# Macroeceonomic Policy in a Heterogenous Monetary Union*

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**Abstract**

We use a two-country model with a central bank maximizing union-wide welfare and two fiscal authorities minimizing comparable, but slightly different country-wide losses. We analyze the rivalry between the three authorities in seven static games. Comparing a homogenous with a heterogeneous monetary union, we find welfare losses significantly larger in the heterogeneous union. But these losses translate to less than a 0.1 percent reduction in consumption. The best-performing scenarios are cooperation between all authorities and monetary leadership, cooperation between the fiscal authorities is harmful to both the union's and the countries' welfare.

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# 1 Introduction

A country participating in a currency union has to abstain from sovereign monetary policy. Union-wide monetary policy aims at stabilizing inflation and output in the whole currency area and cannot pay attention to every specific country in its decision-making. National fiscal policies, instead, typically care about their single country and not the union as a whole. Out of this, there arises a variety of possible strategic behaviors: National fiscal policies can help monetary policy to maximize union-wide welfare (Gali and Monacelli 2002, 2005, Benigno 2004), they can try to adjust the outcomes of monetary policy to maximize nationwide welfare (Dixit 2001, Uhlig 2002), or they can be used to maximize the probability of the current government to stay in office after the next elections (Beetsma and Uhlig 1999). In this paper we incorporate all three possibilities. We analyze monetary and fiscal policy interactions in a monetary union under various scenarios and elaborate which scenarios are preferable from a welfare perspective.

The literature on monetary and fiscal policy in a monetary union is vast, so we only mention the articles that are of special importance to our paper.[1] Dixit and Lambertini (2003b) consider monetary-fiscal policy interactions in a monetary union. They assume that the participating regions and their policy goals are symmetric and in line with the common central bank's target. Thus, it seems to be no surprise that the ideal output and inflation levels can be achieved – even without coordination of the fiscal authorities and the common central bank and without the need for monetary commitment. Dixit (2001), Dixit and Lambertini (2003a) and Lambertini (2004, 2006a) check the implications of this model to the case where monetary policy is conservative in the sense of Rogoff (1985). Among other things, they find that fiscal discretion destroys the positive effect of monetary commitment, while fiscal cooperation typically leads to less efficient outcomes than discretionary fiscal policies.

Lombardo and Sutherland (2004) build a symmetric two-country model that features government spending in the utility function. They find that the last result can be overturned if the share of steady-state government spending in output is positive and supply shocks are not perfectly negatively correlated. Nonetheless, for plausible parameter values the welfare gains of fiscal cooperation are small.

[1] We refer the reader to the textbook of De Grauwe (2003) for an overview of the field as well as references to the less recent literature.

Dixit and Lambertini (2001) allow for some heterogeneities by assuming that fiscal and monetary authorities possibly have conflicting output and inflation goals. They show that without commitment or leadership of either authority, the ideal points of output and inflation cannot be attained.

Chari and Kehoe (2004) take a closer look at the desirability of fiscal debt constraints. They find that such constraints are undesirable if monetary commitment is possible, but the opposite if the central bank cannot commit to its policy. The latter is the result of a time inconsistency problem of monetary policy which leads to free-riding behavior of the fiscal authorities.

In the very recent literature, the topic of monetary and fiscal interactions has also been dealt with in dynamic stochastic general equilibrium models. However, the emphasis in most of these papers is less on strategic behavior and game theoretical scenarios. Gali and Monacelli (2005) e.g. analyze optimal fiscal and monetary policies in a monetary union, where all policy agents care about union-wide variables and Ferrero (2005) considers a two region model and compares the optimal policies to simple policy rules, where all policy agents care about union-wide variables. Canzoneri et al. (2005) study the interactions between monetary and fiscal policy in a monetary union and compare the results of their New Keynesian model to the data. They also asses the effects of regional asymmetries on welfare, but they assume that fiscal policy is described by exogenously given processes for government spending and distortionary taxes.[2] Lambertini (2006b) tries to combine the game theoretical approach of the static models with features of dynamic models. To do so, she assumes that fiscal authorities can commit to their policies. Also, she assumes that government spending is exogenously given.

In a series of papers, van Aarle et al. (2001) and (2002), Engwerda et al. (2002) and Garretsen et al. (2005) focus on macroeconomic policy interactions of national fiscal policies and the monetary policy of a common central bank by using a New Keynesian framework. Out of these papers, van Aarle et al. (2002) is most related to our model: they compare the outcomes of different scenarios by distinguishing between non-cooperation, partial cooperation, and full cooperation between monetary and fiscal policies. They find that the stability of coalitions depend strongly on the policy makers' preferences. When the countries are very heterogenous, a non-cooperative behavior is the

[2]As alternative specifications, they consider fiscal policy rules, such that movements in the budget deficit lead to reactions of either government spending or tax rates. In contrast to this, the government budget is always balanced in our model.

most likely outcome.

In this paper, we consider a two-country model with a single currency and one monetary policy conducted by a common central bank. Each country or region has its own fiscal policy authority which maximizes its objective function with the arguments output and inflation. The equations of the basic model and the loss functions are derived from microfoundation, by enhancing and modifying the Dixit and Lambertini (2003a) and (2003b) approach. Our contribution here is to accurately model the possibility of various differences between two countries in a *heterogenous monetary union.*

As an application of the theory, the participating countries of the European Monetary Union (EMU) are far from being homogeneous. The differentials of output growth and inflation dispersion, both have been significant and rather persistent as will be shown in the following section. The spread of the macroeconomic key indicators of the participating countries becomes presumably even larger when the ten new EU member states will adopt the Euro. Hence, it seems appropriate to incorporate those heterogeneities when analyzing the interactions of monetary and fiscal policies in a currency area like e.g. the Euro area.

We do this in two steps: First, we derive the output equation from microfoundation and state that terms of trades (i.e, inflation differentials) and a country-specific productivity shock both affect the region-specific output levels. Second, we take the view that national fiscal policies care about national output- and inflation-targets, and they do not care directly about output-growth and price changes in other parts of the union, except if they decide to cooperate. As a simple illustration for the case of the European Monetary Union (EMU), the Greek finance minister considers the current wage and house price increases in Ireland not to be of high importance for his economy. Additionally, we assume that fiscal authorities have target rates for output and inflation that are higher than the welfare optimizing rates. Monetary policy, instead, is assumed to target the union-wide optimal rates in terms of welfare

We analyze the fiscal policy makers' and central bank's losses in several scenarios: Policies can be conducted under discretion, simultaneously in the Nash scenario or sequentially in Stackelberg leadership scenarios for each policy. Alternatively, policies can be coordinated between some or all authorities. We investigate the implications for output, inflation and various policy loss functions in a numerical analysis and show that the ranking of the scenarios is relatively robust over different degrees of heterogeneities by using a sensitivity analysis. We, furthermore, compare the outcomes for the different scenarios for two types of fiscal policy: supply-side and demand-side policy.

From the viewpoint of welfare maximization joint cooperation of all policy makers, and monetary leadership produce the smallest losses. The result holds for both cases, supply-side and demand-side fiscal policy, Furthermore, we find that the more asymmetric the regions, the larger the overall losses and the higher the relative gains from a first mover advantage of monetary policy.

The remainder of the paper is structured as follows. Section 2 presents the model, section 3 the different policy scenarios and section 4 parameterization, evaluation method, results and sensitivity analysis. The final section concludes.

# 2 A Microfounded Two-Country Model

We consider a general equilibrium monetary model with monopolistic distortions and staggered-prices. The model is closely related to Dixit and Lambertini (2003b) and refers to the seminal work of Blanchard and Kiyotaki (1987).[3] In the economy there exists an infinity of consumption-goods over the unit interval, which are imperfect substitutes. Households derive utility from consumption and from holding real money balances. Each household produces a specific good and consumes a bundle of goods. We will, henceforth, denote a representative household a "producer-consumer". There are two regions, home $H$ and foreign $F$, with the population on the segment $[0, n)$ belonging to the home region $H$ and the remaining population belonging to the foreign region $F$, with $0 \leq n \leq 1$.[4]

## 2.1 The Problem of a Producer-Consumer

A producer-consumer $j$ in region $i \in \{H, F\}$ derives utility

$$U_i^j = \left(\frac{C^j}{\gamma}\right)^{\gamma} \left(\frac{M_i^j / P^i}{1-\gamma}\right)^{1-\gamma} - \left(\frac{d_i}{\beta}\right)(Y_i^j)^{\beta}, \quad \gamma \in (0,1),\ d_i > 0,\ \beta \geq 1. \tag{1}$$

The utility function depends on consumption, real money balances and labor. The producer-consumer derives a positive utility from consumption of goods and from the stock of real money, whereby the parameter $\gamma$ captures the elasticity of substitution between the two. Labor, which, for simplicity, is assumed to be a linear function of output

[3]For a detailed explanation of the basic model see appendix A of Dixit and Lambertini (2003b) and also Obstfeld and Rogoff (1996, chapter 10).

[4]This setting is taken from Benigno (2004). Other related models are Lombardo and Sutherland (2004), Ferrero (2005) and Gali and Monacelli (2005b).

and, therefore, is replaced by output itself, contributes negatively to the utility of agent $j$. Here, $1+\beta$ is the elasticity of the marginal disutility of labor. The stochastic variable $d_i$ captures both the scaling of disutility of labor and the fluctuations in the total factor productivity. Changes in this variable may be interpreted as changes in technology.[5] Total consumption of agent $j$ – who for reasons of exposition is assumed to live in region $H$ – is given by[6]

$$C^j \equiv \frac{(C_H^j)^{\nu^H}(C_F^j)^{1-\nu^H}}{(\nu^H)^{\nu^H}(1-\nu^H)^{1-\nu^H}}, \tag{2}$$

where $\nu^H$ is a preference shifter with $n \leq \nu^H \leq 1$ that allows for a home bias in consumption.[7] We assume that all regions exhibit the same home-bias, i.e. we use $\nu \equiv \nu^H = \nu^F$, henceforth.

Consumption of goods from each region is given by

$$C_H^j = \left[\left(\frac{1}{n}\right)^{\frac{1}{\theta}} \int_0^n c^j(h)^{\frac{\theta-1}{\theta}} dh\right]^{\frac{\theta}{\theta-1}}, \quad C_F^j = \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\theta}} \int_n^1 c^j(f)^{\frac{\theta-1}{\theta}} df\right]^{\frac{\theta}{\theta-1}}, \tag{3}$$

where $h$ is a generic good produced in region $H$, $f$ a generic good produced in region $F$ and $\theta > 1$ is the elasticity of substitution between different goods of the same region.[8] The elasticity of substitution of the home and foreign bundle of goods equals one. The corresponding consumer price indices – with subscripts denoting the place of production and superscripts denoting variables specific to agent $j$ or region $i$ – are

$$P^H \equiv (P_H^H)^{\nu}(P_F^H)^{1-\nu} \qquad \text{and} \qquad P^F \equiv (P_F^F)^{\nu}(P_H^F)^{1-\nu}, \tag{4}$$

where

$$P_H^i \equiv \left[\frac{1}{n}\int_0^n p^i(h)^{1-\theta} dh\right]^{\frac{1}{1-\theta}} \quad \text{and} \quad P_F^i \equiv \left[\frac{1}{1-n}\int_n^1 p^i(f)^{1-\theta} df\right]^{\frac{1}{1-\theta}} \tag{5}$$

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[5] To see this, assume a production function of $Y_i^j = A_i N_i^j$ with total factor productivity $A_i$ and hours $N_i^j$. Then, rewrite the second summand in the utility function as $\frac{d_i}{\beta}(N_i^j)^{\beta}$ with the help of the definition $d_i \equiv \delta_i A_i^{-\beta}$, where $\delta_i$ captures the disutility of labor. In the welfare derivation we will define $d_i \equiv \delta_i \xi_i$, where for simplicity $\delta_i = 1$, and $\xi_i$ is a stochastic variable capturing technological progress.

[6] For an agent $j$ living in region $F$ total consumption is given by $C^j \equiv \frac{(C_F^j)^{\nu^F}(C_H^j)^{1-\nu^F}}{(\nu^F)^{\nu^F}(1-\nu^F)^{1-\nu^F}}$ for all $j \in [n, 1]$.

[7] To our knowledge this model is the first two-region model of a monetary union that features the possibility of more than proportional demand for goods produced in the agent's home economy.

[8] The weights $(1/n)^{(1/\theta)}$ and $(1/(1-n))^{(1/\theta)}$ are a "normalization with the implication that an increase in the number of products does not affect marginal utility after optimization", see Blanchard and Kiyotaki (1987), p. 649.

denote the market price indices of goods consumed in region $i$ and produced in region $H$ and $F$, respectively. Note that the price index $P^H$ is defined as the minimum expenditure necessary for purchasing goods leading to a consumption index $C^j$ of size one[9] and the price indexes $P^i_H$ and $P^i_F$ are defined as the minimum expenditure required to purchase goods resulting in consumption indexes $C^j_H$ and $C^j_F$, which equal one.

Although producers would have an incentive to set different prices across regions because of the home bias in consumption, we exclude this possibility by assuming that goods-market arbitrage leads to identical prices across borders such that $P^H_H = P^F_H = P_H$ and $P^H_F = P^F_F = P_F$.[10] With output produced by agent $j$ in region $i$ denoted by $Y^j_i$, the budget constraint for this agent is

$$\int_0^n p^i(h)c^j(h)dh + \int_n^1 p^i(f)c^j(f)df + M^j_i = p^i(j)Y^j_i(1-\tau_i) - P_iT_i + \bar{M}^j_i \equiv I^j_i. \qquad (6)$$

The budget constraint guarantees that the sum of consumption expenditures plus money demand equals nominal net income $I^j_i$, which is the sum of sale revenues from the produced good and beginning-of-period money holdings minus net tax payments.

In each region, a government conducts fiscal policy, making use of four instruments: a tax rate $\tau_i$ proportional to sales, real lump-sum taxes $T_i$, government consumption $G^i$ and wasteful government expenditures $X^i$. Government consumption of goods $G^i$ is defined symmetrically to private consumption, as given in equation (3). Sale taxes could also be negative with the interpretation of subsidies. Also, lump-sum transfers $T_i < 0$ are possible. For the two regional government budget constraints we have

$$\begin{aligned} \int_0^n p^H(j)y(j)\tau_H dj + nP_HT_H &= \chi^H[\nu P^H G^H + (1-\nu)P^F G^F] + (1-\chi^H)X^H \\ &\equiv I^g_H \qquad (7) \\ \int_n^1 p^F(j)y(j)\tau_F dj + (1-n)P_FT_F &= \chi^F[\nu P^F G^F + (1-\nu)P^H G^H] + (1-\chi^F)X^F \\ &\equiv I^g_F. \qquad (8) \end{aligned}$$

Following Dixit and Lambertini (2003b) we assume that the government can spend its budget for government consumption $G^i$ or it can be wasted, $X^i$, ruled by the weight $\chi^i \in [0,1]$.

[9]The same argument also holds for region $F$.

[10]In our theoretical model, inflation differentials occur due to the home-bias effect, as the composition of the consumption bundles differ in both regions. This assumption is somewhat critical when referring to the Euro-zone, where significant price differences for the same product exist in different countries (also for tradeable goods).

Consumption maximization is done in two steps: first, suppose that $C_H^j$ is a single good instead of an aggregate. Then, utility maximization of agent $j$ in region $H$ subject to the corresponding aggregated budget constraint implies the two first order conditions

$$\lambda_{BC} = \left(\frac{C^j}{\gamma}\right)^{\gamma-1}\left(\frac{M_H^j/P^H}{1-\gamma}\right)^{1-\gamma}\nu\frac{C^j}{P_H^H C_H^j}, \tag{9}$$

$$\lambda_{BC} = \left(\frac{C^j}{\gamma}\right)^{\gamma}\left(\frac{M_H^j/P^H}{1-\gamma}\right)^{-\gamma}\frac{1}{P^H}. \tag{10}$$

Equalizing the two equations by replacing the Lagrange multiplier $\lambda_{BC}$ and noting that $\frac{P^i C^j}{\gamma} = \frac{M_i^j}{1-\gamma} = I_i^j$ leads to[11]

$$C_H^j = \nu\left(\frac{P^H}{P_H^H}\right)C^j. \tag{11}$$

Second, maximizing $C_H^j$ with respect to two generic elements $c^j(h)$ and $c^j(h')$, subject to $\int_0^n P^i(h)c^j(h)dh = Z$, leads to

$$c^j(h) = \left(\frac{p^i(h)}{p^i(h')}\right)^{-\theta}c^j(h')\ . \tag{12}$$

Then, replacing $c^j(h)$ in equation (3) by the right hand side of the previous equation gives

$$\begin{aligned}
C_H^j &= \left[\left(\frac{1}{n}\right)^{\frac{1}{\theta}}\int_0^n\left(\left(\frac{p^i(h)}{p^i(h')}\right)^{-\theta}c^j(h')\right)^{\frac{\theta-1}{\theta}}dh\right]^{\frac{\theta}{\theta-1}}\\
&= \left[p^i(h')^{\theta-1}c^j(h')^{\frac{\theta-1}{\theta}}\left(\frac{1}{n}\right)^{\frac{1}{\theta}}\int_0^n p^i(h)^{1-\theta}dh\right]^{\frac{\theta}{\theta-1}}\\
&= \left[\left(\frac{1}{n}\right)^{\frac{1-\theta}{\theta}}(p^i(h'))^{\theta-1}(c^j(h'))^{\frac{\theta-1}{\theta}}\left[\frac{1}{n}\int_0^n(p^i(h))^{1-\theta}dh\right]\right]^{\frac{\theta}{\theta-1}}\\
&= n(p^i(h'))^{\theta}c^j(h')\underbrace{\left[\frac{1}{n}\int_0^n(p^i(h))^{1-\theta}dh\right]^{-\frac{\theta}{1-\theta}}}_{=(P_H^i)^{-\theta}}\\
&= p^i(h')^{\theta}c^j(h')n(P_H^i)^{-\theta},
\end{aligned}$$

which implies

$$c^j(h) = \frac{1}{n}\left(\frac{p^i(h)}{P_H^i}\right)^{-\theta}C_H^j. \tag{13}$$

[11]This is a result of the Cobb-Douglas structure of the utility function.

Adding steps one and two as well as the symmetric results for the foreign good – agent $j$ is still assumed to live in region $H$ for ease of exposition – results in[12]

$$c^j(h) = \frac{\nu}{n}\left(\frac{p^H(h)}{P_H^H}\right)^{-\theta}\frac{P^H}{P_H^H}C^j \quad \text{and} \quad c^j(f) = \frac{1-\nu}{1-n}\left(\frac{p^H(f)}{P_F^H}\right)^{-\theta}\frac{P^H}{P_F^H}C^j. \tag{14}$$

We assume that government spending is subject to the same home bias as private consumption expenditures. This assumption lies in between the extreme positions of no home bias in government expenditures, as proposed by LOMBARDO and SUTHERLAND (2004), and complete home bias, as proposed by BEETSMA and JENSEN (2002), BENIGNO (2004) and GALI and MONACELLI (2005a).[13] The symmetric results for optimal expenditures of the home government are

$$g^H(h) = \frac{\nu}{n}\left(\frac{p^H(h)}{P_H^H}\right)^{-\theta}\frac{P^H}{P_H^H}G^H \quad \text{and} \quad g^H(f) = \frac{1-\nu}{1-n}\left(\frac{p^H(f)}{P_F^H}\right)^{-\theta}\frac{P^H}{P_F^H}G^H. \tag{15}$$

## 2.2 Terms of Trade and Aggregate Demand

As explained before, in the considered economy the law of one price holds, i.e. $p^H(h) = p^F(h)$ and $p^H(f) = p^F(f)$. Nonetheless, agents appreciate consumption of domestically produced goods more. Hence, the (consumer) price index in the home region $P^H$ includes a larger share of domestic goods than the (consumer) price index in the foreign region $P^F$. This implies nontrivial terms of trade. Defining the terms of trade as the price of imports relative to the price of exports,[14] from the viewpoint of economy $i$ we have

$$S_i \equiv \frac{P_{-i}^i}{P_i^{-i}} = \frac{P_{-i}}{P_i}, \tag{16}$$

where "not $i$" is denoted by "$-i$". The latter equality holds as the rate of substitution between domestic goods is constant in both economies, so that the basket of domestically produced goods has the same composition in both economies, though not the same relative size. Therefore, a change in the price index of domestically produced goods has the same

[12]An agent $j$ of region $F$ would demand $c^j(h) = \frac{1-\nu}{n}\left(\frac{p^H(h)}{P_H^F}\right)^{-\theta}\frac{P^F}{P_H^F}C^j$ and $c^j(f) = \frac{\nu}{1-n}\left(\frac{p^F(f)}{P_F^F}\right)^{-\theta}\frac{P^F}{P_F^F}C^j$.

[13]Our solution is in line with the comment by LEITH (2004) alluded to by LOMBARDO and SUTHERLAND (2004) in footnote 8. GALI and MONACELLI (2005a) cite "evidence on a strong home bias in government procurement" in their footnote 8.

[14]This notation is the reciprocal of the usual definition, see e. g. OBSTFELD and ROGOFF (1996), p. 242. The notation is in line with the standard literature from the viewpoint of the foreign economy.

impact on e.g. $P_H^F$ and on $P_H^H$ and we can drop the superscript. It is useful to relate the terms of trade to the consumer price indices $P^H$ and $P^F$ and to the price indices of goods produced in each region, $P_H$ and $P_F$, using the definitions $P^H \equiv (P_H)^\nu (P_F)^{1-\nu}$ and $P^F \equiv (P_F)^\nu (P_H)^{1-\nu}$, which are generalizations of (4):

$$\frac{P^H}{P_H} = (S_H)^{1-\nu}, \quad \frac{P^H}{P_F} = \frac{1}{(S_H)^\nu}, \quad \frac{P^F}{P_H} = (S_H)^\nu \quad \text{and} \quad \frac{P^F}{P_F} = \frac{1}{(S_H)^{1-\nu}}. \tag{17}$$

In the case of an identical home-bias in both regions which we assume here, the ratios of the two measures of inflation are inversely related to each other:[15] $S_i = 1/S_{-i}$. Movements in the terms of trade imply movements in relative prices and, therefore, shift demand across the border. Using the terms of trade and the fact that $C^j = \frac{\gamma I_i^j}{P^i}$ we can rewrite the first-order condition of the producer-consumers with respect to their consumption of a single good and – in a similar manner – to their money holdings $M_i^j$ as

$$c^j(h) = \frac{\nu}{n}\left(\frac{p^H(h)}{P_H}\right)^{-\theta} \frac{\gamma I_H^j}{P_H}, \tag{18}$$

$$c^j(f) = \frac{1-\nu}{1-n}\left(\frac{p^H(f)}{P_F}\right)^{-\theta} \frac{\gamma I_H^j}{P_F}, \tag{19}$$

$$c^j(h) = \frac{1-\nu}{n}\left(\frac{p^H(h)}{P_H}\right)^{-\theta} \frac{\gamma I_F^j}{P_H}, \tag{20}$$

$$c^j(f) = \frac{\nu}{1-n}\left(\frac{p^F(f)}{P_F}\right)^{-\theta} \frac{\gamma I_F^j}{P_F}, \tag{21}$$

$$M_i^j = (1-\gamma) I_i^j. \tag{22}$$

The first two equations determine a home resident's optimal choice of home and foreign goods, the next two equations determine the analog for a foreign resident, while the last equation shows the optimality condition with respect to money holdings.

Total nominal expenditure by consumers in region $H$ is $I_H = \int_0^n I_H^j dj$, and in region $F$ is $I_F = \int_n^1 I_F^j dj$. The demand function for a good $h$ is given by

$$\begin{aligned} Y^d(h) &= \int_0^1 c^j(h)dj + \chi^H g^H(h) + \chi^F g^F(h) \\ &= \left(\frac{p^H(h)}{P_H}\right)^{-\theta} \frac{1}{n} \\ &\quad \cdot \left[\gamma \frac{\nu I_H + (1-\nu) I_F}{P_H} + \nu \chi^H \frac{P^H}{P_H} G^H + (1-\nu)\chi^F \frac{P^F}{P_H} G^F\right]. \end{aligned} \tag{23}$$

[15] See Gali and Monacelli (2002) for a similar treatment in a small open economy setting.

Similarly, the demand for a certain foreign good $f$ is given by

$$
\begin{aligned}
Y^d(f) &= \int_0^1 c^j(f)dj + \chi^H g^H(f) + \chi^F g^F(f) \\
&= \left(\frac{p^F(f)}{P_F}\right)^{-\theta} \frac{1}{1-n} \\
&\quad \cdot \left[\gamma \frac{(1-\nu)I_H + \nu I_F}{P_F} + \nu\chi^F \frac{P^F}{P_F} G^F + (1-\nu)\chi^H \frac{P^H}{P_F} G^H\right]. \qquad (24)
\end{aligned}
$$

Denoting "not $i$" by $-i$, we define a variable proportional to "wealth":

$$
W \equiv \gamma \frac{\nu I_i + (1-\nu)I_{-i}}{P_i} + \nu\chi^i \frac{P^i}{P_i} G^i + (1-\nu)\chi^{-i} \frac{P^{-i}}{P_i} G^{-i}. \qquad (25)
$$

At this point it is useful to note that this definition includes the terms of trade between domestic and foreign goods, as $I_i = \frac{P^i C}{\gamma}$ measures the nominal consumption expenditures using the level of the consumer price index (CPI), while the denominator involves the level of the producer price index (PPI) as a reference. Using the identities from (17), one can easily transform this notation into one that includes real expenditures and the terms of trade $S$:

$$
W = \begin{cases} \nu(S_H)^{1-\nu}\left(\gamma\frac{I_H}{P^H} + \chi^H G^H\right) + (1-\nu)(S_H)^{\nu}\left(\gamma\frac{I_F}{P^F} + \chi^F G^F\right) & \text{if } i = H, \\ \nu(S_H)^{\nu-1}\left(\gamma\frac{I_F}{P^F} + \chi^F G^F\right) + (1-\nu)(S_H)^{-\nu}\left(\gamma\frac{I_H}{P^H} + \chi^H G^H\right) & \text{if } i = F. \end{cases}
$$

To get a single equation for demand, we define the following weights:

$$
w_i = \begin{cases} n & \text{if } i = H, \\ 1-n & \text{if } i = F. \end{cases}
$$

Then, demand for a specific good $j$ of region $i$ amounts to

$$
Y^d(j) = \left(\frac{p^i(j)}{P_i}\right)^{-\theta} \frac{W}{w_i}. \qquad (26)
$$

Analogously to Benigno (2004), the terms of trade effect on regional output (included in the $W$ term) is bigger the smaller the size of that region, i. e. the higher the degree of openness.[16]

[16] Note that our demand functions are more complicated than the ones in Benigno (2004) because of the preference parameter $\nu$. This destroys the identity $P^H = P^F$ that holds in Benigno (2004) as long as $\nu^H \neq n$. If $\nu^H = \nu^F = n$ and $1-\nu^H = 1-\nu^F = 1-n$, the consumer price indices of both regions are identical and the demand functions get as simple as in Benigno (2004).

### 2.3 Price Setting

Each producer is a monopolist when selling the product. The producer, therefore, decides upon the price of the product by maximizing the indirect utility function. The indirect utility function is obtained by plugging $C^j = \frac{\gamma I_i^j}{P^i}$ and $M_i^j = (1-\gamma)I_i^j$ into the utility function (1), replacing $I_i^j$ by the right hand side of the budget constraint, replacing the price ratio with the help of equation (26) and simplifying:

$$U_i^j = (1-\tau_i)\left(\frac{W}{w_i}\right)^{\frac{1}{\theta}}(Y_i^j)^{\frac{\theta-1}{\theta}} - T_i + \frac{\bar{M}_i^j}{P_i} - \left(\frac{d_i}{\beta}\right)(Y_i^j)^{\beta}. \tag{27}$$

The indirect utility function of agent $j$ is maximized with respect to the price $p^i(j)$, noting that the output produced by agent $j$ is equal to its demand, i.e. $Y_i^j = Y^d(j)$.[17] We obtain the optimal ratio of prices as

$$\begin{aligned}\left(\frac{p^i(j)}{P_i}\right) &= \left(\frac{-d_i\theta\left(\frac{W}{w_i}\right)^{\beta-1}}{(1-\tau_i)(1-\theta)}\right)^{\frac{1}{-\theta+\theta\beta+1}} \\ &= \left(\frac{\theta d_i}{(\theta-1)(1-\tau_i)}\left(\frac{W}{w_i}\right)^{\beta-1}\right)^{\frac{1}{1+\theta(\beta-1)}} .\end{aligned} \tag{28}$$

Furthermore, we assume that some prices are fixed in advance, comparable to a static version of the staggered price-setting introduced by Calvo (1983). A fraction $\Phi^i$ of producers cannot change their prices and thus have to take constant prices from the past, whereas a fraction $(1-\Phi^i)$ of producers is able to set their prices freely after the realization of the shocks in region $i$. The price level of goods from region $H$ is a weighted sum of the average of pre-set prices $E[\bar{p}^H(h)]$ and the newly set prices $\tilde{p}^H(h)$ which due to symmetry are equal for all producers. Based on equation (5), we obtain

$$P_H^{1-\theta} = \Phi^H(E\bar{p}^H(h))^{1-\theta} + (1-\Phi^H)(\tilde{p}^H(h))^{1-\theta}. \tag{29}$$

For goods produced in region $F$ the equivalent equation is

$$P_F^{1-\theta} = \Phi^F(E\bar{p}^F(f))^{1-\theta} + (1-\Phi^F)(\tilde{p}^F(f))^{1-\theta}. \tag{30}$$

For convenience, the price ratio in region $i$ may be defined to be

$$\lambda_i \equiv \Phi^i\left(\frac{E\bar{p}^i(j)}{P_i}\right)^{1-\theta} + (1-\Phi^i)\left(\frac{\tilde{p}^i(j)}{P_i}\right)^{1-\theta} = 1. \tag{31}$$

[17] As the decision of a single individuum only has marginal impact on terms of trade and the price indices, this effect is neglected in the optimization.

The aggregate consumer price index in region $i$ is — in line with equation (4) — given by

$$
\begin{aligned}
P^H &= \left[\Phi^H \left(E\bar{p}^H(h)\right)^{1-\theta} + (1-\Phi^H)\left(\tilde{p}^H(h)\right)^{1-\theta}\right]^{\frac{\nu}{1-\theta}} \\
&\quad \cdot \left[\Phi^F \left(E\bar{p}^F(f)\right)^{1-\theta} + (1-\Phi^F)\left(\tilde{p}^F(f)\right)^{1-\theta}\right]^{\frac{1-\nu}{1-\theta}} \qquad (32) \\
P^F &= \left[\Phi^F \left(E\bar{p}^F(f)\right)^{1-\theta} + (1-\Phi^F)\left(\tilde{p}^F(f)\right)^{1-\theta}\right]^{\frac{\nu}{1-\theta}} \\
&\quad \cdot \left[\Phi^H \left(E\bar{p}^H(h)\right)^{1-\theta} + (1-\Phi^H)\left(\tilde{p}^H(h)\right)^{1-\theta}\right]^{\frac{1-\nu}{1-\theta}}. \qquad (33)
\end{aligned}
$$

This can be written in terms of the overall price level[18]

$$
\begin{aligned}
P &\equiv (P^H)^n (P^F)^{1-n} \\
&= \left[\Phi^H \left(E\bar{p}^H(h)\right)^{1-\theta} + (1-\Phi^H)\left(\tilde{p}^H(h)\right)^{1-\theta}\right]^{\frac{n\nu+(1-n)(1-\nu)}{1-\theta}} \\
&\quad \cdot \left[\Phi^F \left(E\bar{p}^F(f)\right)^{1-\theta} + (1-\Phi^F)\left(\tilde{p}^F(f)\right)^{1-\theta}\right]^{\frac{n(1-\nu)+(1-n)\nu}{1-\theta}}. \qquad (34)
\end{aligned}
$$

## 2.4 Aggregate Output and Fiscal Policy

Aggregate output in each region is defined by the following equations:

$$
Y_H \equiv \int_0^n \frac{p^H(h)Y(h)}{P_H} dh \quad \text{and} \quad Y_F \equiv \int_n^1 \frac{p^F(f)Y(f)}{P_F} df. \qquad (35)
$$

Using the demand functions (23) and (24) as well as the price index definitions (5), and denoting the lower and upper integral limits of each region $i$ by $lli$ and $uli$, respectively,[19] aggregate output produced in region $i$ is rewritten as

$$
\begin{aligned}
Y_i &= \int_{lli}^{uli} \frac{p^i(j)}{P_i}\left(\frac{p^i(j)}{P_i}\right)^{-\theta} \frac{W}{w_i} dj = \left[\int_{lli}^{uli} \left(\frac{p^i(j)}{P_i}\right)^{1-\theta} dj\right] \frac{W}{w_i} \qquad (36) \\
&= \lambda_i \frac{W}{w_i} = \frac{W}{w_i}.
\end{aligned}
$$

Essentially, this implies that the goods' supply of region $i$ is equal to its demand, which is originating from both regions according to equation (25). Total output is given as the geometric average of output in both regions:

$$
Y \equiv Y_H^n Y_F^{1-n}. \qquad (37)
$$

[18] Note that the numerators of the exponents exactly sum to one.

[19] I.e., $lli = \begin{cases} 0 & \text{if } i = H, \\ n & \text{if } i = F, \end{cases}$ and $uli = \begin{cases} n & \text{if } i = H, \\ 1 & \text{if } i = F. \end{cases}$

We specify fiscal policy as follows: Each fiscal authority uses per-capita taxes $T_i$ to subsidize production, i. e., $T_i > 0$, $\tau_i < 0$. We assume for the moment, that there is no other government spending, i.e. $\chi_i = X^i = G^i = 0$. In this case, wealth $W$ simplifies to

$$\begin{aligned} W &= \gamma \frac{\nu I_i + (1-\nu) I_{-i}}{P_i} \\ \Leftrightarrow W &= \gamma \frac{\bar{M}}{P} \frac{1}{1 - \gamma \frac{\nu}{w_i} - \gamma \frac{1-\nu}{w_{-i}} S_i}, \end{aligned} \tag{38}$$

where we use the assumption of identical beginning-of-period real money holdings of all agents $\frac{\bar{M}}{P} = \frac{\bar{M}_i^j}{P_i}$ for all $i, j$.[20] This fiscal policy uses distortionary taxation to offset the market distortion due to monopolistic competition. Therefore, this type of fiscal policy is closest to the theoretical optimum. Nonetheless, our framework allows for various other fiscal policies.[21]

## 2.5 Log-Linear Equilibrium Fluctuations: Price Setting

We loglinearize the model as follows. First, note that a linear approximation of equation (4) around $P_i = P^i = P$ for all $i$ results in

$$\pi^H = \nu \pi_H + (1-\nu)\pi_F \qquad \text{and} \qquad \pi^F = \nu \pi_F + (1-\nu)\pi_H, \tag{39}$$

where the inflation rates are defined as percentage deviations of the respective price level from its steady state level,[22] i.e.

$$\pi^i \equiv \log(P^i) - \log(\bar{P}^i), \text{ given } \bar{P}^i \neq 0. \tag{40}$$

Then, equations (29) and (30) linearize[23] to

$$\pi_H = \Phi^H \bar{\pi}_H + (1-\Phi^H)\tilde{\pi}_H \qquad \text{and} \qquad \pi_F = \Phi^F \bar{\pi}_F + (1-\Phi^F)\tilde{\pi}_F. \tag{41}$$

[20] Without the assumption of internationally identical money holdings, $\bar{M}/P$ has to be replaced by $[n\bar{M}_i + (1-n)\bar{M}_{-i}]/P_i$.

[21] Two alternative fiscal policies – with distortionary taxation that is either wasted or used for government spending – are analyzed in DIXIT and LAMBERTINI (2003b): in the first one, $\tau_i > 0$, $\chi_i = G^i = T_i = 0$ and $X^i > 0$. In the latter case, $\tau_i > 0$ (as long as $G^i > 0$), $\chi_i = 1$, $T_i = 0$. Analyzing the effects of these policies might be a topic for future research.

[22] Under the assumption that $\bar{P}^i \equiv 1$, one can equivalently define $\pi^i \equiv \log(P^i)$ .

[23] To see this, compare the following procedure done with a simplified, yet similar equation: $P^b = \phi Q^b + (1-\phi)R^b \quad \Rightarrow \quad \bar{P}^b e^{b\pi} = \phi \bar{Q}^b e^{b\bar{\pi}} + (1-\phi)\bar{R}^b e^{b\tilde{\pi}}$, which is approximately equal to $\bar{P}^b(1+b\pi) = \phi\bar{Q}^b(1+b\bar{\pi}) + (1-\phi)\bar{R}^b(1+b\tilde{\pi}) \quad \Rightarrow \quad b\pi = \phi\frac{\bar{Q}^b}{\bar{P}^b}b\bar{\pi} + (1-\phi)\frac{\bar{R}^b}{\bar{P}^b}b\tilde{\pi}$. As the fractions are equal to unity, this simplifies to $\pi = \phi\bar{\pi} + (1-\phi)\tilde{\pi}$.

Combining the results gives

$$\pi^H = \nu(\Phi^H \bar{\pi}_H + (1-\Phi^H)\tilde{\pi}_H) + (1-\nu)(\Phi^F \bar{\pi}_F + (1-\Phi^F)\tilde{\pi}_F) \quad (42)$$

$$\pi^F = \nu(\Phi^F \bar{\pi}_F + (1-\Phi^F)\tilde{\pi}_F) + (1-\nu)(\Phi^H \bar{\pi}_H + (1-\Phi^H)\tilde{\pi}_H). \quad (43)$$

Now, we turn to the optimal price a producer would set if he could choose the price freely. According to DIXIT and LAMBERTINI (2003a), we refer to the idea of CALVO-staggered pricing, which reflects a dynamic setting (for details see again CALVO, 1983). Analogously to the procedure of DIXIT and LAMBERTINI, we introduce a discount factor $\eta$ with $\eta < 1$ (which means that pseudo-future period utilities have a lower weight than present utility). We, at first, make the assumption that $\eta$ equals unity to explain the "intuitional proceeding". For the case that prices are allowed to change, the optimal log price equals

$$\tilde{\pi}_H = (1-\Phi^H)\pi_H^j + \Phi^H \bar{\pi}_H$$

$$\tilde{\pi}_F = (1-\Phi^F)\pi_F^j + \Phi^F \bar{\pi}_F.$$

where $\pi_i^j$ is the log steady state deviation of the price that would be optimal if prices could be adjusted freely. The log price set by producer $j$ is a sum of the weighted optimal price of producer $j$, if prices were fully flexible, and the weighted price that maximizes the expected indirect utility, if prices are supposed to be fixed in future periods. The weights equal the probability of being able, $(1-\Phi^i)$, and being not able, $\Phi^i$, to change the price in the following period(s).

Now we refer again to the discount factor $\eta < 1$: as mentioned, the individuals put lower weight on future utilities. Therefore, the fact that the producer cannot change the price in future periods with a certain probability is expressed by a lower weight as the pure probability on future price setting (given by $\eta\Phi^i$) and a higher weight for the present period $(1-\eta\Phi^i)$. Hence, we obtain

$$\tilde{\pi}_H = (1-\Phi^H\eta)\pi_H^j + \Phi^H \eta \bar{\pi}_H, \quad (44)$$

$$\tilde{\pi}_F = (1-\Phi^F\eta)\pi_F^j + \Phi^F \eta \bar{\pi}_F. \quad (45)$$

In case $\eta = 0$, this setting would be purely static: Here, the (deviation from the steady state of the) optimal price once an individual is allowed to change her price $\tilde{\pi}_i$ is identical to the price that is optimal for the current period only, as there is no future periods to form expectations about.

Using equations (44) and (45) to replace the optimal prices in the consumer price indices (42) and (43) gives

$$\begin{aligned}
\pi^H &= \nu\Phi^H[1+(1-\Phi^H)\eta]\bar{\pi}_H + \nu(1-\Phi^H)(1-\Phi^H\eta)\pi^j_H \\
&\quad +(1-\nu)\Phi^F[1+(1-\Phi^F)\eta]\bar{\pi}_F + (1-\nu)(1-\Phi^F)(1-\Phi^F\eta)\pi^j_F \qquad (46)\\
\pi^F &= \nu\Phi^F[1+(1-\Phi^F)\eta]\bar{\pi}_F + \nu(1-\Phi^F)(1-\Phi^F\eta)\pi^j_F \\
&\quad +(1-\nu)\Phi^F[1+(1-\Phi^F)\eta]\bar{\pi}_H + (1-\nu)(1-\Phi^F)(1-\Phi^F\eta)\pi^j_H\ . \qquad (47)
\end{aligned}$$

The overall inflation rate can be calculated using the previous equations together with equation (34):

$$\begin{aligned}
\pi &= n\pi^H + (1-n)\pi^F \qquad (48)\\
&= [n\nu + (1-n)(1-\nu)]\pi_H + [n(1-\nu) + (1-n)\nu]\pi_F. \qquad (49)
\end{aligned}$$

Equation (48) states that union-wide inflation is the sum of the regional CPI inflation weighted by the size of each region. The second equation (49) links union-wide inflation to the PPI inflation rates in each region, where the influence of regional PPI inflation depends on both the size of the region and the preference of agents for goods from that region.

## 2.6 Inflation Determination

In general, a producer sets its price by maximizing the indirect utility function which results in equation (28) used above. A loglinear approximation of this equation around the steady state, solved for the relative deviation of wealth from its steady state level, $\hat{W}$, is

$$\hat{W} = \frac{1+\theta(\beta-1)}{\beta-1}(\hat{p}^i(j)-\pi_i) - \frac{1}{\beta-1}\hat{d}_i - \frac{\bar{\tau}_i}{\beta-1}\hat{\tau}_i, \qquad (50)$$

where $\pi_i \equiv \hat{P}_i$, and a "hat" above a variable denotes percentage deviations of the variable from its steady state.[24] To replace $\hat{W}$ in the last expression, we loglinearize the policy dependent wealth equation. For the fiscal policy considered here, we use equation (38), and obtain the result

$$\hat{W} = \frac{\gamma\bar{m}}{\omega}\hat{m} + \frac{\gamma(1-\nu)}{\omega w_{-i}}s_i, \qquad (51)$$

[24]For the approximation of the fiscal policy term, note that $\widehat{(1-\tau_i)} = \frac{-\bar{\tau}_i}{1-\bar{\tau}_i}\hat{\tau}_i$.

where $\omega$ is given by $\omega \equiv 1 - \gamma[\frac{\nu}{w_i} + \frac{1-\nu}{w_{-i}}]$ and $s_i \equiv \hat{S}_i = \pi_{-i} - \pi_i$. $\hat{m} = \widehat{M/P}$ is the change in the beginning-of-period real money holdings.

In the next step, equation (50) – with $\hat{W}$ replaced by the fiscal-policy dependent equation – is evaluated at both $E[\hat{\bar{p}}^i(j)] \equiv \bar{\pi}_i$, the (log deviation of the) price that maximizes the future indirect utility, and at $\hat{p}_i^j \equiv \pi_i^j$, the (log deviation of the) price that maximizes the current period indirect utility. Starting with the first case $\bar{\pi}_i$, we obtain

$$\begin{aligned}
\bar{\pi}_i &= E[\pi_i] + \frac{1}{1+\theta(\beta-1)}E[\hat{d}_i] + \frac{\bar{\tau}_i}{1+\theta(\beta-1)}E[\hat{\tau}_i] \\
&\quad + \frac{\beta-1}{1+\theta(\beta-1)}E\left[\frac{\gamma\bar{m}}{\omega}\hat{m} + \frac{\gamma(1-\nu)}{\omega w_{-i}}s_i\right] \\
&= \bar{\omega}_{0,i} + \omega_1 E[\hat{\tau}_i] + \omega_2 E[\hat{\tau}_{-i}] + \omega_3 E[\pi_i] + \omega_4 E[\pi_{-i}],
\end{aligned} \tag{52}$$

where $\bar{\omega}_{0,i} \equiv \frac{1}{1+\theta(\beta-1)}E[\hat{d}_i] + \frac{\beta-1}{1+\theta(\beta-1)}\frac{\gamma\bar{m}}{\omega}E[\hat{m}]$, $\omega_1 \equiv \frac{\bar{\tau}_i}{1+\theta(\beta-1)}$, $\omega_2 \equiv 0$, $\omega_3 \equiv \left(1 - \frac{\beta-1}{1+\theta(\beta-1)}\frac{\gamma(1-\nu)}{\omega w_{-i}}\right)$ and $\omega_4 \equiv \frac{\beta-1}{1+\theta(\beta-1)}\frac{\gamma(1-\nu)}{\omega w_{-i}}$.[25] Notice that via $s_i = \pi_{-i} - \pi_i$ the terms in $s_i$ have been replaced by terms in $\pi_i$ and $\pi_{-i}$. For the price that maximizes the current period indirect utility only, we get accordingly

$$\begin{aligned}
\pi_i^j &= \frac{1}{1+\theta(\beta-1)}\hat{d}_i + \frac{\beta-1}{1+\theta(\beta-1)}\frac{\gamma\bar{m}}{\omega}\hat{m} + \frac{\bar{\tau}_i}{1+\theta(\beta-1)}\hat{\tau}_i \\
&\quad + \left(1 - \frac{\beta-1}{1+\theta(\beta-1)}\frac{\gamma(1-\nu)}{\omega w_{-i}}\right)\pi_i + \frac{\beta-1}{1+\theta(\beta-1)}\frac{\gamma(1-\nu)}{\omega w_{-i}}\pi_{-i} \qquad (53) \\
&= \omega_{0,i} + \omega_1\hat{\tau}_i + \omega_2\hat{\tau}_{-i} + \omega_3\pi_i + \omega_4\pi_{-i}. \qquad (54)
\end{aligned}$$

Using equations (41), (44) and (45), we obtain an equation that expresses the regional producer inflation rate in terms of the log of the price that maximizes the future indirect utility and the one that maximizes only the current period indirect utility:

$$\pi_i = \rho^i\bar{\pi}_i + (1-\rho^i)\pi_i^j, \qquad \rho^i = \Phi^i[1 + (1-\Phi^i)\eta]. \tag{55}$$

Henceforth, we neglect the superscript $i$ for the parameter $\rho$ for reasons of clarity, because the results derived in the following have exactly the same structure for both regions.

We use (55) and combine the two log prices in equations (52) and (54):

$$\begin{aligned}
\pi_i &= \rho\left[\bar{\omega}_{0,i} + \omega_1 E[\hat{\tau}_i] + \omega_2 E[\hat{\tau}_{-i}] + \omega_3 E[\pi_i] + \omega_4 E[\pi_{-i}]\right] \\
&\quad + (1-\rho)\left[\omega_{0,i} + \omega_1\hat{\tau}_i + \omega_2\hat{\tau}_{-i} + \omega_3\pi_i + \omega_4\pi_{-i}\right].
\end{aligned} \tag{56}$$

[25] We add the term $\omega_2$ to show that under alternative fiscal policies this spillover effect can be non-zero.

For the other region, analogue steps yield

$$\begin{aligned}\pi_{-i} \;=\;& \rho\left[\bar{\omega}_{0,-i} + \omega_1 E[\hat{\tau}_{-i}] + \omega_2 E[\hat{\tau}_i] + \omega_3 E[\pi_{-i}] + \omega_4 E[\pi_i]\right] \\ & +(1-\rho)\left[\omega_{0,-i} + \omega_1 \hat{\tau}_{-i} + \omega_2 \hat{\tau}_i + \omega_3 \pi_{-i} + \omega_4 \pi_i\right], \qquad (57)\end{aligned}$$

where $\omega_{0,-i}$ differs from $\omega_{0,i}$ only by the stochastic disutility of labor variable $\hat{d}_{-i}$ instead of $\hat{d}_i$.

Combining (56) and (57) and solving this system of equations for the region-specific inflation rates, one gets

$$\begin{aligned}\pi_i =\;& \Omega\rho\left[\bar{\omega}_{0,i} + \frac{(1-\rho)\omega_4}{1-(1-\rho)\omega_3}\bar{\omega}_{0,-i}\right] \\ & +\Omega\rho\left[\left(\bar{\omega}_1 + \frac{(1-\rho)\omega_4}{1-(1-\rho)\omega_3}\omega_2\right)E[\hat{\tau}_i] + \left(\omega_2 + \frac{(1-\rho)\omega_4}{1-(1-\rho)\omega_3}\omega_1\right)E[\hat{\tau}_{-i}]\right] \\ & +\Omega\rho\left[\left(\omega_3 + \frac{(1-\rho)\omega_4}{1-(1-\rho)\omega_3}\omega_4\right)E[\pi_i] + \left(\omega_4 + \frac{(1-\rho)\omega_4}{1-(1-\rho)\omega_3}\omega_3\right)E[\pi_{-i}]\right] \\ & +\Omega(1-\rho)\left[\omega_{0,i} + \frac{(1-\rho)\omega_4}{1-(1-\rho)\omega_3}\omega_{0,-i}\right] \\ & +\Omega(1-\rho)\left(\omega_1 + \frac{(1-\rho)\omega_4}{1-(1-\rho)\omega_3}\omega_2\right)\hat{\tau}_i \\ & +\Omega(1-\rho)\left(\omega_2 + \frac{(1-\rho)\omega_4}{1-(1-\rho)\omega_3}\omega_1\right)\hat{\tau}_{-i} \qquad (58)\end{aligned}$$

with $\Omega \equiv \frac{1-(1-\rho)\,\omega_3}{[1-(1-\rho)\,\omega_3]^2-[(1-\rho)\,\omega_4]^2}$. Written in a more compact way, this result will be used in the following sections:

$$\pi_i = \mu_i + c^i\hat{\tau}_i + c^{-i}\hat{\tau}_{-i}, \quad i \in \{H, F\}. \qquad (59)$$

When referring to the supply-side fiscal policy introduced above, we assume that $\omega_2 = 0$ and obtain[26]

$$\begin{aligned}\mu_i \equiv\;& \Omega\rho\left[\bar{\omega}_{0,i} + \frac{(1-\rho)\omega_4}{1-(1-\rho)\omega_3}\bar{\omega}_{0,-i}\right] + \Omega\rho\left[\omega_1 E[\hat{\tau}_i] + \frac{(1-\rho)\omega_4}{1-(1-\rho)\omega_3}\omega_1 E[\hat{\tau}_{-i}]\right] \\ & +\Omega\rho\left[\left(\omega_3 + \frac{(1-\rho)\omega_4}{1-(1-\rho)\omega_3}\omega_4\right)E[\pi_i] + \left(\omega_4 + \frac{(1-\rho)\omega_4}{1-(1-\rho)\omega_3}\omega_3\right)E[\pi_{-i}]\right] \\ & +\Omega(1-\rho)\left[\omega_{0,i} + \frac{(1-\rho)\omega_4}{1-(1-\rho)\omega_3}\omega_{0,-i}\right],\end{aligned}$$

[26]Note that the calculations made so far hold more generally to facilitate an enhancement of the micro-model with respect to other types of fiscal policies. Henceforth, we assume that $\omega_2 = 0$.

which captures the terms dependent of monetary policy, but also the expectational terms and the stochastic terms, following the example of Dixit and Lambertini (2003a). The parameters

$$c^i \equiv \Omega(1-\rho)\omega_1 \qquad \text{and} \qquad c^{-i} \equiv \Omega(1-\rho)\frac{(1-\rho)\omega_4}{1-(1-\rho)\omega_3}\omega_1$$

denote the impact of domestic and foreign fiscal policy on inflation, respectively. Equation (59) states that regional PPI inflation can be explained as the outcome of influences from monetary policy and stochastic events, from fiscal policy of the same region and from fiscal policy of the other region.

## 2.7 Output Determination

To get an equation for regional output $y_i$, we start with equation (36) and plug in equation (28):

$$\begin{aligned} Y_i &= \int_{lli}^{uli} \left(\frac{p^i(j)}{P_i}\right)^{1-\theta} dj \frac{W}{w_i} \\ &= \int_{lli}^{uli} \left(\frac{\theta \hat{d}_i}{(\theta-1)(1-\tau_i)} \left(\frac{W}{w_i}\right)^{\beta-1}\right)^{\frac{1-\theta}{1+\theta(\beta-1)}} \frac{W}{w_i} dj \\ &= \left(\frac{\theta \hat{d}_i}{(\theta-1)(1-\tau_i)} \left(\frac{W}{w_i}\right)^{\beta-1}\right)^{\frac{1-\theta}{1+\theta(\beta-1)}} \frac{W}{w_i}. \end{aligned}$$

Loglinearizing this equation and using the notation $y_i \equiv \hat{Y}_i$, we get

$$y_i = \frac{1-\theta}{1+\theta(\beta-1)}\hat{d}_i + \frac{1-\theta}{1+\theta(\beta-1)}\bar{\tau}_i\hat{\tau}_i + \frac{(\beta-1)(1-\theta)}{1+\theta(\beta-1)}\hat{W} + \hat{W}. \tag{60}$$

Now we refer to the proceedings of Dixit and Lambertini (2003b) and apply equation (50) in two ways: First, we replace the first $\hat{W}$ in (50) with $i$ indices and the second $\hat{W}$ with $-i$ indices. We obtain

$$\begin{aligned} y_i = {} & \frac{1-\theta}{1+\theta(\beta-1)}\hat{d}_i + \frac{1-\theta}{1+\theta(\beta-1)}\bar{\tau}_i\hat{\tau}_i \\ & + \frac{(\beta-1)(1-\theta)}{1+\theta(\beta-1)}\left[\frac{1+\theta(\beta-1)}{\beta-1}(\hat{p}^i(j)-\pi_i) - \frac{1}{\beta-1}\hat{d}_i - \frac{\bar{\tau}_i}{\beta-1}\hat{\tau}_i\right] \\ & + \left[\frac{1+\theta(\beta-1)}{\beta-1}(\hat{p}^{-i}(j)-\pi_{-i}) - \frac{1}{\beta-1}\hat{d}_{-i} - \frac{\bar{\tau}_{-i}}{\beta-1}\hat{\tau}_{-i}\right]. \end{aligned} \tag{61}$$

Second, we do it the other way round, leading to

$$\begin{aligned} y_i &= \frac{1-\theta}{1+\theta(\beta-1)}\hat{d}_i + \frac{1-\theta}{1+\theta(\beta-1)}\bar{\tau}_i\hat{\tau}_i \\ &+\frac{(\beta-1)(1-\theta)}{1+\theta(\beta-1)}\left[\frac{1+\theta(\beta-1)}{\beta-1}(\hat{p}^{-i}(j)-\pi_{-i}) - \frac{1}{\beta-1}\hat{d}_{-i} - \frac{\bar{\tau}_{-i}}{\beta-1}\hat{\tau}_{-i}\right] \\ &+\left[\frac{1+\theta(\beta-1)}{\beta-1}(\hat{p}^{i}(j)-\pi_{i}) - \frac{1}{\beta-1}\hat{d}_{i} - \frac{\bar{\tau}_{i}}{\beta-1}\hat{\tau}_{i}\right]. \end{aligned} \tag{62}$$

In the next step, we add up the two equations and divide by two. We evaluate $\hat{p}^i(j)$ in both regions for the flexible price firms, i.e. we replace $\hat{p}^i(j)$ by $\pi_i^j$, the price that maximizes current period indirect utility only. Using equation (55) to replace $\pi_i^j$ and simplifying leads to

$$\begin{aligned} y_i =& \left(\frac{1-\theta}{2[1+\theta(\beta-1)]} - \frac{1}{2(\beta-1)}\right)\bar{\tau}_i\hat{\tau}_i - \left(\frac{1-\theta}{2[1+\theta(\beta-1)]} + \frac{1}{2(\beta-1)}\right)\bar{\tau}_{-i}\hat{\tau}_{-i} \\ &+\frac{2\beta\rho}{(\beta-1)(1-\rho)}(\pi_i-\bar{\pi}_i) + \frac{\beta\rho}{(\beta-1)(1-\rho)}(s_i-\bar{s}_i) \\ &+\left(\frac{1-\theta}{2[1+\theta(\beta-1)]} - \frac{1}{2(\beta-1)}\right)\hat{d}_i - \left(\frac{1-\theta}{2[1+\theta(\beta-1)]} + \frac{1}{2(\beta-1)}\right)d_{-i}, \end{aligned} \tag{63}$$

where we have used equation (55) to replace the terms in $\pi_i^j$. The notation $\bar{s}_i = E[s_i]$ is used to denote region $i$'s expected terms of trade. Given the steady state of $\bar{P}_i = \bar{P}^i = \bar{P}$ for all $i$, we have $\bar{s}_i \equiv 0$ so that we can drop this term. For ease of exposition we rewrite the last equation as follows:

$$y_i = \bar{y}_i + a^i\hat{\tau}_i + a^{i,-i}\hat{\tau}_{-i} + b^i(\pi_i - \pi_i^e) + \kappa^i s_i + \phi_i, \tag{64}$$

where $\bar{y}_i = 0$, $a^i \equiv \left(\frac{1-\theta}{2[1+\theta(\beta-1)]} - \frac{1}{2(\beta-1)}\right)\bar{\tau}_i$ captures the effect of the home country's fiscal policy instrument and $a^{i,-i} \equiv -\left(\frac{1-\theta}{2[1+\theta(\beta-1)]} + \frac{1}{2(\beta-1)}\right)\bar{\tau}_{-i}$ the effect of foreign fiscal policy on domestic output.[27] The effect of domestic surprise inflation on output is captured by $b^i \equiv \frac{2\beta\rho}{(\beta-1)(1-\rho)}$, with $\pi_i^e = \bar{\pi}_i = E[\pi_i]$, whereas the effect of a surprise change in the terms of trade, $s_i$, is measured by $\kappa^i \equiv \frac{\beta\rho}{(\beta-1)(1-\rho)}$. The variable $\phi_i$ replaces the effects of both productivity shocks, as given by

$$\phi_i = \left(\frac{1-\theta}{2[1+\theta(\beta-1)]} - \frac{1}{2(\beta-1)}\right)\hat{d}_i - \left(\frac{1-\theta}{2[1+\theta(\beta-1)]} + \frac{1}{2(\beta-1)}\right)\hat{d}_{-i}.$$

[27]Note that the steady-state level of subsidies $\bar{\tau}_i$ is negative as will be shown in section 4. Therefore, an expansionary fiscal policy is given if $\tau_i < \bar{\tau}_i$, i.e. if $\hat{\tau}_i = \frac{\tau_i - \bar{\tau}_i}{\bar{\tau}_i} > 0$. It is important to keep this on mind to follow the fiscal policy description in the section 3.

Henceforth, $\phi_i$ is denoted as the "region-specific" output shock. In the policy analysis done in section 3, we will focus attention on equations (59) and (64), which summarize the microeconomic model.

# 3 Policy Analysis

## 3.1 Framework

As in the micro-model we consider two regions, previously denoted by home region $H$ and foreign region $F$. Henceforth, we will use the notation region $A$ and region $B$ instead, to take a neutral point of view. We consider a region to be defined by a set of countries characterized by a high degree of homogeneity and exposed to similar shocks. Thus, fiscal policies within one such region can be considered as being coordinated, as each region has to optimize a similar problem. Alternatively, one region could capture one specific country of interest, while the other region denotes the "rest of the monetary union".

In the whole currency area, the population is given by a continuum of agents on the interval $[0, 1]$, with $[0, n]$ living in region $A$ and $[n, 1]$ in region $B$. The fiscal authority in region $i$ chooses a policy variable $\tau_i$, with $i = A, B$, where $\tau_i$ is a shortcut to $\hat{\tau}_i$, the notation used in the previous sections. Fiscal policy affects national output, $y_i$, and inflation, $\pi_i$, as well as union-wide output, $y$, and inflation ,$\pi$.[28] Union-wide variables are given by the weighted sum of the region-specific levels, where the weights of the regions are given by $n$ and $(1-n)$, respectively. In the following, we exhibit the essential building blocks of our model:

**Output Equation of Country $i$**

Output in region $i$ is derived in the micro-model in section 2 and explicitly given in equation (64). For convenience, we restate it here:

$$y_i = \bar{y}_i + a^i \tau_i + a^{i,j} \tau_j + b^i (\pi_i - \pi_i^e) + \kappa^i s_i + \phi_i \ , \qquad (65)$$

where $j$ denotes "not region $i$".

[28]Precisely speaking, $y_i$ denotes the percentage deviation of output from its steady state. We, henceforth, use "output" for reasons of brevity.

According to KYDLAND and PRESCOTT (1979) and BARRO and GORDON (1983), surprise inflation may generate an increase in the national output level. Workers demand nominal wages that are sufficiently high to cover expected average future price increases. When the inflation rate reaches an unexpectedly high level, i. e. $\pi > \pi^e$, it leads ex post to lower real wages and increases employment and, thereby, output. Therefore, $b_i$ has a positive sign.

A higher $\tau_i$ corresponds to a more expansionary fiscal policy. It can be interpreted (i) as subsidies granted by the fiscal policies to reduce the frictions stemming from monopolistic power (an interpretation of $\tau_i$ which is in line with our microfoundation of section 2 and which is also typically used in New Keynesian Dynamic Stochastic General Equilibrium (DSGE) models), and (ii) as demand for public goods (which accords better with actual fiscal policies in the European Monetary Union).[29]

We consider both interpretations of fiscal policies in section 4. In both cases an expansionary fiscal policy is represented by an increase in $\tau_i$. Furthermore, we derived that fiscal policies have positive spillovers onto the other region. For the baseline supply-side fiscal policy as well as for the demand-side fiscal policy $a^i$ and $a^{ij}$, both, have a positive sign.[30]

The term $\kappa^i s_i$ denotes the change in the current account, with $\kappa^i > 0$ and the terms of trade, $s_i$, from the perspective of region $i$, which is given by the log-linear approximation of equation (16)

$$s_i = (\pi_j - \pi_i) \ . \tag{66}$$

We know from empirical work that the terms of trade effect depends also on the region's size. This means that a smaller region has typically a higher $\kappa^i$, implying that inflation differentials have a greater effect on output, something that is missing here.[31] A higher

[29] While we have not incorporated this interpretation in our model, one can easily see from inspecting the fairly general budget constraint of the fiscal authorities given in equation (7) and (8) that this is a straightforward exercise.

[30] Note that $a^i$ and $a^{ij}$ can principally also be negative, e.g. for demand-side policy if an expansionary governmental policy has a great negative impact on private consumption or investment. We will, however, neglect such situations in our analysis.

[31] Note that we implicitly make the assumption that the intensity of trade inside the currency area is that high, such that effects from outside the union can be neglected. Another possibility to eliminate outside effects is to assume that all regions within the monetary union have similar trade relations with the rest of the world and are, thus, negligible for our results.

inflation rate in region $j$ relatively to region $i$ corresponds to a real depreciation of region $i$ and thus increases its net exports. This shift of the consumption from foreign goods (region $j$) towards domestic goods (region $i$) increases domestic income.

Finally, a random shock $\phi_i$ enters the output equation, which is an i.i.d. shock with an expected value of zero and variance $\sigma^2_{\phi_i}$. In the microfounded model we have shown that this shock is the weighted sum of the deviations of the two regional (stationary) productivity processes from their respective steady states.[32]

### Inflation Equation of Country $i$

Inflation differences within the monetary union are caused by asymmetric shocks and country-specific fiscal policy actions. Thus, inflation in region $i$ evolves according to

$$\pi^i = \mu + c^i \tau_i + c^{ij} \tau_j \ , \tag{67}$$

as derived in section 2 and stated in equation (59). Again, the superscript $j$ denotes "not region $i$". The central bank influences a policy variable $\mu$, where we assume that monetary policy has the same impact on inflation in both regions.[33] Analogously to Dixit and Lambertini (2003a), "$\mu$ stands for some actual policy variable such as the base money supply or a nominal interest rate, and determines a component of the price level," (p. 1525). Therefore, a higher $\mu$ implies a more expansionary monetary policy.

The parameters $c^i$ describes the influence of national fiscal policies on inflation and $c^{ij}$ measures the effect of foreign expenditure on region $i$'s inflation rate, i. e. it captures the spillover effects stemming from fiscal policy.

Note that the parameters $c^i$ and $c^{ij}$ can have either sign. Dixit and Lambertini (2003a) discuss that the sign of the parameters may become negative when tax cuts and subsidies raise the supply of goods and are at the same time financed by income taxes

[32] Dixit and Lambertini (2003a) use a nonlinear shock vector of structural parameters, as laid out in the appendix of their paper. We depart from this, as we find it difficult to assume distributions of the single parameters and also the correlations between them. Instead, we make the standard RBC assumption that output is influenced by a normally distributed random variable capturing total factor productivity. This shock may be interpreted as comprising the effects of the shock vector in Dixit and Lambertini. Our shock effects output deviation as well as inflation directly, but also indirectly through the policy variables.

[33] In this context Adão et al (2004) show that monetary policy cannot be used to offset idiosyncratic shocks within different countries belonging to a monetary union, as common monetary policy affects the monetary union as a whole.

which leads to a crowding out of private demand. This is conform with the microfounded model of section 2. On the contrary, a positive sign appears when fiscal policies are characterized by demand-side policies. This effect may be stronger if government expenditures are financed by distortionary production taxes that reduce supply. $c^i$ and $c^{ij}$ have the same sign, but the absolute value of $c^i$ is supposed to be higher than that of $c^{ij}$, i. e., direct effects from fiscal policies are stronger than the resulting spillovers to the other region.

### Rational Expectations

The private sector has rational expectations about inflation, i. e. the following condition holds:

$$\pi_i^e = E(\pi_i). \tag{68}$$

### Target Functions of Fiscal Authorities

Fiscal authorities minimize a quadratic loss function, which aims at national inflation and national output. The functional form of the loss function is identical to that of regional welfare derived in an Appendix available from the authors upon request.

$$L_{F^i} = \frac{1}{2}\left[(\pi_i - \pi_F^i)^2 + \theta_F^i(y_i - y_F^i)^2\right] \ . \tag{69}$$

Note that $\pi_F^i$ is the fiscal policy's inflation target in region $i$, and $y_F^i$ is the desired output level of the fiscal authority in region $i$. According to the utility based welfare criterion, these reference values should be equal to zero for inflation and to the flexible price output plus the steady state deviation from the efficient steady state in the case of output.[34] If both fiscal authorities and the monetary authority agree on the targets, the first best situation with the highest possible welfare can be obtained. This was shown in Dixit and Lambertini (2003b) and corresponds to the joint cooperation case of our model, which will be introduced later.

However, in the EMU national governments and the ECB have often disagreed about the suitable strategy of their policies, so far. Therefore, we deviate from the microeconomic model by presuming that the fiscal targets are different from the socially optimal level. More specifically, *we assume target levels for inflation and output that are both above the socially optimal levels.* This could be justified by fiscal policy makers' desire to attain a greater government size (Fatas and Rose, 2001) and/or their incentive to

[34] With some simplifying assumptions, the optimal target for output is also zero.

maximize the reelection probability (Beetsma and Uhlig, 1999). To illustrate this, one can easily imagine that fiscal authorities are able to deceive their voters about the socially optimal targets, particularly during election campaigns. Especially, this would hold for a monetary union, where fiscal policy communicates with the *domestic* society, but monetary policy is *centralized* and cares about the whole society of the monetary union, and reaches, therefore, the private sector of the individual regions from a greater distance.

Furthermore, the inflation and output targets of fiscal policies in both regions may differ from each other: An economic intuition for considering different inflation targets of the agents may be given by home-bias effects in the consumption of goods, or by different elasticities of substitution in the representative agents' utility function across regions, by different fractions of tradeable and non-tradeable goods in both regions. In our microeconomic model, we have incorporated a home-bias effect in consumption and have considered region-specific productivity shocks, which determine possible reasons for different fiscal targets among the two regions.

### Target Function of the Common Central Bank

The common central bank is assumed to optimize the union-wide social welfare function.[35] Using a notation with indices $M$ to denote monetary policy, this is

$$\begin{aligned} L_M &= \frac{1}{2}\left[n\left((\pi_A - \pi_M^A)^2 + \theta_M^A (y_A - y_M^A)^2\right)\right. \\ &\quad \left. + (1-n)\left((\pi_B - \pi_M^B)^2 + \theta_M^B (y_B - y_M^B)^2\right)\right] \ . \end{aligned} \tag{70}$$

In case of excessive fiscal targets, as motivated above, we can state that the central bank is relatively conservative compared to fiscal policies, given by $\pi_M^i < \pi_F^i$ and $y_M^i < y_F^i$ for all $i$. Our model differs in that respect from the approach of Dixit and Lambertini (2003b): They assume that fiscal policies act socially optimal and the central bank is too conservative, whereas we claim that the central bank maximizes union-wide welfare and fiscal policies act too expansionary.

The different weights on output-stabilization and the different output and inflation targets of monetary and fiscal policies give rise to trade-offs among policy makers. Whereas the fiscal authorities put a higher weight on output stabilization (and on pushing output and inflation above their natural levels), the common central bank puts a relatively higher weight on the stabilization of inflation. These conflicting targets cause strategic behavior among the policy makers, which is examined in the following.

[35]The derivation is available from the authors upon request.

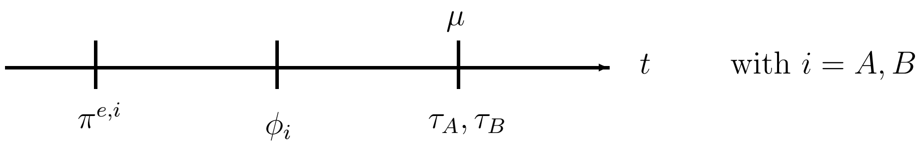
## 3.2 Scenarios of Simultaneous Decision-Making

In this subsection, we consider the scenario in which both fiscal authorities and the common central bank choose their optimal policies simultaneously. As the analytical results are woefully complicated, we restrict our policy analysis to a numerical examination which is done in section 4.

### 3.2.1 Nash Behavior

First, we consider the scenario of uncoordinated fiscal and monetary policies. The policy makers decide upon their optimal policies after having observed the realizations of the region-specific shocks. Thereby, they take the households' expectations on inflation as given. For a better understanding, the sequence is depicted in figure 1.

Figure 1: Time Structure for Simultaneous Decision-Making




The optimization problem of the policy authorities is briefly sketched in the following: Country $A$'s fiscal policy maker optimizes the social loss function (69) with respect to $\tau_A$, while taking the decision of the other region's fiscal policy, $\tau_B$, and the policy choice of the common central bank, $\mu$, as given.

Using equations (69) and (70) as well as the definitions of output and inflation, we obtain the following first order conditions:

$$\frac{\partial L_F^i}{\partial \tau^i} = (\pi_i - \pi_F^i)c^i + \theta_{F^i}(y_i - y_F^i)(a^i + b^i c^i + \kappa^i(c^{ji} - c^i)) = 0, \tag{71}$$

with $i = A, B$,$j = A, B$ and $i \neq j$,

$$\frac{\partial L_M}{\partial \mu} = (\pi - n\pi_M^A - (1-n)\pi_M^B) + n\theta_M^A b^A(y_A - y_M^A) + (1-n)\theta_M^B b^B(y_B - y_M^B) = 0 \ , \tag{72}$$

with $\pi = n\pi_A + (1-n)\pi_B$. Solving the fiscal first order condition of region $A$ for $\pi_A$ yields

$$\pi_A = \pi_F^A - \theta_F^A(y_A - y_F^A)\left(\frac{a^A + \kappa^A c^{BA}}{c^A} + b^A - \kappa^A\right) \ . \tag{73}$$

For most of the scenarios when considering demand-side fiscal policy, there exists a negative correlation between inflation and output, since the parameters $a^A, b^A, c^A$ and $c^{AB}$

are assumed to be positive in our policy analysis.[36] However, if the terms of trade effect is dominant, i. e. if $\kappa^A$ is extremely large, inflation depends positively on output. Hofmann and Remsperger (2005) show that the inflation differentials in the EMU are significantly persistent since 1999. This implies – at least until today – that terms of trade effects have tended to be rather small and, therefore, strengthen the view stated above. We will consider this issue more thoroughly in a sensitivity analysis in section 4. The first-order condition for the fiscal policy of region $B$ follows the same scheme.

Monetary policy optimizes the union-wide social loss function (70), taking the fiscal policy actions and the expectations of the private sector as given. Solving for $\pi$ leads to

$$\pi = n\pi_M^A + (1-n)\pi_M^B - n\theta_M^A b^A (y_A - y_M^A) - (1-n)\theta_M^B b^B (y_B - y_M^B) \ . \tag{74}$$

As the parameters $b^A$ and $b^B$ are assumed to be strictly positive, the first order condition of monetary policy reflects also a negative correlation between inflation and the national output levels.

### 3.2.2 Cooperation of Monetary and Fiscal Policies

According to many economists and politicians, coordination plays a major role. This is emphasized by the fact that regions and international organizations create institutions like the stability and growth pact and aim at positioning further common targets like tax harmonizations, which are only a few examples of coordination instruments. In this subsection, we analyze the scenario of coordination under discretion characterized by an agreement of the political authorities on common policy goals, i. e. $\pi_F^A = \pi_F^B = \pi_M = \pi_{JC}$, $y_F^A = y_F^B = y_M = y_{JC}$ and $\theta_F^A = \theta_F^B = \theta_M = \theta_{JC}$, where the subscript $JC$ denotes the "joint cooperation"- scenario. The timing of political decision-making corresponds to the Nash scenario and is illustrated in figure 1. We assume here, that the policy makers share a combined loss function of the following form:

$$\begin{aligned} L_{JC} &= n\frac{1}{2}[(\pi_A - \pi_{JC})^2 + \theta_{JC}(y_A - y_{JC})^2] \\ &\quad +(1-n)\frac{1}{2}[(\pi_B - \pi_{JC})^2 + \theta_{JC}(y_B - y_{JC})^2] \ . \end{aligned} \tag{75}$$

The minimizing problem follows the same pattern as in the Nash-scenario, the only difference is that all authorities face the same loss function. We, implicitly, treat the joint

[36] For fiscal policy aiming at reducing monopolistic distortions by granting subsidies, the opposite correlation is likely to hold as shown in section 4.

cooperation case as if the policy makers are committed to the socially optimal targets: *we assume that all policy makers aim at attaining the social optimum in this scenario, and that the private sector is aware of that when building its expectations on inflation.* We do not incorporate possible deviations from this strategy, which could be an interesting case for an enhancement of this model. Thus, the first-best optimum for the private agents is attainable under joint cooperation. Dixit and Lambertini (2003b) use the same assumption in their model. We refer to that point in section 4.

### 3.2.3 Independent Monetary Policy and Cooperation of Fiscal Policies

In situations of union-wide stagnation of economic growth and rising unemployment the fiscal authorities may put the common central bank under pressure to lower interest rates and to increase money growth. In a case where the common central bank maintains its focus on the primary objective, i. e. a high degree of price stability, Beetsma and Bovenberg (1998) argue that coordination of fiscal players, in the sense that each fiscal player internalizes the effects of a unilateral tax change on the other fiscal players, is profitable, at least for the fiscal policy makers. This may encourage the fiscal authorities to coordinate their tax decisions so as to induce the common central bank to set the inflation rate in the direction preferred among the fiscal authorities. However, this behavior may lead to an increase in inflation, taxes and expenditures at the same time and harms welfare.

In our model, the fiscal authorities optimize a similar loss function as in the joint cooperation scenario, but with target values of inflation and output above the socially optimal levels. The fiscal objective function of both regions is given by

$$\begin{aligned} L_{FC} &= n\frac{1}{2}\left[(\pi_A - \pi_{FC}^A)^2 + \theta_{FC}(y_A - y_{FC}^A)^2\right] \\ &\quad +(1-n)\frac{1}{2}\left[(\pi_B - \pi_{FC}^B)^2 + \theta_{FC}(y_B - y_{FC}^B)^2\right] \ , \end{aligned} \tag{76}$$

where the subscript $FC$ denotes "fiscal cooperation". The results of Beetsma and Bovenberg (1998) for cooperation of fiscal policies are almost in line with our numerical results shown in section 4 for the case of a demand-side policy.

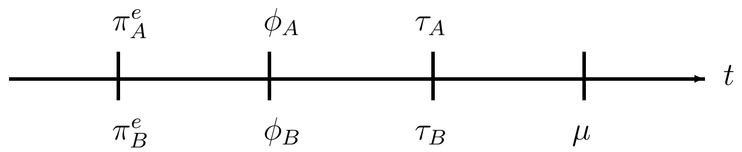
## 3.3 Scenarios of Sequential Decision-Making

The policy choice of monetary and fiscal authorities may possibly take place at different times due to certain pre-scheduled rules, bureaucracy or special intrinsic features of the political institutions. Therefore, we focus here on interactions of fiscal and monetary policies when both authorities act sequentially. The evaluation of the different scenarios is done in section 4.

### 3.3.1 Stackelberg Leadership of Fiscal Policy

We begin with the scenario of fiscal leadership, i. e. fiscal policy makers have to decide on their policy actions before monetary policy is conducted and after having observed the realization of the regional shocks $\phi_i$. Thereby, they take the household's inflation expectation as given. Beetsma and Bovenberg (1998) argue that fiscal leadership seems to be more likely when monetary policy can be conducted and adjusted more quickly than fiscal policy. This may be applicable when choices for taxes and subsidies are accompanied by bureaucratic and legislative processes which provide the fiscal authority leadership against monetary policy. The sequence of that scenario is depicted in figure 2.

Figure 2: Time Structure for Sequential Decision-Making (Fisc. Leadership)

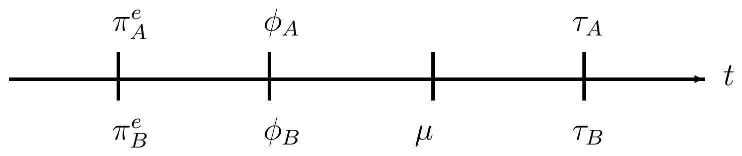



The solution of the game is obtained by backward induction. Solving the monetary policy's optimization problem at the second stage of the game leads to the optimal choice of $\mu$ while taking the fiscal policy variables $\tau_A$ and $\tau_B$ as given. The monetary reaction function is again given by (72). At the first stage, the fiscal policy maker of region $i$ optimizes $\tau_i$ to react to the action of the policy maker of region $j$, $\tau_j$, and subject to the monetary reaction function, which was derived from the second stage of the game.

### 3.3.2 Stackelberg Leadership of Monetary Policy

In contrast to the previous case, monetary policy attains Stackelberg leadership over fiscal policies if it affects the economy only with a lag of time which exceeds the legislative and bureaucratic time need for fiscal policy decision-making. The timing is shown in figure 3. The solution is similar to the former scenario of fiscal leadership. At the second stage, fiscal policy makers minimize the loss function (69) analogously to the above shown Nash scenario, given the other region's fiscal policy and the monetary policy variable $\mu$. The

Figure 3: Time Structure for Sequential Decision-Making (Mon. Leadership)




common central bank chooses $\mu$ at the first stage, given the best responses of the fiscal policies $\tau_A$ and $\tau_B$.

### 3.3.3 Fiscal Cooperation and Sequential Policy Actions

Analogously to the fiscal corporation scenario where the policy makers chose their optimal policies simultaneously, one can also suppose coordination of national fiscal policies when the decision-making of monetary and fiscal policies takes place at different stages. The motivation for a coordinated fiscal policy in a sequential policy game corresponds to that of fiscal coordination in a simultaneous game. Therefore, we also analyze the scenarios (i) *fiscal cooperation when fiscal policy moves first* and (ii) *fiscal cooperation when monetary policy moves first*.

The time structure of scenario (i) corresponds to the one in figure 2, and the time structure of scenario (ii) corresponds to that in figure 3. The optimization problem under both scenarios follows the same pattern as in the corresponding sequential scenarios without coordination and are, therefore, dropped in this section.

## 4 Results

In the following, we derive numerical results for the seven scenarios of strategic behavior between monetary and fiscal authorities introduced in the previous section.

We, first, analyze our baseline case with a supply-side fiscal policy as described in the microfoundation of section 2 and show the calibration of the model. Second, we show the evaluation methods used for the ranking of the different scenarios. Third, we run simulations for the case of a homogenous and a heterogenous monetary union by using the structural parameters from the microfounded model of section 2. In this case, fiscal policy aims at granting production subsidies and levy per-capita taxes to reduce the distortions caused by monopoly power. We use the results from the homogenous monetary union as a reference case, and compare the rankings of different scenarios in the heterogenous case. Fourth, we strengthen our results by using a sensitivity analysis regarding both the structural parameters and the policy targets. Fifth, we run the simulations once more, now analyzing the strategic interactions among fiscal and monetary policies when fiscal policy is described by demand-side policy. Thereby, we do not refer to the parameter values of our microfoundation, but choose instead the parameter values of the reduced-form model (macroeconomic equations of section 7.1) in a quantitative exploration. In this case, the parameters $a^i, a^{i,j}, c^i$ and $c^{ij}$ have positive signs as already discussed in the previous section. I. e., expansionary fiscal policy raises output and inflation at the same time. Like in the supply-side case, we strengthen the results of our numerical settings by checking the sensitivity of our results to variations in the macroeconomic parameters. Sixth, we show that it is possible to nest the results of Dixit and Lambertini (2001, 2003a and 2003b) in our model.

## 4.1 Calibration

We calibrate the structural parameters of the model according to the standard literature, as referred to in Dixit and Lambertini (2003a, appendix F). The elasticity of marginal disutility of labor is set to 0.45, a value proposed by Blanchard and Fischer (1989).[37] This implies that the disutility parameter $\beta$, which is one plus the inverse of the elasticity of marginal disutility of labor, takes the value $\beta = 3.22$. The Calvo-stickiness parameters $\Phi^H$ and $\Phi^F$ are set to a moderate value of 0.5, implying an average price to be fixed for three periods. The elasticity of substitution between goods of the same region is set to $\theta = 11$ as in Dixit and Lambertini (2003a). Obstfeld and Rogoff (2001) discuss the literature that has found values between 1 and above 20. Note that the elasticity of substitution between goods of different regions is set to unity, like e.g. in Benigno (2004). In setting the steady state of the technology parameter $\bar{d}_i = 1$ and the subjective discount factor $\eta = 0.98$, we strictly follow Dixit and Lambertini (2003a). The steady state value for the fiscal policy instrument is assumed to be set optimally, i. e. to offset the monopolistic distortion. Via $\bar{\tau}_i = 1/(1-\theta)$ we get a subsidy rate of ten percent for both regions at the steady state.

We look at two different cases: In the first case, both regions have the same size of $n = 1 - n = 0.5$ and are completely symmetric, with identical structural parameters, identical fiscal policies and no home bias ($\nu^H = \nu^F = 0.5$). In the second case, region $B$

[37] The authors discuss this parameter on page 341. Dixit and Lambertini (2003a) assume a unit wage elasticity and thus less curvature.

accounts for only 30 percent of the union and features more price rigidities. The latter assumption is based on the findings of BENIGNO and LOPEZ-SALIDO (2004). They estimate the price rigidity in five core EMU countries and find substantial heterogeneities.[38]

In the second case we presume that there is also a considerable home bias in consumption in both regions, following ANDERSON and VAN WINCOOP (2003).

Given the values stated above, we can calculate the various parameters $a^i$, $b^i$, $c^i$ and $\kappa^i$ in the model equations. We, also, can infer the values in the policy loss functions maximizing social welfare: In the symmetric case these are target values for inflation and output of both zero, and a weight on output of $\theta_M^A = \theta_M^B = 0.00763$. In the asymmetric case, the output weight for region $B$ rises to $\theta_M^B = 0.01046$, while all other socially optimal target values remain the same.

As stated earlier, we assume that the common central bank sticks to these values, while the fiscal policy authorities may deviate from them. This could have various reasons: To name two, there could be systematic mismeasurement of the fiscal authorities, or the fiscal authorities maximize a different objective function which they are able to conceal from the households, which was justified in section 7.1. In particular, we assume that the fiscal policy authorities put equal weight on output and inflation of unity. Furthermore, fiscal policies have higher target values for output $y_F^A = y_F^B = 0.015$ and inflation $\pi_F^A = \pi_F^B = 0.02$. In the asymmetric case, fiscal policy in region $B$ even puts a weight of $\theta_F^B = 1.25$ on output, sets its output target to $y_F^B = 0.025$ and its inflation target to $\pi_F^B = 0.03$, which could be seen as the result of its self-perception as a high growth catch-up region. Table 1 summarizes this calibration. The stochastic term is calibrated as in DIXIT and LAMBERTINI (2003a) to match the variance of output around its steady state to be plus/minus six percent, as is the case for the U. S.

As introduced in section 3, we assume that the private sector has rational expectations on inflation. We treat $\pi_A^e$ and $\pi_B^e$ as given in our analytical calculations. The inflation expectations of the private agents of both countries are determined in our model by iteration: We use an arbitrary starting value for the inflation expectations in both countries and repeat the optimization calculations until the inflation expectations differ from realized inflation by a value of less than $10^{-10}$ for both countries, while keeping the shock at

[38]The average price duration varies between around four quarters in the Netherlands and Germany and up to 17 quarters in Spain, implying price rigidity parameters between 0.75 and 0.94. We will choose numbers between 0.5 and 0.58, following the more conservative estimates of BILS and KLENOW (2004). For a closer look at European data, the reader is referred to DHYNE et al. (2005).

its expected value of zero. This approach guarantees that $\pi_i^e = E(\pi_i)$ holds for $i = A, B$. After inflation expectations are determined, we simulate our model by averaging over 100.000 random draws of the stochastic processes.

## 4.2 Evaluation Method

The main purpose of our numerical approach is to rank the different scenarios of strategic behavior of monetary and fiscal policies for the losses they induce. We distinguish between three approaches:

(i) Evaluation of the loss functions, which refer to the policy exercised by the fiscal and monetary authorities. In each cooperation scenario, the corresponding loss function is a compromise of the cooperating authorities.

(ii) Evaluation of the region-specific loss functions. In each cooperation scenario, these are the region-specific loss functions the policy authorities would minimize if they were not cooperating. This approach allows us to infer whether cooperation scenarios are preferable for each participating policy authority.

(iii) Evaluation of social welfare. For each region, we calculate the welfare loss that arises due to deviations in output and inflation from the socially optimal values.

We depict the losses of all three approaches in table 2 for the baseline model and in table 4 for demand-side fiscal policy. In our discussion we incorporate only the second and third approach with the following justification: In approach (i), the losses of the three policy authorities are based on the loss functions used in the optimization calculations. If the policy makers decide to cooperate, they usually compromise on targets which differ from their own *true preferences*. However, the "true losses" which the policy makers face are still based on their specific preferences. Therefore, in approach (ii) we calculate the values of the policy makers' loss functions given by equations (69) and (70), irrespective of the loss function used for optimization in the particular scenarios.[39] One should also take these losses into account, when exploring whether joint cooperation of all policy makers or cooperation of fiscal policy makers can take place on a voluntary base.

[39] Note that by this definition, the losses in case (ii) differ from the losses in case (i) only for the joint cooperation scenario and the scenarios of fiscal cooperation.

The region-specific social welfare losses of approach (iii) are given by[40]

$$\begin{aligned} L_A &= \frac{1}{2}((\pi_A - \pi_M^A)^2 + \theta_M^A(y_A - y_M^A)^2) \\ L_B &= \frac{1}{2}((\pi_B - \pi_M^B)^2 + \theta_M^B(y_B - y_M^B)^2). \end{aligned}$$

Additionally, we express the region-specific social losses in terms of an equivalent reduction in region-specific consumption units, following the example of LUCAS (2003): A scenario "performs best", if it shows the lowest reduction of consumption units compared to the consumption level in the social optimum. The calculation of the consumption equivalent losses follows the approach of ADAM and BILLI (2005):

From our welfare derivation we know that for region $A$

$$U^A = -\bar{Y}_A u_C L_A \tag{77}$$

holds. To derive a relation between a permanent reduction of consumption, given by $\delta_C^A$ percent, and the welfare loss, a second-order Taylor-approximation of the utility loss is generated by

$$\begin{aligned} U^A &\approx \left( -\frac{u_C \bar{Y}_A \delta_C^A}{100} + u_{CC} \left( \frac{\bar{Y}_A \delta_C^A}{100} \right)^2 \right) \\ &= -u_C \bar{Y}_A \left( \frac{\delta_C^A}{100} - \frac{u_{CC}\bar{Y}_A}{u_C} \left( \frac{\delta_C^A}{100} \right)^2 \right) \\ &= -u_C \bar{Y}_A \left( \frac{\delta_C^A}{100} + \frac{(1-\gamma)\bar{Y}_A}{\bar{Y}_A} \left( \frac{\delta_C^A}{100} \right)^2 \right). \end{aligned} \tag{78}$$

Replacing $\frac{U^A}{u_C \bar{Y}_A}$ by $L_A$ yields

$$L_A = \frac{(\delta_C^A)^2}{100^2} + \frac{\delta_C^A}{100}\ . \tag{79}$$

To calculate the reduction of consumption equivalent to the social loss for region $A$, we solve for $\delta_C^A$ to obtain

$$\delta_C^A = 100 \frac{-1 + \sqrt{1 + 4(1-\gamma)L_A}}{2(1-\gamma)}\ . \tag{80}$$

The reduction of consumption equivalent to a certain welfare loss for region $B$ can be obtained analogously. We use this transformation in the following subsections to make the welfare losses more palpable.

[40] Remember from section 3 that the central bank is assumed to optimize the union-wide social loss, which is a region-sized weighted sum of the social losses of region $A$ and $B$.

## 4.3 Monetary and Fiscal Policies in the Baseline Model

Now, we examine the results of the simulations for the supply-side fiscal policy described in section 2. The model calibration was explained in section 4.1 and is summarized by table 1. A summary of the results is given in table 2.

### Homogenous Monetary Union

We begin with a comparison of the losses for the monetary and fiscal policy authorities in the symmetric case. The first columns of table 2 show that the fiscal authorities of both regions face the highest region-specific policy losses under cooperation and in the scenario where monetary policy moves first. The lowest fiscal losses occur when fiscal policies have the greatest influence, i. e. under the scenarios of fiscal cooperation when fiscal policies move first and under fiscal cooperation in the simultaneous scenario. The explanation is simple: Fiscal policies aim at higher inflation and higher output than the central bank, which targets the socially optimal levels. Due to the low relative weight on output stabilization the central bank reacts strongly to offset deviations of inflation from the social optimum level. Fiscal policies, themselves, have a trade-off between inflation and output when fixing their own policy decisions: an expansionary fiscal policy pushes output above the socially optimal level due to granting subsidies to lower production costs, and it thus decreases inflation at the same time. Hence, output is higher than the natural output and lower than the desired fiscal targets. Inflation is below the fiscal target levels and slightly below the social optimum. Note, however, that the central bank reacts strongly to the downward pressure of inflation with an expansionary monetary policy due to its large weight on inflation in the target function.[41]

The loss in the Nash scenario is similar to that of the two scenarios where fiscal policies move first.

In the scenarios where monetary policy takes leadership (with or without coordination of fiscal policies), fiscal policies internalize that the central bank cannot offset a too expansionary fiscal policy. Therefore, fiscal policies are less expansionary, and output and inflation deviate by more from the fiscal targets than in the previously analyzed scenarios. This implies higher losses for the fiscal policy authorities. The highest losses occur when

[41] When fiscal policies are characterized by demand-side policy, an expansionary fiscal policy pushes both output and inflation into the desired direction. Therefore, fiscal policy is much more expansionary when fiscal policy raises demand, and the ranking of the losses differs from that under a supply-side fiscal policy.

policy makers cooperate and agree on the socially optimal targets: the realized value for inflation is on average close to zero (but still dependent on stochastics) and output is farthest below the desired levels. It is, therefore, questionable whether overall cooperation at the socially optimal targets can be implemented in this setting.

The rankings of the central bank losses correspond to the rankings of the union-wide social losses by our assumption of a welfare maximizing monetary policy. The social losses, in turn, can be transformed into welfare equivalent consumption reductions relative to the social optimum. Hence, we consider only the consumption losses of the private agents in the following. We find that the ranking of the scenarios is quite different compared to the (fiscal) policy makers' losses (see again table 2): The first best can be attained in the cooperation scenario.[42] The consumption loss is also very low in both monetary leadership scenarios, when fiscal policies do not cooperate as well as when fiscal policies are coordinated. The highest social losses occur when fiscal policies are dominant in the sense that they are Stackelberg leaders, and in the Nash scenario. Correspondingly to the explanation of the fiscal policy makers' losses, inflation and output levels are closest to the social optimum when monetary policy takes leadership (besides the joint cooperation case, of course).

**Heterogenous Monetary Union**

For analyzing the case of a heterogenous monetary union, we assume that the fiscal policy of region $A$ follows the same strategy as in the homogenous case, whereas fiscal policy of region $B$ targets higher levels of both inflation and output. We, furthermore, assume that region $B$ is smaller than region $A$ and is characterized by a slightly higher degree of price-stickiness. The exact parameter values for region $A$ are again depicted in the second column of table 1, whereas the "alternative" parameter values for region $B$ are summarized in the third column of this table. Results for the heterogenous case are shown in columns seven to eleven of table 2.

Beginning with the losses for region $A$, we find that the values of the fiscal policy maker's losses are much higher for all scenarios in the heterogenous case, except one: The cooperation scenario corresponds to the homogenous case by definition, as all policy makers agree on the socially optimal targets. The ranking of the scenarios with respect to the region-specific fiscal policy makers' losses is similar to that in the homogenous case: the highest losses occur when monetary policy has the greatest influence (monetary

[42]The (monetary) policy loss is slightly larger than zero because of the shock in our simulation.

leadership scenarios), and the smallest losses occur in the scenarios in which fiscal policies have the greatest influence, (fiscal cooperation when fiscal policy takes leadership, fiscal cooperation and simultaneous decision-making, and fiscal leadership when monetary policy is uncoordinated), and in the Nash scenario. The fiscal policy maker again faces the highest loss in the joint cooperation scenario. We observe almost the same ranking for region $B$, but the losses are higher compared to region $A$.

We find that the losses of the common central bank and, therefore, also the consumption losses of the private agents show also a similar ranking as in the homogenous monetary union: The lowest losses are attained when monetary policy moves first or when all policy makers agree on the socially optimal targets (=first best). The highest losses occur when fiscal policies moves first (uncoordinated and coordinated) and when fiscal policies are coordinated and monetary and fiscal policy decisions take place simultaneously. This result seems, at first glance, to be contrary to the findings of LOMBARDO and SUTHERLAND (2004), who state that fiscal cooperation is welfare-improving. But a closer look reveals that our calibration of a unit elasticity of substitution between domestic and foreign goods implies also in LOMBARDO and SUTHERLAND (2004), according to their Proposition 1, that fiscal cooperation no longer is welfare-improving.[43]

The welfare equivalent consumption reductions under Nash, fiscal leadership and the two fiscal cooperation scenarios with simultaneous actions or with fiscal leadership are about three times larger in the (smaller) region $B$. Also, the equivalent consumption reductions are relatively higher in the heterogenous case compared to the homogenous case, by about 50 percent for region $A$ and a factor of above four for region $B$. This implies that a model of a homogeneous monetary union that does not properly take into account heterogeneities possibly underestimates the welfare effects of certain policies. This finding also suggests that homogeneity is a desirable feature of the currency area for all policy makers (fiscal and monetary authorities) and the private agents. We take up this point again in section 4.5 and consider the implications for the European Monetary Union.

## 4.4 Sensitivity Analysis for Supply-side Policy (Baseline-Case)

Are the results of the previous section robust to changes in the structural parameters of the model? To examine this, we vary the structural parameters in plausible ranges. In

[43]Note also that LOMBARDO and SUTHERLAND (2004) features government consumption in the utility function. We will refer to that point again in section 4.5.

figure 4 we plot the parameter variations that show the highest sensitivity of results. The corresponding parameters are the elasticity of marginal disutility of labor, (emdl), the price rigidity, $\phi_i$, and the elasticity of substitution, $\theta$. We plot their effects on fiscal policy makers' losses and social welfare, which is equivalent to the central bank loss, for both the symmetric and the asymmetric case.[44]

**Variation of the Elasticity of Marginal Disutility of Labor**

We vary the elasticity of marginal disutility of labor (emdl) between zero and one, where the lower bound is given in Blanchard and Fischer (1989), while the upper bound is often used in New Keynesian models, see e. g. Gali and Monacelli (2005a). The effects of these variations on the policy losses in the three simultaneous scenarios are depicted in the first row of figure 4, while the second row shows the effects in the four sequential scenarios.

An increasing elasticity of marginal disutility of labor leads to higher central bank losses. This result is obvious, as, given the other parameters, the same outcome is produced at higher costs, meaning that the same effort in the production of goods leads now to a higher reduction of utility than before.

Referring to the homogenous case, we see that the rankings for both, the fiscal authorities' losses and the central bank losses are stable: fiscal policies suffer from the smallest losses in the Nash scenario and if they obtain fiscal leadership, as they are able to follow their inflation and output targets (above the socially optimal levels) better compared to the other scenarios. The central bank's welfare function shows the smallest losses under the joint cooperation case (which determines the first best) and in the scenario where monetary policy takes leadership. In the latter scenario, the fiscal policies are restrained, as a too expansionary fiscal policy would lead to low inflation, which will not be corrected by the central bank, afterwards. Therefore, monetary leadership has a disciplining-effect on supply-side oriented fiscal policies. That joint cooperation leads to the first best from a welfare perspective comes as no surprise, as all policy makers agree upon the socially optimal targets, as mentioned in the previous section.

[44] In the figures, we use the following abbreviations to save space. For the policy scenarios, Nash = Nash, Coop = cooperation, FCoop = fiscal cooperation, FLead = fiscal leadership, MLead = monetary leadership, FCFL = fiscal cooperation with fiscal leadership, FCML = fiscal cooperation with monetary leadership. The labels on the x-axis denote emdl = elasticity of marginal disutility of labor, $\Phi$ = Calvo parameter, i.e. the percentage of firms that cannot adjust their prices, $\theta$ = elasticity of substitution between different goods produced in the same region.

In the heterogenous case, the losses are higher for the fiscal policies of both regions, the one with the more conservative and the one with the more aggressive targets, and also for the central bank. However, the rankings seem to be robust with two exceptions: (i) Fiscal losses are strongly increasing for higher values of the elasticity of disutility of labor when monetary policy moves first. (ii) The losses in the fiscal cooperation fiscal leadership cases "explode" for a value of 0.4, which may be an indication that there is no equilibrium in that case to which rational inflation expectations could converge. It would be interesting to take up this point in further research.

### Variation of Price Rigidity

The third and fourth row of figure 4 examine the effect of varying price-rigidities on fiscal and monetary losses. The figure shows that the ranking of the scenarios is stable in the homogenous and heterogenous case for almost the whole parameter set, and it is in line with the results of table 2: Fiscal policies face the smallest loss under fiscal leadership, whereas monetary policy suffer from the smallest losses when it takes leadership and, of course, under the joint cooperation scenario. Again, the fiscal cooperation fiscal leadership scenario leads to dramatically increasing losses for more rigid prices, something that demands an analysis in future research.[45]

### Variation of the Elasticity of Substitution of Consumption Goods

In the fifth and sixth row of figure 4, we consider the effect of changes from the elasticity of substitution of consumption goods, $\theta$, on the losses over the range discussed by Obstfeld and Rogoff (2001). The figure confirms one intuitive result, that an increasing $\theta$ leads to smaller fiscal policy and welfare losses: higher substitutability between goods implies less distortions from monopoly power. There is again one interesting exception: for a relatively small value of $\theta$ below 10 the losses explode, which, again, may possibly induce indeterminacy of equilibria.

[45] The variations of the intertemporal discount factor $\eta$, which determines the importance of "pseudo-future" periods relative to the present period in the producer-consumers price-setting behavior, shows almost the same results as shown for variations of the price rigidity parameter. We, therefore, abstain from depicting and discussing the figures for $\eta$.

### Summary of the Findings

For all considered parameter variations over the ranges used in standard literature (see model-calibration), we found that the rankings of the different scenarios illustrated by table 2 are relatively robust. The sensitivity analysis has also confirmed that the losses in a heterogenous monetary union tend to be higher. From the perspective of welfare-maximization, joint cooperation and monetary leadership are the best-performing scenarios.

## 4.5 Alternative Fiscal Policy: Demand-side Policy

In this section, we consider an alternative interpretation of fiscal policy: Governments try to push output and inflation above their natural levels by raising demand for public goods to lower unemployment below its natural rate. This type of fiscal policy is not incorporated in our microfounded model. Nevertheless, we are interested in analyzing how the different scenarios describing the interplay between policy makers are ranked when using a parametrization for demand-side oriented fiscal policies.[46]

### A homogenous monetary union

First, we consider the case of a homogenous monetary union. The parametrization we use here is depicted in table 3. We assume that an expansionary fiscal policy leads to an increase in output, i. e. $a^i > 0$ and $a^{ij} > 0$. In contrast to the supply-side policy, the coefficients $c^i$ and $c^{ij}$, which denote the effect of fiscal policies on inflation, now have a positive sign: The additional demand of goods by fiscal policies causes an upward pressure on goods' prices.[47] The values of the remaining parameters are equal to those in the previous subsection or have, at least, the same sign, but differ in their absolute size. The results are depicted in the first columns of table 4. The ranking of the policy makers' losses shows some interesting changes compared to the supply-side case: The policy losses in both fiscal-leadership scenarios, i. e. in the uncoordinated and coordinated scenarios, are higher compared to the losses in the scenarios where monetary policy moves first. The

[46] A microfoundation of demand-side oriented fiscal policy would also be possible, if adding public goods to the representative household's utility function. The reader is referred to Beetsma and Jensen (2005) or Lombardo and Sutherland (2004) for related models with this feature.

[47] We assume that the demand-side effect of fiscal policies outweighs the crowding-out effect on private demand.

result is the outcome of a monetary policy that fights inflation strongly when fiscal policy moves first: The monetary policy variable $\mu$ exhibits a relatively strong negative value in the fiscal leadership scenarios compared to the monetary leadership scenarios. We also find that joint cooperation of fiscal and monetary policies — characterized by agreeing on the socially optimal output and inflation targets — reduces the losses of fiscal policy makers when underlying their true preferences on domestic inflation and domestic output.[48] A further interesting result is that the scenarios in which monetary policy moves first show the smallest losses *for all policy makers*, the governments and the common central bank.

The ranking of the scenarios according to the welfare equivalent consumption losses corresponds almost to that found for supply-side fiscal policy. The first best is obtained if all policy makers agree on the socially optimal targets.[49] Monetary leadership leads to a lower consumption reduction compared to the fiscal leadership and the Nash scenario. Under both monetary leadership scenarios monetary policy has a great influence which leads to relatively low welfare equivalent consumption reductions. The result holds due to the common central bank's target function, which is assumed to maximize social welfare.

### A heterogenous monetary union

In a heterogenous monetary union conflicts do not only occur between the targets of monetary and fiscal policies, but also among fiscal authorities themselves.

Therefore, we analyze also for the case of demand-side fiscal policy the interactions of monetary and fiscal policies in a monetary union comprising two heterogenous regions. To relate this topic to a practical situation, one could think of the European Monetary Union, where region $A$ describes the richer northern and central European countries and region $B$ consists of southern and in the near future eastern European countries. We choose a parametrization to analyze strategic behavior under heterogeneities which can

[48]At first glance, this suggests that the cooperation solution would be easy to implement. However, we possibly have a prisoner's dilemma: if the fiscal policy maker under cooperation deviates from the cooperation strategy and optimizes his own target function, he can reduce the loss by more as long as the other policy maker abstains from deviating. Cooperation of all policy makers would then only be attainable if deviations were associated with a large enough imminent sanction.

[49]Note, again, that this scenario is equivalent to a joint commitment scenarios due to our modeling: we assume that the private sector has rational expectations on inflation and knows the true structure of the policy maker's target function and identifies the scenario perfectly. This is a critical assumption as the true preferences of the policy makers do not necessarily coincide with the targets under cooperation meaning that a deviation from the current strategy cannot be excluded, but this is not our main focus.

be applied to the situation in European Monetary Union. For the richer countries in region $A$ we use the same structural parameters as in the homogenous case. Region $B$, which can be called "catch-up"-region, is characterized by relatively higher output and inflation goals and also by a higher relative-weight on the output goal compared to region $A$. Furthermore, the parameters $a^i, b^i$ and $c^i$ are assumed to be relatively higher in the catch-up region, meaning that the same fiscal policy has a stronger impact on inflation and output in region $B$. This may be caused by a higher price-stickiness in the catch-up region due to greater labor-market frictions and a higher ratio of administered prices in the goods market.[50] The exact parameter values are listed in table 5. The results are depicted in the last columns of table 4. Compared to the symmetric case, the policy authorities' losses are higher for region $A$ in a heterogenous monetary union, although the structural parameters remained the same. The reason is a too expansionary policy in region $B$ to which the common central bank reacts to. This implies that monetary policy acts stronger for region $A$ compared to the homogenous case.

The overall ranking of the scenarios for region $A$ is similar to that in the symmetric case. The scenarios in which fiscal policy is dominant (leadership and/or fiscal cooperation scenarios) and the Nash scenario exhibit the highest losses. Remember, in this context, that the joint targeted inflation and output levels are a country-size weighted average of the single countries' preferences when fiscal policies cooperate.

The lowest losses occur if monetary policy moves first or if all policies cooperate. Again, the relatively small losses under monetary dominance are due to the fact that, when monetary policy moves first, fiscal policy makers know that the central bank will not react to a too expansionary fiscal policy. Therefore, fiscal policy itself is more restrained compared to the fiscal leadership scenarios.

For region $B$ we have some changes in the ranking: the three scenarios in which fiscal policies are dominant (cooperation of fiscal policies in a simultaneous game, in a sequential game where fiscal policies move first, and in the scenario where fiscal policies move first but act independently) and the Nash scenario show the highest losses. The reasons for the high losses under the two fiscal cooperation scenarios are easy to explain: As has been discussed for region $A$, the common central bank reacts strongly to fiscal policies by aiming at lower inflation rates. At the same time the fiscal targets, themselves, which are a weighted average of the regions' targets, are more conservative than region $B$'s desired

[50]See Benigno and Lopez-Salido (2004) and Dhyne et al. (2005) for an empirical assessment of this assumption.

levels. Both effects together amount to an even higher loss compared to the one of region $A$.

The lowest losses for the fiscal authority in region $B$ occur under (i) monetary leadership and fiscal cooperation, and (ii) leadership of fiscal policies. In (ii), fiscal policy of region $B$ can follow its own targets best; in (i), fiscal policy makers recognize, again, that they cannot exploit monetary policy to reach their own goals due to the time-sequence of the game and abstain from too expansionary a fiscal policy.

The ranking of the central bank losses correspond again to the rankings of the union-wide social losses by our assumption of a welfare maximizing monetary policy. We, therefore, consider the welfare equivalent consumption losses in the following. A comparison of the social losses under the symmetric and asymmetric case shows that, of course, the region closer to the social optimum achieves generally higher losses when heterogeneities exist. This may underline the meaning of the convergence criteria, which have to be fulfilled by the new European member states before admitted to adopt the Euro.[51]

In our example, the targets of the fiscal policy maker in region $A$ are closer to the social optimum, meaning that fiscal policy is more conservative in region $A$ than in $B$. When comparing the welfare based consumption losses, we find for region $A$ that the losses are higher than for region $B$ in scenarios where fiscal policy is coordinated or/and has a first mover advantage, i. e. in scenarios where fiscal policies have the greatest influence. These are also the scenarios under which the private agents achieve the highest consumption losses in region $B$. The smallest consumption losses occur when monetary policy moves first, leading to equilibria of output and inflation closer to the social optimum, i.e. monetary policy gains a first mover-advantage in these scenarios.

## 4.6 Sensitivity Analysis for Demand-side Policy

Analogously to the procedure in section 4.4, we use a sensitivity analysis to examine whether the results derived in the previous section still hold when the structural param-

[51]We agree that a certain level of (real and nominal) convergence is a necessary requirement for the new EU member states to be able to abstain from an independent monetary policy as a stabilization tool, and to participate successfully in the European Monetary Union. However, the way in which the convergence criteria are used in practice is often debatable. E. g., an economic justification of the strict interpretation of the Maastricht Criteria in the assessment of Lithuania's state of preparation to adopt the Euro by stating that Lithuania has slightly missed the inflation criterion is questionable: the convergence criteria focus primarily on nominal convergence, but this may even hamper real convergence (see for a detailed discussion e.g. Feuerstein and Grimm, 2004 and Siebke et al., 2003).

eters are varied. We begin with varying $a^i$, $b^i$ and $c^i$ for $i = A, B$ simultaneously in both regions. We consider how this affects the rankings of the different scenarios with respect to the fiscal policy makers' and central bank's loss functions. The result is shown in figure 5. After that, we examine how the rankings change, when a parameter is changed in one region while it is kept fixed for the other region. These results are depicted in the figures 6 and 7.

**Identical Variations of Parameters in Both Regions (Figure 5)**

The first obvious result is that the losses in a heterogenous monetary union are higher for almost all scenarios over the whole parameter ranges. A result that we also found for supply-side fiscal policy. The only exception is the cooperation case: Here we reach always the first best for the central bank and, thus, the private agents due to the agreement of all policy makers upon the socially optimal targets. However, if fiscal policies can, instead, enforce (partially) their own targets, the result may not hold any longer and cooperation can have worse outcomes than other scenarios exhibit.

**Identical Variation of Both $a^i$**

Beginning with a more detailed discussion of the different cases, we see that for an increasing $a^i$, which raises the influence of fiscal policies on output, the losses of the central bank and fiscal policy makers decrease in all scenarios except for fiscal cooperation in the symmetric case (=homogenous currency area). We also find that a value of $a^i > 0.6$ leads to relatively small central bank losses in the scenarios where monetary policy has leadership, no matter whether fiscal policies cooperate or not. The opposite is true for the scenarios in which fiscal policies take leadership. The latter case stands in line with the findings of the simulation output discussed in the previous section, where we used $a^i = 0.8$.

In the asymmetric case (=heterogenous currency area), monetary leadership contributes also to small losses when $a^i$ is large for the fiscal policy maker of region $A$, which is the more conservative region: a large $a^i$ facilitates an expansionary fiscal policy in region $B$ to push inflation and output into the desired direction more easily. The central bank reacts with a strong contractionary fiscal policy. Therefore, the fiscal policy maker in country $A$ suffers from too low an inflation.

For region $B$, the Nash scenario and the simultaneous fiscal cooperation scenario show the smallest losses around $a^i = 0.5$; fiscal leadership creates for $a^B > 0.6$ the smallest loss together with monetary leadership when fiscal policies cooperate.

The two scenarios of monetary leadership (with fiscal cooperation and with independently acting fiscal policies) lead to small welfare losses, as the central bank gains a first-mover advantage and is able to implement its policy mostly in line with its targets in these scenarios. Fiscal leadership, the Nash scenario, and fiscal cooperation when fiscal and monetary policies act simultaneously produce the highest central bank losses.

### Identical Variation of Both $b^i$

We, here, consider the pictures in the third and fourth row of figure 5. An increasing $b^i$ together with fiscal authorities' output targets above the socially optimal rate implies a more severe time inconsistency problem of fiscal policies as explained in section 3. Hence, an increasing $b^i$ tends to produce higher policy losses in almost all cases.

In the symmetric case, both monetary leadership scenarios contribute to the smallest losses, whereas the Nash scenario, the fiscal cooperation scenario where fiscal policies move first and where fiscal and monetary policies act simultaneously lead to the highest losses for the fiscal policy makers. The realized losses are of a similar size. This supports the findings of the previous section.

Nearly the same ranking can be observed for the fiscal authority of region $A$ in the heterogenous case, with one exception: the fiscal leadership case creates higher losses. The reason is that the inflation and output targets of region $B$ are above those of the relatively more conservative region $A$. The policy maker in $A$ suffers, therefore, from a too expansionary a fiscal policy in $B$ to which the central bank reacts with a restrictive monetary policy: for region $A$, output is above and inflation below the social optimum.

In contrast, for region $B$ the cooperation scenario and the fiscal cooperation scenario (when all players act simultaneously) produce the highest policy losses. Under the uncoordinated fiscal leadership case the losses are relatively small, because the fiscal authority in region $B$ can follow its own targets most aggressively.

From the viewpoint of the central bank, the monetary leadership scenario, and, interestingly, the fiscal cooperation and monetary leadership scenario lead to the best outcomes for $0 < b^i < 0.8$. This holds as fiscal cooperation dampens the extreme expansionary fiscal policy of country $B$ as the policy maker of $B$ internalizes now the target function of $A$. For a high value of $b^i$ monetary leadership contributes again to the smallest central bank loss besides the joint cooperation scenario.

### Identical Variation of Both $c^i$

The parameter $c^i$ measures the direct impact of fiscal policies on inflation. The graphs in the fifth and sixth row of figure 5 show that a high value of $c^i$ leads to a worse performance of all three fiscal cooperation cases (simultaneous movement, fiscal leadership and monetary leadership).

We find again that in the symmetric case the two monetary leadership scenarios produce relatively small losses for the fiscal authorities for values of $c^i < 0.5$. The highest losses occur under the Nash case, in the simultaneous fiscal cooperation case, and in the fiscal cooperation case where fiscal policies move first (with the exception of $c^i$ close to 1). We have a similar ranking for the central bank losses as in the two former cases: Stackelberg leadership of monetary policy implies the lowest losses, again, besides the joint cooperation scenario.

For a heterogenous monetary union, we observe similar rankings for the losses of the policy maker in region $A$ and the common central bank. Region $B$, in contrast, faces small losses when fiscal policies move first and are uncoordinated.

### Summary of the Findings For Identical Parameter Variations (Figure 5)

The sensitivity analysis has proven that the ranking of the different scenarios with respect to the fiscal policy makers' target function and the central bank's target function (= union-wide social loss function) given in table 4 is relatively stable for variations in $a^i, b^i$ and $c^i$. The main implications, which we have found are summarized in the following:

- Joint cooperation, monetary leadership and monetary leadership with coordinated fiscal policies lead to the lowest central bank losses. This implies also that these three scenarios generate the smallest welfare losses for the private agents.
- The two monetary leadership scenarios contribute also to relatively small losses faced by the fiscal authorities in the case of a homogenous monetary union.
- The two fiscal leadership scenarios (for coordinated and uncoordinated fiscal policies) and the Nash-scenario lead to relatively high losses for both, the fiscal authorities and the central bank, in a homogenous monetary union.
- In a heterogenous monetary union where region $B$ is characterized by a more aggressive inflation and output goal compared to region $A$ and the central bank, fiscal

leadership produces in many scenarios the smallest losses in region $B$, but high losses for the central bank and region $A$.

- For a low value of $a < 0.6$ and a high value of $c > 0.5$, the qualitative results become for several scenarios unstable. However, both $a > 0.6$ and $c < 0.5$ seem to accord best with reality.

**Individual Parameter Variations**

Figures 6 and 7 depict the fiscal and monetary authorities' losses when the parameters $a^A$, $b^A$ or $c^A$ are varied in country $A$, while no changes occur in country $B$. The results are almost in line with the results of figure 5. For the homogenous monetary union, the ranking of the results from table 4 are widely confirmed (see figure 6). For the heterogenous monetary union, the findings of table 4 are confirmed for $a^A < 0.5$ and $c^A > 0.5$ by figure 7.

## 4.7 Nesting of the Results by Dixit and Lambertini

We are able to replicate the qualitative results of Dixit and Lambertini (2001, 2003a, 2003b) in our model, as explained in the following.

Dixit and Lambertini (2001) find that under Nash, $\pi_N^i < \pi_M < \pi_F^i$ and $y_N^i > y_F^i > y_M$, under Monetary Stackelberg $\pi_{STM}^i > \pi_M$ and under Fiscal Stackelberg $y_{STF}^i > y_M$. We obtain the same results if we set $\kappa^i = 0$ for all $i$ and fulfill the conditions stated in equation (7) of that paper.

Dixit and Lambertini (2003b) find that if all authorities share the same output and inflation targets, those targets can be achieved without coordination and no matter how the timing of actions is or whether the output weights are equal or not. We obtain their results by setting $\kappa^i = c^{ij} = 0$ and equalizing the target values $\pi_M = \pi_F^A = \pi_F^B$ and $y_M = y_F^A = y_F^B$.

Dixit and Lambertini (2003a) find that $y_N < y_M \leq y_F$ and $\pi_N > \pi_F \geq \pi_M$. For the Stackelberg scenarios, no clear pattern emerges, as the stochastic terms can change either inequality sign. Furthermore, they simulate and explore the implications for welfare under different discretionary policy scenarios. We replicate their qualitative results by setting $n = 1$ and $\kappa^i = c^{i,j} = a^{ij} = 0$, $c^i < 0$, $\pi_M < \pi_F^A = \pi_F^B$ and $y_M = y_F^A = y_F^B$.

## 5 Conclusion

In this paper we have examined the interactions of fiscal and monetary policies in a monetary union. One main focus of our model was to derive a theoretical model which allows for capturing heterogeneities among the different countries participating in a monetary union, and for analyzing strategic interactions of fiscal and monetary authorities.

Why do heterogeneities matter? It is quite easy to answer this question: with adopting the Euro, the participating countries abstain from an own monetary policy and the fiscal policy remains the only instrument to follow region-specific goals and to stabilize region-specific shocks. The common central bank has to exercise a monetary policy which is most eligible for the whole monetary union, and it cannot respond to idiosyncratic shocks and country-specific political targets. This makes the role of fiscal policies more important and leaves room for strategic behavior to achieve the national goals.

To examine these heterogeneities, we enhanced and modified the model of Dixit and Lambertini (2003b). We elaborated from microfoundation that terms of trade, i. e. inflation differentials, have an impact on regional output.

In our reduced-form framework, elaborated in section 3, we introduced the different scenarios of strategic interactions between fiscal and monetary policies. In this context we presumed that fiscal policies deviate from maximizing regional welfare and aim, instead, at higher inflation and output levels compared to the union-wide central bank. In contrast, monetary policy is assumed to maximize union-wide welfare.

We used simulations to evaluate the different scenarios of strategic behavior, and explored two types of fiscal policies: (i) a supply-side policy in line with the micro-model, where fiscal policies grant subsidies to increase output financed by per-head taxes, and (ii) demand-side policy, where fiscal policies try to push output by raising demand. We, further, considered a heterogenous monetary union with two different regions: a "conservative region" and a "catch-up"-region. We assumed that the desired inflation and output targets of the "conservative region" are relatively closer to the social optimum.

To evaluate the supply-side policy (i), we used a calibration of our micro-model using the parameters from standard economic literature. We have shown that the losses of fiscal policies are relatively small in in the Nash scenario, in the fiscal leadership scenario (for both, cooperation of fiscal policies and independently acting fiscal policies), and when fiscal policies cooperate and all policy makers move simultaneously. In these scenarios, fiscal policies achieve an output-level closest to their preferred levels, whereas inflation is stabilized nearby the socially optimal level by the common central bank.

The losses of monetary policy, which correspond to the welfare losses of the private agents, are lowest when monetary policy moves first. The first best situation is attained when all policy makers agree upon the socially optimal levels. As the central bank and fiscal policy makers, however, consider different scenarios as optimal such an agreement appears to be unrealistic on a voluntary base.

If fiscal authorities exercise a demand-side oriented policy (ii), which accords best with the policies in the EMU, fiscal leadership leads to relatively low losses for the catch-up region. In contrast, monetary leadership produces the lowest losses for the conservative region. If monetary policy moves first, fiscal cooperation would be preferable for the catch-up region, whereas the conservative region prefers to act independently.

From the viewpoint of monetary policy (and welfare), the smallest losses are again attained when monetary policy moves first and, of course, when monetary and fiscal policies agree on the socially optimal level.

In the EMU fiscal policies appear to track primarily national interests. However, the analysis has shown that fiscal policies in a heterogenous monetary union can contribute to high welfare losses under both types of fiscal policies. From a welfare-perspective, monetary leadership or cooperation would then be a desired scenario for both types of fiscal policies.

To summarize, if the authorities' preferences do not coincide or are at least relatively far apart, worse outcomes are likely to occur. In such a case, designing the institutions so that monetary policy occupies a leadership role generates the smallest losses for the agents living in both regions, also with existing heterogeneities.

The European Central Bank aggressively follows the price stability goal, meaning that the inflation rate should not exceed 2%, and seems, therefore, to act as a first mover, which is beneficial for welfare. At the same time, fiscal policies are restricted in their actions by the Stability and Growth Pact, which leaves less room to follow too excessive fiscal targets and implies a reduction of the trade-offs caused by strategic behavior. Recent experience, however, has shown that in bad times meeting the stability criteria may be not highly credible for fiscal policies. Especially, when the culprits judge about their own sanctions as it happened in the European Union. Therefore, to reduce heterogeneities and to bring the fiscal policies targets closer to the socially optimal levels is an essential task to guarantee stability in the EMU for a longer-term horizon.

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Table 1: Calibration of the Baseline Model

| Parameter | Value* | Alternative× | Explanation |
|---|---|---|---|
| *Structural parameters* | | | |
| $n$ | 0.50 | 0.70 | Size of region $A$ |
| $\nu$ | 0.50 | 0.80† | Parameter capturing preference for home goods |
| $\beta$ | 3.22 | 3.22 | One plus one over the elasticity of marginal disutility of labor |
| $\Phi$ | 0.50 | 0.58 | Fraction of firms that cannot adjust prices |
| $\theta$ | 11.00 | 11.00 | Elasticity of substitution between goods |
| $d_i$ | 1.00 | 1.00 | Technology parameter |
| $\eta$ | 0.98 | 0.98 | Subjective discount factor |
| $\bar{\tau}_i$ | -0.10 | -0.10 | Steady state value of taxes |
| *Loss functions* | | | |
| $\theta_M^i$ | 0.00736 | 0.01046 | Central bank's weighting factor for output |
| $\pi_M^i$ | 0.00 | 0.00 | Inflation target of the central bank |
| $y_M^i$ | 0.00 | 0.00 | Output target of the central bank |
| $\theta_F^i$ | 1.00 | 1.25 | Fiscal policy's weighting factor for output |
| $\pi_F^i$ | 0.02 | 0.03 | Inflation target of fiscal policy |
| $y_F^i$ | 0.015 | 0.025 | Output target of fiscal policy |

*Remarks:*

)* The term "Value" denotes the value chosen for both regions in the symmetric case and for region $A$ in the asymmetric case.

)× "Alternative" denotes the value chosen for region $B$ in the asymmetric case.

)† For the heterogeneous case the home-bias parameter is set in both regions equal to 0.8.

Table 2: Baseline Model: Analysis of Welfare and Policy Losses

| | *Symmetric case* | | | | | *Asymmetric case* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Calculated Policy Losses | | | Equivalent Consumption Reduction, % | | Calculated Policy Losses | | | Equivalent Consumption Reduction, % | |
| Policy | $L_{FA}$ | $L_{FB}$ | $L_M$ | $CR_A$ | $CR_B$ | $L_{FA}$ | $L_{FB}$ | $L_M$ | $CR_A$ | $CR_B$ |
| Nash | 21.90936 | 21.90935 | 0.11895 | 0.012 | 0.012 | 23.82412 | 51.16257 | 0.36286 | 0.024 | 0.065 |
| | (0.033) | (0.033) | (0.000) | (0.000) | (0.000) | (0.019) | (0.054) | (0.000) | (0.000) | (0.000) |
| Stackelberg, fiscal leadership | 21.91073 | 21.91072 | 0.11582 | 0.012 | 0.012 | 23.80327 | 51.17020 | 0.35035 | 0.024 | 0.062 |
| | (0.033) | (0.033) | (0.000) | (0.000) | (0.000) | (0.019) | (0.054) | (0.000) | (0.000) | (0.000) |
| Stackelberg, monetary leadership | 23.63918 | 23.63917 | 0.01599 | 0.002 | 0.002 | 33.43925 | 85.52175 | 0.00407 | 0.000 | 0.001 |
| | (0.032) | (0.032) | (0.000) | (0.000) | (0.000) | (0.016) | (0.055) | (0.000) | (0.000) | (0.000) |
| Cooperation | 0.00001 | 0.00001 | 0.00001 | 0.000 | 0.000 | 0.00001 | 0.00001 | 0.00001 | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| ... region-specific policy losses | 31.25024 | 31.25020 | — | — | — | 31.25001 | 101.25024 | — | — | — |
| | (0.125) | (0.125) | | | | (0.063) | (0.193) | | | |
| Fiscal cooperation, simultaneous | 21.90926 | 21.90926 | 0.11848 | 0.012 | 0.012 | 32.02629 | 32.02629 | 0.36256 | 0.024 | 0.065 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.003) | (0.003) | (0.000) | (0.000) | (0.000) |
| ... region-specific policy losses | 21.90927 | 21.90926 | — | — | — | 23.82536 | 51.16177 | — | — | — |
| | (0.033) | (0.033) | | | | (0.019) | (0.054) | | | |
| Fiscal cooperation, fiscal leadership | 21.64560 | 21.64560 | 0.11056 | 0.011 | 0.011 | 32.46600 | 32.46600 | 0.41334 | 0.022 | 0.087 |
| | (0.010) | (0.010) | (0.000) | (0.000) | (0.000) | (0.042) | (0.042) | (0.001) | (0.000) | (0.000) |
| ... region-specific policy losses | 21.64561 | 21.64559 | — | — | — | 23.34691 | 53.74388 | — | — | — |
| | (0.041) | (0.026) | | | | (0.012) | (0.146) | | | |
| Fiscal cooperation, mon. leadership | 31.24131 | 31.24131 | 0.00011 | 0.000 | 0.000 | 52.22477 | 52.22477 | 0.00012 | 0.000 | 0.000 |
| | (0.377) | (0.377) | (0.000) | (0.000) | (0.000) | (0.434) | (0.434) | (0.000) | (0.000) | (0.000) |
| ... region-specific policy losses | 31.24143 | 31.24120 | — | — | — | 31.23737 | 101.19537 | — | — | — |
| | (0.740) | (0.740) | | | | (0.718) | (1.745) | | | |

*Remarks*: $L_{Fi}$ is fiscal loss in region $i$, $L_M$ loss of the common central bank, all multiplied by $10^5$. $CR_i$ denotes welfare loss measured in terms of an equivalent permanent percent reduction in consumption in region $i$. The numbers in parentheses denote standard deviations.

Table 3: Demand-side Policy: Parameter Values in the Symmetric Case

| Parameter | Value | Explanation |
|---|---|---|
| *Output Equation* | | |
| $\bar{y}^i$ | 0 | Natural output level |
| $a^i$ | 0.8 | Effect of fiscal policy on the same region's output |
| $a^{ij}$ | 0.1 | Effect of fiscal policy on the other region's output |
| $b^i$ | 1.0 | Effect of surprise inflation on the same region's output |
| $\kappa^i$ | 0.2 | Terms of trade effect of an inter-regional difference in inflation rates |
| $\sigma_{\phi^i}$ | 0.01 | Variance of regional shocks to output |
| *Inflation Equation* | | |
| $c^i$ | 0.5 | Effect of fiscal policy on the same region's inflation |
| $c^{ij}$ | 0.15 | Effect of fiscal policy on the other region's inflation |
| *Loss Functions* | | |
| $\theta^i_M$ | 0.5 | Central bank's weighting factor for output |
| $\pi^i_M$ | 0.0 | Inflation target of the central bank |
| $y^i_M$ | 0.0 | Output target of the central bank |
| $\theta^i_F$ | 1.3 | Fiscal policy's weighting factor for output |
| $\pi^i_F$ | 0.02 | Inflation target of fiscal policy |
| $y^i_F$ | 0.015 | Output target of fiscal policy |
| $n$ | 0.5 | GDP share of region $A$ on union-wide GDP |

*Remarks:* $i = A, B$, $j = A, B$ and $j \neq i$.

Figure 4: Identical Parameter Variations in Region $A$ and $B$ (Supply-Side Policy)

Symmetric case | Asymmetric case

sym. $L_{FA}$ | sym. $L_M$ | asym. $L_{FA}$ | asym. $L_{FB}$ | asym. $L_M$

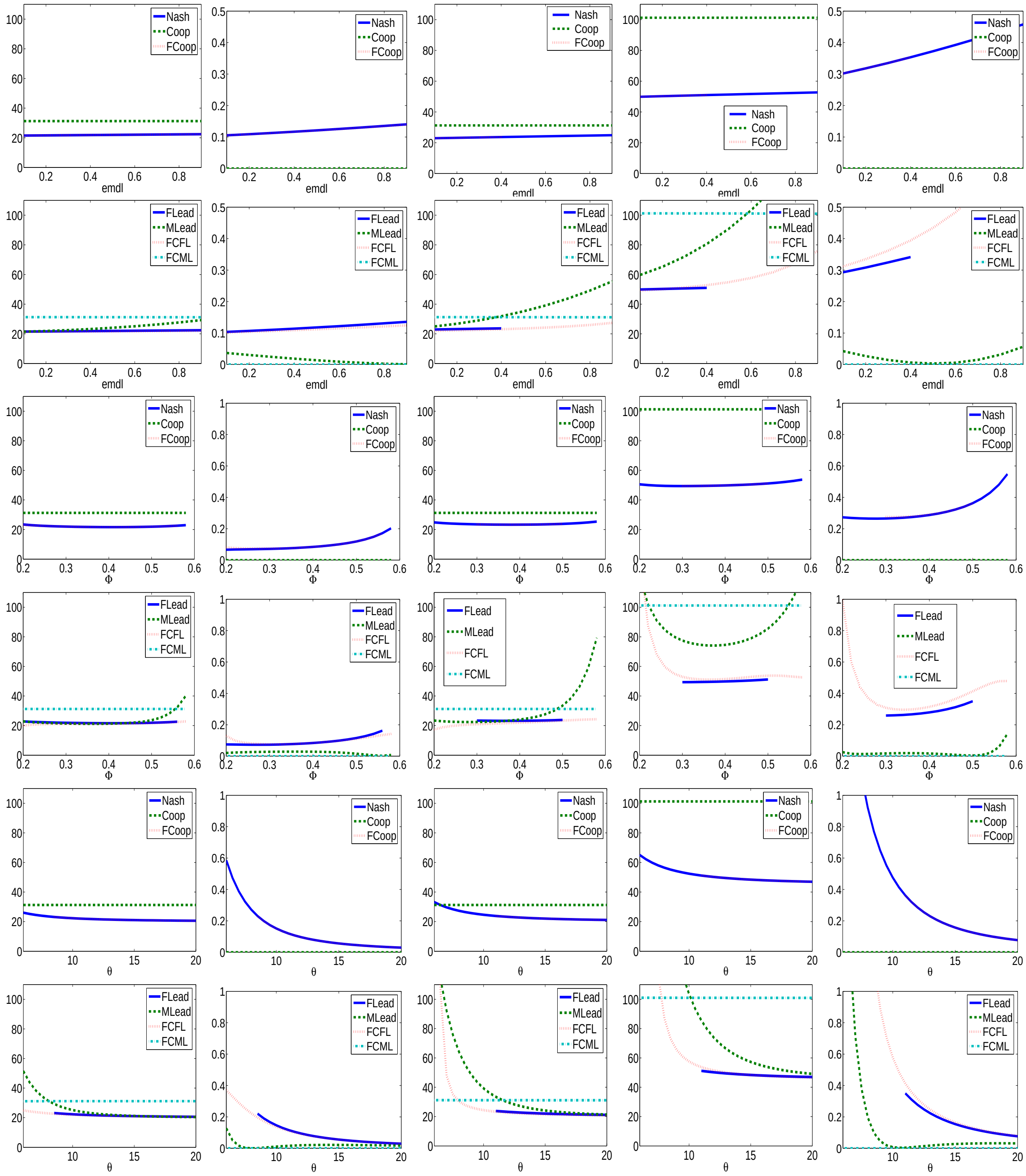

Table 4: Demand-side Policy: Analysis of Welfare and Policy Losses

| | *Symmetric case* | | | | | *Asymmetric case* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Calculated Policy Losses | | | Equivalent Consumption Reduction, % | | Calculated Policy Losses | | | Equivalent Consumption Reduction, % | |
| Policy | $L_{FA}$ | $L_{FB}$ | $L_M$ | $CR_A$ | $CR_B$ | $L_{FA}$ | $L_{FB}$ | $L_M$ | $CR_A$ | $CR_B$ |
| Nash | 59.88023 | 59.88042 | 23.80139 | 2.380 | 2.380 | 96.03430 | 80.34667 | 38.87501 | 4.229 | 3.090 |
| | (0.536) | (0.536) | (0.002) | (0.000) | (0.000) | (0.494) | (1.029) | (0.103) | (0.000) | (0.000) |
| Stackelberg, fiscal leadership | 43.39911 | 43.39928 | 10.66685 | 1.067 | 1.067 | 87.68806 | 36.68796 | 25.13275 | 2.729 | 2.009 |
| | (0.477) | (0.477) | (0.002) | (0.000) | (0.000) | (0.436) | (0.749) | (0.169) | (0.000) | (0.000) |
| Stackelberg, monetary leaders. | 21.78963 | 21.78971 | 1.35417 | 0.135 | 0.135 | 33.64416 | 56.98092 | 1.32407 | 0.037 | 0.355 |
| | (0.229) | (0.229) | (0.002) | (0.000) | (0.000) | (0.172) | (0.415) | (0.057) | (0.000) | (0.000) |
| Cooperation | 0.00103 | 0.00103 | 0.00103 | 0.000 | 0.000 | 0.00109 | 0.00109 | 0.00109 | 0.000 | 0.000 |
| | (0.001) | (0.001) | (0.001) | (0.000) | (0.000) | (0.002) | (0.002) | (0.002) | (0.000) | (0.000) |
| ... region-specific policy losses | 34.62639 | 34.62642 | — | — | — | 34.62549 | 107.50532 | — | — | — |
| | (0.063) | (0.063) | | | | (0.008) | (0.312) | | | |
| Fiscal coop., simultaneous | 60.76041 | 60.76041 | 24.41184 | 2.441 | 2.441 | 90.60180 | 90.60180 | 38.94619 | 4.237 | 3.095 |
| | (0.002) | (0.002) | (0.002) | (0.000) | (0.000) | (0.039) | (0.039) | (0.106) | (0.000) | (0.000) |
| ... region-specific policy losses | 60.76031 | 60.76051 | — | — | — | 98.34502 | 71.62484 | — | — | — |
| | (0.539) | (0.539) | | | | (0.461) | (0.998) | | | |
| Fiscal coop., fiscal leadership | 93.63063 | 93.63063 | 13.33663 | 1.334 | 1.334 | 495.16384 | 495.16384 | 155.18772 | 13.72 | 19.71 |
| | (0.285) | (0.285) | (0.085) | (0.000) | (0.000) | (0.359) | (0.359) | (0.202) | (0.000) | (0.001) |
| ... region-specific policy losses | 93.63037 | 93.63089 | — | — | — | 387.47316 | 781.26691 | — | — | — |
| | (0.369) | (0.591) | | | | (0.347) | (1.386) | | | |
| Fiscal coop., mon. leadership | 19.83643 | 19.83643 | 7.58544 | 0.759 | 0.759 | 32.72155 | 32.72155 | 21.99331 | 1.716 | 3.326 |
| | (0.018) | (0.018) | (0.068) | (0.000) | (0.000) | (0.129) | (0.129) | (0.128) | (0.000) | (0.000) |
| ... region-specific policy losses | 19.83638 | 19.83649 | — | — | — | 36.21712 | 23.29640 | — | — | — |
| | (0.285) | (0.286) | | | | (0.181) | (0.668) | | | |

*Remarks*: $L_{Fi}$ is fiscal loss in region $i$, $L_M$ loss of the common central bank, all multiplied by $10^5$. $CR_i$ denotes welfare loss measured in terms of an equivalent permanent percent reduction in consumption in region $i$. The numbers in parentheses denote standard deviations.

Table 5: Demand-side Policy: Parameter Values in the Asymmetric Case

| Parameter | $i = A$ | $i = B$ | Explanation |
|---|---|---|---|
| *Output Equation* | | | |
| $\bar{y}^i$ | 0 | 0 | Natural output level |
| $a^i$ | 0.8 | 1.0 | Effect of fiscal policy on the same region's output |
| $a^{ij}$ | 0.1 | 0.1 | Effect of fiscal policy on the other region's output |
| $b^i$ | 1.0 | 1.5 | Effect of surprise inflation on the same region's output |
| $\kappa^i$ | 0.2 | 0.2 | Terms of trade effect of an inter-regional difference in inflation rates |
| $\sigma^2_{\phi^i}$ | 0.01 | 0.058 | Variance of regional shocks to output |
| *Inflation Equation* | | | |
| $c^i$ | 0.5 | 0.7 | Effect of fiscal policy on the same region's inflation |
| $c^{ij}$ | 0.15 | 0.15 | Effect of fiscal policy on the other region's inflation |
| *Loss Functions* | | | |
| $\theta^i_M$ | 0.5 | 0.5 | Central bank's weighting factor for output |
| $\pi^i_M$ | 0.0 | 0.0 | Inflation target of the central bank |
| $y^i_M$ | 0.0 | 0.0 | Output target of the central bank |
| $\theta^i_F$ | 1.3 | 2.0 | Fiscal policy's weighting factor for output |
| $\pi^i_F$ | 0.02 | 0.03 | Inflation target of fiscal policy |
| $y^i_F$ | 0.015 | 0.025 | Output target of fiscal policy |
| $n$ | 0.7 | | GDP share of region $A$ on union-wide GDP |

*Remarks:* $i = A, B$, $j = A, B$ and $j \neq i$.

Figure 5: Identical Parameter Variations in Region $A$ and $B$ (Demand-Side Policy)

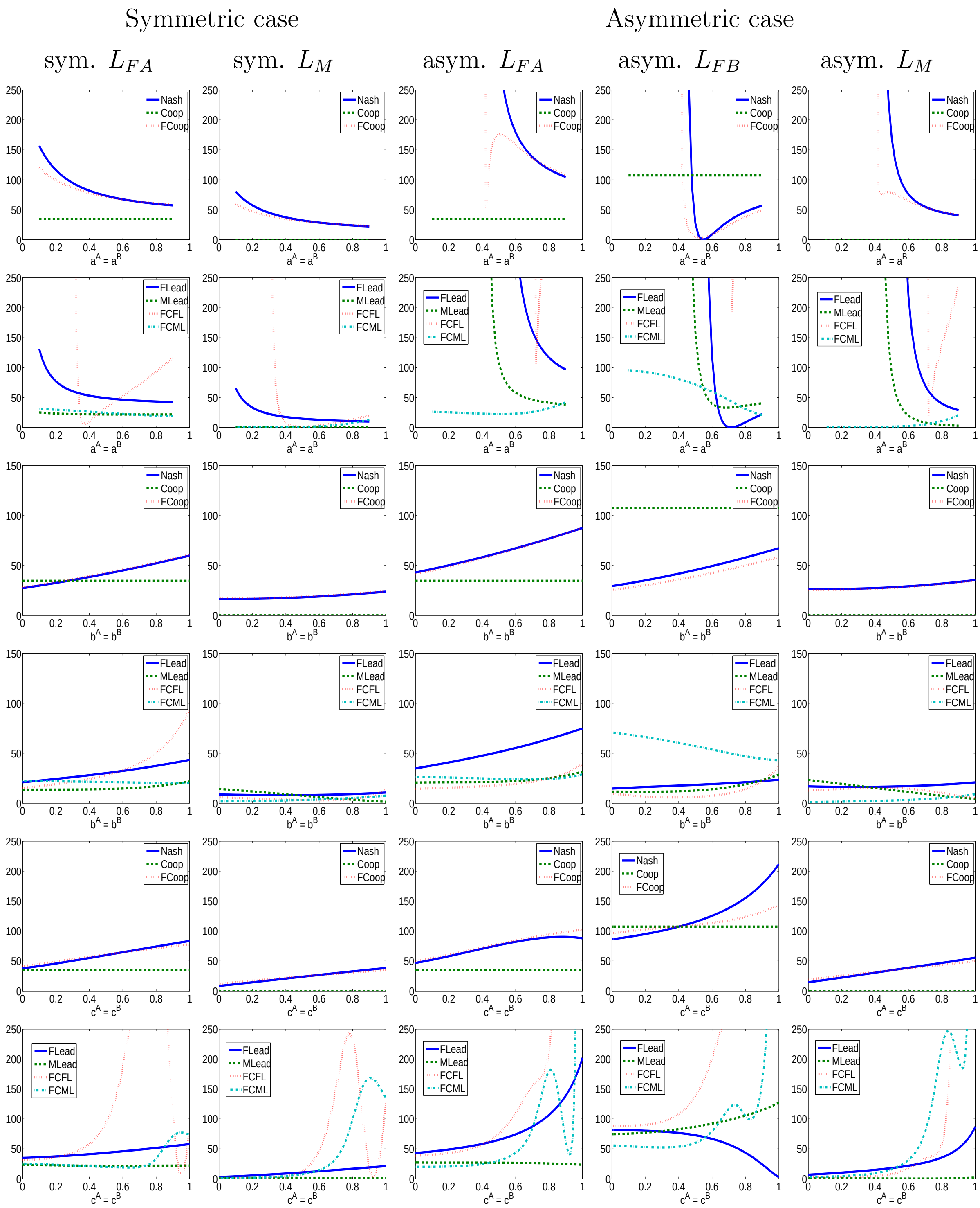

Figure 6: Sensitivity Analysis for Demand-side Policy in the Symmetric Case

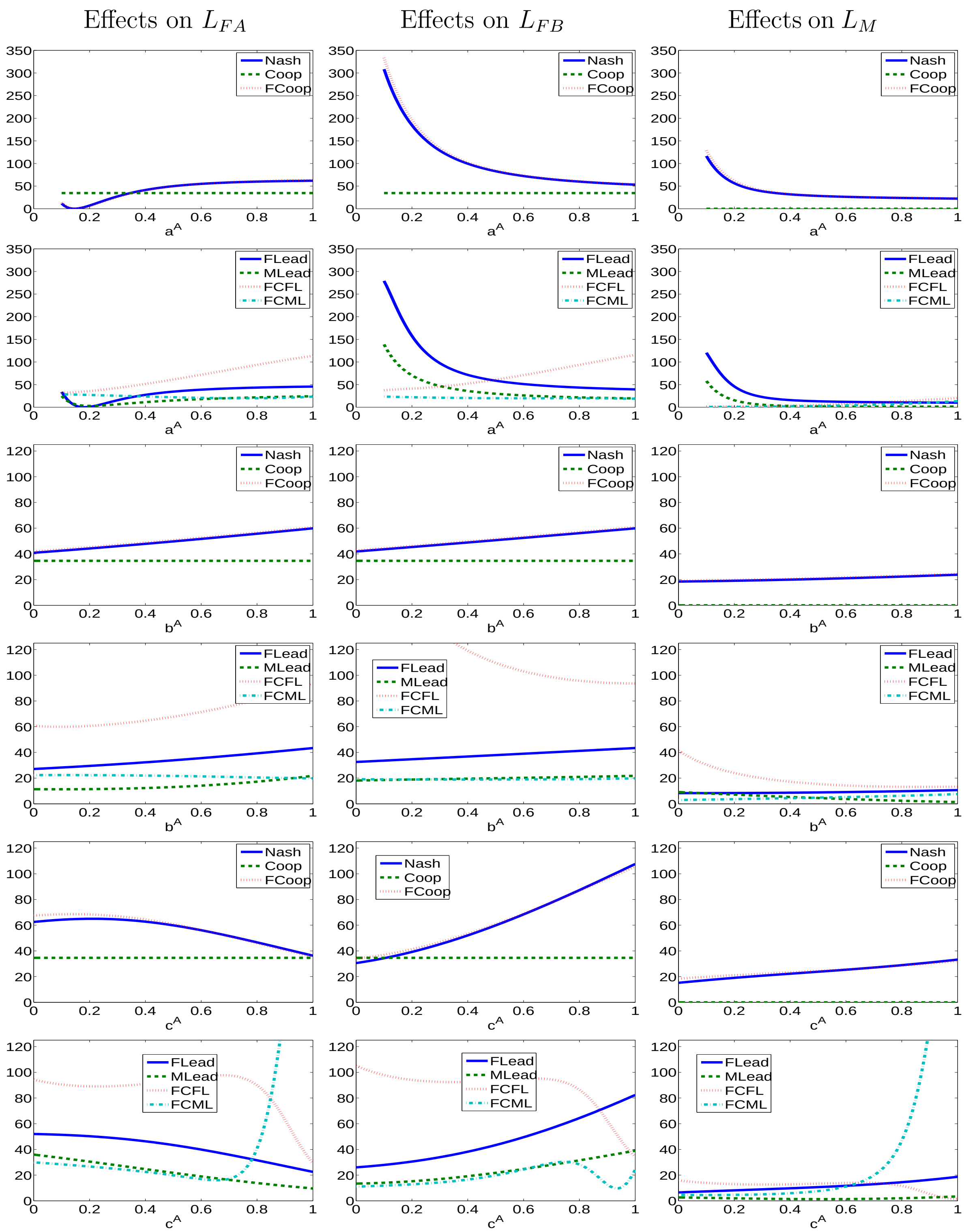

Figure 7: Sensitivity Analysis for Demand-side Policy in the Asymmetric Case