without explicitly modeling a financial sector, adding a more elaborated financial sector or taxes on financial activity may provide interesting results.

3.8 Appendices

3.8.A Ramsey Problem and Solution

Ramsey problem:

$\max E_t \sum_{t=0}^{\infty} \beta^t U_t$ with $\beta \equiv s\beta^s + (1-s)\beta^b$ and

$$U_t \equiv \widetilde{s}\left[1-\exp(-zC_t^s)-\frac{(L_t^s)^{1+\eta}}{1+\eta}\right]+(1-\widetilde{s})\left[1-\exp(-zC_t^b)-\frac{(L_t^b)^{1+\eta}}{1+\eta}\right]$$

subject to

$$\Phi(D_t^b) = 1+\phi\exp\left(\frac{D_t^b}{\bar{D}_t^b}-1\right)-\phi \tag{λ. 1}$$

$$\exp(-zC_t^s) = \beta^s \exp(-zC_{t+1}^s)\frac{1+i_t}{\Pi_{t+1}}\frac{1+\tau_t^c}{1+\tau_{t+1}^c} \tag{λ. 2}$$

$$\exp(-zC_t^b) = \beta^b \exp(-zC_{t+1}^b)\frac{(1+i_t)\Phi_t}{\Pi_{t+1}}\left[1-D_t^b\frac{\Phi_t'}{\Phi_t}\right]^{-1}\frac{1+\tau_t^c}{1+\tau_{t+1}^c} \tag{λ. 3}$$

$$(L_t^s)^{\eta} = zW_t^s\exp(-zC_t^s)\frac{1-\tau_t^w}{1+\tau_t^c} \tag{λ. 4}$$

$$(L_t^b)^{\eta} = zW_t^b\exp(-zC_t^b)\frac{1-\tau_t^w}{1+\tau_t^c} \tag{λ. 5}$$

$$Y_t = (L_t^s)^s(L_t^b)^{1-s} \tag{λ. 6}$$

$$W_t^sL_t^s = W_t^bL_t^b \tag{λ. 7}$$

$$MC_t = W_t^s\left(\frac{L_t^s}{L_t^b}\right)^{1-s} \tag{λ. 8}$$

$$\theta(1-MC_t)-1+\kappa(\Pi_t-1)\Pi_t=\beta\kappa\frac{u_{ct+1}}{u_{ct}}(\Pi_{t+1}-1)\Pi_{t+1}\frac{Y_{t+1}}{Y_t} \qquad (\lambda.\ 9)$$

$$Y_t=sC_t^s+(1-s)C_t^b+\frac{\kappa}{2}(\Pi_t-1)^2Y_t \qquad (\lambda.\ 10)$$

$$\frac{D_t^b}{(1+i_t)\Phi_t}-\frac{D_{t-1}^b}{\Pi_t}=(1+\tau_t^c)\left[C_t^b-C_t^s\right]s \qquad (\lambda.\ 11)$$

$$\tau_t^c(sC_t^s+(1-s)C_t^b)+\tau_t^wW_t^bL_t^b-\phi_{\tau^w}\tau_t^w=T_t \qquad (\lambda.\ 12)$$

$$\Pi_t=\bar{\Pi}\ \text{ if }\ i_t\geq 0 \qquad (\lambda.\ 13)$$
$$i_t=0\ \text{ else} \qquad (\lambda.\ 14)$$

where $u_{ct}=s\exp(-zC_t^s)+(1-s)\exp(-zC_t^b)$.

First order conditions:

$$\begin{aligned}z\exp(-zC_t^s)\widetilde{s}-\lambda_{2t}z\exp(-zC_t^s)+\lambda_{2t-1}\frac{\beta^s}{\beta}z\exp(-zC_t^s)\frac{1+i_{t-1}}{\Pi_t}\frac{1+\tau_{t-1}^c}{1+\tau_t^c}\\+\lambda_{4t}z^2W_t^s\exp(-zC_t^s)\frac{1-\tau_t^w}{1+\tau_t^c}+\lambda_{9t}\beta\kappa(\Pi_{t+1}-1)\Pi_{t+1}\frac{Y_{t+1}}{Y_t}\frac{u_{ct+1}}{u_{ct}^2}zs\exp(-zC_t^s)\\-\lambda_{9t-1}\kappa(\Pi_t-1)\Pi_t\frac{Y_t}{Y_{t-1}}\frac{sz\exp(-zC_t^s)}{u_{ct-1}}-\lambda_{10t}s+\lambda_{11t}s(1+\tau_t^c)\\+\lambda_{13t}s\tau_t^c=0\end{aligned} \qquad \left(\frac{\delta\Lambda_t}{\delta C_t^s}\right)$$

$$\begin{aligned}z(1-\widetilde{s})\exp(-zC_t^b)-\lambda_{3t}z\exp(-zC_t^b)\\+\lambda_{3t-1}\frac{\beta^b}{\beta}z\exp(-zC_t^b)\frac{1+i_{t-1}}{\Pi_t}\frac{1+\tau_{t-1}^c}{1+\tau_t^c}\left[\Phi_{t-1}-\phi\frac{D_{t-1}^b}{\bar{D}_{t-1}^b}\exp\left(\frac{D_{t-1}^b}{\bar{D}_{t-1}^b}-1\right)\right]^{-1}\\+\lambda_{5t}z^2W_t^b\exp(-zC_t^b)\frac{1-\tau_t^w}{1+\tau_t^c}\\+\lambda_{9t}\beta\kappa(\Pi_{t+1}-1)\Pi_{t+1}\frac{Y_{t+1}}{Y_t}\frac{u_{ct+1}}{u_{ct}^2}z(1-s)\exp(-zC_t^b)\\-\lambda_{9t-1}\kappa(\Pi_t-1)\Pi_t\frac{Y_t}{Y_{t-1}}\frac{(1-s)z\exp(-zC_t^b)}{u_{ct-1}}\\-\lambda_{10t}(1-s)-\lambda_{11t}(1+\tau_t^c)s+\lambda_{13t}(1-s)\tau_t^c=0\end{aligned} \qquad \left(\frac{\delta\Lambda_t}{\delta C_t^b}\right)$$

$$
\begin{aligned}
-\widetilde{s}(L_t^s)^{\eta} + \lambda_{4t}\eta(L_t^s)^{\eta-1} - \lambda_{6t}s\left(\frac{L_t^b}{L_t^s}\right)^{1-s} + \lambda_{7t}W_t^s \\
-\lambda_{8t}(1-s)W_t^s(L_t^s)^{-s}(L_t^b)^{s-1} = 0
\end{aligned}
\qquad (\tfrac{\delta\Lambda_t}{\delta L_t^s})
$$

$$
\begin{aligned}
-(1-\widetilde{s})(L_t^b)^{\eta} + \lambda_{5t}\eta(L_t^b)^{\eta-1} - \lambda_{6t}(1-s)\left(\frac{L_t^s}{L_t^b}\right)^{s} - \lambda_{7t}W_t^b \\
+\lambda_{8t}(1-s)W_t^s(L_t^s)^{1-s}(L_t^b)^{s-2} + \lambda_{13t}\tau_t^w W_t^b = 0
\end{aligned}
\qquad (\tfrac{\delta\Lambda_t}{\delta L_t^b})
$$

$$
\begin{aligned}
\lambda_{6t} + \lambda_{10t}\left(1 - \frac{\kappa}{2}(\Pi_t - 1)^2\right) - \lambda_{9t}\beta\kappa\frac{u_{ct+1}}{u_{ct}}(\Pi_{t+1} - 1)\Pi_{t+1}\frac{Y_{t+1}}{Y_t^2} \\
+\lambda_{9t-1}\kappa\frac{u_{ct}}{u_{ct-1}}(\Pi_t - 1)\frac{\Pi_t}{Y_t} = 0
\end{aligned}
\qquad (\tfrac{\delta\Lambda_t}{\delta Y_t})
$$

$$
\lambda_{8t} + \theta\lambda_{9t} = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta MC_t})
$$

$$
-\lambda_{4t}z\exp(-zC_t^s)\frac{1-\tau_t^w}{1+\tau_t^c} + \lambda_{7t}L_t^s - \lambda_{8t}\left(\frac{L_t^s}{L_t^b}\right)^{1-s} = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta W_t^s})
$$

$$
-\lambda_{5t}z\exp(-zC_t^b)\frac{1-\tau_t^w}{1+\tau_t^c} - \lambda_{7t}L_t^b + \lambda_{13t}\tau_t^w L_t^b = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta W_t^b})
$$

$$
\begin{aligned}
\lambda_{1t} - \lambda_{11t}\frac{D_t^b}{1+i_t}\frac{1}{\Phi_t^2} - \lambda_{3t}\beta^b\exp(-zC_{t+1}^b)\frac{1+i_t}{\Pi_{t+1}}\frac{1+\tau_t^c}{1+\tau_{t+1}^c} \\
\left\{\left[1 - D_t^b\frac{\Phi_t^{'}}{\Phi_t}\right]^{-1} + \Phi_t\left[1 - D_t^b\frac{\Phi_t^{'}}{\Phi_t}\right]^{-2} D_t^b\Phi_t^{'}\frac{1}{\Phi_t^2}\right\} = 0
\end{aligned}
\qquad (\tfrac{\delta\Lambda_t}{\delta\Phi_t})
$$

$$
\begin{aligned}
&-\lambda_{1t}\phi\frac{1}{\bar{D}_t^b}\exp\left(\frac{D_t^b}{\bar{D}_t^b}-1\right)\\
&-\lambda_{3t}\left\{\beta^b\exp(-zC_{t+1}^b)\frac{1+i_t}{\Pi_{t+1}}\frac{1+\tau_t^c}{1+\tau_{t+1}^c}\left[\Phi_t-\phi\frac{D_t^b}{\bar{D}_t^b}\exp\left(\frac{D_t^b}{\bar{D}_t^b}-1\right)\right]^{-2}\right.\\
&\left.\phi\left(\frac{1}{\bar{D}_t^b}\exp\left(\frac{D_t^b}{\bar{D}_t^b}-1\right)+\frac{D_t^b}{(\bar{D}_t^b)^2}\exp\left(\frac{D_t^b}{\bar{D}_t^b}-1\right)\right)\right\}\\
&+\lambda_{11t}\frac{1}{(1+i_t)\Phi_t}-\lambda_{11t+1}\beta\frac{1}{\Pi_{t+1}}=0 \qquad \left(\tfrac{\delta\Lambda_t}{\delta D_t^b}\right)
\end{aligned}
$$

$$
\begin{aligned}
&-\lambda_{2t}\beta^s\exp(-zC_{t+1}^s)\frac{1+i_t}{\Pi_{t+1}}\frac{1}{1+\tau_{t+1}^c}+\lambda_{2t-1}\frac{\beta^s}{\beta}\exp(-zC_t^s)\frac{1+i_{t-1}}{\Pi_t}\frac{1+\tau_{t-1}^c}{(1-\tau_t^c)^2}\\
&-\lambda_{3t}\beta^b\exp(-zC_{t+1}^b)\frac{1+i_t}{\Pi_{t+1}}\frac{1}{1+\tau_{t+1}^c}\left[\Phi_t-\phi\frac{D_t^b}{\bar{D}_t^b}\exp\left(\frac{D_t^b}{\bar{D}_t^b}-1\right)\right]^{-1}\\
&-\lambda_{3t-1}\frac{\beta^b}{\beta}\exp(-zC_t^b)\frac{1+i_{t-1}}{\Pi_t}\frac{1+\tau_{t-1}^c}{(1+\tau_t^c)^2}\left[\Phi_{t-1}-\phi\frac{D_{t-1}^b}{\bar{D}_{t-1}^b}\exp\left(\frac{D_{t-1}^b}{\bar{D}_{t-1}^b}-1\right)\right]^{-1}\\
&+\lambda_{4t}zW_t^s\exp(-zC_t^s)\frac{1-\tau_t^w}{(1+\tau_t^c)^2}+\lambda_{5t}zW_t^b\exp(-zC_t^b)\frac{1-\tau_t^w}{(1+\tau_t^c)^2}\\
&-\lambda_{11t}(C_t^b-C_t^s)s+\lambda_{13t}(sC_t^s+(1-s)C_t^b)=0 \qquad \left(\tfrac{\delta\Lambda_t}{\delta\tau_t^c}\right)
\end{aligned}
$$

$$
\begin{aligned}
&\lambda_{4t}zW_t^s\exp(-zC_t^s)\frac{1}{1+\tau_t^c}+\lambda_{5t}zW_t^b\exp(-zC_t^b)\frac{1}{1+\tau_t^c}\\
&+\lambda_{13t}(W_t^bL_t^b-\phi_{\tau^w})=0 \qquad \left(\tfrac{\delta\Lambda_t}{\delta\tau_t^w}\right)
\end{aligned}
$$

Solution:

I solve the complete model by using a Newton-type algorithm via Dynare (by way of using the "simul"-command). This means all equations (equilibrium conditions (λ. 1) to (λ. 12) plus the Ramsey FOCs plus the restriction on the monetary policy defined in the following) are given in the model-block of the mod.file such that using Dynare involves solving all equilibrium equations as well as the Ramsey FOCs simultaneously.

Monetary policy is restricted by the following feature: The monetary authority follows an inflation-targeting policy if the nominal interest rate is above zero which means in this case $\Pi_t = \bar{\Pi}$ holds while the nominal interest is determined by the agents' decisions. If, on the contrary, the nominal interest rate is at the zero lower bound, the monetary authority cannot follow an inflation-targeting strategy but sets $i_t = 0$. In this case, the inflation rate has to adjust via the Euler equations. To implement this issue, I solve the model under perfect foresight meaning all shocks are perfectly anticipated such that the deleveraging shock is modeled as a deterministic shock. This ensures that the exact solution to the model can be found via the "simul"-command by taking nonlinearities into account. Consequently, occasionally binding constraints can easily be implemented e.g. by use of "max"-operators or "if"-commands. More specifically, the occasionally binding inflation-targeting policy can be implemented by replacing equation (λ. 13) with

$$(i_t \leq 0)\lambda_{13t} + (i_t > 0)(\Pi_t - \bar{\Pi}) = 0 \tag{3.A.1}$$

in the model-block of the Dynare mod.-file. The respective FOC with respect to Π_t reads

$$\begin{aligned}
&\lambda_{2t-1}\frac{\beta^s}{\beta}\exp(-zC_t^s)\frac{1+i_{t-1}}{\Pi_t^2}\frac{1+\tau_{t-1}^c}{1+\tau_t^c} \\
&+\lambda_{3t-1}\frac{\beta^b}{\beta}\exp(-zC_t^b)\frac{1+i_{t-1}}{\Pi_t^2}\frac{1+\tau_{t-1}^c}{1+\tau_t^c}\left[\Phi_{t-1} - \phi\frac{D_{t-1}^b}{\bar{D}_{t-1}^b}\exp\left(\frac{D_{t-1}^b}{\bar{D}_{t-1}^b} - 1\right)\right]^{-1} \\
&-\lambda_{9t}\kappa(2\Pi_t - 1) + \lambda_{9t-1}\kappa\frac{u_{ct}}{u_{ct-1}}\frac{Y_t}{Y_{t-1}}(2\Pi_t - 1) \\
&-\lambda_{10t}\kappa(\Pi_t - 1)Y_t + \lambda_{11t}\frac{D_{t-1}^b}{\Pi_t^2} + \lambda_{13t} = 0.
\end{aligned} \tag{3.A.2}$$

This shows that if $i_t \leq 0$, (3.A.1) gives $\lambda_{13t} = 0$. Consequently, (3.A.2) gives the derivative of the Lagrangian with respect to Π_t without the existence of an inflation-targeting policy such that Π_t can be chosen constrained-optimal. On the contrary, if $i_t > 0$, equation (3.A.1) determines $\Pi_t = \bar{\Pi}$ while not determining λ_{13t} such that equation (3.A.2) gives λ_{13t} residually as it is the only equation including λ_{13t}. Consequently, the inflation rate cannot be chosen constrained-optimal but is given and fixed at its target value.

Furthermore, applying a zero lower bound on the nominal interest rate implies that the complementary slackness condition $\lambda_{14t}i_t = 0$ as well as $\lambda_{14t} \geq 0$ must hold. To implement this feature, instead of using the FOC with respect to i_t, the following two equations are added to the model-block in the Dynare mod.file:

$$\lambda_{14t} = \max\left(0, \frac{\delta\Lambda_t}{\delta i_t} - \lambda_{14t}\right)$$

and

$$(i_t \leq 0) i_t + (i_t > 0)\left(\frac{\delta\Lambda_t}{\delta i_t} - \lambda_{14t}\right) = 0, \tag{3.A.3}$$

where

$$\begin{gathered}\frac{\delta\Lambda_t}{\delta i_t} = \lambda_{2t}\beta^s \exp(-zC^s_{t+1})\frac{1}{\Pi_{t+1}}\frac{1+\tau^c_t}{1+\tau^c_{t+1}} \\ +\lambda_{3t}\beta^b \exp(-zC^b_{t+1})\frac{1}{\Pi_{t+1}}\frac{1+\tau^c_t}{1+\tau^c_{t+1}}\left[\Phi_t - \phi\frac{D^b_t}{\bar{D}^b_t}\exp\left(\frac{D^b_t}{\bar{D}^b_t}-1\right)\right]^{-1} \\ +\lambda_{11t}\frac{D^b_t}{\Phi_t}\frac{1}{(1+i_t)^2} + \lambda_{14t}.\end{gathered}$$

The first equation is not needed to solve the Ramsey-optimal equilibrium since it only determines λ_{14t} which is otherwise not present in the model equations.

3.8.B Social Planner Equilibrium

Lagrangian:

$$\begin{gathered}\Lambda_t = \widetilde{s}\left[1 - \exp\left(-zC^s_t\right) - \frac{\left(L^s_t\right)^{1+\eta}}{1+\eta}\right] + (1-\widetilde{s})\left[1 - \exp\left(-tC^b_t\right) - \frac{\left(L^b_t\right)^{1+\eta}}{1+\eta}\right] \\ +\lambda_{1t}\left[Y_t - \left(L^s_t\right)^s\left(L^b_t\right)^{1-s}\right] + \lambda_{2t}\left[Y_t - sC^s_t - (1-s)C^b_t - \frac{\kappa}{2}(\Pi_t - 1)^2 Y_t\right]\end{gathered}$$

w.r.t. C^s_t, C^b_t, L^s_t, L^b_t, Y_t, Π_t

First order conditions:

$$\frac{\delta\Lambda_t}{\delta C^s_t}: \quad \widetilde{s}\, z\exp(-zC^s_t) = s\ \lambda_{2t} \tag{3.B.1}$$

$$\frac{\delta\Lambda_t}{\delta C^b_t}: \quad (1-\widetilde{s})\ z\exp(-zC^b_t) = (1-s)\ \lambda_{2t} \tag{3.B.2}$$

$$\frac{\delta \Lambda_t}{\delta L_t^s}: \quad -\widetilde{s}(L_t^s)^\eta = \lambda_{1t} s \left(\frac{L_t^b}{L_t^s}\right)^{1-s} \tag{3.B.3}$$

$$\frac{\delta \Lambda_t}{\delta L_t^b}: \quad -(1-\widetilde{s})(L_t^b)^\eta = \lambda_{1t}(1-s) \left(\frac{L_t^s}{L_t^b}\right)^{s} \tag{3.B.4}$$

$$\frac{\delta \Lambda_t}{\delta Y_t}: \quad \lambda_{1t} + \lambda_{2t}\left(1 - \frac{\kappa}{2}(\Pi_t - 1)^2\right) = 0 \tag{3.B.5}$$

$$\frac{\delta \Lambda_t}{\delta \Pi_t}: \quad -\lambda_{2t}\kappa(\Pi_t - 1)Y_t = 0. \tag{3.B.6}$$

Solution:

For any solution with $Y_t > 0$, equation (3.B. 6) requires $\Pi_t = 1$ ($\lambda_{2t} = 0$ would imply that there is no solution to (3.B. 1)).
Combining equations (3.B. 1) and (3.B. 2) delivers

$$C_t^s = C_t^b - \ln\left(\frac{1-\widetilde{s}}{1-s}\frac{s}{\widetilde{s}}\right)\frac{1}{z} \tag{3.B.7}$$

and combining equations (3.B. 3) with (3.B. 4) gives

$$L_t^s = L_t^b \left(\frac{1-\widetilde{s}}{1-s}\frac{s}{\widetilde{s}}\right)^{\frac{1}{1+\eta}}. \tag{3.B.8}$$

Rearranging equation (3.B. 3) and plugging in (3.B. 5) and (3.B. 2) delivers

$$\left(L_t^b\right)^\eta = z\exp(-zC_t^b)\left(\frac{s}{\widetilde{s}}\frac{1-\widetilde{s}}{1-s}\right)^{\frac{s}{1+\eta}}\left(1 - \frac{\kappa}{2}(\Pi_t - 1)^2\right). \tag{3.B.9}$$

Using $\Pi_t = 1$ and combining the production function with the resource constraint gives

$$(L_t^s)^s(L_t^b)^{1-s} = sC_t^s + (1-s)C_t^b + G_t. \tag{3.B.10}$$

Consequently, the Social planner's equilibrium is defined by the set of equations (3.B. 7), (3.B. 8), (3.B. 9), and (3.B. 10) defining C_t^s, C_t^b, L_t^s, and L_t^b as well as $\Pi_t = 1$ and $Y_t = (L_t^s)^s(L_t^b)^{1-s}$.

3.8.C Efficiency of the Exogenous Policy Equilibrium

The exogenous policy equilibrium can be described by the following set of equations defining C_t^s, C_t^b, L_t^s, L_t^b, W_t^s, W_t^b, Π_t, i_t, and D_t^b:

$$\exp(-zC_t^s) = \beta^s E_t \left\{ \exp(-zC_{t+1}^s)(1+i_t)\frac{1}{\Pi_{t+1}}\frac{1+\tau_t^c}{1+\tau_{t+1}^c} \right\} \tag{3.C.1}$$

$$\exp(-zC_t^b) = \beta^b E_t \left\{ \exp(-zC_{t+1}^b)\frac{1+i_t^b}{\Pi_{t+1}}\frac{1+\tau_t^c}{1+\tau_{t+1}^c} \left[1 - D_t^b \frac{\Phi_t'}{\Phi_t}\right]^{-1} \right\} \tag{3.C.2}$$

$$(L_t^s)^\eta = W_t^s z \exp(-zC_t^s)\frac{1-\tau_t^w}{1+\tau_t^c} \tag{3.C.3}$$

$$(L_t^b)^\eta = W_t^b z \exp(-zC_t^b)\frac{1-\tau_t^w}{1+\tau_t^c} \tag{3.C.4}$$

$$L_t^s W_t^s = L_t^b W_t^b \tag{3.C.5}$$

$$sC_t^s + (1-s)C_t^b = (L_t^s)^s (L_t^b)^{1-s} \left[1 - \frac{\kappa}{2}(\Pi_t - 1)^2\right] \tag{3.C.6}$$

$$\frac{D_t^b}{1+i_t^b} - \frac{D_{t-1}^b}{\Pi_t} = (1+\tau_t^c)\left[C_t^b - (L_t^s)^s (L_t^b)^{1-s}\left(1 - \frac{\kappa}{2}(\Pi_t - 1)^2\right)\right] \tag{3.C.7}$$

$$\begin{aligned} &\beta\kappa\frac{u_{ct+1}}{u_{ct}}(\Pi_{t+1}-1)\,\Pi_{t+1}\frac{(L_{t+1}^s)^s (L_{t+1}^b)^{1-s}}{(L_t^s)^s (L_t^b)^{1-s}} \\ &= \theta\left(1 - W_t^s\left(\frac{L_t^s}{L_t^b}\right)^{1-s}\right) - 1 + \kappa(\Pi_t - 1)\Pi_t \end{aligned} \tag{3.C.8}$$

together with a monetary policy specification and given the tax instruments τ_t^w and τ_t^c as well as the definition of the interest spread (3.2).

Combining equations (3.C.6) with (3.C.7) delivers

$$\frac{D_t^b}{1+i_t^b} - \frac{D_{t-1}^b}{\Pi_t} = (1+\tau_t^c)\left[C_t^b - sC_t^s - (1-s)C_t^b\right]$$
$$\Leftrightarrow C_t^s = C_t^b - \frac{\frac{D_t^b}{1+i_t^b} - \frac{D_{t-1}^b}{\Pi_t}}{s(1+\tau_t^c)}. \tag{3.C.9}$$

Comparing (3.C. 9) with the Social planner's conditions (3.B. 7) and $\Pi_t = 1$ shows that efficiency of the exogenous policy equilibrium requires

$$\frac{\frac{D_t^b}{1+i_t^b} - D_{t-1}^b}{s(1+\tau_t^c)} = \ln\left(\frac{1-\widetilde{s}}{1-s}\frac{s}{\widetilde{s}}\right)\frac{1}{z}$$
$$\Leftrightarrow \tau_t^c = z\frac{\frac{D_t^b}{1+i_t^b} - D_{t-1}^b}{s\ln\left(\frac{1-\widetilde{s}}{1-s}\frac{s}{\widetilde{s}}\right)} - 1. \tag{3.C.10}$$

Moreover, equations (3.B.7) to (3.B.10) show that the efficient allocation of real variables is independent of the deleveraging shock and, thus, constant over time. Efficiency of the exogenous policy allocation, as a consequence, requires that the Euler equations (3.C.1) and (3.C.2) become

$$1 = \beta^s \frac{1+i_t}{\Pi_{t+1}}\frac{1+\tau_t^c}{1+\tau_{t+1}^c}$$

and

$$1 = \beta^b \frac{1+i_t^b}{\Pi_{t+1}}\frac{1+\tau_t^c}{1+\tau_{t+1}^c}\left[1 - D_t^b\frac{\Phi_t'}{\Phi_t}\right]^{-1}.$$

Combining both equations gives

$$\Phi_t\left(1 - D_t^b\frac{\Phi_t'}{\Phi_t}\right)^{-1} = \frac{\beta^s}{\beta^b}.$$

This shows that – recalling that β^b is calibrated to ensure $\beta^s/\beta^b = 1/(1-\phi)$ – $D_t^b = \bar{D}_t^b$ must hold implying $\Phi_t = 1$ and $\Phi_t' = \phi/\bar{D}_t^b$. Consequently, the debt level must be equal to the risk-free debt level in each period to ensure efficiency of the exogenous policy equilibrium. Using this finding together with the Social planner's condition $\Pi_t = 1$, the optimal rule for consumption taxes (3.C.10) can be written as

$$1+\tau_t^c = \frac{\beta^s \bar{D}_t^b}{\frac{\bar{D}_{t-1}^b}{1+\tau_{t-1}^c} + \frac{s}{z}\ln\left(\frac{1-\widetilde{s}}{1-s}\frac{s}{\widetilde{s}}\right)}. \tag{3.C.11}$$

Plugging in equations (3.C.3) and (3.C.4) into (3.C.5) gives

$$(L_t^s)^{1+\eta}\exp(zC_t^s) = (L_t^b)^{1+\eta}\exp(zC_t^b) \tag{3.C.12}$$

which, together with (3.C.9), can be written as

$$\left(\frac{L_t^s}{L_t^b}\right)^{1+\eta} = \exp\left(z\frac{\frac{D_t^b}{1+i_{t-1}^b} - \frac{D_{t-1}^b}{\Pi_t}}{s(1+\tau_t^c)}\right). \tag{3.C.13}$$

This shows that if the efficiency condition (3.C. 11) holds, equation (3.C. 13) delivers the efficient allocation given in (3.B.8):

$$L_t^s = L_t^b\left(\frac{1-\widetilde{s}}{1-s}\frac{s}{\widetilde{s}}\right)^{\frac{1}{1+\eta}}. \tag{3.C.14}$$

Finally, to obtain the optimal rule for the wage tax, using the efficiency condition $\Pi_t = 1$ to replace Π_t in equation (3.C.8), W_t^s evolves as

$$W_t^s = \frac{\theta-1}{\theta}\left(\frac{L_t^b}{L_t^s}\right)^{1-s}$$

which means equation (3.C.5) gives W_t^b as

$$W_t^b = \frac{\theta-1}{\theta}\left(\frac{L_t^b}{L_t^s}\right)^{-s}.$$

Plugging in this expression for W_t^b into (3.C.4) delivers

$$\frac{\theta-1}{\theta}\left(\frac{L_t^s}{L_t^b}\right)^{s} = (L_t^b)^{\eta}\frac{1}{z}\exp(zC_t^b)\frac{1+\tau_t^c}{1-\tau_t^w}. \tag{3.C.15}$$

Combining equation (3.C.14) with (3.C.15) then delivers

$$\begin{aligned}\frac{\theta-1}{\theta}(L_t^b)^{-s}(L_t^b)^{s}\left(\frac{1-\widetilde{s}}{1-s}\frac{s}{\widetilde{s}}\right)^{\frac{s}{1+\eta}} &= (L_t^b)^{\eta}\frac{1}{z}\exp(zC_t^b)\frac{1+\tau_t^c}{1-\tau_t^w}\\ \Leftrightarrow (L_t^b)^{\eta} &= \frac{\theta-1}{\theta}\left(\frac{1-\widetilde{s}}{1-s}\frac{s}{\widetilde{s}}\right)^{\frac{s}{1+\eta}} z\exp(-zC_t^b)\frac{1-\tau_t^w}{1+\tau_t^c}.\end{aligned}$$

Comparing this equation with the efficient allocation (3.B.9) shows that

$$\tau_t^w = 1 - \frac{\theta}{\theta - 1}(1 + \tau_t^c) \tag{3.C.16}$$

must hold. Overall, tax rates must be set to follow (3.C.11) and (3.C.16) and $\Pi_t = 1$ must hold to ensure efficiency of the exogenous policy equilibrium.

3.8.D Utility Measures

Period-by-period utility losses for the economy as a whole (ξ_t) are defined such that

$$U\left(C_t^s, C_t^b, L_t^s, L_t^b\right) = U\left((1-\xi_t)C_{ss}^s, (1-\xi_t)C_{ss}^b, L_{ss}^s, L_{ss}^b\right)$$

$$\begin{aligned}\Leftrightarrow \widetilde{s}\left([1-\exp(-zC_t^s)] - \frac{(L_t^s)^{1+\eta}}{1+\eta}\right) + (1-\widetilde{s})\left(\left[1-\exp(-zC_t^b)\right] - \frac{(L_t^b)^{1+\eta}}{1+\eta}\right) \\ = \widetilde{s}\left([1-\exp(-z(1-\xi_t)C_{ss}^s)] - \frac{(L_{ss}^s)^{1+\eta}}{1+\eta}\right) \\ +(1-\widetilde{s})\left(\left[1-\exp(-z(1-\xi_t)C_{ss}^b)\right] - \frac{(L_{ss}^b)^{1+\eta}}{1+\eta}\right)\end{aligned}$$

holds, where X_t denotes the value of the respective variable in period t while X_{ss} denotes the respective steady-state value. Utility losses for savers (ξ_t^s) are defined such that

$$U\left(C_t^s, L_t^s\right) = U\left((1-\xi_t^s)C_{ss}^s, L_{ss}^s\right)$$

$$\Leftrightarrow\ [1-\exp(-zC_t^s)] - \frac{(L_t^s)^{1+\eta}}{1+\eta} = [1-\exp(-z(1-\xi_t^s)C_{ss}^s)] - \frac{(L_{ss}^s)^{1+\eta}}{1+\eta}$$

applies and for borrowers, the period-by-period utility loss (ξ_t^b) is defined such that

$$U\left(C_t^b, L_t^b\right) = U\left((1-\xi_t^b)C_{ss}^b, L_{ss}^b\right)$$

$$\Leftrightarrow\ \left[1-\exp(-zC_t^b)\right] - \frac{(L_t^b)^{1+\eta}}{1+\eta} = \left[1-\exp(-z(1-\xi_t^b)C_{ss}^b)\right] - \frac{(L_{ss}^b)^{1+\eta}}{1+\eta}$$

is fulfilled.

Lifetime utility losses are defined as ξ, ξ^s, and ξ^b such that

$$E_t \sum_{t=0}^{\infty} \beta^t U_t = \widetilde{s} \left([1 - \exp(-z(1-\xi) C_{ss}^s)] - \frac{(L_{ss}^s)^{1+\eta}}{1+\eta} \right)$$
$$+ (1-\widetilde{s}) \left(\left[1 - \exp(-z(1-\xi) C_{ss}^b)\right] - \frac{(L_{ss}^s)^{1+\eta}}{1+\eta} \right) + \sum_{t=1}^{\infty} \beta^t U_{ss},$$

$$E_t \sum_{t=0}^{\infty} \beta^t \left([1 - \exp(-z C_t^s)] - \frac{(L_t^s)^{1+\eta}}{1+\eta} \right)$$
$$= [1 - \exp(-z(1-\xi^s) C_{ss}^s)] - \frac{(L_{ss}^s)^{1+\eta}}{1+\eta} + \sum_{t=1}^{\infty} \beta^t U_{ss}^s,$$

and

$$E_t \sum_{t=0}^{\infty} \beta^t \left(\left[1 - \exp(-z C_t^b)\right] - \frac{(L_t^b)^{1+\eta}}{1+\eta} \right)$$
$$= \left[1 - \exp(-z(1-\xi^b) C_{ss}^b)\right] - \frac{(L_{ss}^b)^{1+\eta}}{1+\eta} + \sum_{t=1}^{\infty} \beta^t U_{ss}^s$$

are fulfilled where

$$U_t = \widetilde{s} \left([1 - \exp(-z C_t^s)] - \frac{(L_t^s)^{1+\eta}}{1+\eta} \right) + (1-\widetilde{s}) \left(\left[1 - \exp(-z C_t^b)\right] - \frac{(L_t^b)^{1+\eta}}{1+\eta} \right).$$

3.8.E Optimal Monetary Policy

With respect to the Ramsey problem defined in Appendix A, the different monetary policy scenarios can be implemented by replacing equations (3.A.1), (3.A. 2), and (3.A.3) in the Dynare mod-file with the following set of equations:

- Inflation targeting without the ZLB:

$$\Pi_t = \bar{\Pi}$$

$$\lambda_{14t} = 0$$

$$
-\lambda_{2t}\beta^s \exp(-zC^s_{t+1})\frac{1}{\Pi_{t+1}}\frac{1+\tau^c_t}{1+\tau^c_{t+1}} - \lambda_{11t}\frac{D^b_t}{\Phi_t}\frac{1}{(1+i_t)^2}
$$

$$
-\lambda_{3t}\beta^b \exp(-zC^b_{t+1})\frac{1}{\Pi_{t+1}}\frac{1+\tau^c_t}{1+\tau^c_{t+1}}\left[\Phi_t - \phi\frac{D^b_t}{\bar{D}^b_t}\exp\left(\frac{D^b_t}{\bar{D}^b_t}-1\right)\right]^{-1}
$$

- Optimal monetary policy without the ZLB:

$$
\lambda_{13t} = 0
$$

$$
\lambda_{14t} = 0
$$

$$
-\lambda_{2t}\beta^s \exp(-zC^s_{t+1})\frac{1}{\Pi_{t+1}}\frac{1+\tau^c_t}{1+\tau^c_{t+1}} - \lambda_{11t}\frac{D^b_t}{\Phi_t}\frac{1}{(1+i_t)^2}
$$

$$
-\lambda_{3t}\beta^b \exp(-zC^b_{t+1})\frac{1}{\Pi_{t+1}}\frac{1+\tau^c_t}{1+\tau^c_{t+1}}\left[\Phi_t - \phi\frac{D^b_t}{\bar{D}^b_t}\exp\left(\frac{D^b_t}{\bar{D}^b_t}-1\right)\right]^{-1}
$$

- Optimal monetary policy under the existence of the ZLB:

$$
\lambda_{13t} = 0
$$

$$
\lambda_{14t} = \max\left(0, \frac{\delta\Lambda_t}{\delta i_t} - \lambda_{14t}\right)
$$

$$
(i_t \le 0)i_t + (i_t > 0)\left(\frac{\delta\Lambda_t}{\delta i_t} - \lambda_{14t}\right) = 0
$$

where

$$
\frac{\delta\Lambda_t}{\delta i_t} = \lambda_{2t}\beta^s \exp(-zC^s_{t+1})\frac{1}{\Pi_{t+1}}\frac{1+\tau^c_t}{1+\tau^c_{t+1}}
$$

$$
+\lambda_{3t}\beta^b \exp(-zC^b_{t+1})\frac{1}{\Pi_{t+1}}\frac{1+\tau^c_t}{1+\tau^c_{t+1}}\left[\Phi_t - \phi\frac{D^b_t}{\bar{D}^b_t}\exp\left(\frac{D^b_t}{\bar{D}^b_t}-1\right)\right]^{-1}
$$

$$
+\lambda_{11t}\frac{D^b_t}{\Phi_t}\frac{1}{(1+i_t)^2} + \lambda_{14t}
$$

4. Optimal Fiscal Policy with Heterogeneous Agents: The Role of Nominal Rigidities and the Social Welfare Function

4.1 Introduction

In almost all advanced countries, distributional issues seem to be quite an as important goal for policy makers as pursuing economy-wide welfare maximization. In dynamic stochastic general equilibrium (DSGE) literature, however, most models are based on the assumption of a representative agent such completely excluding distributive effects. In this framework, obviously, there is no need for discussing an appropriate social welfare function since maximizing total welfare is equivalent to maximizing individual welfare. But even in models including heterogeneous agents, optimal fiscal policy is generally modeled from a utilitarian perspective meaning a Ramsey planner maximizes economy-wide welfare defined by the sum of individual utilities. With heterogeneous agents this does not coincide with maximizing utility of an individual agent. Focusing on welfare-maximizing policies alone may cover important distributional effects. And in this context, the question of choosing a social welfare function arises where the possible choices range from applying a utilitarian concept of maximizing the sum of individual utilities to following the Rawlsian proposition of maximizing the utility of the poorest agent only. While recent DSGE literature excessively explores optimal policy measures during financial crises, distributional matters of these policy reactions have rarely been investigated and the possibility of choosing any other social welfare function than a purely utilitarian definition is all but neglected.

This paper builds on the literature on (constrained-) optimal fiscal policy reactions to financial shocks but explores the distributional effects as well as their determinants in a model with patient and impatient households where an interest spread shock occurs. The focus, here, it twofold: On the one hand, the effectiveness of optimal wage income taxation versus the effectiveness of interest income taxation is considered and welfare gains from being able to use different tax rates on both types of income are computed. On the other hand, the different effects of these tax measures on the disparity between groups are considered by investigating which group gains and which looses from applying a Ramsey-optimal policy. Within this context, the influence of the degree of price as well as wage rigidity is investigated. Finally, while the main part of the paper follows the common utilitarian assumption of the social welfare function being the sum of individual utilities, I compare the results to the case of a Ramsey planner using a social welfare concept in the spirit of Rawls where the weight the planner puts on the utility of one of the two groups of agents is the higher the lower their respective welfare level.

The present paper is related to existing literature in several aspects. To begin with, there is a literature exploring the distributional issues of optimal capital taxation under idiosyncratic risk as for example Evans (2014), Shourideh (2012), and Panousi and Reis (2014). Each of them focuses on capital taxation and does not explore the determinants of the distributional effects. Dyrda and Pedroni (2017) explore welfare effects of a Ramsey-optimal policy consisting in choosing government debt and income taxes in a real incomplete market economy where heterogeneity evolves either by differences in productivity or in the initial wealth distribution. They calibrate the model to US data and find that changing fiscal policy to follow a Ramsey-optimal policy would decrease inequality in the US relative to the current policy. The present paper is closely related to their paper as it focuses on distributional effects and regards heterogeneous agents but differs in various ways as it features a more elaborated fiscal sector, explicitly investigates the effect of nominal rigidities, and explores fiscal policy reactions following a spread shock in contrast to Dyrda and Pedroni (2017) exploring the shift from non-optimal to optimal policy without the occurrence of additional shocks. In addition, the present paper builds on Ivens (2018b) who explores optimal fiscal policy reactions to a private debt deleveraging shock in a model with savers and borrowers. It differs, however, as it incorporates interest income taxes and explicitly regards the importance of wage and price rigidities while Ivens (2018b) focuses on the presence of a ZLB in a model with flexible wages where the only nominal rigidity evolves by the presence of Rotemberg-type price adjustment costs. Beyond that, the present paper extends the analysis to the case of a Ramsey planner maximizing a Rawlsian social welfare function.

Moreover, the current paper is related to the small strand of literature stressing the role of price rigidity for optimal fiscal policy. Siu (2004) computes optimal fiscal and monetary policy in a cash-in-advance model and finds that the presence of sticky prices has substantial influence on the optimal income tax rate. Schmitt-Grohe and Uribe (2006a) explore optimal policy in a closed economy with price and wage rigidity and find price stickiness to be the most important distortion influencing policy making. Furthermore, Schmitt-Grohe and Uribe (2004) compute optimal fiscal and monetary policy in a closed economy with money and state that under a specific calibration of the degree of price stickiness policy makers find it more important to obtain price stability than to smooth income taxes. None of these papers, though, does allow for heterogeneous agents.

Finally, there is a very limited number of papers regarding the possibility of departing from the utilitarian concept of computing (constrained-) optimal policy. Areosa et al. (2017) compute optimal monetary policy by using a Rawlsian social welfare function – meaning weighting the utility of one group of agents only – in a textbook New-Keynesian model. They find that the inflation and interest rate differences between the two scenarios of using the Rawlsian versus the utilitarian social welfare function crucially depend on the kind of shock regarded. While in case of a monetary shock, the optimal response does not significantly depend on the social welfare function applied, there are huge differences in case of a fiscal shock. Swarbick (2012) explores optimal fiscal policy in a model with rule-of-thumb agents and investigates the effect of setting different weights to the utilities of the two groups of agents. The planner's weights are, however, exogenously chosen and, in contrast to the present paper, do not depend on the agents' utility levels.

The current paper contributes to this literature in the following ways: In the first part, regarding the effectiveness of two types of income taxes, it is shown that taxing interest income is a more effective measure in reducing spread shock induced welfare losses than wage taxation. Here, the welfare gains from being able to levy different tax rates on the two types of income are sizable. In the second part, relating to distributional effects, it is found that applying a Ramsey-optimal policy based on the common utilitarian social welfare function may increase the disparity between groups depending on the income tax base used. It is shown that these distributive effects crucially depend on the relation between the degrees of wage and price rigidity. While a higher degree of wage stickiness than of price stickiness implies decreasing the disparity between groups, prices being sufficiently more sticky than wages involves enlarging the wedge between savers and borrowers. Finally, the results are compared to the case of a Ramsey planner maximizing a Rawlsian social welfare function where the weight the planner sets on individual utilities is increasing with a decreasing relative utility level. It is shown that while in this case disparities between groups can completely be eliminated, this takes place at the cost of a huge decrease in the savers' welfare as well as at the cost of noticeably more fluctuations in real variables and tax rates.

The remainder of the paper is organized as follows: In the next section, the model is described and the constrained-optimal fiscal policy is obtained. Section 4.3 contains the simulation of a spread shock for different policies and the respective results regarding effectiveness and distributional effects. In Section 4.4, the role of price and wage rigidity is investigated. Section 4.5 contains the exploration of an alternative social welfare measure while a robustness analysis can be found in Section 4.6. Section 4.7. concludes.

4.2 The Model

4.2.1 Model Description

I consider a closed economy featuring two types of households, namely patient and impatient households, both having the same utility function deriving utility from consumption, leisure, and government spending but differing in their discount factors. Consequently, in equilibrium, patient households will be savers while impatient households will be borrowers. Prices and wages are set on a staggered basis following Calvo. The government spends on the consumption good and levies two types of income taxes: labor income and interest income taxes. The monetary authority sets the nominal interest rate following a simple Taylor rule.

Households

Households maximize the following increasing and concave utility function which is twice continuously differentiable

$$U_t^h = E_t \sum_{t=0}^{\infty} \left(\beta^h\right)^t \left\{ \frac{(C_t^h)^{1-\rho}}{1-\rho} - \frac{(L_t^h)^{1+\eta}}{1+\eta} + v\frac{G_t^{1-\gamma}}{1-\gamma} \right\}. \tag{4.1}$$

Here $h = s, b$ denotes patient (savers) and impatient households (borrowers), respectively, where p is the share of patient households while impatient households are of mass $1-p$. $0 < \beta^h < 1$ holds and C_t^h and L_t^h are consumption and labor per saver or borrower, respectively. G_t denotes real per capita government spending. $\eta > 0$ is the inverse of the Frisch elasticity of labor supply, $\rho > 0$ as well as $\gamma > 0$ holds, and $\nu > 0$ gives the weight of government spending in utility.

Assets markets are incomplete in that borrowers have to pay a risk premium on real debt D_t^b such that the interest rate borrowers have to pay is given by

$$1 + i_t^b = (1 + i_t)\vartheta_t \exp\left(\kappa(D_t^b - \bar{D})\right). \tag{4.2}$$

Here, i_t is the savers' nominal interest rate, κ is a scaling factor determining the extent to which the interest spread reacts to changes in the debt level, and $\bar{D}$ is the steady-state level of debt. ϑ_t denotes an interest spread shock which follows the shock process

$$\vartheta_t = \rho^D \vartheta_{t-1} + 1 - \rho^D + \epsilon_t^D \tag{4.3}$$

where $0 < \rho^D < 1$ holds and ϵ_t^D is an i.i.d. shock.

The budget constraint for savers can be written in real terms as

$$(1 + (1 - \tau_t^i)i_{t-1})\frac{B_{t-1}^s}{\Pi_t} + (1 - \tau_t^w)W_t^s L_t^s = B_t^s + C_t^s + T_t^s - RP_t - Div_t \tag{4.4}$$

with

$$Div_t = Y_t - pW_t^s L_t^s - (1 - p)W_t^b L_t^b \tag{4.5}$$

denoting per capita dividends from firms and

$$RP_t = p(i_{t-1}^b - i_{t-1})\frac{B_{t-1}^s}{\Pi_t}$$

denoting the per-capita risk premium payments assumed to be charged by a financial intermediary which is owned by savers and borrowers. Π_t is inflation, Y_t is output, and T_t^s and B_t^s denote lump-sum taxes and bond holdings per saver, respectively. τ_t^w indicates wage taxes and τ_t^i denotes taxes on interest income.

Maximizing (4.1) subject to (4.4) delivers the following Euler equation for savers:[38]

$$(C_t^s)^{-\rho} = \beta^s E_t \left\{ (C_{t+1}^s)^{-\rho}(1 + (1 - \tau_{t+1}^i)i_t)\frac{1}{\Pi_{t+1}} \right\}. \tag{4.6}$$

[38] It is assumed that agents do not internalize the effects of their choice on dividend payments and on payments from the risk premium. Borrowers do, however, internalize the effect of their choice on the interest spread. While this modeling assumption is chosen to avoid an additional distortion evoked by the fact that borrowers do not internalize the effect on the interest spread which should not be the focus of the analysis conducted here, the results remain qualitatively the same without assuming internalization.

For borrowers, the per borrower budget constraint reads

$$D_t^b + (1-\tau_t^w)W_t^b L_t^b = C_t^b + \frac{(1+i_{t-1}^b)D_{t-1}^b}{\Pi_t} + T_t^b - Div_t - RP_t - T^{\text{eff}}, \quad (4.7)$$

where T_t^b denotes lump-sum taxes per borrower. T^{eff} is a constant subsidy to borrowers set to guarantee steady-state efficiency of the decentralized steady state following Ferrero et al. (2018) as is explained in the next section. The Euler equation for borrowers is given by

$$(C_t^b)^{-\rho} = \beta^b E_t \left\{ (C_{t+1}^b)^{-\rho} \frac{1+i_t^b}{\Pi_{t+1}} (1+\kappa D_t^b) \right\}. \quad (4.8)$$

Labor supply

Households are assumed to supply differentiated labor services $L_t^h(i)$ at wage $W_t^h(i)$ with $h \in \{s, b\}$ to a group-specific labor agency. There is one labor agency for each group of households – savers and borrowers – combining differentiated labor inputs to a homogenous group-specific aggregate subject to the production functions

$$L_t^s = \left[\frac{1}{p} \int_0^p L_t^s(i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}} \quad (4.9)$$

in case of the savers' labor agency and

$$L_t^b = \left[\frac{1}{1-p} \int_1^{1-p} L_t^b(i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}} \quad (4.10)$$

in case of the borrowers' labor agency. Here, $L_t^s(i)$ and $L_t^b(i)$ denote labor supplied by individual i belonging to the group of savers or borrowers, respectively. For the savers' labor agency, taking wages as given, cost minimization implies

$$\min_{L_t^s(i)} W_t^s L_t^s = \int_0^p \frac{1}{p} W_t^s(i) L_t^s(i) \, di$$

such that the first order condition with respect to labor reads

$$W_t^s \left[\frac{1}{p} \int_0^p L_t^s(i)^{\frac{\sigma-1}{\sigma}} \, di \right]^{\frac{1}{\sigma-1}} (L_t^s(i))^{-\frac{1}{\sigma}} = W_t^s(i).$$

Rearranging delivers

$$L_t^s(i) = L_t^s \left(\frac{W_t^s(i)}{W_t^s} \right)^{-\sigma}. \quad (4.11)$$

The zero profit condition implies that

$$W_t^s L_t^s = \frac{1}{p}\int_0^p W_t^s(i) L_t^s(i)\ di \tag{4.12}$$

which can be rearranged by substituting $L_t^s(i)$ with (4.11) to deliver

$$W_t^s = \left[\int_0^p \left(W_t^s(i)\right)^{1-\sigma}\ di\right]^{\frac{1}{1-\sigma}}. \tag{4.13}$$

Each household can adjust its wage in any given period with probability $(1-\xi_w)$. In case of adjustment, it chooses $\widetilde{W}_t^s(i)$. Consequently, equation (4.13) delivers

$$W_t^s = \left[\xi_w \left(W_{t-1}^s\right)^{1-\sigma} + (1-\xi_w)\left(\widetilde{W}_t^s(i)\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{4.14}$$

which can be rearranged to read

$$\frac{\widetilde{W}_t^s(i)}{W_t^s} = \left(\frac{1-\xi_w\left(\frac{W_t^s}{W_{t-1}^s}\right)^{\sigma-1}}{1-\xi_w}\right)^{\frac{1}{1-\sigma}}. \tag{4.15}$$

This shows that in case of adjustment each household belonging to the group of savers chooses the same wage such that the index i can be dropped. Equivalently, for borrowers, the following equations can be derived:

$$L_t^b(i) = L_t^b\left(\frac{W_t^b(i)}{W_t^b}\right)^{-\sigma} \tag{4.16}$$

and

$$\frac{\widetilde{W}_t^b(i)}{W_t^b} = \left(\frac{1-\xi_w\left(\frac{W_t^b}{W_{t-1}^b}\right)^{\sigma-1}}{1-\xi_w}\right)^{\frac{1}{1-\sigma}}. \tag{4.17}$$

Wage setting

In setting its nominal wage $\widetilde{W}_t^s(i)$, each saver maximizes

$$E_t\sum_{c=0}^{\infty}(\beta^s\xi_w)^c\left\{(1-\tau_{t+c}^w)\widetilde{W}_t^s(i)L_{t+c}^s(i)\frac{\left(C_{t+c}^s(i)\right)^{-\rho}}{P_{t+c}} - \frac{\left(L_{t+c}^s(i)\right)^{1+\eta}}{1+\eta}\right\}.$$

The first order condition with respect to $\widetilde{W}_t^s(i)$ reads

$$\sum_{c=0}^{\infty}(\beta^s\xi_w)^c\left\{(1-\sigma)(1-\tau_{t+c}^w)\left(\widetilde{W}_t^s(i)\right)^{-\sigma}L_{t+c}^s\left(W_{t+c}^s\right)^{\sigma}\frac{\left(C_{t+c}^s\right)^{-\rho}}{P_{t+c}}\right\}$$
$$+\sum_{c=0}^{\infty}(\beta^s\xi_w)^c\left\{\sigma\left(\widetilde{W}_t^s(i)\right)^{-\sigma-1}L_{t+c}^s\left(W_{t+c}^s\right)^{\sigma}\left(L_{t+c}^s(i)\right)^{\eta}\right\}=0.$$

Rearranging delivers

$$\left(\frac{\widetilde{W}_t^s(i)}{W_t^s}\right)^{1+\sigma\eta}=\frac{\frac{\sigma}{\sigma-1}E_t\sum_{c=0}^{\infty}(\beta^s\xi_w)^c\left(L_{t+c}^s\right)^{1+\eta}\left(\frac{W_{t+c}^s}{W_t^s}\right)^{\sigma(1+\eta)}}{E_t\sum_{c=0}^{\infty}(\beta^s\xi_w)^c L_{t+c}^s\left(C_{t+c}^s\right)^{-\rho}\frac{(1-\tau_{t+c}^w)W_{t+c}^s}{P_{t+c}}\left(\frac{W_{t+c}^s}{W_t^s}\right)^{\sigma-1}}. \tag{4.18}$$

Combining (4.18) with (4.15) and using a recursive formulation, the wage setting equations for savers can be written as

$$\frac{g_{1t}^s}{g_{2t}^s}=\left(\frac{1-\xi_w\left(\frac{W_{t-1}^s}{W_t^s}\right)^{1-\sigma}}{1-\xi_w}\right)^{\frac{1+\eta\sigma}{1-\sigma}} \tag{4.19}$$

$$g_{1t}^s=\frac{\sigma}{\sigma-1}\left(L_t^s\right)^{1+\eta}+\beta^s\xi_w E_t\left\{\left(\frac{W_{t+1}^s}{W_t^s}\right)^{\sigma(1+\eta)}g_{1\ t+1}^s\right\} \tag{4.20}$$

$$g_{2t}^s=\left(C_t^s\right)^{-\rho}(1-\tau_t^w)W_t^sL_t^s+\beta^s\xi_w E_t\left\{\left(\frac{W_{t+1}^s}{W_t^s}\right)^{\sigma-1}g_{2\ t+1}^s\right\}. \tag{4.21}$$

Equivalently, the wage setting equations for borrowers can be obtained to read

$$\frac{g_{1t}^b}{g_{2t}^b}=\left(\frac{1-\xi_w\left(\frac{W_{t-1}^b}{W_t^b}\right)^{1-\sigma}}{1-\xi_w}\right)^{\frac{1+\eta\sigma}{1-\sigma}} \tag{4.22}$$

$$g_{1t}^b=\frac{\sigma}{\sigma-1}\left(L_t^b\right)^{1+\eta}+\beta^b\xi_w E_t\left\{\left(\frac{W_{t+1}^b}{W_t^b}\right)^{\sigma(1+\eta)}g_{1\ t+1}^b\right\} \tag{4.23}$$

$$g_{2t}^b=\left(C_t^b\right)^{-\rho}(1-\tau_t^w)W_t^bL_t^b+\beta^b\xi_w E_t\left\{\left(\frac{W_{t+1}^b}{W_t^b}\right)^{\sigma-1}g_{2\ t+1}^b\right\}. \tag{4.24}$$

Production

There is a continuum of monopolistically competitive intermediate goods producers indexed by j and a representative final goods producer operating under perfect competition. The final goods producer combines differentiated intermediate goods $y_t(j)$ purchased from firms to a homogeneous aggregate good subject to the technology

$$Y_t = \left[\int_0^1 y_t(j)^{\frac{\sigma-1}{\sigma}} dj\right]^{\frac{\sigma}{\sigma-1}}, \tag{4.25}$$

with $\sigma > 1$ denoting the constant elasticity of substitution between differentiated goods and Y_t being per capita aggregate output. The associated cost minimization problem is given by

$$\min_{y_t(j)} P_t Y_t \equiv \int_0^1 p_t(j) y_t(j) dj$$

subject to the technology (4.25) such that the per capita demand for an individual good of firm j is

$$y_t(j) = \left(\frac{p_t(j)}{P_t}\right)^{-\sigma} Y_t. \tag{4.26}$$

Intermediate goods firms produce output using labor supplied by the two labor agencies subject to the production function

$$y_t(j) = pL_t^s(j) + (1-p)L_t^b(j). \tag{4.27}$$

They choose their labor inputs to minimize costs by taking wages as given. Consequently, cost minimization implies

$$\min_{L_t^s, L_t^b} W_t L_t \equiv pW_t^s L_t^s + (1-p)W_t^b L_t^b$$

$$\text{s.t.} \quad pL_t^s + (1-p)L_t^b = \text{const.}$$

The first order conditions with respect to L_t^s and L_t^b can be rearranged to read

$$W_t^s = W_t^b \equiv W_t \tag{4.28}$$

such that equations (4.15) and (4.17) can be rewritten to give

$$\frac{\widetilde{W}_t(i)}{W_t} = \left(\frac{1 - \xi_w \left(\frac{W_t}{W_{t-1}}\right)^{\sigma-1}}{1-\xi_w}\right)^{\frac{1}{1-\sigma}}. \tag{4.29}$$

This means, on an aggregate level, savers and borrowers obtain the same wage.

Prices are set on a staggered basis following Calvo, where in each period a fraction $(1-\xi)$ of firms is able to reset its prices facing the optimal price setting problem

$$\max_{\widetilde{p}_t(j)} E_t \sum_{c=0}^{\infty} (\xi_p \beta)^c \frac{Q_{t+c}}{Q_t} \left[\widetilde{p}_t(j) - W_{t+c}\right] y_{t+c}(j)$$

subject to the demand for the specific good (4.26), where $\beta \equiv p\beta^s + (1-p)\beta^b$ and

$$Q_{t+c} \equiv p(C^s_{t+c})^{-\rho} + (1-p)(C^b_{t+c})^{-\rho}.$$

After some manipulations, the first order condition can be written as

$$\frac{\widetilde{p}_t(j)}{P_t} = \frac{\sigma}{\sigma-1} \frac{E_t \sum_{c=0}^{\infty} (\xi\beta)^c Q_{t+c} \frac{W_{t+c}}{P_{t+c}} Y_{t+c} \left(\frac{P_{t+c}}{P_t}\right)^{\sigma}}{E_t \sum_{c=0}^{\infty} (\xi\beta)^c Q_{t+c} Y_{t+c} \left(\frac{P_{t+c}}{P_t}\right)^{\sigma-1}}. \tag{4.30}$$

The assumption of zero profits for the final goods producer gives the aggregate price index as

$$P_t = \left[\int_0^1 p_t(j)^{1-\sigma} dj\right]^{\frac{1}{1-\sigma}},$$

which can be written, due to the assumption of staggered price setting, as

$$P_t = \left[\xi P_{t-1}^{1-\sigma} + (1-\xi)\widetilde{p}_t(j)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}.$$

Rearranging delivers the following relationship between the optimal relative reset price and the inflation rate

$$\frac{\widetilde{p}_t(j)}{P_t} = \left(\frac{1-\xi\Pi_t^{1-\sigma}}{1-\xi}\right)^{\frac{1}{1-\sigma}}, \tag{4.31}$$

with $\Pi_t = P_t/P_{t-1}$. Combining the first order conditions of firms (4.30) with equation (4.31) and using a recursive formulation following Schmitt-Grohe and Uribe (2006), the price Philips curve can be expressed as

$$\frac{f1_t}{f2_t} = \left(\frac{1-\xi_p\Pi_t^{\sigma-1}}{1-\xi_p}\right)^{\frac{1}{1-\sigma}}, \tag{4.32}$$

$$f1_t = \frac{\sigma}{\sigma-1}\left[p(C^s_t)^{-\rho} + (1-p)(C^b_t)^{-\rho}\right] Y_t W_t + \beta\xi_p E_t\left\{\Pi^{\sigma}_{t+1} f1_{t+1}\right\}, \tag{4.33}$$

$$f2_t = \left[p(C^s_t)^{-\rho} + (1-p)(C^b_t)^{-\rho}\right] Y_t + \beta\xi_p E_t\left\{\Pi^{\sigma-1}_{t+1} f2_{t+1}\right\}. \tag{4.34}$$

Monetary policy

There is a central bank setting the nominal interest rate following a simple Taylor rule such that

$$1 + i_t = \Pi_t^{\mu}(1 + \bar{i}) \tag{4.35}$$

where $\bar{i}$ is the steady-state value of the interest rate of savers and $\mu > 1$ is a policy parameter determining the extent to which the central bank reacts to changes in inflation.

Government

The government spends on the consumption good, levies two types of income taxes, namely wage taxes and interest taxes, and (in some specifications) has access to lump-sum taxes such that the government budget reads

$$G_t + (1-p)T^{\text{eff}} = \tau_t^w W_t(pL_t^s + (1-p)L_t^b) + \tau_t^i \frac{D_{t-1}^b}{\Pi_t}(1-p)i_{t-1} + T_t \tag{4.36}$$

where per-capita lump-sum taxes are the same for both savers and borrowers such that

$$T_t \equiv T_t^s = T_t^b. \tag{4.37}$$

Aggregation and Equilibrium

By regarding the production side, the unweighted integral of per capita output can be written as

$$\int_0^1 y_t(j)dj = \int_0^1 pL_t^s(j) + (1-p)L_t^b(j)dj.$$

Alternatively, by using the demand function (4.26), the integral of per capita output can be expressed as

$$\int_0^1 y_t(j)dj = \int_0^1 \left(\frac{p_t(j)}{P_t}\right)^{-\sigma} Y_t dj \equiv \Delta_t Y_t,$$

where

$$\Delta_t \equiv \int_0^1 \left(\frac{p_t(j)}{P_t}\right)^{-\sigma} dj.$$

Combining both expressions delivers the aggregate production function

$$Y_t \Delta_t = pL_t^s + (1-p)L_t^b. \tag{4.38}$$

Following Schmitt-Grohe and Uribe (2006), the index of price dispersion can be rewritten as

$$\begin{aligned}\Delta_t &= \int_0^1 \left(\frac{p_t(j)}{P_t}\right)^{-\sigma} dj \\ &= (1-\xi_p)\sum_{i=c}^{\infty}(\xi_p)^i \left(\frac{\widetilde{p}_{t-i}(j)}{P_t}\right)^{-\sigma} \\ &= (1-\xi_p)\left(\frac{\widetilde{p}_t(j)}{P_t}\right)^{-\sigma} + \xi_p\,(\Pi_t)^{\sigma}\,\Delta_{t-1},\end{aligned}$$

which, by use of (4.31), can be expressed as

$$\Delta_t = (1-\xi_p)\left(\frac{1-\xi_p\Pi_t^{\sigma-1}}{1-\xi_p}\right)^{\frac{\sigma}{\sigma-1}} + \xi_p\Pi_t^{\sigma}\Delta_{t-1}. \tag{4.39}$$

Furthermore, the resource constraint for the consumption good gives

$$Y_t = pC_t^s + (1-p)C_t^b + G_t \tag{4.40}$$

and equilibrium in the asset market requires

$$pB_t^s = (1-p)D_t^b. \tag{4.41}$$

Finally, by combining the budget constraint of borrowers, (4.7), with equations (4.5), (4.36), (4.37), and (4.41), the evolution of debt can be expressed as

$$\begin{aligned}&D_t^b - \frac{D_{t-1}^b}{\Pi_t}\left[(1+i_{t-1}) + p(i_{t-1}^b - i_{t-1}) - (1-p)\tau_t^i i_{t-1}\right] \\ &= p\left[(C_t^b - C_t^s) + (1-\tau_t^w)W_t(L_t^s - L_t^b) - T^{\text{eff}}\right].\end{aligned} \tag{4.42}$$

An exogenous policy equilibrium of the model is defined by time-paths of the 18 variables C_t^s, C_t^b, L_t^s, L_t^b, G_t, Y_t, W_t, D_t^b, Π_t, i_t^b, i_t, Δ_t, $f1_t$, $f2_t$, g_{1t}^s, g_{2t}^s, g_{1t}^b, g_{2t}^b determined by the set of equations given by (4.2), (4.6), (4.8), (4.19), (4.20), (4.21), (4.22), (4.23), (4.24), (4.32), (4.33), (4.34), (4.35), (4.36), (4.38), (4.39), (4.40), and (4.42) given the fiscal instruments τ_t^w, τ_t^i, and T_t as well as the interest spread shock process (4.3).

4.2.2 Ramsey Planner and Efficiency

A constrained-optimal policy is defined as a Ramsey planner maximizing the discounted weighted sum of borrowers' and savers' utilities subject to the private sector's behavior which means he maximizes $E_t \sum_{t=0}^{\infty} \beta^t U_t$ with

$$U_t = p\left(\frac{(C_t^s)^{1-\rho}}{1-\rho} - \frac{(L_t^s)^{1+\eta}}{1+\eta}\right) + (1-p)\left(\frac{(C_t^b)^{1-\rho}}{1-\rho} - \frac{(L_t^b)^{1+\eta}}{1+\eta}\right) + v\frac{G_t^{1-\gamma}}{1-\gamma} \quad (4.43)$$

subject to (4.2), (4.6), (4.8), (4.19), (4.20), (4.21), (4.22), (4.23), (4.24), (4.32), (4.33), (4.34), (4.35), (4.36), (4.38), (4.39), (4.40), and (4.42) with respect to C_t^s, C_t^b, L_t^s, L_t^b, G_t, Y_t, W_t, D_t^b, Π_t, i_t^b, Δ_t, $f1_t$, $f2_t$, g_{1t}^s, g_{2t}^s, g_{1t}^b, g_{2t}^b as well as one or several of the fiscal instruments τ_t^w, τ_t^i, and T_t where it is assumed that the weight the Ramsey planner puts on the utility of savers is equal to the share of savers.[39]

The Social planner chooses $C_t^s, C_t^b, L_t^s, L_t^b$, and G_t to maximize $E_t \sum_{t=0}^{\infty} \beta^t U_t$ where U_t is given by (4.43) subject to

$$pC_t^s + (1-p)C_t^b + G_t = pL_t^s + (1-p)L_t^b.$$

Rearranging gives the Social planner's (efficient) equilibrium as

$$L^{b,\text{eff}} = \left(1 + (1/v)^{-\frac{1}{\gamma}}\right)^{\frac{\rho}{\eta+\rho}} \quad (4.44)$$

$$C^{b,\text{eff}} = \left(1 + (1/v)^{-\frac{1}{\gamma}}\right)^{\frac{-\eta}{\eta+\rho}} \quad (4.45)$$

$$G^{\text{eff}} = (1/v)^{-\frac{1}{\gamma}} \left(1 + (1/v)^{-\frac{1}{\gamma}}\right)^{\frac{-\rho\eta}{\gamma(\eta+\rho)}} \quad (4.46)$$

$$L^{s,\text{eff}} = L^{b,\text{eff}} \quad (4.47)$$

$$\left(L^{s,\text{eff}}\right)^{\eta} = \left(C^{s,\text{eff}}\right)^{-\rho}. \quad (4.48)$$

The Ramsey planner's problem will be solved from a timeless perspective following Woodford (2003) which means that a welfare comparison between different policies requires starting in the efficient steady state. Any other starting point would imply that the government has an incentive to deviate from its initial policy which would not be compatible with the concept of the "timeless perspective".

The Ramsey allocation, however, generally will not coincide with the effi-

[39] As the complexity of the model rules out the possibility of formulating the Ramsey problem via the primal form, I solve the problem by regarding a Ramsey planner choosing both allocation and policy variables. A detailed description of the Ramsey planner's equilibrium as well as of the solution method can be found in Appendix A.

cient allocation for the following reasons: For one thing, the model features two sources of nominal rigidities, namely price and wage stickiness. For another thing, asset markets are assumed to be incomplete. While the Ramsey planner can eliminate the inefficiency induced by price and wage dispersion – at least if lump-sum taxation and wage taxes are available – he cannot completely offset the inefficiency evoked by the incomplete financial markets as he cannot transfer funds from savers to borrowers but is constrained by the households' behavior. Finally, the definition of government spending being utility enhancing means that the first-best allocation can only be obtained if lump-sum taxes are set to such a level that the efficient level of government spending can be completely financed by lump-sum taxes. Equivalence of the Ramsey planner's and the Social planner's allocation can only be obtained if all of these obstacles are eliminated. Moreover, the Ramsey steady state will be equivalent to the exogenous policy steady state if the latter is efficient since in this case fiscal authorities have no incentive to deviate from this allocation. Consequently, conditions will be obtained under which the exogenous policy steady state will be efficient such that all three policies – exogenous, Ramsey planner's, and Social planner's – will start in the same (efficient) steady state.

Staring with the exogenous policy steady state, the steady-state versions of equations (4.2), (4.6), and (4.8) give

$$\frac{1}{\beta^s} = \frac{1 + (1 - \tau^i)i}{\Pi}$$

and

$$\frac{1}{\beta^b} = \frac{(1 + i)\exp(\kappa(D_t^b - \bar{D}))}{\Pi}(1 + \kappa D^b),$$

which, together with the steady-state version of the Taylor-rule, determine i, Π, and D^b for given values of τ^i. I calibrate

$$\beta^b = \left[1 + \frac{1 - \beta^s}{\beta^s} \frac{1}{1 - \tau^i}\right]^{-1} \frac{1}{1 + \kappa \bar{D}}$$

and

$$\bar{i} = \left(\frac{1}{\beta^s} - 1\right) \frac{1}{1 - \tau^i}$$

to ensure that $\Pi = 1$, $i = \bar{i}$, and $D^b = \bar{D}$ hold, implying $i = i^b$. In steady state, the wage-setting equations collapse to

$$(L^s)^\eta = \left(\frac{\sigma - 1}{\sigma}\right)^2 (C^s)^{-\rho} (1 - \tau^w) \tag{4.49}$$

and

$$(L^b)^\eta = \left(\frac{\sigma-1}{\sigma}\right)^2 \left(C^b\right)^{-\rho} (1-\tau^w) \tag{4.50}$$

and the price-setting equations deliver $W = \frac{\sigma-1}{\sigma}$ and $\Delta = 1$. Consequently, the steady-state version of the evolution of debt (4.42) reads

$$\bar{i}\bar{D}\frac{\tau^i(1-p)-1}{p} = (C^b - C^s) + (1-\tau^w)\frac{\sigma-1}{\sigma}\left(L^s - L^b\right) - T^{\text{eff}} \tag{4.51}$$

and the government budget reads

$$G + (1-p)T^{\text{eff}} = \tau^w \frac{\sigma-1}{\sigma} Y + \tau^i \bar{D}(1-p)i + T. \tag{4.52}$$

A comparison of the exogenous policy equations (4.49), (4.51), and (4.52) with the efficient allocation (4.46), (4.47), and (4.48) shows that three conditions have to be fulfilled to ensure efficiency of the exogenous policy steady state:[40] First, the wage tax has to be set to satisfy

$$\tau^w = 1 - \left(\frac{\sigma}{\sigma-1}\right)^2. \tag{4.53}$$

Second, as the efficient allocation requires $L^s = L^b$, the evolution of debt implies that T^{eff} must be set to ensure

$$T^{\text{eff}} = \frac{\bar{D}}{p}\left(\frac{1}{\beta^s} - 1\right) \tag{4.54}$$

while the steady-state value of the interest tax is set to be zero ($\tau^i = 0$). Finally, to ensure an efficient level of government spending, lump-sum taxes T must be set to finance the efficient level of government spending (4.46) as well as both the lump-sum payments to borrowers (T^{eff}) and the wage subsidy given by (4.53) implying

$$T = G^{\text{eff}} + (1-p)T^{\text{eff}} + \frac{2\sigma-1}{\sigma(\sigma-1)}L^{s,\text{eff}}. \tag{4.55}$$

In the following, an exogenous policy equilibrium is defined as a decentralized equilibrium as defined above where wage taxes are set to fulfill (4.53), government spending is set to G^{eff}, and lump-sum subsidies and taxes are set to follow (4.54) and (4.55) but all instruments are held constant at these initial values. To abstract from government budget effects caused by variations in wage in-

[40]A detailed description can be found in Appendix B.

come (meaning τ^w remains constant but the tax base $W_t(pL_t^s + (1-p)L_t^b)$ varies in response to a shock), I assume that these revenue changes are equated via a different non-specified source of lump-sum taxes. This means that all fiscal instruments (income tax, wage tax, and government spending) remain constant in case of an exogenously given policy even in the presence of a spread shock.

For Ramsey-optimal policies this assumption implies that wage taxes τ_t^w can be divided into a flexible part ($\tau_t^{w,R}$, chosen by the Ramsey planner) and the constant steady-state value (τ^w). The respective flexible revenue part ($\tau_t^{w,R} W_t(pL_t^s + (1-p)L_t^b)$) is part of the government budget and has to be rebated (or financed) with one of the other fiscal instrument available to the Ramsey planner. The constant part ($\tau^w W_t(pL_t^s + (1-p)L_t^b)$) is assumed to be financed via some kind of non-specified lump-sum taxes. The same holds true for government spending ($G_t = G + G_t^R$). In case of a Ramsey planner having access to e.g. government spending and wage taxes but not being able to levy lump-sum taxes this assumption means that the amount of government spending a Ramsey planner chooses above (beyond) the efficient level of government spending must be financed (rebated) with wage tax revenues being above (beyond) the efficient steady-state value ($G_t^R = \tau_t^{w,R} W_t(pL_t^s + (1-p)L_t^b)$). On the contrary, if the Ramsey planner is defined to have access to lump-sum taxes, this means that he may finance the flexible part of government spending with lump-sum taxes ($G_t^R = T_t$) or rebate the flexible part of wage or interest taxes via lump-sum subsidies ($\tau_t^{w,R} = -T_t$). The terminology "a Ramsey planner having access to lump-sum taxes" used in the following such refers to the fact that lump-sum taxes are an instrument to the Ramsey planner while the scenario "without lump-sum taxes" means that lump-sum taxes are used only to equate the fluctuations in the tax revenues of the constant part of wage taxes but cannot be chosen by the Ramsey planner. This way, it is ensured that there are no effects contained emerging by the fact that the government is forced to balance its budget in response to a shock due to the assumption of constant wage subsidies since – for simplicity – there is no government debt regarded in the model.

4.3 Simulation

4.3.1 An Illustrative Example

To explore the mechanisms of an interest spread shock as well as the effects of optimal fiscal policy, I start with considering a simple version of the model by assuming that the monetary authority is able to follow a strict inflation-targeting policy where the target value is one. Consequently, the Taylor rule is replaced by $\Pi_t = \bar{\Pi} = 1$. This largely simplifies the model as it completely offsets the effects of nominal rigidities and would be equal to the real version of the model. This can be seen by regarding the wage- and price-setting equations: With $\Pi_t = 1$, equations (4.32) to (4.34) collapse to $W_t = (\sigma - 1)/\sigma$. Consequently, there is no price dispersion and wages are constant. This, in turn, means that the wage setting equations (4.19) to (4.24) collapse to

$$(L_t^s)^\eta = \left(\frac{\sigma-1}{\sigma}\right)^2 (C_t^s)^{-\rho} (1-\tau_t^w) \tag{4.56}$$

and

$$\left(L_t^b\right)^\eta = \left(\frac{\sigma-1}{\sigma}\right)^2 \left(C_t^b\right)^{-\rho} (1-\tau_t^w), \tag{4.57}$$

which is equivalent to the labor supply equations obtained under perfectly competitive labor markets up to a constant. This implies that, under inflation-targeting, the exogenous policy equilibrium can be defined by a set of the labor supply equations (4.56) and (4.57) as well as the six equations

$$(C_t^s)^{-\rho} = \beta^s (C_{t+1}^s)^{-\rho} \left(1 + (1-\tau_{t+1}^i) i_t\right) \tag{4.58}$$

$$(C_t^b)^{-\rho} = \beta^b (C_{t+1}^b)^{-\rho} (1+i_t^b)(1+\kappa D_t^b). \tag{4.59}$$

$$pL_t^s + (1-p)L_t^b = pC_t^s + (1-p)C_t^b + G_t \tag{4.60}$$

$$G_t + (1-p)T^{\text{eff}} = T_t + \tau_t^w \frac{\sigma-1}{\sigma}(pL_t^s + (1-p)L_t^b) + \tau_t^i D_{t-1}^b i_{t-1}(1-p) \tag{4.61}$$

$$\begin{aligned} D_t^b - D_{t-1}^b &\left[(1+i_t) + p(i_{t-1}^b - i_{t-1}) - (1-p)\tau_t^i i_{t-1}\right] \\ = p &\left[(C_t^b - C_t^s) + (1-\tau_t^w)\frac{\sigma-1}{\sigma}(L_t^s - L_t^b) + T^{\text{eff}}\right] \end{aligned} \tag{4.62}$$

$$1 + i_t^b = (1+i_t)\vartheta_t \exp(\kappa(D_t^b - \bar{D})) \tag{4.63}$$

determining the 8 variables C_t^s, C_t^b, L_t^s, L_t^b, G_t, D_t^b, i_t, and i_t^b given the fiscal instruments τ_t^w, τ_t^i, and T_t.[41]

Parameter choice

I start with exploring the effects of an interest spread shock under an exogenously given policy. For this purpose, I set $\bar{D}^b$ to match an initial steady-state

[41] Expectations operators are dropped since the model is solved under perfect foresight.

β^s	0.98	Discount factor of savers
β^b	0.94	Discount factor of borrowers
κ	0.03	Debt elastic risk premium parameter
$\bar{D}^b/Y$	1	Initial debt-to-GDP ratio
ρ	1.5	Intertemp. elasticity of substitution in consumption
γ	1.5	Intertemp. elasticity of substitution in gov. spending
η	1.5	Inverse of labor supply elasticity
v	0.4	Weight of government spending in utility
p	0.5	Share of patient households
ρ_D	0.9	Persistence parameter of the spread shock
$\bar{\Pi}$	1	Inflation target

Table 4.1: Parametrization of the illustrative model

debt-to-GDP ratio of 100% and define the share of patient households, p, to be 0.5. The savers' discount factor is set to be $\beta^s = 0.98$ to match an annual interest rate of 8% where the relatively high value roughly matches the Euro area average of interest rates for consumer credit between 2000 and 2008 and represents the assumption of starting in the pre-crisis period when the interest spread hits the economy. Furthermore, I set κ to be 0.03. While the value is chosen somewhat arbitrarily, a robustness test shows that varying this value does change the results only quantitatively. As described above, the discount factor of borrowers is chosen to ensure that the steady-state level of debt will be equal to $\bar{D}$ requiring $\beta^b = \frac{1}{\beta^s(1+\kappa\bar{D})}$ such that $\beta^b = 0.94$. The weight of government spending in utility, v, is set to match a steady-state government-spending-to-GDP ratio of 35%. The inverse of the labor supply elasticity, η, the intertemporal elasticity in consumption, ρ, as well as the elasticity of government spending, γ, are set to be 1.5. The persistence parameter of the credit shock, ρ^D, is defined to be 0.9. Table 4.1 gives an overview about the parameter values.

Spread shock under an exogenously given policy

Figure 4.1 gives the responses of real variables as well as interest rates and the debt-to-GDP ratio to an interest spread shock calibrated to decrease the debt-to-GDP ratio by 5 percentage points at the maximum under an exogenous fiscal policy, meaning all fiscal instruments (government spending, wage tax, and income tax) are held constant at their initial steady-state levels as described

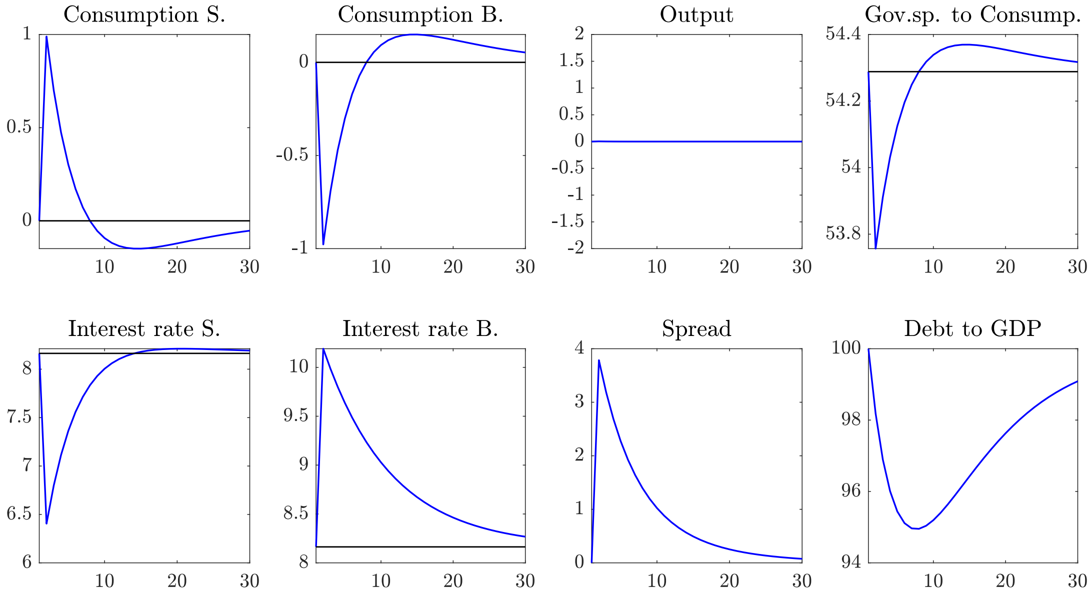

Figure 4.1: Impulse responses to an interest spread shock in the illustrative model under an exogenous policy. For real variables percentage changes are given. Interest rates, the interest spread, as well as in the debt-to-GDP ratio are measured in percentage points. For government spending, the ratio of government spending to consumption of savers in percent is given.

above. It can be seen that, on impact, the interest spread shock increases the spread by 3.79 percentage points implying an increase in the borrowers' interest rate by about 2.03 percentage points such that borrowers decrease consumption and start to pay down their debt. As a consequence, the interest rate for savers decreases which means that savers find it optimal to increase consumption. Output remains constant as the increase in savers' consumption equates the decrease in borrowers' consumption while government spending remains constant. Over time, the reduction in the debt level as well as the abating effect of the spread shock induces the spread to return to zero. Consequently, consumption of borrowers increases and consumption of borrowers decreases over time. It should be highlighted that, due to the lower debt level, consumption of borrowers increases above its initial steady-state level after 8 periods before it reverts back to its steady-state level in the long-run while for savers the opposite holds true. This feature indicates that the effects of an interest spread shock on the two groups of agents are twofold: In the short-run, savers gain while borrowers loose from being hit by a spread shock. Over time, however, the effect reverts.

Furthermore, the Figure gives the relation of government spending to consumption of savers. Equations (4.44) to (4.48) showed that efficiency requires a

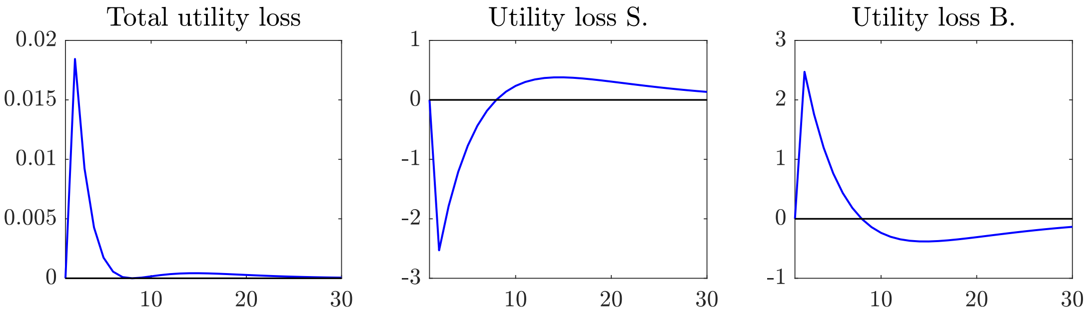

Figure 4.2: Period-by-period utility losses (in percent) of an interest spread shock in the illustrative model under an exogenous policy.

positive and constant government-spending-to-consumption ratio given by

$$(C_t^s)^{-\rho} = \nu(G_t)^{-\gamma}.$$

Under the exogenous policy, however, it can be seen that the ratio diverts from this optimal ratio as consumption of savers increases while government spending is held constant. Consequently, the exogenous policy features an inefficient level of government spending. This shows that the utility effects of an interest spread shock are twofold: On the one hand, agent specific effects via changes in the interest rates imply increasing the utility of one group of agents while implying a utility loss for the other group. On the other hand, government spending diverging from the optimal level implies a common (negative) effect for both agents.

To look at these utility effects more in detail, Figure 4.2 shows the period-by-period consumption-equivalent utility losses for the economy as a whole as well as for savers and borrowers separately.[42] Here, three observations stand out: First, while the utility loss is quite small for the economy as a whole – amounting to 0.0184% at the maximum – the individual effects for savers and borrowers are sizable. Second, in the short-run, savers gain from being hit by a spread shock in the amount of 2.53% while borrowers loose in the amount of 2.47%. And, finally, this effect reverses over time where the gains and losses are relatively small, however.

To gauge the overall effect of a spread shock on the two agents, lifetime utility losses meaning the share of steady-state consumption an agents is willing

[42]Meaning the percentage share of steady-state consumption an agent is willing to give up in period t to be indifferent between staying in steady state and receiving the utility level resulting in period t if the economy is hit by a spread shock in the initial period. The definitions of all utility measures can be seen in detail in Appendix D.

to give up in the initial period to be indifferent between a constant stream of steady-state consumption, labor, and government-spending and the series of the respective real variables resulting from the economy being hit by an interest spread shock can be computed. Here, the utility loss for the economy as a whole is relatively small amounting to about 0.0364%. Savers, in contrast, gain in the amount of 3.0019% while borrowers loose in the amount of 2.9421% of steady-state consumption. Hence, it can be stated that an interest spread shock drives a wedge between the utilities of borrowers and savers and induces utility losses for the economy as a whole. For this reason, Ramsey-optimal policy reactions to a spread shock will be considered aiming at reducing the total utility loss and the effects of these measures on the two groups of agents will be explored.

Ramsey-optimal policy

Equations (4.44) to (4.48) showed that, in the efficient equilibrium, all real variables are independent of the spread shock ϑ_t and such constant over time meaning $C_t^s = C_t^b = \text{const}$ and $L_t^s = L_t^b = \text{const}$. Plugging in these conditions, the Euler equation for savers, the Euler equation for borrowers as well as the evolution of debt give:

$$\frac{1}{\beta^s} = 1 + (1 - \tau_{t+1}^i) i_t, \tag{4.64}$$

$$\frac{1}{\beta^b} = (1 + i_t)\vartheta_t \exp(\kappa(D_t^b - \bar{D}))(1 + \kappa D_t^b), \tag{4.65}$$

$$\begin{aligned} D_{t-1}^b \left[(1-p)(1 + i_{t-1}(1 - \tau_t^i)) + p(1 + i_{t-1})\vartheta_{t-1} \exp\left(\kappa\left(D_{t-1}^b - \bar{D}\right)\right)\right] \\ = D_t^b + pT^{\text{eff}}. \end{aligned} \tag{4.66}$$

The labor supply equations together with the efficiency condition (4.48) can be written as

$$\tau_t^w = 1 - \left(\frac{\sigma}{\sigma - 1}\right)^2 \tag{4.67}$$

and the government budget becomes

$$G_t + (1-p)T^{\text{eff}} = T_t + L^{s,\text{eff}} \frac{\sigma - 1}{\sigma} \tau_t^w + \tau_t^i D_{t-1}^b i_{t-1}(1-p). \tag{4.68}$$

This shows that the interest income tax τ_t^i can be set to ensure efficiency of the decentralized equilibrium if lump-sum taxes are available to ensure the efficient level of government spending as well as the efficient constant wage subsidies.[43]

[43]The detailed derivation can be seen in Appendix C.

Rearranging equations (4.64) to (4.68) gives the optimal rule for the interest income tax rate as

$$\tau_t^i = 1 - \frac{1-\beta^s}{\beta^s}\left[\frac{1}{\beta^s \vartheta_{t-1}} - 1\right]^{-1},$$

while the debt level remains fixed at its steady-state level ($D_t^b = \bar{D}$) and the interest rate follows

$$i_t = \frac{1}{\beta^s \vartheta_t} - 1.$$

Here, three observations can be highlighted: First, under inflation-targeting, the Ramsey policy is efficient if lump-sum taxes as well as taxes on interest income are available. Second, in this case, the Ramsey policy consists in choosing the interest income tax such that all real variables as well as the debt level are held constant while the interest rate of savers adjusts. Third, if there are no lump-sum taxes available or the Ramsey planner relies on wage taxes only, the efficient allocation cannot be obtained.

Figure 4.3 illustrates the responses of the debt level and interest rates as well as the optimal tax rate under the Ramsey-optimal policy in comparison with the case of an exogenously given policy. It can be seen that the key mechanism of the Ramsey-optimal policy lies in holding the interest rate of borrowers constant, meaning completely eliminating the effect of the interest spread on borrowers. Consequently, the interest rate of savers has to fall to equate the increase in the interest spread. For this purpose, the Ramsey planner decreases the interest tax. The combination of the decrease in the tax rate and the decrease in the interest rate implies that the savers' consumption decision is not affected by the interest spread shock. All real variables can be held constant at their efficient levels.

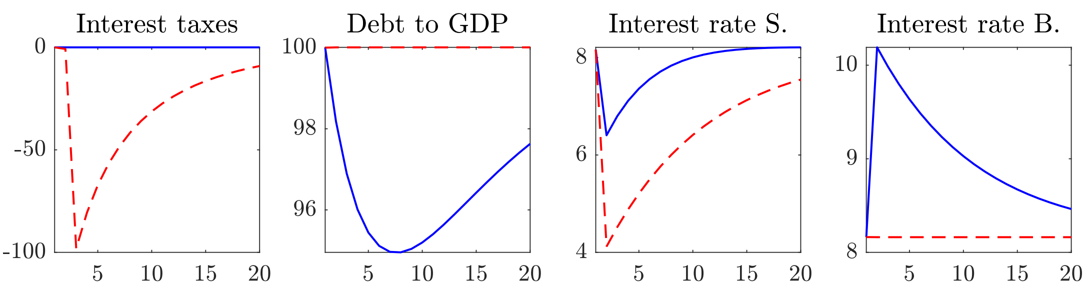

Figure 4.3: Ramsey-optimal policy reaction to an interest spread shock in the illustrative model with wage taxes, interest taxes, government spending, and lump-sum taxes. All variables are measured in percentage points. **Blue solid line:** Exogenous policy. **Red dashed line:** Ramsey policy.

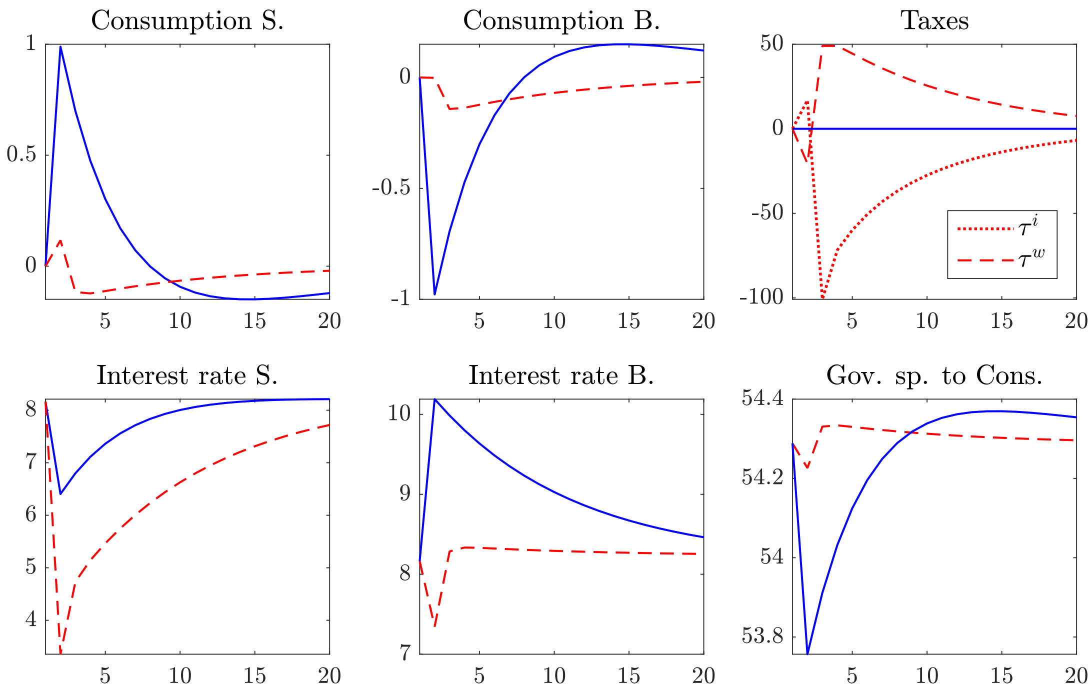

Figure 4.4: Ramsey-optimal policy reaction to an interest spread shock in the illustrative model with wage taxes, interest taxes, and government spending but without lump-sum taxes. For real variables percentage changes are given. The nominal interest rates as well as tax rates are measured in percentage points. For government spending, the ratio of government spending to consumption of savers in percent is given. **Blue solid line:** Exogenous policy. **Red dashed line:** Ramsey policy.

This is different in case of a Ramsey planner completely relying on distortionary tax instruments but not having access to lump-sum taxes as can be seen in Figure 4.4. In this case, government spending must be financed by the sum of interest income and wage income tax revenues. This contrasts with the optimal reaction shown above consisting in decreasing interest taxes while holding wage taxes and government spending constant. Efficiency can, thus, not be obtained any more. The Figure shows that the constrained-optimal policy reaction implies increasing interest taxes on impact and decreasing interest taxes after the first period while for wage taxes the opposite holds true. This way, the borrowers' interest rate decreases only on impact and is slightly above its steady-state value after the first period. Consequently, the impact of the interest spread shock on borrowers is largely diminished. The same holds true for savers as the decrease in the savers' interest rate is equated by the decrease (after the first period) in interest taxes. Government spending diverts only slightly from its efficient level.

Consequently, utility gains and losses can be all but eliminated as is depicted in Figure 4.5. It can be seen that applying the Ramsey-optimal policy decreases the gains of savers as well as the losses of borrowers and almost completely offsets the total economy-wide utility loss. While a Ramsey-optimal policy, consequently, may be highly effective in eliminating economy-wide utility losses, it implies discriminating against one of the two groups of agents. Under inflation-targeting, however, this implies decreasing the disparity between groups by eliminating the wedge an interest spread shock drives between the utilities of patient and impatient households. In the following, it is explored if and how this result changes if allowing for nominal rigidities.

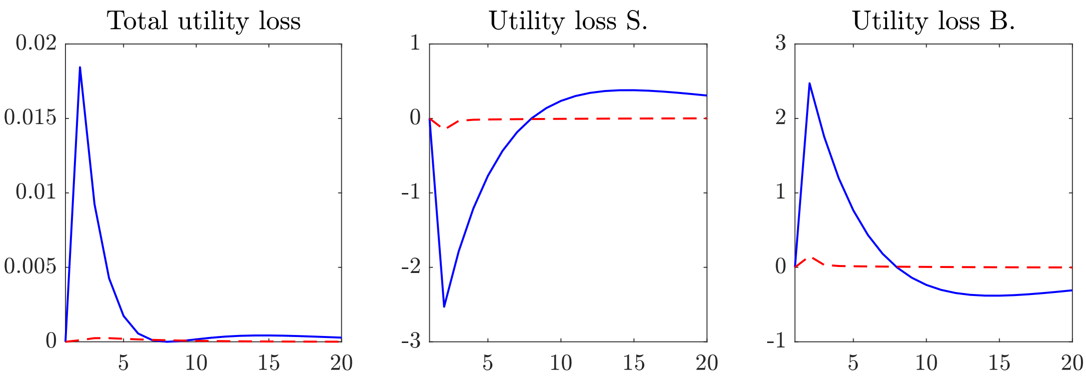

Figure 4.5: Utility losses (in percent) of an interest spread shock in the illustrative model with wage taxes, interest taxes, and government spending but without lump-sum taxes. **Blue solid line:** Exogenous policy. **Red dashed line:** Ramsey policy.

4.3.2 The General Case

After having clarified the mechanisms, in the following a spread shock is simulated in the full version of the model meaning the monetary authority follows a Taylor rule instead of being able to apply inflation-targeting.[44] Regarding the parameters determining the degree of nominal rigidities, I set both the degree of price and of wage stickiness to be $\xi_p = \xi_w = 0.75$. Furthermore, the elasticity of substitution between differentiated labor inputs and between differentiated goods, σ, is assumed to be 6. Finally, I set the response parameter of the interest rate to inflation, μ, to be 2.

I focus on the case of a Ramsey planner having access to lump-sum taxes as well as one or two types of distortionary taxes in addition to government spending. Figure 4.6 illustrates the responses of main variables to a spread

[44] Especially in the context of a country being a member of a monetary union, inflation-targeting does not seem to be a realistic feature as the monetary authority sets the interest rate for the union as a whole and, such, presumably will not aim at holding inflation constant in one specific country.

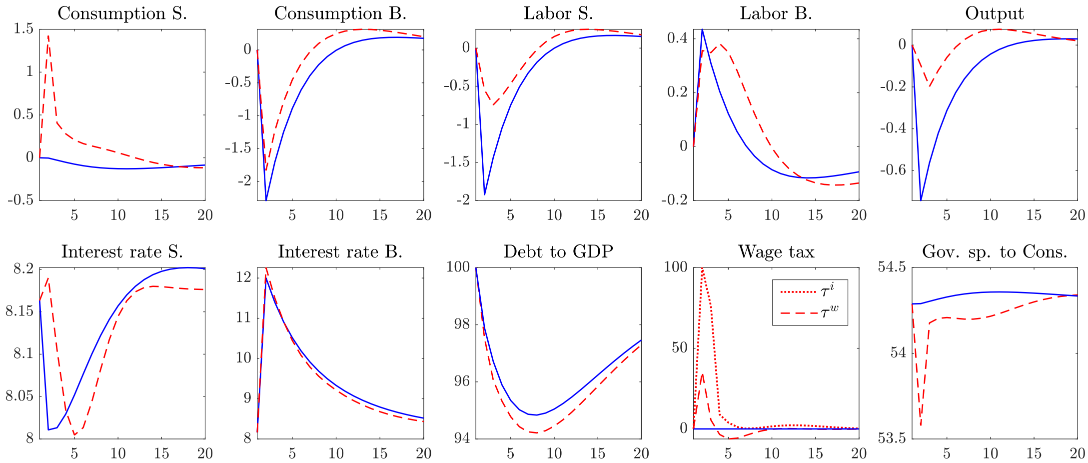

Figure 4.6: Impulse responses to an interest spread shock under a Ramsey-optimal policy with wage, interest, and lump-sum taxes as well as government spending. For real variables percentage changes are given. Interest rates, the interest spread, tax rates, as well as the debt-to-GDP ratio are measured in percentage points. For government spending, the ratio of government spending to consumption of savers is given in percent. The debt level is measured as percentage share of debt in steady-state output. **Blue solid line:** Exogenous policy. **Red dashed line:** Ramsey policy.

shock for the case of a Ramsey planner having access to both wage and interest taxes in comparison with the case of an exogenously given policy.[45] As regards the exogenous policy scenario, it can be seen that with the monetary authority following a simple Taylor rule, the savers' nominal interest rate falls only slightly such that the interest rate of borrowers increases much more than under inflation-targeting. Consequently, consumption of savers remains almost constant while consumption of borrowers falls much more than under inflation-targeting. This, in turn, implies a drop in output. The economy-wide lifetime loss of a spread shock is much higher in this scenario than under strict inflation-targeting amounting to 0.0913 % instead of 0.0364 % as before.

Turning to the constrained-optimal policy, the Ramsey planner has to deal with different sources of inefficiency: First, the drop in output implies an inefficiency due to price dispersion. Second, the change in consumption implies that the optimal level of government spending adjusts. And third, the increase in the interest spread causes an inefficient distribution of consumption and labor between savers and borrowers. In contrast to the case of inflation-targeting, however, the Ramsey planner cannot obtain the efficient allocation since the monetary authority following a Taylor rule prevents the possibility of holding

[45] I restrict both income tax rates to lie in the range between -100% and 100%. This does, however, not influence the result that efficiency cannot be obtained in this case: Even if tax rates could be raised unboundedly, efficiency could not be obtained.

inflation constant and, at the same time, decreasing the nominal interest rate – as was the optimal response of the Ramsey planner in the simple case before. Consequently, the Ramsey planner faces a trade-off. Figure 4.6 shows that, in this case, the constrained-optimal policy consists in increasing interest taxes on impact to boost consumption of savers which prevents output from falling such eliminating the inefficiency evoked by price dispersion to a large extent. This measure, however, implies increasing the interest rate of borrowers as well as allowing a larger deviation of government spending from its efficient level.

Figures 4.7 and 4.8 illustrate the responses of main variables if the Ramsey planner has access to only one distortionary tax instrument at a time. It can be seen that while for both tax instruments the constrained-optimal response consists in increasing taxes, the interest tax is increased much more than the wage tax. This is due to the tax base being much smaller in case of the interest tax. Tax income amounts to only 2.5% of wage income in the model. Both policies, nevertheless, aim at preventing output from falling such reducing the inefficiency induced by price dispersion. In case of interest taxes being available, this output effect is combined with a larger decrease in the debt level such implying a somewhat lower interest rate for borrowers than under the exogenous policy. In contrast, the policy reaction with wage taxes implies a smaller decrease

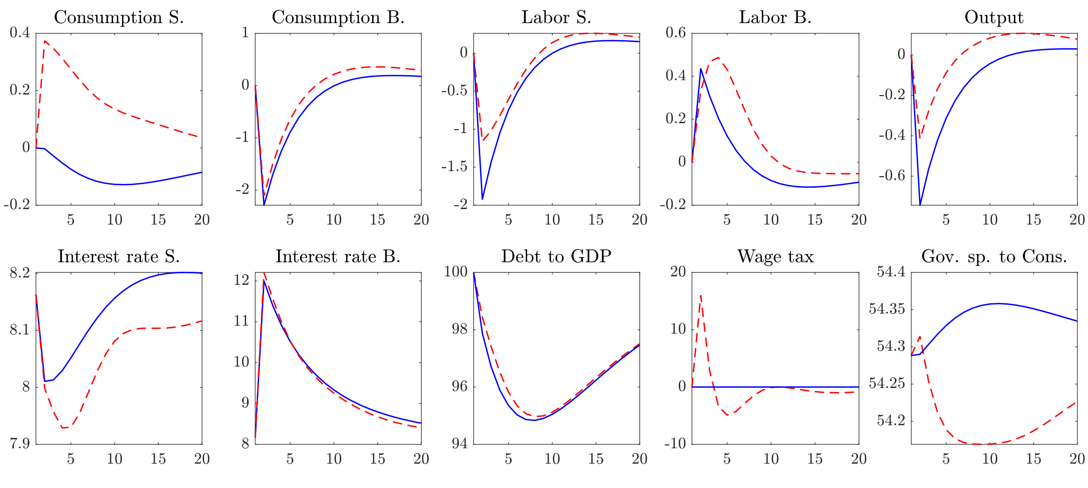

Figure 4.7: Impulse responses to an interest spread shock under the Ramsey-optimal policy with wage and lump-sum taxes as well as government spending. For real variables percentage changes are given. Interest rates, the interest spread, tax rates, as well as the debt-to-GDP ratio are measured in percentage points. For government spending, the ratio of government spending to consumption of savers is given in percent. The debt level is measured as percentage share of the debt level in steady-state output. **Blue solid line:** Exogenous policy. **Red dashed line:** Ramsey policy.

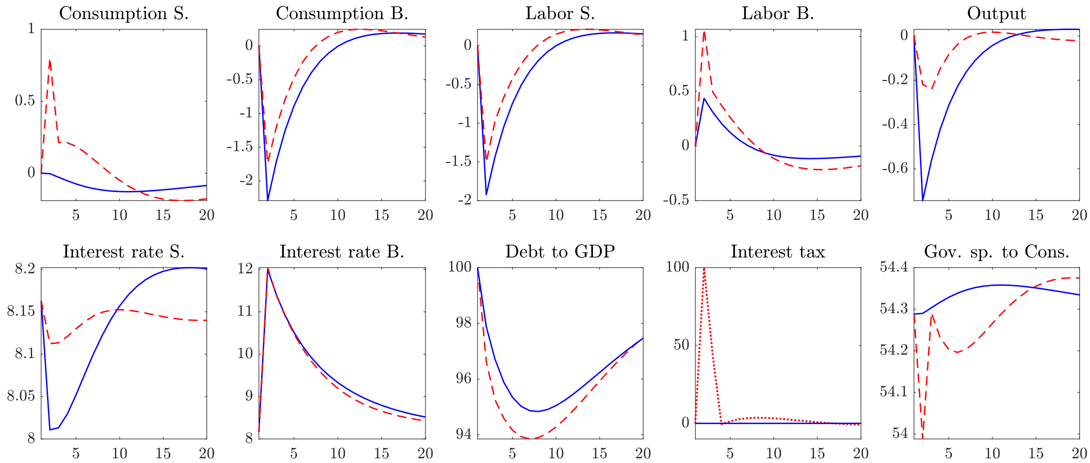

Figure 4.8: Impulse responses to an interest spread shock under the Ramsey-optimal policy with interest income and lump-sum taxes as well as government spending. For real variables percentage changes are given. Interest rates, the interest spread, tax rates, as well as the debt-to-GDP ratio are measured in percentage points. For government spending, the ratio of government spending to consumption of savers is given in percent. The debt level is measured as percentage share of debt in steady-state output. **Blue solid line:** Exogenous policy. **Red dashed line:** Ramsey policy.

in the debt level and, consequently, a slightly higher interest rate for borrowers.[46] As this shows that especially the effect on the borrowers' interest rate differs between policies, in the next step, the effects on the two groups of agents will be considered in addition to economy-wide effects of optimal policy.

For this purpose, policy gains are computed where a policy gain is defined as the share of steady-state consumption an agent is willing to give up in the initial period to be indifferent between the exogenous policy induced stream of consumption, labor, and government spending and the respective series under the Ramsey-optimal policy. A positive policy gain, consequently, implies that the agent is better off under the Ramsey-optimal policy than under the exogenous policy.[47]

Table 4.2 gives policy gains for a huge set of different Ramsey policies. Here, several observations stand out: First, the gains from applying a constrained-optimal fiscal policy can be sizable. In case of both income taxes as well as

[46] The result of the interest tax being increased by 100 percentage points is due to the constraint of both tax rates lying between -100% and 100%. Without imposing this upper bound, the interest income tax would be increased by 850% in the first period while being slightly negative in the subsequent periods. Even without the upper bound, the efficient allocation cannot be reached, however.

[47] While for the economy as a whole, each Ramsey-optimal policy must imply policy gains relative to the exogenous policy, this does not necessarily hold for an individual agent. The detailed definition of policy gains can be seen in Appendix D.

	Total	Savers	Borrowers
Lump-sum taxes			
(1) τ_t^w and τ_t^i	0.0783	-10.4805	12.6215
(2) τ_t^w	0.0173	-0.0629	0.0975
(3) τ_t^i no restriction	0.0765	-10.9053	13.2213
(4) $\tau_t^i \leq 1$	0.0309	-2.1226	2.2563
(5) $\tau_t^i \leq 0.17$	0.0197	-0.9008	0.9531
(6) $\tau_t^i = \tau_t^w$	0.0147	-0.2817	0.3124
No lump-sum taxes			
(7) τ_t^w and τ_t^i	0.0752	-10.8637	13.1586
(8) τ_t^w	0.0078	-0.0938	0.1095
(9) τ_t^i	0.0185	-0.8933	0.9429
(10) $\tau_t^i = \tau_t^w$	0.0075	-0.0955	0.1106

Table 4.2: Policy gains of Ramsey-optimal policies (in percent)

lump-sum taxes being available, the policy gain amounts to 0.0783% (as can be seen in line 1) which indicates – compared to the total utility loss of a spread shock of about 0.0913% – that optimal fiscal policy does imply a substantial gain for the economy as a whole. Second, using interest income taxes implies larger gains than using wage taxes even if an upper bound on the interest tax of 100% is imposed as can be seen in line 4. It should be noted, however, that this measure implies increasing the interest tax much more than the wage tax. But even if the interest tax is constrained to be smaller than 17% – which is the amount to which the wage tax is increased in case of conducting the Ramsey policy with wage and lump-sum taxes – the policy gain is somewhat larger than in case of wage taxation as can be seen in line 5. This indicates that a tax on interest income is more effective in eliminating welfare losses of an interest spread shock than a tax on wage income. Third, a government using the same tax rate for both sources of income – as is the case e.g. in Germany at least for all taxable persons with a maximum tax rate on labor income of less than 25% – implies huge welfare losses. As can be seen in line 6, if the fiscal authority does not differentiate between wage income and interest income, the policy gain of applying a Ramsey-optimal policy amounts to 0.0147 % only. All results are qualitatively the same if there are no lump-sum taxes available as can be seen in lines 7-10. The difference consists in the fact that without lump-sum taxes, all policy gains are smaller than their respective counterparts with lump-sum taxes.

Finally, regarding the agent-specific level, all policies imply policy gains for borrowers and at the same time policy losses for savers. As a spread shock originally implied utility losses for borrowers and gains for savers and, such, drives a (inefficient) wedge between the utilities of the two agents, applying a Ramsey-optimal fiscal policy decreases the disparity between groups. This feature, however, depends on the degree of nominal rigidities as will be shown in the next section.

4.4 The Role of Nominal Rigidities

In this section, the role of nominal rigidities in shaping the distributional effects of fiscal policy is examined. For this purpose, Figures 4.9 and 4.10 show policy gains of a Ramsey-optimal policy with wage and lump-sum taxes in addition to government spending for different degrees of price and wage rigidity. In Figure 4.9, the wage rigidity is held constant at $\xi^w = 0$, $\xi^w = 0.5$, and $\xi^w = 0.75$, respectively, while the degree of price rigidity is varied. The opposite holds true for Figure 4.10. And here it becomes apparent that the distributive effect of optimal fiscal policy obtained so far (fiscal policy reducing the disparity between groups) crucially depends on the degree of nominal rigidities – at least in case of wage income taxes. Two cases can be distinguished: On the one hand, if prices are perfectly flexible, applying a constrained-optimal fiscal policy with wage taxes implies decreasing the disparity between groups independent of the degree of wage rigidity. This can be seen by considering the first row of Figure 4.10 and the points at the extreme left of each panel in Figure 4.9. In this case, borrowers feature a policy gain and savers incur a policy loss for each degree of wage rigidity which implies that the spread shock induced wedge between the utilities of agents is diminished by conducting a constrained-optimal fiscal policy. The same holds true for all parameter combinations where wages are more sticky than prices as is indicated by the gray areas in the two figures. On the contrary, if prices are sufficiently more rigid than wages, each Ramsey-optimal policy implies enlarging the wedge between savers and borrowers. This shows that the distributive effects of optimal fiscal policy with wage taxes crucially depend on the relative degrees of wage and price rigidity.

The reason for this result can be found by regarding the three different objectives a Ramsey planner is dedicated to and the emphasis he sets on each of these targets: Choosing the optimal level of government spending, eliminating

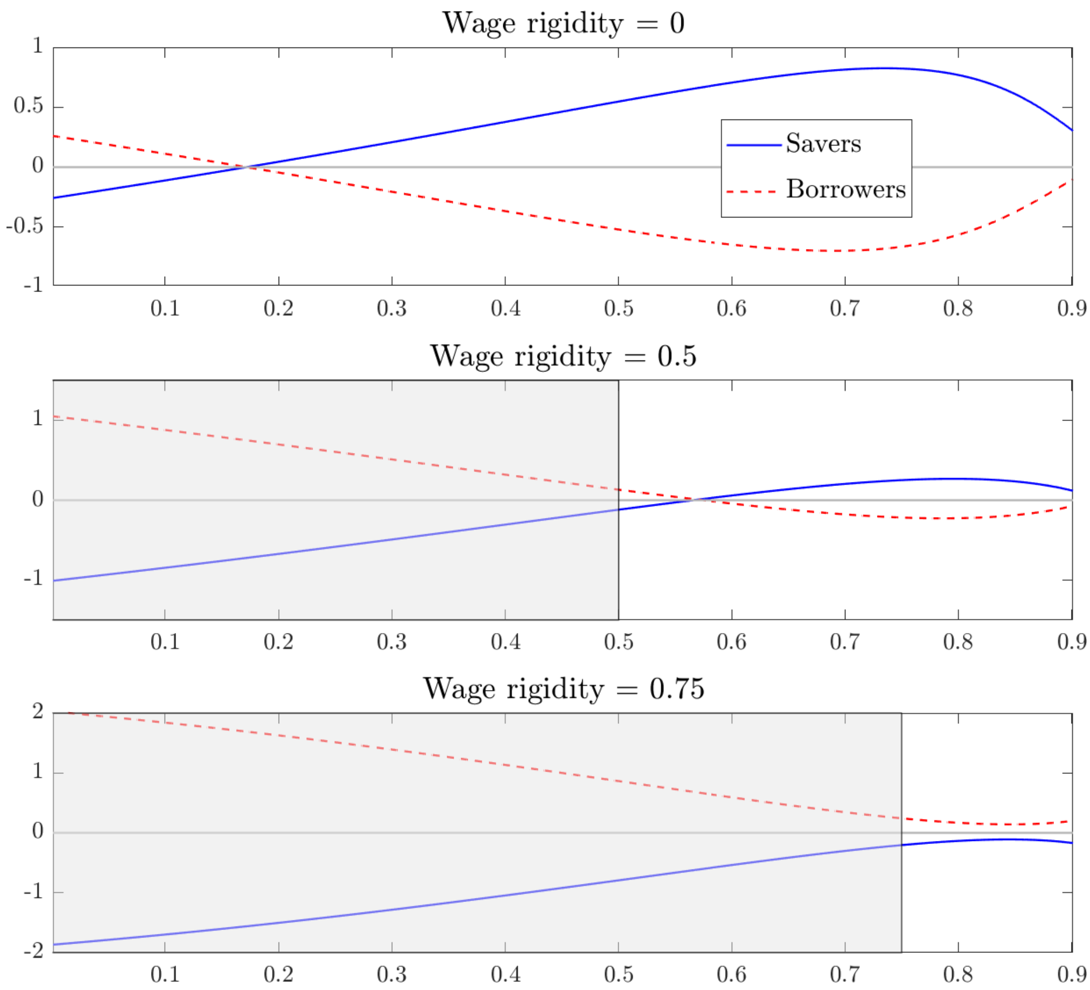

Figure 4.9: Agent-specific policy gains (in percent) for different degrees of price rigidity under Ramsey-optimal policy with wage and lump-sum taxes as well as government spending. **Gray areas** indicate parameter spaces where the degree of wage rigidity is larger than the degree of price rigidity.

price dispersion, and eliminating wage dispersion. Setting government spending at its efficient level improves welfare for savers and borrowers at the same time and to the same amount. Reducing wage distortions implies utility gains for both agents as the spread shock implies a nominal wage deflation such that the Ramsey policy results in higher nominal wages. The effects are quantitatively different for savers and borrowers, however, since labor supply differs between groups. Eliminating price distortions, on the contrary, implies eliminating deflationary tendencies which has a negative effect on borrowers via the Taylor rule since this implies that the nominal interest rate – and, as a consequence thereof, the borrowers' interest rate – does not decrease as much as in the case of an exogenous policy. For relatively low levels of price rigidity, the Ramsey planner puts little weight on counteracting price dispersion but much weight on

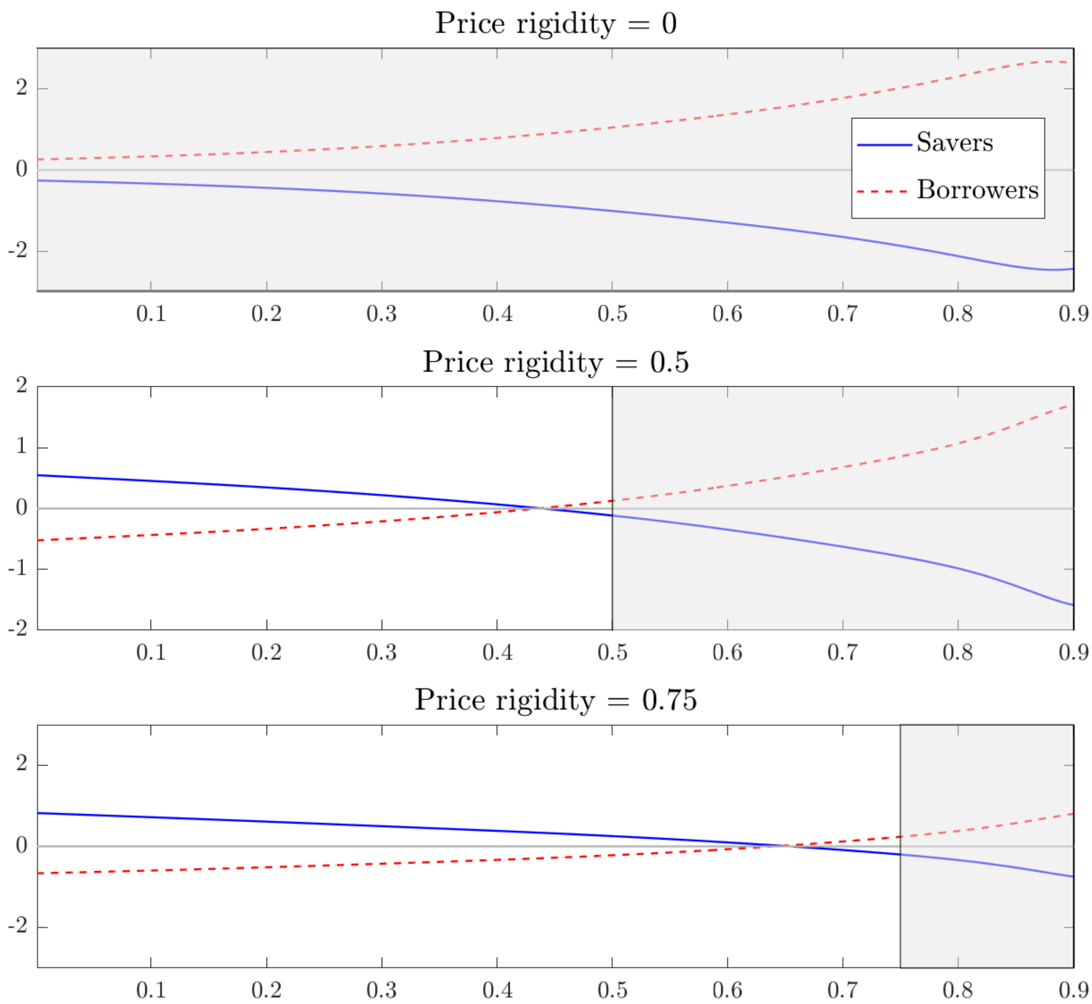

Figure 4.10: Agent-specific policy gains (in percent) for different degrees of wage rigidity under Ramsey-optimal policy with wage and lump-sum taxes as well as government spending. **Gray areas** indicate parameter spaces where the degree of wage rigidity is larger than the degree of price rigidity.

mitigating the inefficiencies caused by wage rigidity such that borrowers gain from conducting the optimal policy while savers loose.

Figure 4.11 illustrates an interesting feature of optimal fiscal policy related to nominal rigidities by again showing policy gains but focusing on the small range of price rigidities between $\xi^p = 0.56$ and $\xi^p = 0.58$ for $\xi^w = 0.5$. For each value of the degree of wage rigidity, there is a value of the degree of price rigidity such that the Ramsey planner weights all objectives in such a relation that gains and losses mitigate for savers meaning that the optimal policy does not affect their utility level. The Figure shows that for $\xi^w = 0.5$ the respective degree of price rigidity is $\xi^p = 0.5645$. And there is a degree of price rigidity at which the Ramsey policy does not affect the utility of borrowers ($\xi^p = 0.5735$ in case of $\xi^w = 0.5$). Only in the negligibly small range between these values

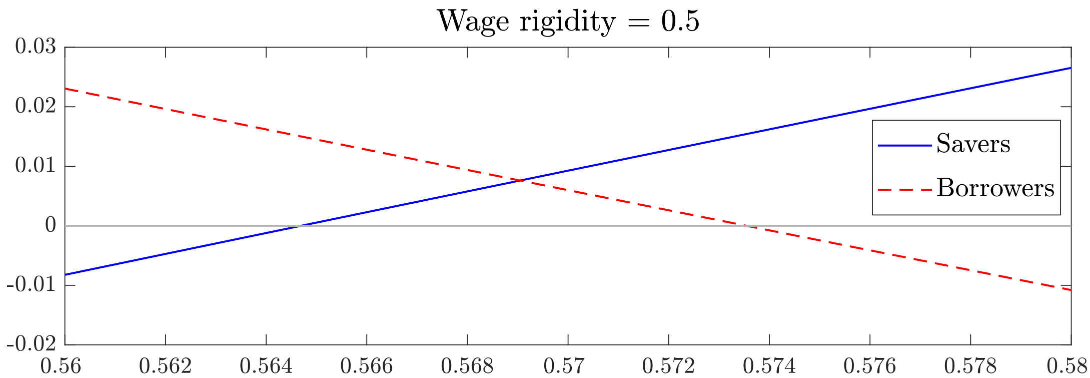

Figure 4.11: Agent-specific policy gains (in percent) for different degrees of price rigidity between $0.56 \leq \xi^p \leq 0.58$ under Ramsey-optimal policy with wage and lump-sum taxes as well as government spending.

$(0.5645 < \xi^p < 0.5735)$, both agents gain from being subject to the optimal policy. More specifically, at the point $\xi^p = 0.5690$ and $\xi^w = 0.5$ both agents gain in the same amount. In any other case, conducting an optimal fiscal policy with wage taxes implies discriminating against one of the two groups.

This is different in case of interest taxes. As interest taxes are levied on bond holdings and exclusively paid by savers, a Ramsey policy with interest taxes will always discriminate against savers. This is due to the fact that both eliminating price and wage dispersion implies increasing interest taxes which states a substantial utility loss for savers while leaving borrowers unaffected.

Finally, Figures 4.12 and 4.13 show total gains of a Ramsey policy with wage taxes for different degrees of rigidities. Here, a crucial finding should be highlighted: While the size of economy-wide utility losses depends on the relative degrees of rigidities, exactly the combination of rigidities implying the largest economy-wide policy gain involves enlarging the disparity between groups. More

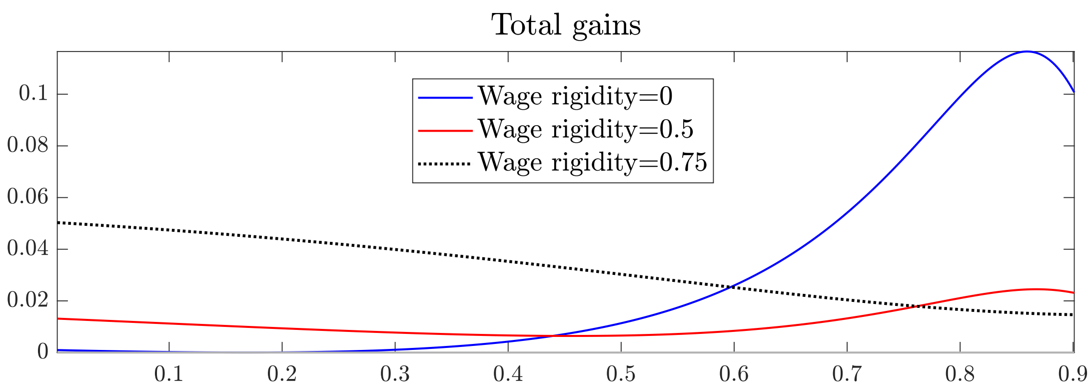

Figure 4.12: Economy-wide policy gains (in percent) for different degrees of price rigidity under Ramsey-optimal policy with wage and lump-sum taxes as well as government spending.

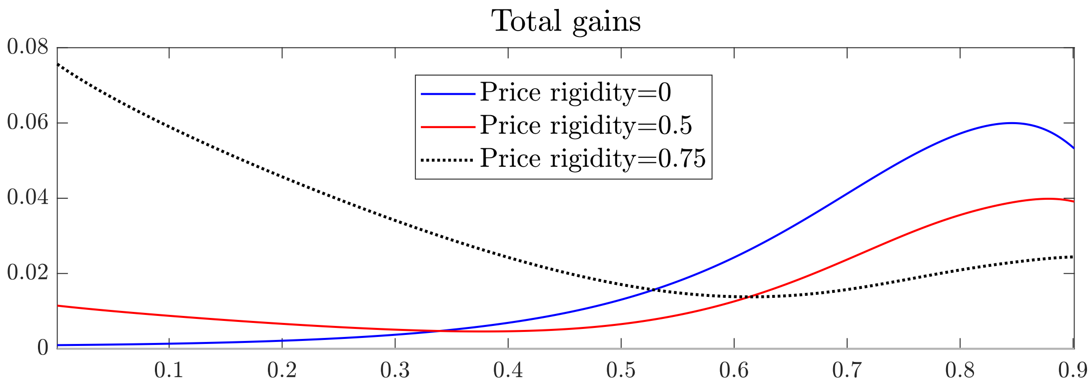

Figure 4.13: Economy-wide policy gains (in percent) for different degrees of wage rigidity under Ramsey-optimal policy with wage and lump-sum taxes as well as government spending.

specifically, the largest policy gain can be obtained in case of perfectly flexible wages when prices are relatively rigid while constrained-optimal policy is nearly effectless in case of flexible prices and wages. The economy-wide policy gain increases with an increasing degree of wage rigidity if prices are more flexible than wages and vice versa.

4.5 An Alternative Social Welfare Measure

The results obtained so far showed that the common way of modeling a Ramsey planner as maximizing the sum of individual utilities implies significant distributive issues. For this reason, I compare the results with the case of using a social welfare function in the spirit of Rawls. More specifically, I assume that the weight the Ramsey planner sets on the utility of one of the two groups of agents increases with a decreasing relative utility level of the respective group. For the sake of computability, I refrain from choosing a purely Rawlsian social welfare function by means of maximizing the utility of the poorest group only as this required the use of a discontinuous function. Instead, I define the weight of patient households to be a continuous function of the difference between the utilities of the two groups taking the following form

$$p_t^{Rawls} = 1 - \frac{1}{1 + \exp(k(U_t^s - U_t^b))}. \tag{4.69}$$

I set the scaling factor k to a very high value ($k = 1000$) to approximate the Rawlsian proposition of a social welfare function. Using this specific form implies that the planner weights both groups equally if their utility levels are equal. In contrast, if the utility level of the patient households is sufficiently higher than the utility of impatient households, the planner neglects the presence of patient

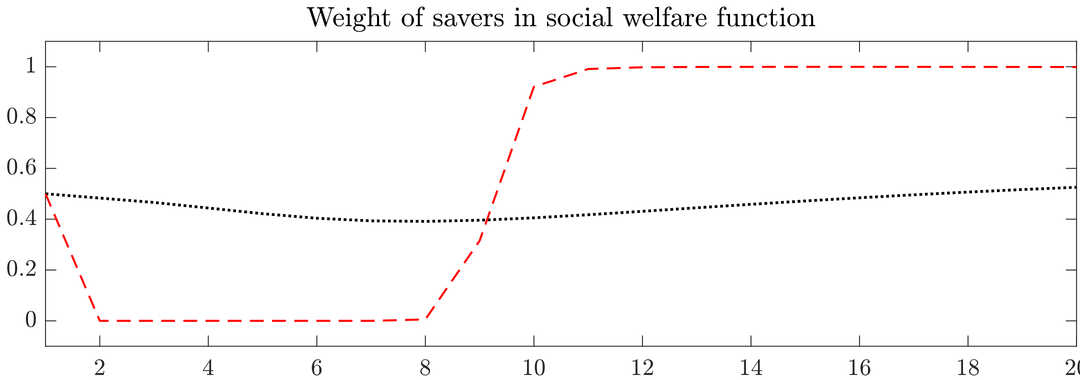

Figure 4.14: Weight of savers in the social welfare function. **Red dashed line:** Ramsey policy with utilitarian welfare measure. **Black dotted line:** Ramsey policy with Rawlsian welfare measure.

households but maximizes the utility of impatient households only. The opposite holds true for the case of the utility of impatient households being sufficiently larger than the utility of patient households. Technically, the Ramsey planner problem is now given by

$$\max E_t \sum_{t=0}^{\infty} \beta^t \left\{ p_t^{Rawls} U_t^s + (1 - p_t^{Rawls}) U_t^b \right\} \tag{4.70}$$

where the respective set of conditions the planner is subject to is extended by equation (4.69) and the FOCs are extended by the derivative of the Lagrangian with respect to p_t^{Rawls}.[48] During the whole section, I focus on the case of wage taxes (in addition to government spending and lump-sum taxes) since the results obtained in the last section indicated that distributive issues seem to be of special interest in this context.

To illustrate the effects of assuming this specific form of the social welfare function on the weight a Ramsey planner puts on the individual group, Figure 4.14 gives p_t^{Rawls} for the first 20 periods following an interest spread shock for two different scenarios: The red dashed line can be interpreted as a counterfactual simulation in the sense that it gives the p_t^{Rawls} that would evolve if the Ramsey planner follows a utilitarian definition of social welfare as regarded in the last sections. This means the utility levels obtained in the utilitarian scenario with constant weights p and $(1 - p)$ are taken and p_t^{Rawls} is computed residually for these values. It can be seen that due to the high chosen value of k, the weight-function approximates the Rawlsian proposition quite well. With the exception

[48]The respective FOCs can be seen in Appendix E.

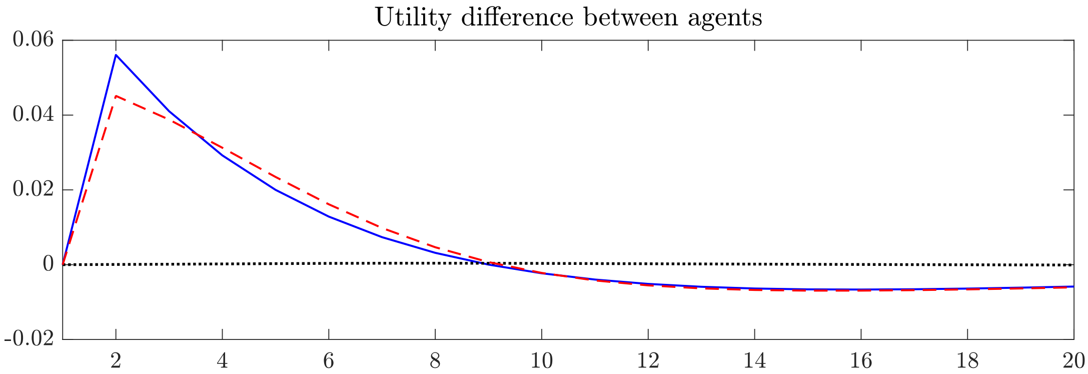

Figure 4.15: Difference between the utilities of savers and borrowers (in levels) for different social welfare measures where the Ramsey planner has access to wage and lump-sum taxes as well as government spending. **Blue solid line:** Exogenous policy. **Red dashed line:** Ramsey policy with utilitarianism. **Black dotted line:** Ramsey policy with Rawlsian welfare measure.

of three periods, the weight of savers is either one or zero. This implies that during the first 8 periods after the shock hits – the time at which savers' utility level is higher than the borrowers' – the Rawlsian Ramsey planner would neglect the presence of savers and maximize the welfare of borrowers. After the eleventh period, on the contrary, the planner would exclusively maximize the welfare of savers. The black dotted line gives p_t^{Rawls} if the Ramsey planner actually internalizes the dependence of the savers' weight on the utility differences and, consequently, maximizes the Rawlsian form of the social welfare function given in equation (4.70). Here, it can be observed that the savers' weight remains roughly at 0.5.[49] This seems to be surprising as the Rawlsian proposition claims just the opposite. It must be regarded, however, that the p_t^{Rawls} plotted are the outcome of the Ramsey planner's maximization problem. More specifically, the dependence of the savers' weight on the savers' utility level causes the Ramsey planner to minimize utility differences between groups. This, in turn, implies that he puts the same weight on the utilities of patient and impatient households as can be seen by regarding equation (4.69).

This feature is depicted in Figure 4.15. The Figure gives the difference between the savers' and borrowers' utilities for three different policy scenarios: the exogenous policy case, the case of a Ramsey planner being based on a utilitar-

[49]In spite of the high value of k, it can be seen that p_t^{Rawls} is not exactly 0.5 in the Rawlsian scenario. This is due to the fact that the utility differences between the two groups are negligibly small in the Rawlsian framework as can be seen in Figure 4.15. As the weight function used features the highest deviations from a purely Rawlsian concept in the region around zero, this implies that for these small values of the utility differences, p_t^{Rawls} diverges somewhat from 0.5.

ian social welfare function, and the case of a Ramsey planner maximizing social welfare in a Rawlsian sense. It can be seen that the Ramsey planner following a Rawlsian principle results in utility levels being all but equal for savers and borrowers. Regarding the common definition of a utilitarian Ramsey planner, the effects differ over time. On impact, a Ramsey policy in a utilitarian sense diminishes utility differences relative to an exogenously given policy while in the medium-run the opposite can be observed. In the long-run, both policies yield almost identical utility differences.

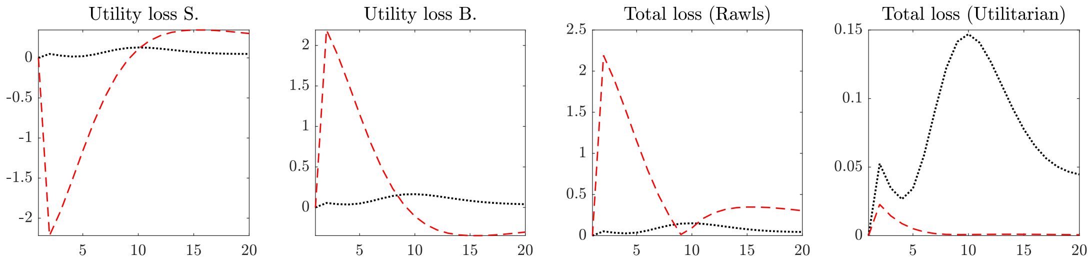

Figure 4.16: Utility losses (in percent) of an interest spread shock for different social welfare measures under a Taylor-rule where the Ramsey planner has access to wage and lump-sum taxes as well as government spending. **Red dashed line:** Ramsey policy with utilitarianism. **Black dotted line:** Ramsey policy with Rawlsian welfare measure.

To explore the different utility effects more in detail, Figure 4.16 gives period-by-period utility losses of being subject to an interest spread shock under a Ramsey-optimal policy in a Rawlsian sense compared to the baseline scenario of a utilitarian welfare function. They are given both for the two groups of agents separately and on an aggregate level where the total utility losses are computed, once, based on the Rawlsian social welfare function and, additionally, for the counterfactual case. This means the utility levels obtained under the Rawlsian maximization are used to compute the utility loss taking the utilitarian welfare function as a basis. On an individual level, it can be seen that in the Rawlsian case utility gains and losses are largely diminished. Consequently, using the Rawlsian welfare measure, total utility losses are quite small. Taking the sum of individual utilities as basis, however, shows that following the Rawlsian maximization principle implies huge utility losses in a utilitarian sense. The sum of individual utility losses amounts to almost 0.15% at the maximum after 10 periods. Furthermore, it can be seen that borrowers are better of in the Rawlsian framework during the first 8 periods while they prefer the utilitarian concept in the long-run. The opposite can be observed for savers' utilities. Computing lifetime policy gains as defined in the last section but for the case of switching from a utilitarian concept of a Ramsey policy to a Rawlsian framework shows that savers loose from applying the Rawlsian welfare function instead of the utilitarian in the amount 5.79% of steady-state consumption while borrowers gain in the amount of 3.64%.

After having considered the different utility effects of the two concepts of a social welfare function, Figure 4.17 illustrates the different effects on the optimal time-path of the wage tax as well as the implied effects on interest rates, the debt level, and real variables. Starting with the constrained-optimal choice of wage taxes, it can be seen that the tax rate is changed much more in the Rawlsian framework than in the baseline utilitarian framework. This huge increase in wage taxes induces nominal wages to increase while at the same time reducing net wages – both effects being stronger than in the utilitarian framework. The wage increase, in turn, implies higher inflation which – by means of the Taylor rule – increases the savers' nominal interest rate. As a consequence, the borrowers' interest rate increases more than in the utilitarian scenario. Here, for both agents diverging effects can be observed: For savers, the increase in the interest rate implies a positive income gain tending to increase consumption and decrease labor. But at the same time it implies higher opportunity costs of consuming goods as well as leisure such tending to decrease consumption and increase labor and bond holdings. In total, it can be seen that savers' con-

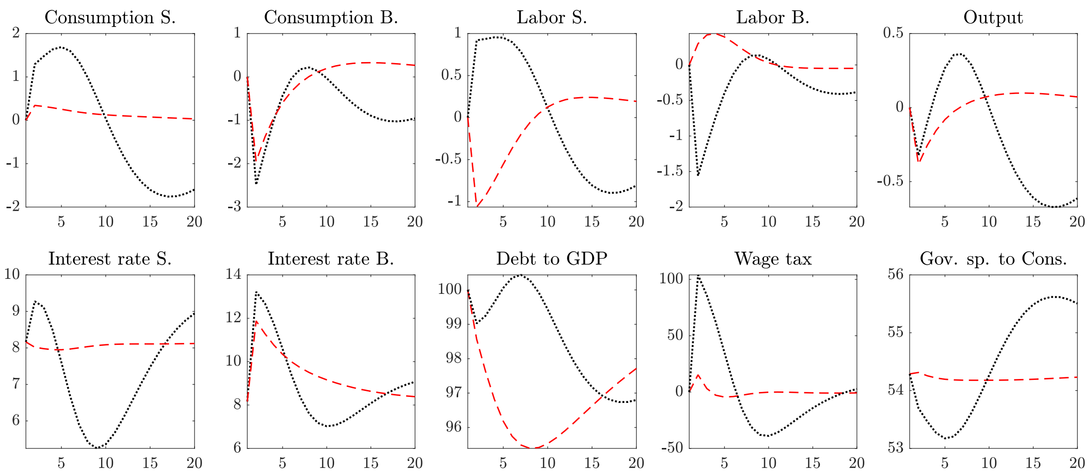

Figure 4.17: Impulse responses to an interest spread shock under the Ramsey-optimal policy for different social welfare measures with wage and lump-sum taxes as well as government spending under a Taylor-rule. For real variables percentage changes are given. Interest rates, the interest spread, tax rates, as well as the debt-to-GDP ratio are measured in percentage points. For government spending, the ratio of government spending to consumption of savers is given in percent. The debt level is measured as percentage share of the debt in steady-state output. **Red dashed line:** Ramsey policy with utilitarianism. **Black dotted line:** Ramsey policy with Rawlsian welfare measure.

sumption as well as labor increase more than in the utilitarian scenario. For borrowers, the increase in the interest rate states a negative income effect such tendentially reducing consumption and increasing labor. The decrease in net wages, however, prevails such that taken as a whole, borrowers' consumption as well as labor decrease more than in the utilitarian framework. Over time, these effects diverge as the wage tax is decreased and even results in wage subsidies after the sixths period. Altogether, it can be seen that the changes in real variables are much more pronounced in the Rawlsian framework than in case of a Ramsey planner in a utilitarian sense, especially implying noticeably higher output fluctuations. Interestingly, the debt level actually increases at least in the medium-run. These results show that applying a Ramsey-optimal policy based on the Rawlsian principle implies real effects being entirely different from the effects of a Ramsey policy in a utilitarian sense.

4.6 Robustness

In this section, robustness of the results to altering the parametrization is checked. Regarding the parameters of the risk premium function, setting κ to smaller (larger) values indicates larger (smaller) effects of a spread shock on the debt level. By setting the size of the decrease in the risk-free debt level adequately to obtain the same debt-to-GDP reduction as in case of the baseline parametrization, however, results can be obtained being almost the same as in the baseline scenario. If the initial level of debt is set to a larger (smaller) value, a spread shock implies smaller (larger) welfare losses while fiscal policy becomes less (more) effective in reducing these losses. The results concerning distributional effects as well as the relative effectiveness of the two income tax measures remain unchanged.

Next, the discount factor is set to be $\beta = 0.99$.[50] This implies smaller effects of a spread shock on the borrowers' interest rate since it is the product of the risk premium and the savers' nominal interest rate. If the shock is computed to induce a decrease in the debt-to-GDP ratio of about 5 percentage points as before, however, the results remain virtually unchanged.

Setting η, ρ, and γ to values smaller than one does not change the results qualitatively. Using a larger elasticity of substitution for consumption than for government spending ($\rho = 1.5$ and $\gamma = 0.5$) implies smaller utility losses

[50]The target nominal interest rate $\bar{i}$ is recalibrated adequately to obtain a steady-state inflation rate of one ($\bar{i} = 1/\beta$).

and a less effective fiscal policy. This is due to the fact that this parameter choice induces a smaller steady-state government-spending-to-output ratio. If v is recalibrated adequately to obtain the same spending-output ratio as under the baseline parametrization, the results are almost the same as in the baseline scenario.

Finally, the role of the share of savers is investigated. Starting with the total utility effects, utility losses of a spread shock increase with a decreasing share of savers. This is due to the fact that savers gain from a spread shock while borrowers loose. Concerning distributional effects, the results remain qualitatively unchanged. The individual effects on the two groups of agents become larger with a decreasing share of savers.

4.7 Conclusions

In the course of this paper, the effectiveness of two different types of optimal income taxation in the face of an interest spread shock as well as their distributional effects and the dependence on the degree of nominal rigidities were investigated. Here, the analysis is twofold: First, regarding the relative effectiveness of different kinds of income taxation, it is found that the most effective form of income taxation consists in taxing interest income. Furthermore, being able to levy different rates on different types of income implies sizable welfare gains. Second, regarding distributive effects, setting tax rates optimally may increase the disparity between groups depending on the tax measure used. While a constrained-optimal fiscal policy using interest taxes reduces the disparity between groups, using wage taxes may involve increasing the wedge between savers and borrowers. Here, the distributional effects of wage taxation are found to depend crucially on the relative degrees of price and wage stickiness. With the degree of wage rigidity being larger than the degree of price rigidity, applying a constrained-optimal fiscal policy implies reducing disparities. If prices are sufficiently more sticky than wages, however, a constrained-optimal policy increases the wedge between savers and borrowers. Finally, the results are compared to the case of basing the Ramsey policy on a social welfare function in a Rawlsian sense and it is found that while this way disparities between groups can completely be eliminated, this takes place at the cost of savers which feature huge welfare losses as well as at the cost of much higher output fluctuations. Overall, the results highlight the importance of regarding distributive effects of fiscal policy and of raising the question of choosing an appropriate social welfare function if allowing for heterogeneous agents.

4.8 Appendices

4.8.A Ramsey Problem and Solution

Maximization problem:

$$\max E_t \sum_{t=0}^{\infty} \beta^t \left\{ p \left[\frac{(C_t^s)^{1-\rho}}{1-\rho} - \frac{(L_t^s)^{1+\eta}}{1+\eta} \right] + (1-p) \left[\frac{\left(C_t^b\right)^{1-\rho}}{1-\rho} - \frac{\left(L_t^b\right)^{1+\eta}}{1+\eta} \right] + \nu \frac{G_t^{1-\gamma}}{1-\gamma} \right\}$$

subject to

$$1 + i_t^b = (1+i_t)\vartheta_t \exp\left(\kappa(D_t^b - \bar{D})\right) \tag{λ. 1}$$

$$(C_t^s)^{-\rho} = \beta^s E_t \left\{ (C_{t+1}^s)^{-\rho} (1 + (1-\tau_{t+1}^i) i_t) \frac{1}{\Pi_{t+1}} \right\} \tag{λ. 2}$$

$$(C_t^b)^{-\rho} = \beta^b E_t \left\{ (C_{t+1}^b)^{-\rho} \frac{1+i_t^b}{\Pi_{t+1}} (1 + \kappa D_t^b) \right\} \tag{λ. 3}$$

$$Y_t = pC_t^s + (1-p)C_t^b + G_t \tag{λ. 4}$$

$$G_t + T^{\text{eff}} = \tau_t^w W_t (pL_t^s + (1-p)L_t^b) + \tau_t^i \frac{D_{t-1}^b}{\Pi_t} (1-p) i_{t-1} + T_t \tag{λ. 5}$$

$$\begin{aligned} D_t^b - \frac{D_{t-1}^b}{\Pi_t} & \left[(1+i_{t-1}) + p(i_{t-1}^b - i_{t-1}) - (1-p)\tau_t^i i_{t-1} \right] \\ &= p\left[(C_t^b - C_t^s) + (1-\tau_t^w) W_t (L_t^s - L_t^b) - T^{\text{eff}}\right]. \end{aligned} \tag{λ. 6}$$

$$\frac{g_{1t}^s}{g_{2t}^s} = \left(\frac{1 - \xi_w \left(\frac{W_{t-1}}{W_t} \right)^{1-\sigma}}{1-\xi_w} \right)^{\frac{1+\eta\sigma}{1-\sigma}} \tag{λ. 7}$$

$$g_{1t}^s = \frac{\sigma}{\sigma-1} \left(L_t^s \right)^{1+\eta} + \beta^s \xi_w E_t \left\{ \left(\frac{W_{t+1}}{W_t} \right)^{\sigma(1+\eta)} g_{1\ t+1}^s \right\} \tag{λ. 8}$$

$$g^s_{2t} = (C^s_t)^{-\rho} (1 - \tau^w_t) W^s_t L^s_t + \beta^s \xi_w E_t \left\{ \left(\frac{W_{t+1}}{W_t} \right)^{\sigma - 1} g^s_{2\ t+1} \right\} \tag{λ. 9}$$

$$\frac{g^b_{1t}}{g^b_{2t}} = \left(\frac{1 - \xi_w \left(\frac{W_{t-1}}{W_t} \right)^{1-\sigma}}{1 - \xi_w} \right)^{\frac{1+\eta\sigma}{1-\sigma}} \tag{λ. 10}$$

$$g^b_{1t} = \frac{\sigma}{\sigma - 1} \left(L^b_t \right)^{1+\eta} + \beta^b \xi_w E_t \left\{ \left(\frac{W_{t+1}}{W_t} \right)^{\sigma(1+\eta)} g^b_{1\ t+1} \right\} \tag{λ. 11}$$

$$g^b_{2t} = \left(C^b_t \right)^{-\rho} (1 - \tau^w_t) W^b_t L^b_t + \beta^b \xi_w E_t \left\{ \left(\frac{W_{t+1}}{W_t} \right)^{\sigma - 1} g^b_{2\ t+1} \right\} \tag{λ. 12}$$

$$\frac{f1_t}{f2_t} = \left(\frac{1 - \xi_p \left(\Pi_t \right)^{\sigma - 1}}{1 - \xi_p} \right)^{\frac{1}{1-\sigma}} \tag{λ. 13}$$

$$f1_t = \frac{\sigma}{\sigma - 1} \left[s(C^s_t)^{-\rho} + (1-s)(C^b_t)^{-\rho} \right] Y_t W_t + \beta \xi_p E_t \left\{ (\Pi_{t+1})^{\sigma} f1_{t+1} \right\} \tag{λ. 14}$$

$$f2_t = \left[s(C^s_t)^{-\rho} + (1-s)(C^b_t)^{-\rho} \right] Y_t + \beta \xi_p E_t \left\{ (\Pi_{t+1})^{\sigma - 1} f2_{t+1} \right\} \tag{λ. 15}$$

$$Y_t \Delta_t = p L^s_t + (1-p) L^b_t \tag{λ. 16}$$

$$\Delta_t = (1 - \xi_p) \left(\frac{1 - \xi_p \left(\Pi_t \right)^{\sigma - 1}}{1 - \xi_p} \right)^{\frac{\sigma}{\sigma - 1}} + \xi_p \left(\Pi_t \right)^{\sigma} \Delta_{t-1} \tag{λ. 17}$$

$$1 + i_t = \left(\Pi_t \right)^{\mu} (1 + \bar{i}) \tag{λ. 18}$$

If the income tax rate is restricted to be smaller than 100%, the Ramsey problem is extended by

$$\tau_t^i \leq 1. \tag{λ. 19}$$

(I drop the restrictions $\tau_t^i \geq -1$ as well as $-1 \leq \tau_t^w \leq 1$ since both are always fulfilled in each simulation scenario.)
If only one tax rate can be applied to both types of income, the Ramsey problem is extended by

$$\tau_t^i = \tau_t^w. \tag{λ. 20}$$

First order conditions:

$$\begin{aligned} p(C_t^s)^{-\rho} - \lambda_{2t}\rho(C_t^s)^{-\rho-1} + \lambda_{2t-1}\frac{\beta^s}{\beta}\rho(C_t^s)^{-\rho-1}\frac{1+(1-\tau_t^i)i_{t-1}}{\Pi_t} - \lambda_{4t} \\ p + \lambda_{6t}\ p + \lambda_{9t}\ \rho(C_t^s)^{-\rho-1}(1-\tau_t^w)W_t L_t^s \\ +\lambda_{14t}\frac{\sigma}{\sigma-1}\ p\ \rho(C_t^s)^{-\rho-1}W_t Y_t + \lambda_{15t}\ p\ \rho(C_t^s)^{-\rho-1}Y_t = 0 \end{aligned} \tag{$\frac{\delta\Lambda_t}{\delta C_t^s}$}$$

$$\begin{aligned} (1-p)(C_t^b)^{-\rho} - \lambda_{3t}\rho(C_t^b)^{-\rho-1} + \lambda_{3t-1}\frac{\beta^b}{\beta}\rho(C_t^b)^{-\rho-1}\frac{1+i_{t-1}^b}{\Pi_t}(1+\kappa D_{t-1}^b) \\ -\lambda_{4t}(1-p) - \lambda_{6t}p + \lambda_{12t}\rho(C_t^b)^{-\rho-1}(1-\tau_t^w)W_t L_t^b \\ +\lambda_{14t}\frac{\sigma}{\sigma-1}(1-p)\rho(C_t^b)^{-\rho-1}Y_t = 0 \end{aligned} \tag{$\frac{\delta\Lambda_t}{\delta C_t^b}$}$$

$$\begin{aligned} -p(L_t^s)^{\eta} - \lambda_{5t}\tau_t^w W_t p - \lambda_{8t}\frac{\sigma}{\sigma-1}(1+\eta)(L_t^s)^{\eta} \\ -\lambda_{9t}(C_t^s)^{-\rho}(1-\tau_t^w)W_t - \lambda_{16t}p = 0 \end{aligned} \tag{$\frac{\delta\Lambda_t}{\delta L_t^s}$}$$

$$\begin{aligned} -(1-p)(L_t^b)^{\eta} - \lambda_{5t}\tau_t^w W_t(1-p) - \lambda_{6t}p(1-\tau_t^w)W_t \\ -\lambda_{11t}\frac{\sigma}{\sigma-1}(1+\eta)(L_t^b)^{\eta} - \lambda_{12t}(C_t^b)^{-\rho}(1-\tau_t^w)W_t - \lambda_{16t}(1-p) = 0 \end{aligned} \tag{$\frac{\delta\Lambda_t}{\delta L_t^b}$}$$

$$\lambda_{4t} - \lambda_{14t}\frac{\sigma}{\sigma-1}\left[p(C_t^s)^{-\rho} + (1-p)(C_t^b)^{-\rho}\right]W_t$$
$$-\lambda_{15t}\left[p(C_t^s)^{-\rho} + (1-p)(C_t^b)^{-\rho}\right] + \lambda_{16t}\Delta_t = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta Y_t})$$

$$-\lambda_{1t}(1+i_t)\vartheta_t\kappa\exp(\kappa(D_t^b - \bar{D})) - \lambda_{3t}\beta^b(C_{t+1}^b)^{-\rho}\frac{1+i_t^b}{\Pi_{t+1}}(1-p)i_t$$
$$+\lambda_{6t} - \lambda_{6t+1}\beta\frac{1}{\Pi_{t+1}}\left[(1+i_t) + p(i_t^b - i_t) - (1-p)\tau_{t+1}^i i_t\right] = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta D_t^b})$$

$$\lambda_{1t} - \lambda_{3t}\beta^b(C_{t+1}^b)^{-\rho}\frac{1+\kappa D_t^b}{\Pi_{t+1}} - \lambda_{6t+1}\beta\frac{D_t^b}{\Pi_{t+1}}p = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta i_t^b})$$

$$\nu G_t^{-\gamma} - \lambda_{4t} + \lambda_{5t} = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta G_t})$$

$$-\lambda_{7t}\frac{1}{g_{2t}^s} + \lambda_{8t} - \lambda_{8t-1}\frac{\beta^s}{\beta}\xi^w\left(\frac{W_t}{W_{t-1}}\Pi_t\right)^{\sigma(1+\eta)} - \lambda_{10t}\frac{1}{g_{2t}^s} = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta g_{1t}^s})$$

$$\lambda_{7t}\frac{g_{1t}^s}{(g_{2t}^s)^2} + \lambda_{9t} - \lambda_{9t-1}\frac{\beta^s}{\beta}\xi^w\left(\frac{W_t}{W_{t-1}}\Pi_t\right)^{\sigma-1} + \lambda_{10t}\frac{g_{1t}^s}{(g_{2t}^s)^2} = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta g_{2t}^s})$$

$$\lambda_{10t}\frac{1}{g_{2t}^b} + \lambda_{11t} - \lambda_{11t-1}\frac{\beta^b}{\beta}\xi^w\left(\frac{W_t}{W_{t-1}}\Pi_t\right)^{\sigma(1+\eta)} = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta g_{1t}^b})$$

$$-\lambda_{10t}\frac{g_{1t}^b}{(g_{2t}^b)^2} + \lambda_{12t} - \lambda_{12t-1}\frac{\beta^b}{\beta}\xi^w\left(\frac{W_t}{W_{t-1}}\Pi_t\right)^{\sigma-1} = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta g_{2t}^b})$$

$$-\lambda_{13t}\frac{1}{f_{2t}} + \lambda_{14t} - \lambda_{14t-1}\xi^p\Pi_t^{\sigma} = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta f_{1t}})$$

$$\lambda_{13t}\frac{f_{1t}}{(f_{2t})^2} + \lambda_{15t} - \lambda_{15t-1}\xi^p \Pi_t^{\sigma-1} = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta f_{2t}})$$

$$\begin{aligned}
&-\lambda_{5t}\tau_t^w(pL_t^s + (1-p)L_t^b) - \lambda_{6t}p(1-\tau_t^w)(L_t^s - Lb_t)\\
&\left[\lambda_{7t}\left(\frac{\Pi_t}{W_{t-1}}\right)^{\sigma-1} W_t^{\sigma-2} - \lambda_{7t+1}\beta(W_{t+1}\Pi_{t+1})^{\sigma-1}W_t^{-\sigma}\right]\\
&+(1+\eta\sigma)\left(\frac{1-\xi^w\left(\frac{W_t}{W_{t-1}}\Pi_t\right)^{\sigma-1}}{1-\xi^w}\right)^{\frac{\sigma(1+\eta)}{1-\sigma}} \frac{\xi^w}{1-\xi^w}\\
&+\lambda_{8t}\beta^s\xi^w g^s_{1t+1}\sigma(1+\eta)(W_{t+1}\Pi_{t+1})^{\sigma(1+\eta)}W_t^{-\sigma(1+\eta)-1}\\
&-\lambda_{8t-1}\frac{\beta^s}{\beta}\xi^w g^s_{1t}\sigma(1+\eta)\left(\frac{\Pi_t}{W_{t-1}}\right)^{\sigma(1+\eta)} W_t^{\sigma(1+\eta)-1}\\
&+\lambda_{9t}\left[\beta^s\xi^w g^s_{2t+1}(\sigma-1)(W_{t+1}\Pi_{t+1})^{\sigma-1}W_t^{-\sigma} - (C_t^s)^{-\rho}(1-\tau_t^w)L_t^s\right]\\
&-\lambda_{9t-1}\frac{\beta^s}{\beta}\xi^w g^s_{2t}(\sigma-1)\left(\frac{\Pi_t}{W_{t-1}}\right)^{\sigma-1} W_t^{\sigma-2}\\
&+\lambda_{11t}\beta^b\xi^w g^b_{1t+1}\sigma(1+\eta)(W_{t+1}\Pi_{t+1})^{\sigma(1+\eta)}W_t^{-\sigma(1+\eta)-1}\\
&-\lambda_{11t-1}\frac{\beta^b}{\beta}\xi^w g^b_{1t}\sigma(1+\eta)\left(\frac{\Pi_t}{W_{t-1}}\right)^{\sigma(1+\eta)} W_t^{\sigma(1+\eta)-1}\\
&+\lambda_{12t}\left[\beta^b\xi^w g^b_{2t+1}(\sigma-1)(W_{t+1}\Pi_{t+1})^{\sigma-1}W_t^{-\sigma} - (C_t^b)^{-\rho}(1-\tau_t^w)L_t^b\right]\\
&-\lambda_{12t-1}\frac{\beta^b}{\beta}\xi^w g^b_{2t}(\sigma-1)\left(\frac{\Pi_t}{W_{t-1}}\right)^{\sigma-1} W_t^{\sigma-2}\\
&-\lambda_{14t}\frac{\sigma}{\sigma-1}\left[p(C_t^s)^{-\rho} + (1-p)(C_t^b)^{-\rho}\right]Y_t = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta W_t})
\end{aligned}$$

$$\lambda_{16t}Y_t + \lambda_{17t} - \lambda_{17t+1}\beta\xi^p\Pi_t^{\sigma} = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta\Delta_t})$$

$$\begin{aligned}
&-\lambda_{1t}\vartheta_t\exp(\kappa(D_t^b - \bar{D})) - \lambda_{2t}\beta^s(C^s_{t+1})^{-\rho}\frac{1-\tau^i_{t+1}}{\Pi_{t+1}}\\
&-\lambda_{5t+1}\beta\tau^i_{t+1}\frac{D_t^b}{\Pi_{t+1}}(1-p) - \lambda_{6t+1}\beta\frac{D_t^b}{\Pi_{t+1}}(1-p)(1-\tau^i_{t+1}) + \lambda_{18t} = 0 \qquad (\tfrac{\delta\Lambda_t}{\delta i_t})
\end{aligned}$$

$$
\begin{aligned}
&\lambda_{2t-1}\frac{\beta^s}{\beta}(C_t^s)^{-\rho}\frac{1+(1-\tau_t^i)i_{t-1}}{\Pi_t^2}(1+\kappa D_{t-1}^b)+\lambda_{5t}\tau_t^i\frac{D_{t-1}^b}{\Pi_t^2}(1-p)i_{t-1}\\
&+\lambda_{6t}\frac{D_{t-1}^b}{\Pi_t^2}\left[(1+i_{t-1})+p(i_{t-1}^b-i_{t-1})-(1-p)\tau_t^i i_{t-1}\right]\\
&+\lambda_{7t}(1+\eta\sigma)\left(\frac{1-\xi^w\left(\frac{W_t}{W_{t-1}}\Pi_t\right)^{\sigma-1}}{1-\xi^w}\right)^{\frac{\sigma(1+\eta)}{1-\sigma}}\frac{\xi^w}{1-\xi^w}\left(\frac{W_t}{W_{t-1}}\right)^{\sigma-1}\Pi_t^{\sigma-2}\\
&-\lambda_{8t-1}\frac{\beta^s}{\beta}\xi^w\sigma(1+\eta)\left(\frac{W_t}{W_{t-1}}\right)^{\sigma(1+\eta)}\Pi_t^{\sigma(1+\eta)-1}g_{1t}^s\\
&-\lambda_{9t-1}\frac{\beta^s}{\beta}\xi^w(\sigma-1)\left(\frac{W_t}{W_{t-1}}\right)^{\sigma-1}\Pi_t^{\sigma-2}g_{2t}^s\\
&-\lambda_{11t-1}\frac{\beta^b}{\beta}\xi^w\left(\frac{W_t}{W_{t-1}}\right)^{\sigma(1+\eta)}\sigma(1+\eta)\Pi_t^{\sigma(1+\eta)-1}g_{1t}^b\\
&-\lambda_{12t-1}\frac{\beta^b}{\beta}\xi^w(\sigma-1)\left(\frac{W_t}{W_{t-1}}\right)^{\sigma-1}\Pi_t^{\sigma-2}g_{2t}^b\\
&+\lambda_{13t}\left(\frac{1-\xi^p\Pi_t^{\sigma-1}}{1-\xi^p}\right)^{\frac{\sigma}{1-\sigma}}\frac{\xi^p}{1-\xi^p}\Pi_t^{\sigma-2}-\lambda_{14t-1}\xi^p\sigma\Pi_t^{\sigma-1}f_{1t}\frac{\beta^s}{\beta}\\
&-\lambda_{15t-1}\ \xi^p\ \Pi_t^{\sigma-2}(\sigma-1)f_{2t}\frac{\beta^s}{\beta}\\
&-\lambda_{17t}\left[\xi^p\sigma\Pi_t^{\sigma-1}\Delta_{t-1}-\sigma\left(\frac{1-\xi^p\Pi_t^{\sigma-1}}{1-\xi^p}\right)^{\frac{1}{\sigma-1}}\xi^p\Pi_t^{\sigma-2}\right]\\
&-\lambda_{18t}\ \mu\ \Pi_t^{\mu-1}(1-\bar{i})=0
\end{aligned}
\tag{$\frac{\delta\Lambda_t}{\delta\Pi_t}$}
$$

$$
\lambda_{5t}=0 \tag{$\frac{\delta\Lambda_t}{\delta T_t}$}
$$

$$
\lambda_{2t-1}\frac{\beta^s}{\beta}(C_t^s)^{-\rho}\frac{i_{t-1}}{\Pi_t}-\lambda_{5t}\frac{D_{t-1}^b}{\Pi_t}(1-p)i_{t-1}+\lambda_{6t}\frac{D_{t-1}^b}{\Pi_t}i_{t-1}(1-p)=0 \tag{$\frac{\delta\Lambda_t}{\delta\tau_t^i}$}
$$

$$
\begin{aligned}
&-\lambda_{5t}W_t(pL_t^s+(1-p)L_t^b)+\lambda_{6t}\ p\ W_t(L_t^s-L_t^b)+\lambda_{9t}(C_t^s)^{-\rho}W_tL_t^s\\
&+\lambda_{12t}(C_t^b)^{-\rho}W_tL_t^b=0
\end{aligned}
\tag{$\frac{\delta\Lambda_t}{\delta\tau_t^w}$}
$$

In case of restricting the interest tax to be smaller than 100%, the complementary slackness condition implies $\lambda_{20t}\ \tau_t^i = 0$ and $\lambda_{20t} \geq 0$ must hold. I solve the complete model (meaning equilibrium conditions plus Ramsey FOCs) by using a Newton-type algorithm via Dynare which involves solving all equilibrium equations as well as the Ramsey FOCs simultaneously. Furthermore, I solve the model under perfect foresight such that the exact solution to the model can be found via the Dynare "simul"-command by taking nonlinearities into account. Consequently, the restriction on the interest tax can easily be implemented by use of "if"-commands. More precisely, the restriction on the interest tax implies adding the equations

$$\lambda_{20t} = \max(0, \frac{\delta \Lambda_t}{\delta i_t} - \lambda_{20t})$$

and

$$(\tau_t^i < 1)\left(\frac{\delta \Lambda_t}{\delta i_t} - \lambda_{20t}\right) + (\tau_t^i \geq 1)(\tau_t^i - 1) = 0$$

to the model-block in the mod.-file, where

$$\frac{\delta \Lambda_t}{\delta i_t} = \lambda_{2t-1} \frac{\beta^s}{\beta} (C_t^s)^{-\rho} \frac{i_{t-1}}{\Pi_t} - \lambda_{5t} \frac{D_{t-1}^b}{\Pi_t} (1-p) i_{t-1} + \lambda_{6t} \frac{D_{t-1}^b}{\Pi_t} i_{t-1} (1-p) + \lambda_{20t}.$$

4.8.B Steady-State Efficiency

In steady state, the exogenous policy equilibrium equations collapse to

$$\frac{1}{\beta^s} = \frac{1 + (1 - \tau^i) i}{\Pi} \tag{4.B.1}$$

$$\frac{1}{\beta^b} = \frac{(1+i)\exp(\kappa(D^b - \bar{D}))}{\Pi}(1 + \kappa\ D^b) \tag{4.B.2}$$

$$G + (1-p)T^{\text{eff}} = \tau^w \frac{\sigma - 1}{\sigma}(pL^s + (1-p)L^b) + \tau^i \frac{D^b}{\Pi}(1-p)i + T \tag{4.B.3}$$

$$
\begin{aligned}
&-\frac{1}{p}\frac{D^b}{\Pi}\left[(1+i)+p(i^b-i)-(1-p)\tau^i i-1\right] \\
&=(C^b-C^s)+(1-\tau_t^w)\frac{\sigma-1}{\sigma}(L^s-L^b)-T^{\text{eff}}
\end{aligned}
\tag{4.B.4}
$$

$$
(L^s)^\eta=\left(\frac{\sigma-1}{\sigma}\right)^2(C^s)^{-\rho}(1-\tau^w) \tag{4.B.5}
$$

$$
(L^b)^\eta=\left(\frac{\sigma-1}{\sigma}\right)^2\left(C^b\right)^{-\rho}(1-\tau^w) \tag{4.B.6}
$$

$$
pL^s+(1-p)L^b=pC^s+(1-p)C^b+G \tag{4.B.7}
$$

$$
1+i=\Pi^\mu(1+\bar{i}) \tag{4.B.8}
$$

Combining (4.B.8) and (4.B.1) delivers

$$
\frac{1}{\beta^s}=\frac{1+(1-\tau^i)(\Pi^\mu(1+\bar{i})-1)}{\Pi}.
$$

I calibrate $\bar{i}$ to ensure $\Pi=1$ which implies setting

$$
\bar{i}=\left(\frac{1}{\beta^s}-1\right)\frac{1}{1-\tau^i}.
$$

Plugging in (4.B.1) into (4.B.2) gives

$$
\frac{1}{\beta^b}=\left[1+\frac{1-\beta^s}{\beta^s}\frac{1}{1-\tau^i}\right]\exp(\kappa(D^b-\bar{D}))(1+\kappa D^b).
$$

I calibrate β^b to ensure that $D^b=\bar{D}$ holds in steady state implying

$$
\beta^b=\left[1+\frac{1-\beta^s}{\beta^s}\frac{1}{1-\tau^i}\right]^{-1}\frac{1}{1+\kappa\bar{D}}.
$$

Consequently, equation (4.B.4) can be written as

$$\begin{aligned} & -\frac{\bar{D}}{p}\left[(1+i)+p(i^b-i)-(1-p)\tau^i i-1\right] \\ & =(C^b-C^s)+(1-\tau_t^w)\frac{\sigma-1}{\sigma}(L^s-L^b)-T^{\text{eff}}. \end{aligned} \tag{4.B.9}$$

In the Social planner's (efficient) equilibrium, $L^s = L^b$ and $C^s = C^b$ holds. Applying this condition, equation (4.B.9) gives

$$T^{\text{eff}}=\frac{\bar{D}}{p}i(1-(1-p)\tau^i).$$

This gives the efficient level of lump-sum subsidies to borrowers in dependence of the chosen steady-state value of interest taxes, meaning the value of lump-sum subsidies borrowers have to obtain to ensure that borrowers and savers feature the same steady-state level of consumption and labor and, as a consequence, the same utility-level. Here, I choose the steady-state interest tax to be zero which implies

$$T^{\text{eff}}=\frac{\bar{D}}{p}i. \tag{4.B.10}$$

Furthermore, in the Social planner's equilibrium, $(L^s)^\eta = (C^s)^{-\rho}$ holds. A comparison with equation (4.B.5) shows that efficiency of the exogenous policy steady state, thus, requires

$$\tau^w=1-\left(\frac{\sigma}{\sigma-1}\right)^2. \tag{4.B.11}$$

Plugging in equations (4.B.10), (4.B.11), and the Social planner's level of government spending into (4.B.3) shows that lump-sum taxes have to be equal to the sum of wage subsidies, lump-sum subsidies payed to borrowers, and the optimal level of government spending. This gives

$$T=G^{\text{eff}}+\frac{\bar{D}}{p}i(1-p)+\frac{2\sigma-1}{\sigma(\sigma-1)}L^{s,\text{eff}}. \tag{4.B.12}$$

Setting the initial steady-state values of the tax instruments following (4.B.10) to (4.B.12) together with $\tau^i = 0$ ensures efficiency of the exogenous policy steady state which is, consequently, identical to the Ramsey policy steady state.

4.8.C Efficiency Under Inflation-Targeting

Efficiency requires $L_t^s = L_t^b$ and $C_t^s = C_t^b$ independent of the spread shock. Plugging in these conditions as well as $\Pi_t = \bar{\Pi} = 1$ into the inflation-targeting equilibrium equations (4.56) to (4.63), the Euler equation for savers (4.58) can be written as

$$\frac{1}{\beta^s} = 1 + (1 - \tau_{t+1}^i) i_t \tag{4.C.1}$$

and the Euler equation for borrowers (4.59) gives

$$\frac{1}{\beta^b} = \frac{(1 + i_t)\vartheta_t \exp(\kappa(D_t^b - \bar{D}))}{\Pi}(1 + \kappa\ D_t^b). \tag{4.C.2}$$

Furthermore, with $L_t^s = L_t^b$ and $C_t^s = C_t^b$ as well as plugging in the definition of the borrowers' interest rate (4.2), the evolution of debt reads

$$\begin{aligned} &D_t^b - D_{t-1}^b \big[(1-p)(1+i_{t-1}) \\ &+p(1+i_{t-1})\vartheta_{t-1}\exp(\kappa(D_{t-1}^b - \bar{D})) - (1-p)\tau_t^i i_{t-1} - 1\big] = -pT^{\text{eff}}. \end{aligned} \tag{4.C.3}$$

Comparing the Social planner's allocation (4.48) with the exogenous policy equilibrium equation (4.56) shows that

$$\tau_t^w = 1 - \left(\frac{\sigma}{\sigma - 1}\right)^2 = \frac{1 - 2\sigma}{(\sigma - 1)^2} \tag{4.C.4}$$

must hold to ensure efficiency of the exogenous policy equilibrium. The optimal policy rule for τ_t^i can be found by rearranging (4.C.2) to give

$$\tau_{t+1}^i = 1 - \frac{1 - \beta^s}{\beta^s}\left[\frac{1}{\beta^b}\frac{1}{\vartheta_t \exp(\kappa(D_t^b - \bar{D}))(1 + \kappa D_t^b)} - 1\right]^{-1}. \tag{4.C.5}$$

Replacing τ_t^i in equation (4.C.1) with (4.C.5) delivers

$$i_t = \frac{1}{\beta^b}\frac{1}{\vartheta_t \exp(\kappa(D_t^b - \bar{D}))(1 + \kappa D_t^b)} - 1. \tag{4.C.6}$$

Plugging in both equations (4.C. 5) and (4.C. 6) into (4.C. 3), the evolution of debt can be written as

$$
\begin{aligned}
&D_t^b - D_{t-1}^b \left[(1-p)\frac{1}{\beta^b}\frac{1}{\vartheta_{t-1}\exp(\kappa(D_{t-1}^b))(1+\kappa D_{t-1}^b)} + \frac{p}{\beta^b(1+\kappa D_{t-1}^b)} \right. \\
&\left. -\frac{1-p}{\beta^b\vartheta_{t-1}\exp(\kappa(D_{t-1}^b-\bar{D}))(1+\kappa D_{t-1}^b)} + (1-p) + (1-p)\frac{1-\beta^s}{\beta^s} \right] = -pT^{\text{eff}}
\end{aligned}
$$

$$
\Leftrightarrow D_t^b - D_{t-1}^b \left[(1-p)\frac{1}{\beta^s} + \frac{p}{\beta^b}\frac{1}{1+\kappa D_{t-1}^b} \right] = -pT^{\text{eff}}. \tag{4.C.7}
$$

Recalling that the discount factor of borrowers is set to be

$$
\beta^b = \left[1 + \frac{1-\beta^s}{\beta^s}\frac{1}{1-\tau^i} \right]^{-1} \frac{1}{1+\kappa\bar{D}},
$$

equation (4.C. 7) shows that $D_t^b = \bar{D}$ must hold to ensure efficiency of the exogenous policy equilibrium which means that the debt level has to remain constant at its steady-state level. Applying this solution, equations (4.C.5) and (4.C.6) give the optimal rule for the interest tax as

$$
\tau_t^i = 1 - \frac{1-\beta^s}{\beta^s}\left[\frac{1}{\beta^s}\frac{1}{\vartheta_{t-1}} - 1 \right]^{-1}
$$

and the corresponding response of the interest rate as

$$
i_t = \frac{1}{\beta^s}\frac{1}{\vartheta_t} - 1.
$$

4.8.D Utility Measures

Period-by-period utility losses are defined on an economy-wide level as ξ_t such that

$$
U\left(C_t^s, C_t^b, L_t^s, L_t^b, G_t\right) = U\left((1-\xi_t)C_{ss}^s, (1-\xi_t)C_{ss}^b, L_{ss}^s, L_{ss}^b, G_{ss}\right)
$$

$$
\begin{aligned}
\Leftrightarrow &\left\{ p\left(\frac{(C_t^s)^{1-\rho}}{1-\rho} - \frac{(L_t^s)^{1+\eta}}{1+\eta} \right) + (1-p)\left(\frac{(C_t^b)^{1-\rho}}{1-\rho} - \frac{(L_t^b)^{1+\eta}}{1+\eta} \right) + v\frac{G_t^{1-\gamma}}{1-\gamma} \right\} \\
&= \frac{((1-\xi)C_{ss}^s)^{1-\rho}}{1-\rho} - \frac{(L_{ss}^s)^{1+\eta}}{1+\eta} + v\frac{G_{ss}^{1-\gamma}}{1-\gamma}
\end{aligned}
$$

holds, where X_t denotes the value of the respective variable in period t when an interest spread shock hits the economy in period 1 while X_{ss} denotes the respective steady-state value. Here, it is used that savers and borrowers feature the same steady-state level of consumption and leisure such that $C^s_{ss} = C^b_{ss}$ and $L^s_{ss} = L^b_{ss}$. Utility losses for savers are defined as ξ^s_t such that

$$U\left(C^s_t, L^s_t, G_t\right) = U\left((1-\xi^s_t)C^s_{ss}, L^s_{ss}, G_{ss}\right)$$

$$\Leftrightarrow \frac{(C^s_t)^{1-\rho}}{1-\rho} - \frac{(L^s_t)^{1+\eta}}{1+\eta} + v\frac{G_t^{1-\gamma}}{1-\gamma} = \frac{((1-\xi^s_t)C^s_{ss})^{1-\rho}}{1-\rho} - \frac{(L^s_{ss})^{1+\eta}}{1+\eta} + v\frac{G_t^{1-\gamma}}{1-\gamma}$$

holds and for borrowers, the utility loss is given by ξ^b_t such that

$$U\left(C^b_t, L^b_t, G_t\right) = U\left((1-\xi^b_t)C^b_{ss}, L^b_{ss}, G_{ss}\right)$$

$$\Leftrightarrow \frac{(C^b_t)^{1-\rho}}{1-\rho} - \frac{(L^b_t)^{1+\eta}}{1+\eta} + v\frac{G_t^{1-\gamma}}{1-\gamma} = \frac{((1-\xi^b_t)C^b_{ss})^{1-\rho}}{1-\rho} - \frac{(L^b_{ss})^{1+\eta}}{1+\eta} + v\frac{G_t^{1-\gamma}}{1-\gamma}$$

applies. Regarding lifetime utility losses, the respective measures are defined as ξ, ξ^s, and ξ^b such that

$$E_t \sum_{t=0}^{\infty} \beta^t \left\{ p\left(\frac{(C^s_t)^{1-\rho}}{1-\rho} - \frac{(L^s_t)^{1+\eta}}{1+\eta}\right) + (1-p)\left(\frac{(C^b_t)^{1-\rho}}{1-\rho} - \frac{(L^b_t)^{1+\eta}}{1+\eta}\right) + v\frac{G_t^{1-\gamma}}{1-\gamma} \right\}$$
$$= \frac{((1-\xi)C^s_{ss})^{1-\rho}}{1-\rho} - \frac{(L^s_{ss})^{1+\eta}}{1+\eta} + v\frac{G_{ss}^{1-\gamma}}{1-\gamma} + \sum_{t=1}^{\infty} \beta^t U_{ss},$$

$$E_t \sum_{t=0}^{\infty} (\beta^s)^t \left(\frac{(C^s_t)^{1-\rho}}{1-\rho} - \frac{(L^s_t)^{1+\eta}}{1+\eta}\right) + v\frac{G_t^{1-\gamma}}{1-\gamma}$$
$$= \frac{((1-\xi^s)C^s_{ss})^{1-\rho}}{1-\rho} - \frac{(L^s_{ss})^{1+\eta}}{1+\eta} + v\frac{G_{ss}^{1-\gamma}}{1-\gamma} + \sum_{t=1}^{\infty} (\beta^s)^t U^s_{ss},$$

and

$$E_t \sum_{t=0}^{\infty} \left(\beta^b\right)^t \left(\frac{(C^b_t)^{1-\rho}}{1-\rho} - \frac{(L^b_t)^{1+\eta}}{1+\eta}\right) + v\frac{G_t^{1-\gamma}}{1-\gamma}$$
$$= \frac{((1-\xi^b)C^b_{ss})^{1-\rho}}{1-\rho} - \frac{(L^b_{ss})^{1+\eta}}{1+\eta} + v\frac{G_{ss}^{1-\gamma}}{1-\gamma} + \sum_{t=1}^{\infty} \left(\beta^b\right)^t U^s_{ss}.$$

hold. For computational issues, it is used that under each policy the economy converts back to steady state after a finite number of periods which means that the lifetime utility loss can be computed as

$$
\begin{aligned}
&E_t \sum_{t=0}^{c} \beta^t \left\{ p \left(\frac{(C_t^s)^{1-\rho}}{1-\rho} - \frac{(L_t^s)^{1+\eta}}{1+\eta} \right) + (1-p) \left(\frac{(C_t^b)^{1-\rho}}{1-\rho} - \frac{(L_t^b)^{1+\eta}}{1+\eta} \right) + v \frac{G_t^{1-\gamma}}{1-\gamma} \right\} \\
&\qquad = \frac{((1-\xi) C_{ss}^s)^{1-\rho}}{1-\rho} - \frac{(L_{ss}^s)^{1+\eta}}{1+\eta} + v \frac{G_{ss}^{1-\gamma}}{1-\gamma} + \sum_{t=1}^{c} \beta^t U_{ss},
\end{aligned}
$$

where it is ensured that c is chosen large enough to ensure that the steady state is reached after c periods.

Regarding policy gains, the economy-wide policy gain ξ^{pol} is defined as

$$
\begin{aligned}
&\sum_{t=0}^{\infty} \beta^t U_t^{Ram} \left(C_t^{s,Ram}, C_t^{b,Ram}, L_t^{s,Ram}, L_t^{b,Ram}, G_t^{Ram} \right) \\
&= \sum_{t=1}^{\infty} \beta^t U_t^{Exog} \left(C_t^{s,Exog}, C_t^{b,Exog}, L_t^{s,Exog}, L_t^{b,Exog}, G_t^{Exog} \right) \\
&\quad + \frac{\left((1-\xi^{pol}) C^{s,eff}\right)^{1-\rho}}{1-\rho} - \frac{\left(L^{s,eff}\right)^{1+\eta}}{1+\eta} + \nu \frac{\left(G^{eff}\right)^{1-\gamma}}{1-\gamma}
\end{aligned}
$$

with U defined in (4.43) while the agent-specific policy gain $\xi^{pol,h}$ is defined as

$$
\begin{aligned}
&\sum_{t=0}^{\infty} \left(\beta^h\right)^t \left\{ \frac{\left(C_t^{h,Ram}\right)^{1-\rho}}{1-\rho} - \frac{\left(L_t^{h,Ram}\right)^{1+\eta}}{1+\eta} + \nu \frac{\left(G_t^{Ram}\right)^{1-\gamma}}{1-\gamma} \right\} \\
&= \sum_{t=1}^{\infty} \left(\beta^h\right)^t \left\{ \frac{\left(C_t^{h,exog}\right)^{1-\rho}}{1-\rho} - \frac{\left(L_t^{h,exog}\right)^{1+\eta}}{1+\eta} + \nu \frac{\left(G_t^{exog}\right)^{1-\gamma}}{1-\gamma} \right\} \\
&\quad + \frac{\left((1-\xi^{pol,h}) C^{s,eff}\right)^{1-\rho}}{1-\rho} - \frac{\left(L^{s,eff}\right)^{1+\eta}}{1+\eta} + \nu \frac{\left(G^{eff}\right)^{1-\gamma}}{1-\gamma}
\end{aligned}
$$

with $h = \{s, b\}$ and X_t^{Ram} denoting variables under the Ramsey-optimal policy, while X_t^{exog} denotes the respective variable under an exogenously given policy.

4.8.E Ramsey FOCs with Alternative Welfare Measure

Using the Rawlsian social welfare measure, the FOCs with respect to consumption and labor read:

$$
\begin{aligned}
&(1-p_t^{Rawls})(C_t^b)^{-\rho} - \lambda_{3t}\rho(C_t^b)^{-\rho-1} \\
&+\lambda_{3t-1}\frac{\beta^b}{\beta}\rho(C_t^b)^{-\rho-1}\frac{1+i_{t-1}^b}{\Pi_t}(1+\kappa D_{t-1}^b) \\
&-\lambda_{4t}(1-p) - \lambda_{6t}p + \lambda_{12t}\rho(C_t^b)^{-\rho-1}(1-\tau_t^w)W_tL_t^b \\
&+\lambda_{14t}\frac{\sigma}{\sigma-1}(1-p)\rho(C_t^b)^{-\rho-1}Y_t \\
&+\lambda_{21t}\left(C_t^b\right)^{-\rho}k\frac{\exp(-kdU_t)}{\left[1+\exp(-kdU_t)\right]^2} = 0
\end{aligned}
\tag{$\frac{\delta\Lambda_t}{\delta C_t^b}$}
$$

$$
\begin{aligned}
&p_t^{Rawls}(C_t^s)^{-\rho} - \lambda_{2t}\rho(C_t^s)^{-\rho-1} + \lambda_{2t-1}\frac{\beta^s}{\beta}\rho(C_t^s)^{-\rho-1}\frac{1+(1-\tau_t^i)i_{t-1}}{\Pi_t} \\
&-\lambda_{4t}\ p + \lambda_{6t}\ p + \lambda_{9t}\ \rho(C_t^s)^{-\rho-1}(1-\tau_t^w)W_tL_t^s \\
&+\lambda_{14t}\frac{\sigma}{\sigma-1}\ p\ \rho(C_t^s)^{-\rho-1}W_tY_t + \lambda_{15t}\ p\ \rho(C_t^s)^{-\rho-1}Y_t \\
&-\lambda_{21t}\left(C_t^s\right)^{-\rho}k\frac{\exp(-kdU_t)}{\left[1+\exp(-kdU_t)\right]^2} = 0
\end{aligned}
\tag{$\frac{\delta\Lambda_t}{\delta C_t^s}$}
$$

$$
\begin{aligned}
&-p_t^{Rawls}(L_t^s)^{\eta} - \lambda_{5t}\tau_t^wW_tp - \lambda_{8t}\frac{\sigma}{\sigma-1}(1+\eta)(L_t^s)^{\eta} \\
&-\lambda_{9t}(C_t^s)^{-\rho}(1-\tau_t^w)W_t - \lambda_{16t}p + \lambda_{21t}\left(L_t^s\right)^{\eta}k\frac{\exp(-kdU_t)}{\left[1+\exp(-kdU_t)\right]^2} = 0
\end{aligned}
\tag{$\frac{\delta\Lambda_t}{\delta L_t^s}$}
$$

$$
\begin{aligned}
&-(1-p_t^{Rawls})(L_t^b)^{\eta} - \lambda_{5t}\tau_t^wW_t(1-p) - \lambda_{6t}p(1-\tau_t^w)W_t \\
&-\lambda_{11t}\frac{\sigma}{\sigma-1}(1+\eta)(L_t^b)^{\eta} - \lambda_{12t}(C_t^b)^{-\rho}(1-\tau_t^w)W_t \\
&-\lambda_{16t}(1-p) - \lambda_{21t}\left(L_t^b\right)^{\eta}k\frac{\exp(-kdU_t)}{\left[1+\exp(-kdU_t)\right]^2} = 0
\end{aligned}
\tag{$\frac{\delta\Lambda_t}{\delta L_t^b}$}
$$

where dU_t is defined as

$$
dU_t = U_t^s - U_t^b = \frac{(C_t^s)^{1-\rho}}{1-\rho} - \frac{(L_t^s)^{1+\eta}}{1+\eta} - \frac{(C_t^b)^{1-\rho}}{1-\rho} + \frac{(L_t^b)^{1+\eta}}{1+\eta}.
$$

Furthermore, the FOCs are extended by the derivative of the Lagrangian with respect to p_t^{Rawls} which gives

$$dU_t = \lambda_{21t}.$$

The rest of the FOCs remains unchanged and can be seen in Appendix A.

5. Concluding Remarks

In the course of this thesis, fiscal policy measures were investigated as a possibility to eliminate economic imbalances and diminish welfare losses of economic disturbances. Starting with an exogenously given one-time tax shift considered in Chapter 2, it was shown that a fiscal devaluation may be quite effective in reducing trade balance deficits in a country being a member of a monetary union. Here, the most effective form of a fiscal devaluation was found to consist of an increase in the standard rate of value added tax and a decrease in the employees' share in social security contributions.

Going one step further, the results in Chapter 3 indicate that if fiscal policy is set constrained-optimal, welfare losses of a financial shock in times of a binding zero lower bound on the nominal interest rate can be reduced to a large extent. Conducting a constrained-optimal fiscal policy in this setup may eliminate roughly one quarter of the total welfare loss of monetary policy being constrained by the zero lower bound. This measure, however, implies staying at the zero lower bound for a longer period.

Regarding distributive effects, Chapter 4 showed that maximizing the sum of individual utilities in a utilitarian sense may imply increasing the disparity between agents depending on the tax base used. Interest taxes are found to be more effective in eliminating welfare losses of a spread shock than wage taxes and, at the same time, decrease the disparity between groups while the distributive effects of wage taxes depend on the relative degrees of wage and price rigidity. As these results indicate the importance of regarding distributive effects, an alternative social welfare measure was regarded and found that using a Rawlsian concept, the disparity between groups can be completely eliminated but only at the cost of decreasing savers' welfare.

Overall, the results highlight the important role fiscal policy may play in the economy-stabilizing task and its potential effectiveness in diminishing shock-induced welfare losses. For the purpose of being able to trace the mechanisms as well as for the sake of computability, in this thesis, all essays focused on a unilaterally conducted fiscal policy and partially limit the analysis to a closed economy. Extending the research to multi-country models and dealing with the issue of policy coordination between different countries as well as regarding the possibility of counteractive policy measures of foreign countries seems to be an interesting issue for further research.

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