

Essays on Heterogeneity in Fiscal Unions

Vladimir Dashkeev

A dissertation
submitted in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy

University of Washington

2017

Reading Committee:

Stephen Turnovsky, Chair

Oksana Leukhina

Judith Thornton

Program Authorized to Offer Degree:
Economics

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University of Washington

Abstract

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Vladimir Dashkeev

Chair of the Supervisory Committee:
Professor Stephen Turnovsky
Department of Economics

This dissertation investigates the implications of heterogeneity in fiscal unions for risk sharing and the welfare cost of business cycles. Each chapter considers the United States as a fiscal union, with a heterogeneous intergovernmental composition of public goods, in a two-region, open economy DSGE framework. Chapter 1 adds the asymmetry of the regional tax systems into the research framework and demonstrates that the productivity of public goods is the unique parameter that determines the specific type of the welfare-maximizing tax system. Conditional on sufficiently high (low) public good productivity, the cost of business cycles is minimized if the union members collect the consumption (labor income) taxes. Chapter 2 focuses on the state-specific borrowing limits as a source of interregional asymmetry, and shows that the asymmetry of balanced-budget rules is detrimental for the risk sharing in the union. The degree of risk sharing is a function of the public good productivity, specification of the technology process, and distribution of productivity shocks in the fiscal union. Chapter 3 explores how the design of the balanced-budget rules should be altered to increase efficiency in the union. It is shown that by adopting symmetric borrowing limits, the shift of resources between the regions is minimized, which increases efficiency as well as improves risk sharing. The space for policy coordination is explored, and it is shown that the objectives of the regional governments and the federal government do not contradict each other. Moreover, welfare gains associated with the adoption of alternative policies are estimated.

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Acknowledgments

I am indebted to my committee chair, Stephen Turnovsky. Without his guidance and support during my graduate study at the UW, this dissertation would have not been written. Additionally, I am grateful for the efforts of Neil Bruce, Natalie Mizik, Charles Nelson, and Eric Zivot, who supported me at the most challenging moments on my way to the graduation. I also gratefully acknowledge advice and comments of members of my committee, Oksana Leukhina and Judith Thornton, as well as Fabio Ghironi, Alberto Bisin, Yu-chin Chen, Mikhail Dmitriev, Theo Eicher, Luca Guerrieri, Levis Kochin, Pavel Krivenko, David Lagakos, Federico Mandelman, B. Ravikumar, Alexander Rodivilov, Antonio Rodriguez-Lopez, Mu-Jeung Yang, and participants of the Public Economic Theory conference, the Western Economic Association International conference, and Macro, Time Series, and International seminars at the UW.

Dedication

To Nina, Ted, Marina, Vladimir, and Maria.

Chapter 1

Tax Competition and Composition of Public Goods in a Fiscal Union

1.1 Introduction

As a part of the series devoted to the analysis of heterogeneity in fiscal unions, this chapter explores the risk sharing and welfare implications of tax system asymmetries in a fiscal union and considers the space for welfare improvement associated with revenue-neutral tax reforms.

My research question is motivated by the fiscal federalism setup of the United States, which is characterized by a substantial degree of fiscal sovereignty for the union members, as well as by intergovernmental separation of expenditure functions.

The first salient aspect of this study is the focus on the tax systems adopted by the regional governments. If one considers the three largest taxes, in terms of tax revenue, in the U.S. (labor income tax, capital income tax, and consumption tax), one will observe that out of the five largest states, as measured by output, three collect most of their tax revenue from the taxes on labor and capital income (California, New York, and Illinois), while two collect the most from the consumption tax (Texas and Florida). Sometimes states with polar-opposite tax systems are located in immediate proximity to each other. For example, the state of Oregon does not collect a sales tax while Washington State does not impose income taxes.

At the national level, 59% of the U.S. GDP is produced by the states that have a tax system biased in favor of the labor and capital income taxes. The states in which tax revenue composition is tilted toward the consumption tax rather than the capital and labor income taxes generate 23% of the national output.¹ This taxonomy is plotted on Figure 1.1.

The second feature of the paper is the special attention given to the intergovernmental heterogeneity of the public good provision in the U.S. About two-thirds of consumption public goods are provided by the U.S. federal government, while approximately three-fourths of public goods are supplied by its regional authorities. One can conclude from Table 1.1 that such expenditure categories as national defense and parks and recreation are labeled consumption public goods since they increase the utility of households. Economic affairs (infrastructure and utilities) and education increase the productivity of private factors, and hence are referred to as productive public goods.

I approach my research question through the lens of a two-region, open economy DSGE model following [Backus, Kehoe, and Kydland \(1992\)](#), and extend it with the public-sector features of a federal state, in which the provision of consumption and productive public goods receives special attention, as in [Turnovsky and Fisher \(1995\)](#).

The model fiscal union consists of two regions. The regional economies are identical (in terms of their size, technology, and preferences), with the exception of the state-specific tax structures.

In the equilibrium, both regions collect the same amount of the tax revenues and provide an identical quantity of the public goods. One region adopts the consumption tax, while the other collects the labor income tax.² Each region is populated by a repre-

¹This taxonomy attributes states to one type or another once the difference of tax revenue shares generated by these two types of taxes exceeds 15 p.p. Once the threshold is decreased to 5 p.p., the shares become 27.3% and 65.1% correspondingly.

² Regional governments are assumed to set their capital tax rates to zero in the model. I make this simplifying assumption for the benefit of interregional comparisons. Otherwise, the steady-state allocations would no longer be symmetric, albeit the qualitative

sentative household and a representative firm. Labor mobility is prohibited between the regions, but there are no barriers to interregional capital mobility.³

The modeling framework serves the following objectives: to analyze the mechanism of the productivity shock propagation in the union, to study the implications of the tax system heterogeneity in the union for welfare and interregional consumption risk sharing, to identify the welfare-maximizing design of the tax system in the union, and to estimate the potential welfare improvement associated with revenue-neutral tax reforms in the regions.

Notice that the identification of the welfare-maximizing design of the union tax system can be interpreted as a constrained-optimal rather than Ramsey-optimal policy. The former policy restricts the choice of the tax instruments between the consumption tax and the labor income tax, as well as the magnitude of the tax-rate adjustments to maintain the tax-revenue neutrality.

My analysis of the shock propagation in the union shows that the asymmetric tax systems generate heterogeneous allocations in the wake of an aggregate productivity shock and also deteriorate risk sharing in the fiscal union. This result hinges on both the revenue and the expenditure actions of the regional governments. On the revenue side, a region collects higher tax revenues after the realization of a negative shock if it imposes the consumption tax rather than the labor income tax. This is due to the representative household's consumption-smoothing motive that ensures the government's tax-revenue smoothing. From the standpoint of public expenditures, the region in which government collects more tax revenues is characterized by a higher marginal productivity due to the greater supply of region-specific productive public goods.

These two aspects of the regional public finance bring about a shift of resources from

results of the macroeconomic performance analysis would be preserved.

³This modeling framework serves to sharpen the asymmetry of interregional allocations created by heterogeneous regional tax systems and government expenditure composition on the time paths of capital accumulation and welfare.

the less productive region to the more productive one, i.e. from the region that collects the labor income tax to the region that collects the consumption tax. The shift of resources amplifies the interregional marginal productivity differential, creates a wider consumption gap between the regions, and additionally deteriorates interregional consumption risk sharing. In the context of the desirability of the inward shift of resources, this asymmetric design of the regional tax systems can be interpreted as regional tax competition.

Next, taking into consideration uncertainty associated with public good productivity estimates, I analyze risk sharing, conditional on alternative levels of the productivity of public goods, and find that the fluctuations are amplified and risk sharing deteriorates to a greater extent as public good productivity increases.

To identify the welfare-maximizing design of the union tax system, I allow for two alternative regional tax structures and expose them to one-time productivity shock realizations. In the first tax structure, both regions collect the consumption taxes. In the second, they collect the labor income taxes only. First, I find that the adoption of any symmetric tax system improves interregional consumption risk sharing.

Second, I demonstrate that the productivity of public goods is the unique parameter that determines the specific type of the welfare-maximizing tax system. Conditional on sufficiently high public good productivity, the cost of business cycles for the union decreases if its members collect the consumption taxes. Conditional on sufficiently low productivity, imposing the labor income taxes minimizes the union welfare cost. Other aspects of the economy, such as the type of technology process, or the shock type (aggregate or idiosyncratic), do not affect the tax system design. Moreover, in a fiscal union with very low or low public good productivity, the risk sharing improvement is negligibly small.

Related Literature

This study is distinct from the existing body of research by the joint analysis of the tax system asymmetries and the heterogeneous structure of the government expenditures in a multiregional model. The closest framework is adopted in the second chapter of this dissertation, which analyzes the effects of asymmetric borrowing limits adopted by members of a fiscal union, while paying attention to the composition of the government expenditures.

The interregional aspect of the present paper relates to the optimum currency area (OCA) literature. Seminal works of [Mundell \(1961\)](#), [McKinnon \(1963\)](#), and [Kenen \(1969\)](#) provide a theoretical foundation for the monetary and fiscal unification. [Kenen \(1969\)](#), whose work is the most relevant for the fiscal aspect of this study, argues in favor of fiscal integration in the presence of idiosyncratic shocks. In this scenario, a fiscal union can improve risk sharing by the means of intergovernmental transfers. [Mundell \(1961\)](#) and [McKinnon \(1963\)](#), the other fountainheads of the OCA literature, motivated monetary integration by pointing out the benefit of greater stability of the union economies, after a realization of aggregate shocks. Results of the present analysis extend [Kenen's](#) argument for fiscal unification by pointing out that members of a fiscal union can benefit from their participation in the union, conditional on the realization of an aggregate shock scenario.

Recent theoretical studies of fiscal unions continue to analyze the conditions for the unification, from the standpoint of the risk-sharing improvement (see, e.g., [Farhi and Werning \(2014\)](#) and [Dmitriev and Hoddenbagh \(2015\)](#)). However, such analyses are undertaken in symmetric environments, in which aggregate shocks would not yield interesting dynamics and there would be no benefit of fiscal unification in the absence of idiosyncratic shocks. Both studies abstract from asymmetric tax systems adopted by the regional governments as well as from the provision of productive public goods.

This analysis also belongs to the fiscal policy research. Taxation received substantial attention in the optimal fiscal policy literature, starting with the celebrated work of

Ramsey (1927) theoretical studies of the XX century established numerous important results, including the optimality of a zero-capital tax rate (Judd (1987)). However, most of the recent fiscal literature considers constrained-optimal policies that acknowledge the existence of political constraints and do not allow drastic deviations from historical tax regimes.

At the same time, the fiscal policy studies focus on the expenditure side as well. For instance, Turnovsky (2004) considers a unitary state with a heterogeneous composition of public expenditures, and analyzes the effects of alternative fiscal reforms that include both the adjustment of three tax rates and the productive- and consumption-public-goods provision on the economy's welfare and growth. More recently, Wang (2017) considers alternative tax reforms aimed at the decumulation of a substantial stock of debt in a highly indebted country, in which the unitary government provides heterogeneous public goods. Wang's study uses Greece as a motivating example.

Studies of fiscal policy in the open economy framework are becoming more common. Leduc and Wilson (2013) depart from the tradition of modeling the unproductive public expenditures in unitary states. They consider a two-region model of the U.S., with a homogeneous regional tax system and the provision of a productive public good, highway infrastructure. Short- to medium-run effects of the productive-public-good provision generated by their structural model match the empirical responses of the key macroeconomic variables.

Finally, the present study is related to the tax competition literature. For example, Mendoza and Tesar (2005) allow for a wide range of tax instruments in an open economy framework representing the economy of the European Union. They analyze conditions for the race-to-the-bottom tax competition that drives national capital income tax rates to zero. Farhi, Gopinath, and Itskhoki (2014) demonstrate how fiscal-policy actions, such as an increase of the consumption tax combined with decreases of the capital and labor income taxes, can have effects of currency devaluations in an open economy. Langot,

[Patureau, and Sopraseuth \(2012\)](#) continue discussion of tax competition in the fiscal devaluation context and study its implications for unit labor costs, terms of trade, and size of the public sector. [Auray, Eyquem, and Ma \(2017\)](#) identify and quantify positive spillovers from the country that conducts a fiscal devaluation to its neighbors.

The rest of the paper is structured as follows. The next section describes the model's environment and the equilibrium conditions. Calibration is summarized in [Section 1.3](#). In [Section 1.4](#), the effects of temporary, adverse productivity shocks on regional performance are analyzed. Also, to gain further insights into the macroeconomic dynamics in the union, alternative public good productivity levels are considered. [Section 1.5](#) studies welfare and risk sharing in the model economy after the realization of one-time productivity shocks, conditional on alternative types of tax systems adopted by the regional governments. [Section 1.6](#) concludes. [Appendix A.1](#) presents a derivation of the equation for net regional asset accumulation, and [Appendix A.2](#) contains some model results estimated under alternative assumptions about technology process specifications.

1.2 Model

This section starts with the description of the model environment, which augments [Backus et al. \(1992\)](#) to include public-sector features of a federal state. Special attention is paid to the provision of consumption and productive public goods, as in [Turnovsky and Fisher \(1995\)](#). The model economy includes households, firms, and two levels of governance: federal and regional. Its stylized structure is presented in [Figures 1.2 and 1.3](#). After describing the environment, equilibrium conditions for the model economy are derived.

1.2.1 Environment

Consider a federal state that consists of two regions, Region 1 and Region 2. The regional economies are identical in terms of their size, technology, and preferences, with the

exception of fiscal policy. Each region is populated by a representative household and a representative firm. Labor mobility is prohibited between the regions, but there are no barriers to interregional capital mobility.⁴

The government in the federal state consists of two levels. The first level is represented by the Federal government, which collects the capital income tax and the labor income tax from both regions and provides a non-rival public consumption good in return.

Regional governments represent the second level of governance. The governments employ different tax systems: θ^C and θ^L . This notation is designed to reflect the fact that Region 1 (or θ^C region) imposes the consumption tax only, while Region 2 (or θ^L region) imposes the labor income tax only. Regional governments are assumed to set their capital tax rates to zero in the model. I make this simplifying assumption for the benefit of interregional comparisons. Otherwise, the region with a non-zero capital income tax would have a lower equilibrium investment and capital stock, and, therefore, a lower consumption level. Albeit the qualitative results of the analysis would be preserved, such asymmetry would make the regional performance comparison opaque. Each regional government provides a rival productive public good to the local representative firm. Besides the productive public good, the firms employ private capital and labor to manufacture a consumption-investment good that is homogeneous across the regions.

Households

The representative household in Region 1 derives instantaneous utility from private and public consumption goods, C and C_G , according to an isoelastic utility function (1.1). Labor is supplied inelastically and $\gamma > 0$ and $\gamma_G > 0$ are inverses of the intertemporal elasticity of substitution for private and public consumption goods, respectively.

$$\frac{C_t^{1-\gamma}}{1-\gamma} + \frac{C_{G,t}^{1-\gamma_G}}{1-\gamma_G}. \quad (1.1)$$

⁴See footnote 3 for the motivation for such a modeling choice.

Unless otherwise stated, the Region 2 environment is symmetric. In what follows, the Region 2 variables are marked with asterisks.

Firms

The Region 1 representative firm hires labor, L , from its region,⁵ employs private capital stock, K , and uses the stock of region-specific publicly provided physical capital, K_{RG} , to produce the homogeneous consumption-investment good, Y , according to the production function (1.2). The output also depends on the total factor productivity, Z , which is affected by the realization of a technology shock, ϵ .

$$Y_t = Z_t K_t^\alpha \bar{L}^{1-\alpha} (K_{RG,t})^{\alpha_G}. \quad (1.2)$$

Finally, the technology processes of the two regions are related by the following specification:

$$\begin{bmatrix} Z_t \\ Z_t^* \end{bmatrix} = \begin{bmatrix} \phi_Z & \phi_{ZZ^*} \\ \phi_{Z^*Z} & \phi_{Z^*} \end{bmatrix} \begin{bmatrix} Z_{t-1} \\ Z_{t-1}^* \end{bmatrix} + \begin{bmatrix} \epsilon_t \\ \epsilon_t^* \end{bmatrix}.$$

Section 1.3 imposes more structure on the matrix Φ .

Federal Government

The Federal government collects the capital and labor income taxes at uniform rates, τ_K and τ_L^{FG} , from both regions, and exogenously provides the non-rival public consumption good, C_G . The government apportions the procurement of the public good equally between the regions. The federal authorities also impose negative lump-sum taxes on the residents of each region, T_{FG} and T_{FG}^* .⁶ The budget constraint of the Federal government

⁵In representative agent models with an inelastic labor supply, whether a firm hires locally or nationally does not make a difference.

⁶The negative lump-sum taxes have an interpretation of transfers, such as welfare and social security payments.

takes the following form:

$$\tau_K(R_t K_t + R_t^* K_t^*) + \tau_L^{FG}(W_t \bar{L} + W_t^* \bar{L}^*) + T_{FG,t} + T_{FG,t}^* = C_{G,t}. \quad (1.3)$$

Regional Governments

The government of the θ^C region collects the consumption tax, τ_C while the government of the θ^L region collects the labor income tax, τ_L^{RG} , from the residents of their own region and provide a rival productive public good, I_{RG} , to the local representative firm. T_{RG} and T_{RG}^* stand for regional lump-sum taxes.⁷

Poterba (1995) and Sorensen and Yosha (2001) find that, in the case of windfall tax revenues, states change their expenditures little. Instead, they direct their budget surplus to finance their lump-sum transfers.⁸

The provision of public goods by regional governments is thus determined by their current tax revenues and is exogenously capped at the steady-state level, \bar{I}_{RG} . The public budget constraint for the θ^C region takes the following form:

$$\begin{aligned} \tau_C C_t + T_{RG,t} &= I_{RG,t}, \\ I_{RG,t} &= \min\{\tau_C C_t, \bar{I}_{RG}\}, \end{aligned} \quad (1.4)$$

while the budget constraint of the θ^L regional government is expressed as follows:

$$\begin{aligned} \tau_L^{RG} W_t \bar{L}^* + T_{RG,t}^* &= I_{RG,t}^*, \\ I_{RG,t}^* &= \min\{\tau_L^{RG} W_t \bar{L}^*, \bar{I}_{RG}^*\}. \end{aligned} \quad (1.5)$$

⁷The same interpretation as described in Footnote 6 applies to the regional lump-sum taxes.

⁸Also, some states use the unexpected tax revenues to reduce their public debt, which I abstract from in this study.

1.2.2 Equilibrium Conditions

Households

The representative household in the θ^C region maximizes its utility (1.6) by optimally choosing its consumption, investment, and holdings of private bonds, where $\beta \in (0, 1)$ is a subjective discount factor, subject to the constraint (1.7):

$$\max_{C_t, I_t, B_{t+1}} E_t \left[\sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\gamma}}{1-\gamma} + \frac{C_{G,t}^{1-\gamma_G}}{1-\gamma_G} \right) \right] \quad (1.6)$$

s.t.

$$\begin{aligned} & (1 - \tau_K)R_t K_t + (1 - \tau_L^{FG})W_t \bar{L} + (1 + R_{PRI,t})B_t \\ & = (1 + \tau_C)C_t + I_t + B_{t+1} + \frac{\eta}{2}(B_{t+1})^2 + T_{FG,t} + T_{RG,t} + T_{\eta,t}. \end{aligned} \quad (1.7)$$

The constraint states that the household allocates its disposable labor and capital income and returns on its bond holdings among consumption spending, investment in productive private capital, and purchases of the one-period, risk-free private bonds. Since the bonds are risk-free, the asset markets are incomplete. Following [Turnovsky \(1985\)](#), households pay the bond-holding adjustment fees η to financial intermediaries. Quadratic bond-holding adjustment costs ensure the uniqueness of the macroeconomic equilibrium and stationarize the response of the economy to transitory shocks. These fees are rebated to households via T_η . Finally, the household pays lump-sum taxes to, or receives lump-sum transfers from, both levels of government, T_{FG} and T_{RG} .

The representative household of the θ_L region has a symmetric utility function and optimizes it subject to constraint (1.8):

$$\begin{aligned} & (1 - \tau_K)R_t^* K_t^* + (1 - \tau_L^{FG} - \tau_L^{RG})W_t^* \bar{L}^* + (1 + R_{PRI,t})B_t^* \\ & = C_t^* + I_t^* + B_{t+1}^* + \frac{\eta}{2}(B_{t+1}^*)^2 + T_{FG,t}^* + T_{RG,t}^* + T_{\eta,t}^*. \end{aligned} \quad (1.8)$$

The solution to the optimization problems yields the set of Euler equations for the households, (1.9) – (1.10). In the absence of the capital controls, these yield a no-arbitrage condition that equates interest rates on bonds with returns on private capital, adjusted for depreciation and the tax on capital income.

$$(C_t)^{-\gamma} = \beta((1 - \tau_K)R_{t+1} + 1 - \delta)E_t [(C_{t+1})^{-\gamma}], \quad (1.9)$$

$$(1 + \eta B_{t+1})(C_t)^{-\gamma} = \beta(1 + R_{PRI,t+1})E_t [(C_{t+1})^{-\gamma}]. \quad (1.10)$$

The perfect risk-sharing condition (1.11) derived for the economy with complete financial markets states that the marginal utilities across the union regions are perfectly correlated. This expression can be rearranged to show that the ratio of the θ^C household's marginal utility to the θ^L household's marginal utility is constant over time under complete markets. The incomplete markets of this model allow to analyze how the asymmetric tax systems distort risk sharing.

$$\frac{(C_t)^{-\gamma}}{(C_{t+1})^{-\gamma}} = \frac{(C_t^*)^{-\gamma}}{(C_{t+1}^*)^{-\gamma}} \quad (1.11)$$

Finally, to satisfy the intertemporal budget constraint, the household is subject to the transversality (1.12) and no-Ponzi game (1.13) conditions. The former ensures that all capital is used by the end of time and the latter implies that the household cannot finance its consumption indefinitely by borrowing.

$$\lim_{t \rightarrow \infty} \beta^t \lambda_t K_{t+1} = 0, \quad (1.12)$$

$$\lim_{t \rightarrow \infty} \beta^t \lambda_t B_{t+1} = 0, \quad (1.13)$$

where λ refers to the shadow value of consumption.

Firms

The representative firm in Region 1 maximizes its profits, which yields the standard optimality conditions (1.14) and (1.15) that equate the wage and the return to private capital to marginal productivities of labor and capital stock, respectively:

$$W_t = (1 - \alpha)Y_t/\bar{L}, \quad (1.14)$$

$$R_t = \alpha Y_t/K_t. \quad (1.15)$$

The law of motion for private capital stock is standard with $\delta \in (0, 1)$ being the depreciation rate.

$$K_t = I_t + (1 - \delta)K_{t-1}. \quad (1.16)$$

The law of motion for the stock of public capital, K_{RG} , is analogous to that for private capital. Parameter $\delta_G \in (0, 1)$ is the rate of depreciation of public capital stock.

$$K_{RG,t} = I_{RG,t} + (1 - \delta_G)K_{RG,t-1}. \quad (1.17)$$

Aggregation and Interregional Trade

The aggregate national accounting identity (1.18) is obtained by combining budget constraints of the households and the governments. It states that markets clear once national income is used for private consumption and investment, provision of the non-rival consumption public good, and investment in the local productive public goods.

$$Y_t + Y_t^* = C_t + C_t^* + I_t + I_t^* + C_{G,t} + I_{RG,t} + I_{RG,t}^*. \quad (1.18)$$

In a multiregional economy, trade between the regions can occur and, in general, does

not have to be balanced. The trade balance is given by:

$$BOT_t = Y_t - C_t - I_t - 0.5C_{G,t} - I_{RG,t}. \quad (1.19)$$

In the case where one region runs a trade deficit, its representative household issues private debt obligations to finance its private expenditures. Then the equation for the Region 1 net regional asset accumulation takes the following form:⁹

$$\begin{aligned} B_{t+1} - (1 + R_{PRI,t})B_t = & \frac{1}{2}(R_t K_t - R_t^* K_t^*) + \frac{1}{2}(W_t \bar{L} - W_t^* \bar{L}^*) \\ & - \frac{1}{2}(C_t - C_t^*) - \frac{1}{2}(I_t - I_t^*) - \frac{1}{2}(I_{RG,t} - I_{RG,t}^*). \end{aligned} \quad (1.20)$$

Finally, in the two-region economy, private bonds issued by one region are necessarily purchased by another, and hence the bonds are in zero net supply:

$$B_t + B_t^* = 0. \quad (1.21)$$

1.3 Calibration

The model's parameters are calibrated at an annual frequency, and their values are summarized in Table 1.2. The discount factor, β , is set to 0.9615. $\gamma = 2$ is a standard choice for intertemporal elasticity of substitution for private consumption goods. $\gamma_G = 2$ is an analogous parameter for the consumption public good.

The share of national income that accrues to private capital, α , is 0.36, while the remainder accrues to labor. The elasticity of the output with respect to public capital, α_G , implies its productivity,¹⁰ and is difficult to pin down. The original estimate of

⁹By construction, the positive net regional asset position of a given region corresponds to the net positive holdings of assets issued by another region by the residents of the former region. See Appendix A.1 for details.

¹⁰Eicher and Turnovsky (2000) interpret low public good productivity as substantial

this parameter reported by [Aschauer \(1989\)](#), 0.39, exceeds the productivity of private capital. Aschauer’s work spurred numerous empirical studies that generated a broad range of productivity estimates for total public expenditures and its finer components. The sweeping majority of the obtained estimates vary between 0.05 and 0.4, with a consensus that some categories of public expenditures increase private sector productivity more than others. Given the uncertainty about the productivity of public investment, I choose 0.2 as a baseline (medium) value and conduct robustness tests with alternative values of the productivity parameter: 0.05 (very low), 0.1 (low), and 0.3 (high).

The depreciation rate is set to 0.1 for private capital stock and 0.08 for more durable public capital.

The effective tax rates are typically estimated according to one of the alternative methods: the effective marginal tax rates using annual data following [Joines \(1981\)](#) and the effective average tax rates using quarterly series following [Mendoza, Razin, and Tesar \(1994\)](#) and [Jones \(2002\)](#). For instance, using [Jones \(2002\)](#) methodology, [Leeper, Walker, and Yang \(2010\)](#) set their capital income, labor income, and consumption taxes to 38.4%, 21.4%, and 9.5%, correspondingly. Using [Joines \(1981\)](#) approach to calculate effective marginal tax rates, [Pappa \(2009\)](#) sets the capital and labor income tax rates at the maximum of 30% and sets the consumption tax to 5–10% in her model.

Using the above-cited papers as a guide, I set the Federal government’s capital income tax rate, τ_K , to 0.305 and its labor income tax rate, τ_L^{FG} , to 0.24. The θ_C region consumption tax rate, τ_C , is equal to 0.1.

In the θ_L region, the consumption tax is substituted with the labor income tax collected by the regional government, τ_L^{RG} , at the rate of 9.7%. That implies that the consolidated labor income tax rate is equal to 33.7% for the households of this region. Therefore, the labor income tax is set just above the upper boundary of the existing estimates, while the θ_L region does not collect the consumption tax. By the same logic, the

congestion of the public goods.

consumption tax in the θ_C region is set equal to the upper range of the consumption tax rate estimates, since Region θ_C does not collect the labor income tax. Such calibration ensures symmetric tax revenues and public good provision across the regions.

The bond-holding adjustment cost, η , is set to the standard value in the literature, 0.0025.

Varying estimates of exogenous productivity processes exist in the open economy literature that differ in their assessment of the technology persistence and spillovers.¹¹ Hence, I consider two alternative specifications. First, without interregional spillovers and high persistence of shocks, as in [Baxter \(1995\)](#):

$$\begin{bmatrix} \phi_Z & \phi_{ZZ^*} \\ \phi_{Z^*Z} & \phi_{Z^*} \end{bmatrix} = \begin{bmatrix} 0.995 & 0 \\ 0 & 0.995 \end{bmatrix}. \quad (1.22)$$

Second, with spillovers and lower persistence of own shocks, as in [Backus et al. \(1992\)](#):

$$\begin{bmatrix} \phi_Z & \phi_{ZZ^*} \\ \phi_{Z^*Z} & \phi_{Z^*} \end{bmatrix} = \begin{bmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{bmatrix}. \quad (1.23)$$

The technology process without spillovers, eq. (1.22), has the analytical advantage of sharpening the tax competition effects on the dynamics of the endogenous variables, while the other specification is more plausible for the U.S. economy.

Finally, consumption, investment, and government expenditure shares are calibrated to 62.4%, 17.9%, and 19.7% of national output, respectively.¹² I calibrate the share of the consumption public good provided by the federal government and the share of productive

¹¹[Baxter and Farr \(2005\)](#) characterize the task of the parameter estimation for international macro models as follows: “Many researchers have attempted to estimate the parameters of [the productivity] process... It has proved impossible to estimate [its] parameters with much precision...”

¹²The average values for 1977–2000 were calculated from the NIPA Table 1.1. The national output is defined as domestic absorption consistently with the market-clearing condition (1.18).

public goods provided by the regional governments to the corresponding shares of current and capital operations budgets in the national income, 15.3% and 4.4%, respectively. This approach is adopted for a number of reasons. It is consistent with fiscal policy studies that model general government behavior. Moreover, it helps to mitigate the uncertainty regarding the attribution of different types of public expenditures to consumption and productive public goods. First, not all capital expenditures are productive. For example, [Aschauer \(1989\)](#), [Finn \(1993\)](#), and others show little productive effect of national defense expenditures and some smaller categories of government investment. Second, some authors argue that the current expenditures can be productive; for instance, [Evans and Karras \(1994\)](#) emphasize the productive role of current expenditures on education. Such arguments, combined with the fact that current expenditures on education amount to 41% of state expenditures, make it worrisome to dismiss the entire current expenditures category as completely unproductive.

1.4 Transmission of Shocks

Parameters calibrated in the previous section, together with equilibrium conditions from [Section 1.2](#), are used to numerically solve for the unique symmetric steady state. Decision rules and dynamic responses of the endogenous variables to productivity shocks are obtained with the first-order perturbation technique. The choice of the linear solution method is dictated by the compatibility requirements of the [Guerrieri and Iacoviello \(2015\)](#) occasionally binding constraints toolkit.

Using the numerical results, this section focuses on the analysis of the macroeconomic performance of the fiscal union that consists of the θ^C region and the θ^L region, while the former regional government finances its expenditures with the consumption tax, and the latter imposes the tax on labor income. I refer to this type of the fiscal union as θ^{CL} .

In [Section 1.4.1](#), transmission of an aggregate shock is studied conditional on the

most plausible, medium public good productivity. Next, the response of the economy to idiosyncratic disturbances is analyzed in Sections 1.4.2 and 1.4.3. In both cases, technology processes of different types, without and with spillovers, are considered. To gain further insights into the macroeconomic dynamics in the union, alternative public good productivity levels, from very low to high, are considered in Section 1.4.4. Finally, Section 1.4.5 analyzes welfare implications of the tax system asymmetry in the fiscal union, in the context of the alternative public good productivity, technology spillovers, and types of realized productivity shocks.

1.4.1 Aggregate Shock

Regardless of the technology process specification, the model's endogenous variables respond to an aggregate shock in an identical qualitative and almost identical quantitative manner. Figure 1.4 plots the impulse responses for the specification without spillovers.¹³ Most variables are measured as percentage deviations from their respective steady-state levels. Because the equilibrium levels of bonds and balance of trade are equal to zero, their time paths are presented relative to regional output. Interest rate is reported as a percentage.

As the figure suggests, the realization of an aggregate shock in the economies with identical steady states generates asymmetric allocations. Initially, output and wages decline by the same magnitude in both regions, which is directly proportional to the size of the technology shock. Importantly, consumption declines less than wages in both regions, which implies higher tax revenues of the θ^C region's government. Recalling that regional governments provide productive public goods, one can immediately conclude that the asymmetric tax revenues yield a marginal productivity differential. This differential is additionally widened due to the shift of resources from the less productive θ^L region to the more productive θ^C region. Notice that the representative household of the θ^L region

¹³Impulse responses for the specification with spillovers are available on request.

holds a net positive asset position against the θ^C region. Moreover, private investment and capital stock in the θ^L region lag behind those in the other region. The dynamics of the macroeconomic variables have an unfavorable consequence for the union: deterioration of the interregional consumption risk sharing.

1.4.2 Shock to θ^C region

After the realization of region-specific shocks, consumption risk sharing inevitably deteriorates regardless of the presence of spillovers. However, the effects of the idiosyncratic shocks are most evident when technology spillovers are absent. Figure 1.5 illustrates the realization of an adverse productivity shock in the θ^C region. The marginal productivity differential is tilted in favor of the θ^L region, hence resources are shifted to that region from the θ^C region. Output, wages, consumption, and private investment in the θ^L region exceed their respective steady-state levels in the wake of the shock and converge to their long-run values from above.

The opposite is true for the θ^C region macroeconomic variables. Moreover, its post-shock convergence is slowed down by the lower tax revenue and depressed public good provision, which further deteriorates interregional consumption risk sharing.

In the specification with technology spillovers, the negative dynamics of total factor productivity in the θ^C region proliferate to the economy of the θ^L region (Figure A.1). The magnitude of this spilled-over productivity slowdown in the θ^L region is by construction¹⁴ smaller than the original shock that realized in the θ^C region. Hence, risk sharing deteriorates less than in the absence of spillovers.

¹⁴See Equation 1.23.

1.4.3 Shock to θ^L region

Figure 1.6 presents dynamics of the endogenous variables after the realization of a shock in the θ^L region, when interregional technology spillovers are prohibited.¹⁵ Similarly to the scenario of idiosyncratic shocks to the θ^C region, the region directly affected by the shock experiences a contraction and an outward shift of resources. The underprovision of the public goods amplifies the recession and the risk sharing deterioration.

The distinctive feature of the idiosyncratic shock to the θ^L region scenario is the deeper contraction of the regional tax revenues in the region directly affected by the shock. The θ^C region has a more stable tax revenue flow due to the representative household's consumption-smoothing motive. Hence, the marginal productivity of the θ^C region remains higher in the scenario of an idiosyncratic shock to the θ^C region as compared to the marginal productivity of the θ^L region after the realization of a shock in the θ^L region.

1.4.4 Sensitivity to Public Good Productivity

This section explores the sensitivity of macroeconomic dynamics to the assumptions about the public good productivity, and shows that public good productivity is the unique parameter that determines the degree of risk sharing in the fiscal union. As the productivity of public goods increases from low to high, the interregional asymmetry of allocations sharpens (Figure 1.7), and the shift of resources becomes larger. This process holds true in the scenarios of both aggregate and idiosyncratic shocks.

However, the results change conditional on very low productivity of public goods. Consider the aggregate shock realization. Although output is still higher in the θ^C region, as before, the time path of consumption in the θ^L region marginally exceeds that of the

¹⁵As shown in the preceding subsection, risk sharing deteriorates to the greater extent once the technology spillovers are allowed. Figure A.2 presents impulse responses for the case with the technology spillovers.

θ^C region, which translates into modestly higher welfare of the representative household in the θ^L region.

Next, public investment and the stock of public capital in the θ^L region decrease much more sharply than in the θ^C region. However, there is not such a wide interregional gap for private investment. The θ^L region investment time path is just marginally below that of the θ^C region.

Higher tax revenue in the θ^C region does support provision of a higher level of the regional productive public good. Yet, its low productivity does not justify the withdrawal of resources from the private use.

Due to the very low productivity of public capital, the marginal productivity of private capital in the θ^C region (that invests sizably more in the productive public good provision) is just marginally higher. The difference in the rates of return on capital is in the third decimal. The balance of trade peaks at 0.01% of the regional output, that is the shift of resources in response to the interregional productivity differential is immaterial. As Figure A.3 suggests, the fluctuations of the endogenous variables are larger in the specification without spillovers.

To sum up, consumption in the θ^L region exceeds consumption in the θ^C region, albeit the opposite is true for the output of two regions. The extra output produced by the θ^C region is channeled to the provision of the public good with very low productivity. This inefficient behavior determines lower consumption and welfare of the representative household in the θ^C region relative to the θ^L region household. Therefore, conditional on the low public good productivity, the household in the θ^L region enjoys a higher utility level.

1.4.5 Welfare

This section presents the welfare analysis after a one-time, 1% adverse productivity shock realization. I begin with the model specification with technology spillovers that is more

empirically plausible for the U.S. economy.

Consider initially the baseline, medium public good productivity. According to Panel A of Table 1.3, after the realization of an aggregate shock, the interregional consumption differential is equal to 0.11% of lifetime consumption or, equivalently, 9.7% of the θ^C region loss. Panel B reports a consumption differential of 0.39% of lifetime consumption or 92% of the θ^L region's consumption loss after the realization of the shock in the θ^C region only. Finally, when the shock arrives in the θ^L region only, its consumption loss is 0.5 p.p. higher than the θ^C region's consumption loss. These estimates imply that more than 0.1% of lifetime consumption loss is due to the alternative tax systems adopted by the regional governments.

Other columns of Table 1.3 suggest that as the productivity of public goods increases, the risk sharing deteriorates further. Conditional on the realization of an aggregate shock, the interregional consumption differential widens to 0.27% of lifetime consumption. The representative household in the θ^C region withstands the shocks better than the household in the θ^L region. After the realization of region-specific shocks in the θ^C region and the θ^L region, the interregional consumption gap widens to 0.43% and 0.7% of lifetime consumption, correspondingly.

Additionally, as α_G declines to the very low level, the interregional consumption differential shrinks to a half of one-hundredth of 1% of lifetime consumption, conditional on an aggregate shock realization. At the same time, the interregional consumption differential after the realization of idiosyncratic shocks amounts to 0.34%, regardless of the destination of the shock. These results suggest that the interregional tax system differences stop having a substantial impact on regional performance once public good productivity is very low.

In the specification without technology spillovers, the interregional differences are necessarily sharper. The welfare estimates obtained after the realization of an aggregate shock differ between the two technology process specifications by several tenths of a

percentage point of lifetime consumption. The corresponding results are presented in Table A.1.

After the idiosyncratic shocks realization in the economy without technology spillovers, only one region would experience an economic contraction, while the other would benefit from the shift of resources and approach its steady state from above. Consequently, risk sharing deteriorates more substantially with the interregional consumption differential ranging between 1.64% and 2.54% of lifetime consumption. Similarly to the case without spillovers above, the exact value of the welfare differential depends on the productivity of public goods.

1.5 Comparative Performance

This section explores welfare and risk sharing properties of alternative, symmetric tax systems and compares them to the properties of the asymmetric regional tax system θ^{CL} analyzed in Section 1.4. In the fiscal union with the θ^{LL} symmetric tax system, the tax revenues of Region 1 and Region 2 are derived from the labor income taxes. In the union with the θ^{CC} tax system, both regions impose the consumption tax. The transition from any of the three tax systems to another two can be interpreted as a revenue-neutral reform and can serve as a guide for tax competition. I start with the model with spillovers and medium productivity of the public goods before considering alternative public good productivity and technology-process parameterization.

1.5.1 Baseline Public Good Productivity

In the medium productivity of public goods specification, even an aggregate shock generates asymmetric allocations in the θ^{CL} fiscal union. As Table 1.4 reports, the interregional consumption differential is equal to 0.11% of lifetime consumption.

By imposing the labor income tax in both regions, the lifetime consumption loss of

Region 2 (the former θ^L region) would decrease by 0.03%, yet the loss of Region 1 (the former θ^C region) would increase by 0.09%. Although risk sharing improves, the net effect of such tax system reform would be negative, from the θ^{LL} union standpoint as well, and would lead to a loss of 0.06% of aggregate lifetime consumption.

In the case where both regions adopt the tax on consumption, Region 1's (the former θ^C region) lifetime consumption loss following an aggregate shock would increase as well, but by a modest 0.03%. At the same time, the welfare gain of Region 2 would amount to 0.08% of lifetime consumption. Therefore, the θ^{CC} system has an advantage of the union welfare maximization combined with the improved risk sharing, so that the interregional consumption differential disappears. The latter is due to the symmetric provision of the public goods by the regional governments. The uniform provision of the productive public goods across the regions does not create the interregional marginal productivity differential and, hence, does not incentivize the shift of resources.

1.5.2 Alternative Public Good Productivity

The welfare cost of the asymmetric tax system θ^{CL} increases with the public good productivity and reaches 2.88% of lifetime consumption in the model, with $\alpha_G = high$ (Table 1.5). In this case, the interregional consumption differential amounts to 0.27% of lifetime consumption. By switching to the collection of the labor income tax, interregional consumption differential can be closed, but the welfare cost of productivity shocks for the θ^{LL} fiscal union would increase by 0.15% of lifetime consumption. This is due to the underprovision of the public goods becoming costlier as the public good productivity increases.

To the contrary, conducting a revenue-neutral tax reform and substituting the labor income tax in Region 2 with the consumption tax improves the θ^{CC} union welfare by 0.12% of lifetime consumption.

As public good productivity falls, several observations can be made. First, the cost

of the public good underprovision decreases, as measured by the lower welfare cost of the shocks and smaller interregional consumption differentials. Second, conditional on the low public good productivity level, the interregional consumption differential in the asymmetric θ^{CL} union amounts to a moderate 0.03% of lifetime consumption and shrinks to 0.005% of lifetime consumption as the productivity declines to very low. Although tax reforms imposing symmetric tax systems across the regions improve the welfare of each region and of the union, the improvement is quite limited and is in the range of 0.01–0.02% of lifetime consumption.

Lastly, the θ^{CC} fiscal union remains the welfare-maximizing tax system conditional on low-to-high public good productivity, whereas the θ^{LL} union becomes welfare-maximizing once public good productivity drops to very low. Therefore, the welfare-maximizing design of the union tax system is a function of the unique parameter, the productivity of public goods.

The above qualitative conclusions carry over to the specification without technology spillovers. By removing interregional spillovers, the established effects of the tax systems are amplified by up to 0.05% of lifetime consumption.¹⁶ Benefits of the tax reform are higher or, put alternatively, the cost of maintaining the *status quo* asymmetric θ^{CL} tax system is higher in the specification without spillovers.

1.6 Conclusions

In this study, the implications of the tax system asymmetries for the welfare cost of business cycles and interregional consumption risk sharing in a fiscal union were explored, and the welfare-maximizing design of the regional tax systems was identified. The research question was approached through the lens of a two-region, open economy DSGE model

¹⁶The estimates for the specification without spillovers are available per request.

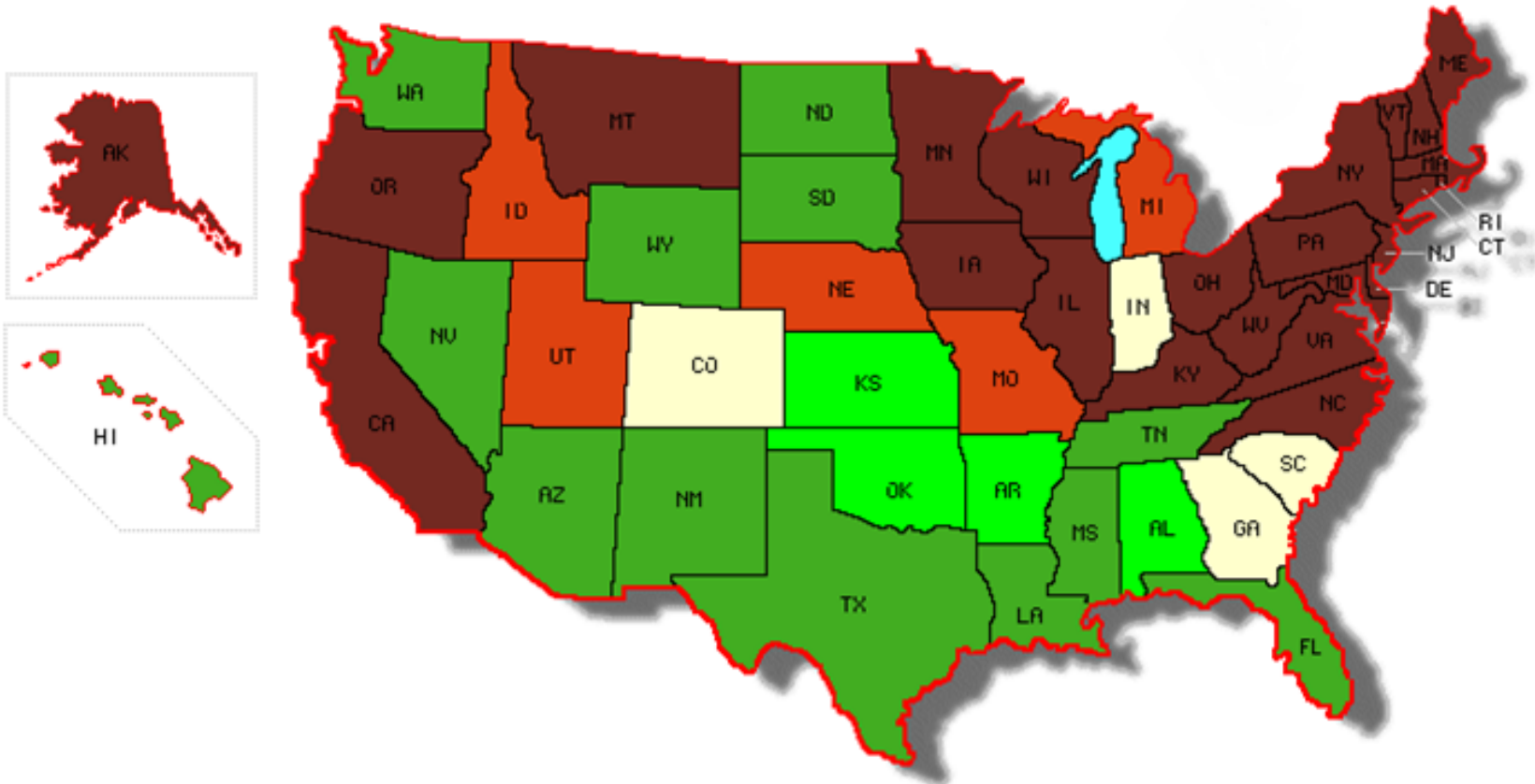
that is augmented with the public-sector features of a federal state.

The unique parameter that determines the tax system design in the fiscal union is the public good productivity. Other aspects of the economy, such as the type of technology process, or the shock type (aggregate or idiosyncratic), do not affect the tax system design. A substitution of the labor tax with the consumption tax by the regional governments decreases the cost of a 1% adverse aggregate productivity shock by 0.12% of lifetime consumption, in the environment with high public good productivity. Conditional on low productivity of the public goods, the welfare benefits are immaterial. If public good productivity is very low, the regional tax reforms substituting the labor income taxes for the consumption taxes can produce limited benefits.

To conclude, this study established adverse effects of the asymmetric tax system for interregional risk sharing in the fiscal union for the empirically plausible range of model parameters. It also serves as an argument for the harmonization of taxes adopted in the fiscal union and the substitution of the consumption tax for the labor income tax.

These welfare estimates are conservative, as the model regions are equally sized, while in reality, the output of the U.S. states that collect most of their tax revenues from the labor income tax is about 2.4 times larger than the output of the states that rely predominantly on the consumption tax. Therefore, the positive effect of the revenue-neutral tax reform would be higher.

Figure 1.1: Tax Systems in the U.S. States.



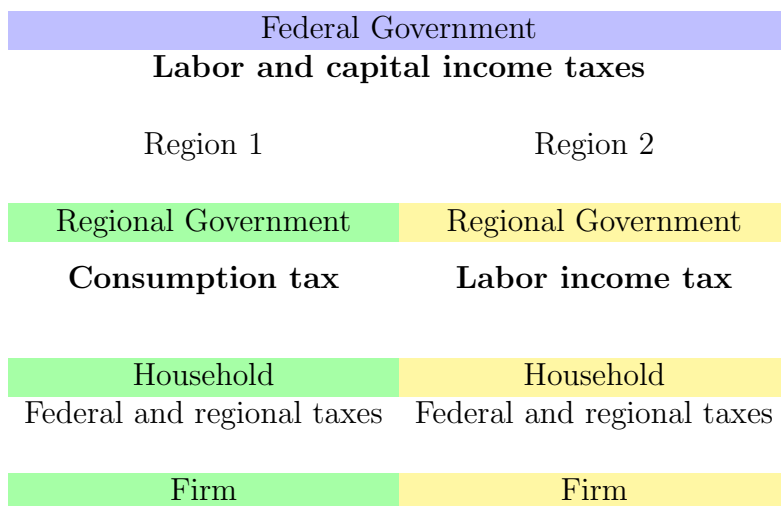
Source: U.S. Census Bureau (2014), data for FY 2013. Note: This classification accounts for labor income taxes, capital income taxes, and consumption taxes, i.e. it ignores property taxes, excise taxes, severance taxes, stock transfer taxes, estate and gift taxes, and other miscellaneous taxes. The brown (dark green) color represents the states with majority of their tax revenues collected from labor and capital income (consumption) taxes, while orange (light green) color represent the states, whose tax revenue is based 5 to 15% more on labor and capital income (consumption) taxes. Yellow color refers to the states with mixed tax revenue.

Figure 1.2: Structure of the model economy. Public expenditures.

Federal Government	
Consumption public good	
Region 1	Region 2
Regional Government	Regional Government
Productive public good	Productive public good
Household	Household
Consumption public good	Consumption public good
Firm	Firm
Productive public good	Productive public good

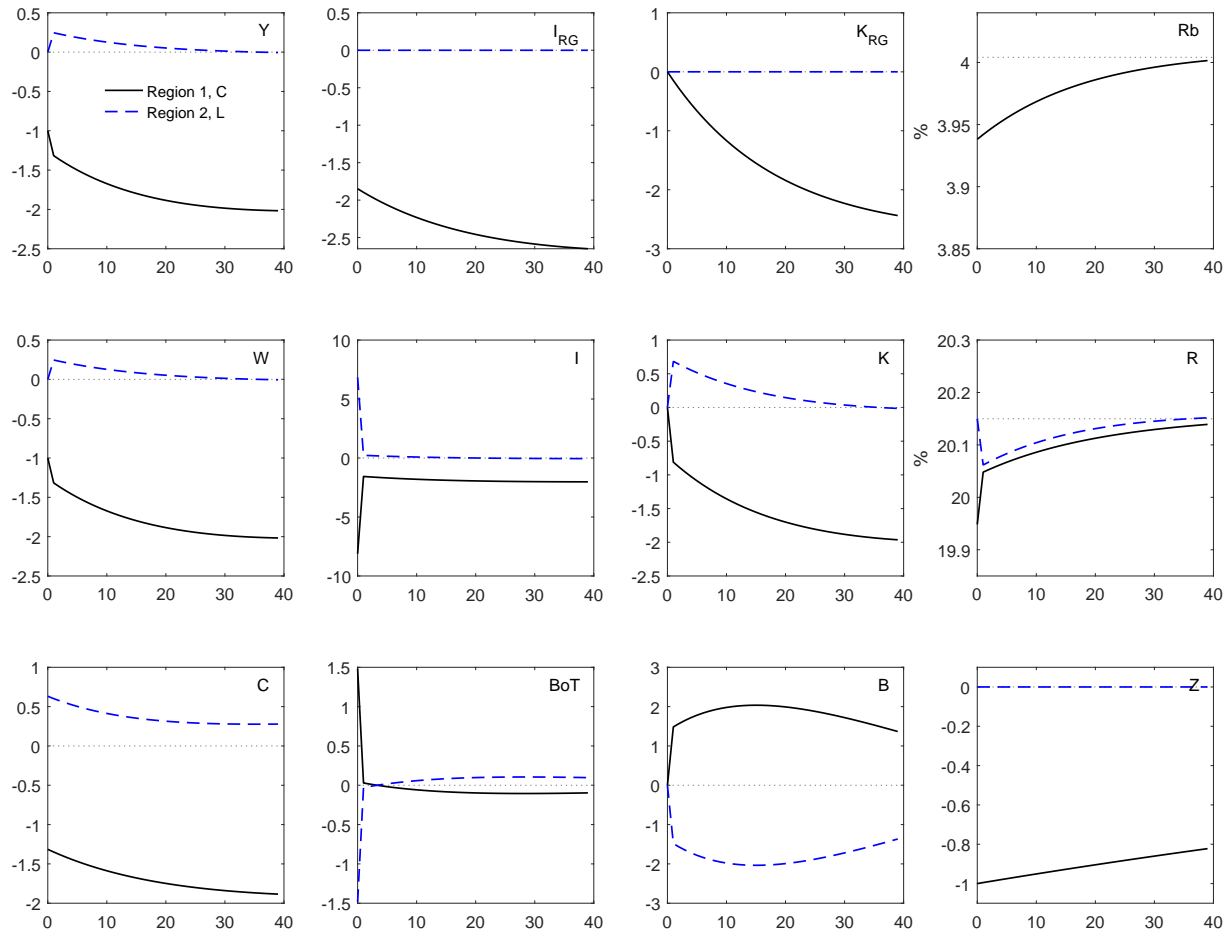
Note: The bold entries refer to the supply of public goods and the regular entries refer to their utilization.

Figure 1.3: Structure of the model economy. Tax system.



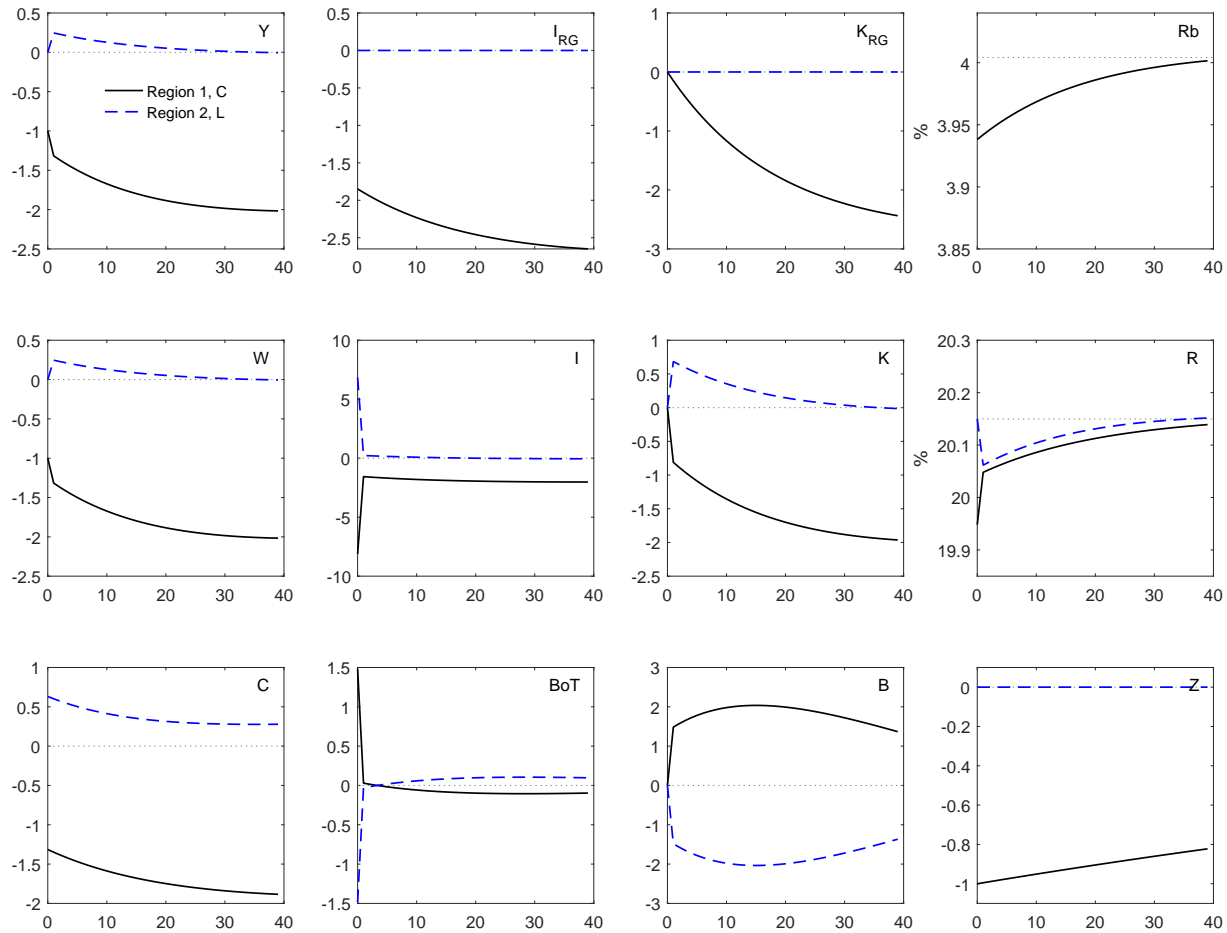
Note: The bold entries refer to the imposed taxes and the regular entries refer to the paid taxes.

Figure 1.4: Responses of the endogenous variables to the aggregate -1% productivity shock.



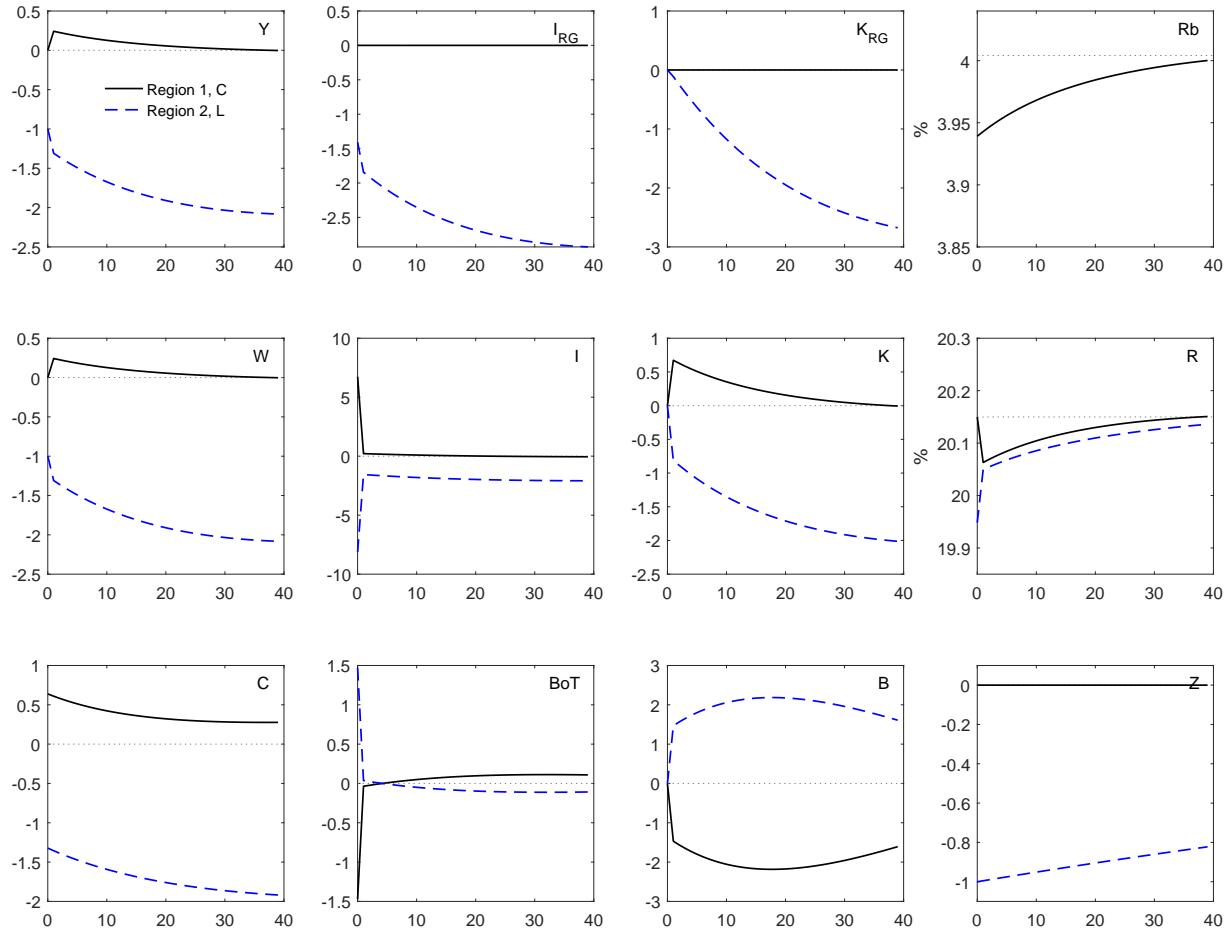
Notes: The fiscal union consists of the θ^C region and the θ^L region. The technology process without spillovers is adopted. The vertical axis measures percentage deviations of the endogenous variables from their respective steady states with the exception of the balance of trade and bonds measured relative to the steady-state output as well as the interest rate measured as percentages. The horizontal axis measures periods after the shock.

Figure 1.5: Response of the endogenous variables to the idiosyncratic -1% productivity shock to the θ^C region.



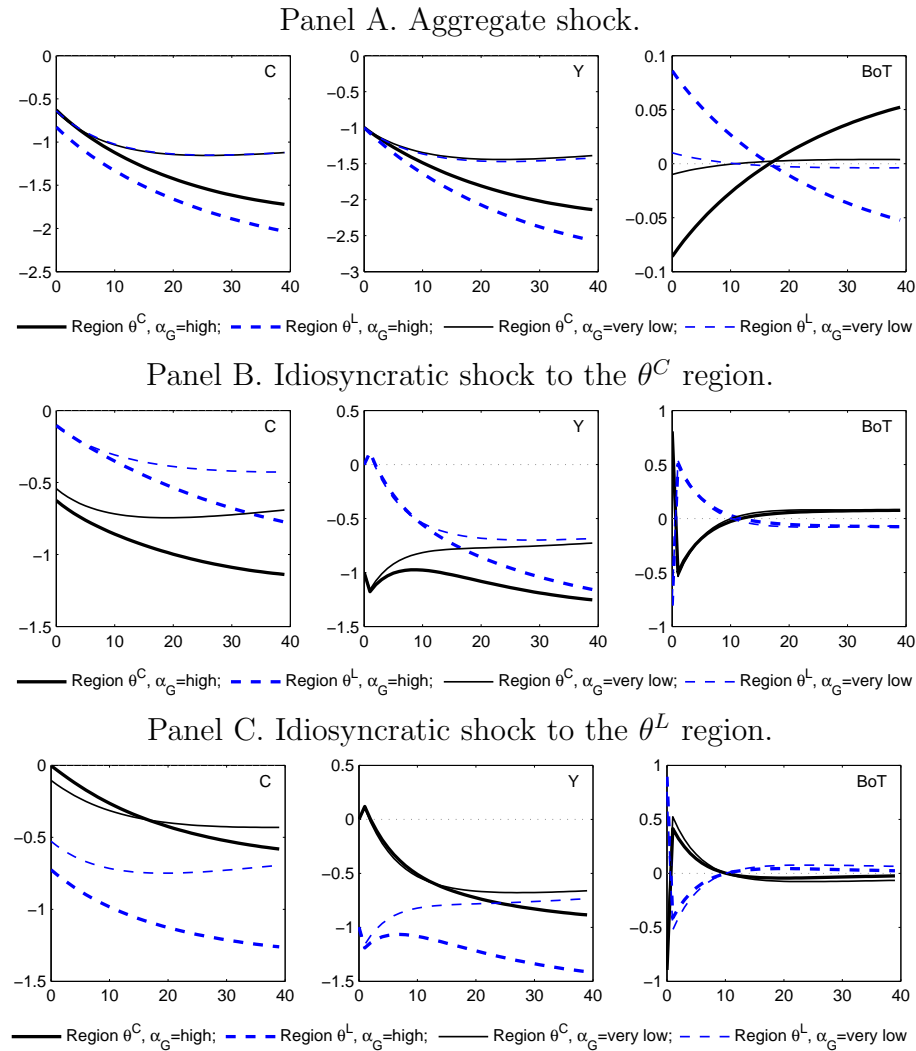
Notes: The fiscal union consists of the θ^C region and the θ^L region. The technology process without spillovers is adopted. The vertical axis measures percentage deviations of the endogenous variables from their respective steady states with the exception of the balance of trade and bonds measured relative to the steady-state output as well as the interest rate measured as percentages. The horizontal axis measures periods after the shock.

Figure 1.6: Response of the endogenous variables to the idiosyncratic -1% productivity shock to the θ^L region.



Notes: The fiscal union consists of the θ^C region and the θ^L region. The technology process without spillovers is adopted. The vertical axis measures percentage deviations of the endogenous variables from their respective steady states with the exception of the balance of trade and bonds measured relative to the steady-state output as well as the interest rate measured as percentages. The horizontal axis measures periods after the shock.

Figure 1.7: Responses of output, consumption, and investment to the -1% productivity shocks under alternative assumptions about the productivity of public goods.



Notes: The fiscal union consists of the θ^C and θ^L regions. The vertical axis measures percentage deviations from the steady state. The technology process with spillovers is adopted. The horizontal axis measures periods after the shock.

Table 1.1: Functional composition of the federal and state government expenditures, 1977–2000, % of general government expenditures.

	Federal expenditures	State expenditures
Total expenditures	47.8	52.2
Consumption public goods	37.8	20.9
National defense	29.9	0.0
General public service	2.1	6.0
Health	3.2	2.6
Housing and community services	0.9	1.2
Income security	0.5	2.3
Public order and safety	1.0	7.7
Recreation and culture	0.2	1.1
Productive public goods	10.0	31.3
Education	0.7	23.8
Economic affairs	9.3	7.5

Source: U.S. National Income and Product Accounts, Section 3.

Note: The data in the table are consistent with the NIPA expenditures approach.

Namely, transfers from the federal government to state governments are included in the expenditures of the federal government and transfers from governments to individuals are not reported as a part of government expenditures.

Table 1.2: Calibrated parameters.

Parameter		Value
Preferences		
β	discount factor	0.9615
γ	inverse of intertemporal elasticity of substitution for private consumption	2
γ_G	inverse of intertemporal elasticity of substitution for public consumption	2
Technology		
α	capital income share	0.36
α_G	elasticity of output with respect to public capital	0.05, 0.1, 0.2, 0.3
δ	rate of depreciation of private capital	0.10
δ_G	rate of depreciation of public capital	0.08
Policy		
τ_K	capital income tax	0.305
τ_L^{FG}	labor income tax, federal	0.24
τ_L^{RG}	labor income tax, regional	0.097
τ_C	consumption tax	0.10
η	bond-holding adjustment cost	0.0025

Table 1.3: Lifetime welfare dynamics under alternative assumptions about the productivity of public goods in the fiscal union, with technology spillovers.

Panel A. Aggregate shock.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in the θ^C region, %	1.004	1.05	1.17	1.31
Loss of lifetime welfare in the θ^L region, %	0.999	1.08	1.29	1.58
θ^C - θ^L loss differential, p.p.	0.005	-0.03	-0.11	-0.27
θ^C - θ^L loss differential as % of the θ^C region loss	0.5	-2.4	-9.8	-20.7
Panel B. Idiosyncratic shock to the θ^C region.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in the θ^C region, %	0.67	0.71	0.81	0.94
Loss of lifetime welfare in the θ^L region, %	0.33	0.36	0.42	0.51
θ^C - θ^L loss differential, p.p.	0.34	1.36	0.39	0.43
θ^C - θ^L loss differential as % of the θ^L region loss	103	100	92	84
Panel C. Idiosyncratic shock to the θ^L region.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in the θ^C region, %	0.33	0.34	0.36	0.36
Loss of lifetime welfare in the θ^L region, %	0.67	0.72	0.86	1.07
θ^L - θ^C loss differential, p.p.	0.34	0.38	0.50	0.70
θ^L - θ^C loss differential as % of the θ^C region loss	101	111	140	193

Notes: The fiscal union consists of the θ^C and θ^L regions. The table entries are calculated using consumption scale factors and have the interpretation of compensating variation measured in terms of private lifetime consumption.

Table 1.4: Comparative performance. Aggregate shocks, Spillovers, $\alpha_G = med.$

Panel A. Lifetime consumption loss, %			
	θ^{CL}	θ^{LL}	θ^{CC}
Region 1	1.17	1.26	1.20
Region 2	1.29	1.26	1.20
Union	2.46	2.51	2.41
Interregional C differential	-0.11	0.00	0.00

Panel B. Lifetime consumption loss relative to CL			
	% θ^{CL}	Relative to CL, p.p.	
		θ^{LL}	θ^{CC}
Region 1	1.17	0.09	0.03
Region 2	1.29	-0.03	-0.08
Union	2.46	0.06	-0.05

Notes: Entries of this table are calculated using consumption scale factors and have interpretation of compensating variation measured in terms of private consumption units.

Table 1.5: Comparative performance. Aggregate shocks, Spillovers, $\alpha_G = high.$

Panel A. Lifetime consumption loss, %			
	θ^{CL}	θ^{LL}	θ^{CC}
Region 1	1.31	1.51	1.38
Region 2	1.57	1.51	1.38
Union	2.88	3.03	2.76
Interregional C differential	-0.27	0.00	0.00

Panel B. Lifetime consumption loss relative to CL			
	% θ^{CL}	Relative to CL, p.p.	
		θ^{LL}	θ^{CC}
Region 1	1.31	0.21	0.07
Region 2	1.57	-0.06	-0.19
Union	2.88	0.15	-0.12

Notes: Entries of this table are calculated using consumption scale factors and have interpretation of compensating variation measured in terms of private consumption units.

Table 1.6: Comparative performance. Aggregate shocks, Spillovers, $\alpha_G = low$.

Panel A. Lifetime consumption loss, %			
	θ^{CL}	θ^{LL}	θ^{CC}
Region 1	1.05	1.07	1.07
Region 2	1.08	1.07	1.07
Union	2.14	2.14	2.13
Interregional C differential	-0.03	0.00	0.00

Panel B. Lifetime consumption loss relative to CL			
	% θ^{CL}	Relative to CL, p.p.	
		θ^{LL}	θ^{CC}
Region 1	1.05	0.01	0.01
Region 2	1.08	-0.01	-0.01
Union	2.14	0.00	0.00

Notes: Entries of this table are calculated using consumption scale factors and have interpretation of compensating variation measured in terms of private consumption units.

Table 1.7: Comparative performance. Aggregate shocks, Spillovers, $\alpha_G = very low$.

Panel A. Lifetime consumption loss, %			
	θ^{CL}	θ^{LL}	θ^{CC}
Region 1	1.00	0.99	1.01
Region 2	1.00	0.99	1.01
Union	2.00	1.99	2.02
Interregional C differential	0.005	0.00	0.00

Panel B. Lifetime consumption loss relative to CL			
	% θ^{CL}	Relative to CL, p.p.	
		θ^{LL}	θ^{CC}
Region 1	1.00	-0.01	0.00
Region 2	1.00	0.00	0.01
Union	2.00	-0.01	0.01

Notes: Entries of this table are calculated using consumption scale factors and have interpretation of compensating variation measured in terms of private consumption units.

Chapter 2

Balanced-Budget Rules and Risk Sharing in a Fiscal Union

2.1 Introduction

Federal states can be classified as fiscal unions with varying degrees of fiscal sovereignty. They range from unions with substantial fiscal freedom for their members, such as the United States, to unions with a powerful centralized supraregional authority, such as Australia.

There are numerous research questions that arise when considering the former structure of governance. This chapter addresses the following one: What are the implications of the asymmetry of balanced-budget rules for the interregional risk sharing in a fiscal union? This question is motivated by two stylized facts about the U.S. as a fiscal union: there are asymmetric public borrowing limits¹ across the U.S. states and there is a heterogeneous structure of government expenditures across different levels of the union government.

The asymmetry of public borrowing limits adopted by state governments is institutionalized as state-specific, balanced-budget rules and presents one of the salient features

¹ From this point on, the terms “balanced-budget rules” and “borrowing limits” are used interchangeably to refer to the set of institutional constraints on the government’s ability to incur a budget deficit.

of the U.S. federal system.² To make an analysis of the balanced-budget rules tractable, the economics profession has classified the states into the following two categories: states with strict balanced-budget rules and those with less stringent rules. This dichotomization is based on the Advisory Commission on Intergovernmental Relations index, [ACIR \(1987\)](#), which takes into account characteristics of the rules in each state.³ According to the accepted taxonomy in the fiscal federalism literature, the states with an ACIR index between 7 and 10 (0 and 6) are classified as those with strict (less stringent) borrowing rules. The latter group consists of 13, mostly large, states ([Figure 2.1](#)). Cumulatively, the states with less stringent balanced-budget rules produced 46.2% of the U.S. GDP between 1977 and 2000.^{4,5} As discussed below, the states' balanced-budget rules have real effects on the states' fiscal policy, especially their stabilization policy over business cycles.

The second inherent aspect of the U.S. fiscal federalism system captured in the present study is the asymmetric provision of different types of public expenditures by the federal government and state governments. Centralization makes it possible to achieve a substan-

²The ability of the federal government to borrow is taken as a given in the present study.

³ The index assumes values from 0 to 10, so that Vermont (the only state without a balanced-budget requirement) is at 0, while the states that require their budgets to be balanced at the end of the budgetary period are at 10. The states receive intermediate values according to other characteristics of their balanced-budget rules, such as provisions for carrying debt over to future budget periods, and if done, then for how long, or whether the borrowing limits are constitutional or statutory. Additional details about the balanced-budget rules in the U.S. are presented in [Appendix B.1](#).

⁴Unless otherwise noted, this study uses 1977–2000 data due to the limited availability of state-level public finance and income series. Annual U.S. Census data start in 1977 and the BEA series for Gross State Product have a break in 2000 due to a transition from the SIC to NAICS.

⁵In line with the literature, Alaska and Hawaii are omitted from the present analysis due to their idiosyncratic characteristics. Alaska has persistent surpluses driven by its small economic size and dependence on oil production, while Hawaii has a unique public education system. Both states have strict balanced-budget rules. The re-estimated share of the cumulative output by the states with less stringent balanced-budget rules changes modestly to 45.7%.

tial economy of scale in the provision of certain consumption public goods, such as national defense. Hence, this function is delegated to the federal authorities. The provision of local, predominantly productive, public goods is usually the responsibility of regional governments, because decentralization is preferable in addressing local needs. The majority of these expenditures are composed of outlays for infrastructure and education-related items.⁶ In the U.S., more than three-quarters of productive public goods are provided by state governments, and over two-thirds of consumption public goods are supplied by the federal government (Table 2.1).

Hence, the U.S. presents a case in point for the study of the asymmetry of borrowing limits in a fiscal union with heterogeneous public goods. To the best of my knowledge, these two empirically relevant forms of heterogeneity – asymmetry of the borrowing limits and of the public goods provision – have not been simultaneously considered in structural form studies.

I investigate my research question in a microfounded, dynamic market-clearing general equilibrium framework. I augment the open economy model by [Backus et al. \(1992\)](#) to include the public-sector features of a federal state, in which the provision of consumption and productive public goods receives special attention, as in [Turnovsky and Fisher \(1995\)](#).

The model federal state consists of two regions: Rigid and Flexible. The regional economies are identical (in terms of their size, technology, and preferences), with the

⁶The term “productive public goods” means different things to different scholars. The seminal work of [Aschauer \(1989\)](#) operates with a narrow definition of productive public goods. It includes only investment in “core infrastructure,” i.e., highways, railroads, seaports, airports, utilities, etc. Such an approach remains popular in the theoretical literature, e.g., [Turnovsky and Fisher \(1995\)](#) or, more recently, [Leeper et al. \(2010\)](#), and [Leduc and Wilson \(2013\)](#).

Yet, a broad definition of productive public goods that includes expenditures that enhance the productivity of the private sector and encourage private investment suggests that Aschauer’s definition should be expanded. For example, models with human capital that treat education as an important factor of development suggest that expenditures on education should be included in the category of productive public goods. See, e.g., [Lucas \(1988\)](#) for a theoretical approach and [Mankiw, Romer, and Weil \(1992\)](#), for an empirical.

exception of fiscal policy, specifically their regional borrowing limits and expenditures. Each region is populated by a representative household and a representative firm. Labor mobility is prohibited between the regions, but there are no barriers to interregional capital mobility.⁷

I employ this framework to analyze the transmission of productivity shocks in the union as well as to study the implications of the asymmetry for welfare and interregional consumption risk sharing.

The analysis of the transmission mechanism of productivity shocks reveals dynamic responses of the union members and shows that the asymmetric balanced-budget rules endogenously create heterogeneous allocations, even in the scenario of aggregate shocks. Therefore, the asymmetric public borrowing limits deteriorate interregional risk sharing. The region without a borrowing limit stabilizes its economy after the adverse shocks faster by attracting resources from the region with the limit.

The intuition for this result merits attention. The driving force of the heterogeneous responses across union members to the aggregate productivity shock in this model is the asymmetric dynamics of the regional public expenditures. After the realization of the shock, the declining supply of the productive public good from the Rigid government combined with the steady supply from Flexible yields interregional differentials of marginal productivities. The interregional marginal productivity ratios are tilted in favor of Flex-

⁷The treatment of regions in this approach serves to sharpen the asymmetry of interregional allocations created by heterogeneous balanced-budget rules. This approach is different from that taken by urban economics (which allows for labor mobility and the asymmetry of technology).

The labor supply is modeled as fixed to contrast the effects of borrowing limits and government expenditure composition on the time paths of capital accumulation and welfare. If not shut down, the negative wealth effect channel would increase the supply of labor and, subsequently, capital stock and output, and then ultimately narrow the regional differences.

Relaxing the assumption of the symmetric technology could either amplify or mitigate the interregional differences induced by the asymmetric fiscal policy. The exact outcome would depend on the direction of the technological asymmetry and the relative productivity of the regions.

ible, which leads to a shift of resources to the more productive jurisdiction in the union and, in turn, deteriorates risk sharing. The state-specific provision of productive public goods dwindles in the region with the restriction on public borrowing, which amplifies the interregional differences. Note that this mechanism is in contrast with standard models, such as [Backus, Kehoe, and Kydland \(1992\)](#), where resources are shifted in response to idiosyncratic shocks.

Finally, I show the crucial role of public goods productivity for risk sharing in the fiscal union. The higher productivity amplifies the fluctuations as the cuts of public productive expenditures have more profound implications for the regional economies' marginal productivity. Then, the Flexible fiscal policy improves well-being of the local representative household, while the Rigid policy makes the Rigid household worse off. As a consequence, risk sharing deteriorates.

On the opposite end of the public good productivity specification, when it is very low, the interregional consumption differential is smaller and the representative household enjoys a higher level of consumption if its regional government adopts the Rigid policy. At first glance, this result might look surprising, as it seems to contradict [Barro's \(1979\)](#) tax-smoothing hypothesis, which implies the optimality of public borrowing.⁸ However, there is no contradiction. Barro's analysis assumes away productive government expenditures. Once productive public goods are modeled explicitly, as in the present study, the optimality of public borrowing is determined by two counteracting forces associated with the provision of productive public goods: an enhanced private-factor productivity due to productive public expenditures, on one hand, and, on the other, decreased private investment and consumption due to the resource-withdrawal effect. Hence, in the case of sufficiently low productivity of public goods, debt financing of public expenditures is

⁸In Barro's model, public borrowing helps to maintain a constant tax rate after a realization of adverse shocks. The government debt eliminates wedges associated with the adjustment of distortionary tax rates. Hence, public debt that is brought about by a budget deficit can be viewed as a byproduct of optimal fiscal policy.

not justified, since the cost of public investment is greater than its benefit, and refraining from public borrowing improves welfare of the local representative household.

Therefore, the degree of risk sharing in the fiscal union is a function of the public good productivity, specification of the technology process, and distribution of productivity shocks in the union.

Related Literature

This analysis sets itself apart from the existing literature by its simultaneous focus on regional integration, the composition of public goods, and balanced-budget rules.

The optimum currency area (OCA) literature provides the theoretical foundation for regional integration. Seminal works, including those of [Mundell \(1961\)](#), [McKinnon \(1963\)](#), and [Kenen \(1969\)](#), motivate integration through the improved ability of the union, rather than individual states, to withstand different types of adverse shocks. [Mundell \(1961\)](#) and [McKinnon \(1963\)](#) argue that monetary unions are optimal in the face of aggregate shocks. However, if the union economy is affected by member-specific shocks, no benefit is accrued from monetary integration. [Kenen \(1969\)](#) points out the desirability of complementing monetary integration with fiscal unification. He supports his argument with the U.S. experience in which transfers from federal to state governments serve as interregional fiscal risk sharing. Results of the present analysis can be interpreted as an extension of [Kenen \(1969\)](#) in that members of a fiscal union can benefit from their membership after a realization of aggregate shocks.

Recent theoretical studies of fiscal unions continue to analyze the conditions for the unification, from the standpoint of the risk-sharing improvement. See, e.g., [Farhi and Werning \(2014\)](#) and [Dmitriev and Hoddenbagh \(2015\)](#). However, such analyses are undertaken in symmetric environments, in which aggregate shocks would not yield interesting dynamics and there would be no benefit of the fiscal unification in the absence of idiosyncratic shocks. Both studies abstract from public borrowing limits as well as

productive public goods.

An empirical fiscal union analysis focuses on the channels of risk sharing. [Asdrubali, Sorensen, and Yosha \(1996\)](#) find that 13% of output shocks are smoothed by the U.S. federal government through taxes, transfers, and grants, while about two-thirds of the shocks are accommodated by capital and credit markets. A similar relative importance of the consumption-smoothing channels is found in other federations, e.g., [Hepp and von Hagen \(2013\)](#) obtain close results for unified Germany. [Sorensen and Yosha \(1998\)](#) examine consumption smoothing in the European Union and find that the transfers among its eight oldest members smooth at most 7% of output shocks.

This study is distinct from debt union literature and from the corollary fiscal common pool problem.⁹ The U.S. states' individual debts are their individual responsibility and states' debts are not guaranteed collectively, as they would have been in the debt union case. Neither does the common pool problem arise in my model, as a given regional government does not have access to another region's tax revenues. Each region relies on its own revenues for provision of the local productive public goods. The supply of the consumption public good is taken by the regional governments as a given, because it is provided by the federal government and financed from the supragovernmental budget.

Structural form studies of the public expenditure composition are few. To the best of my knowledge, all such studies model public expenditures on the part of the general government in a unitary state and without consideration of public borrowing limits. For example, [Turnovsky and Fisher \(1995\)](#) consider heterogeneous public goods. They model both productive and consumption public expenditures and analyze macroeconomic effects of temporary and permanent changes in the expenditures on capital accumulation and

⁹Some economists raised concerns about the fragility of the European Union in the absence of fiscal unification and debt union institutions even before the European sovereign debt crisis unraveled, e.g., [De Grauwe \(2014\)](#) and [Eichengreen \(2010\)](#). [Hallerberg \(2004\)](#) pointed out the fiscal common pool problem in the EMU. The research intensified in the context of the Eurozone crisis, e.g., [Fuest and Peichl \(2012\)](#), [von Hagen \(2014\)](#), and [Aguiar, Amador, Farhi, and Gopinath \(2015\)](#).

welfare.

Leduc and Wilson (2013) depart from the tradition of modeling the general government public expenditure in unitary states. They consider a two-region model of the U.S., with the provision of a productive public good, highway infrastructure. Short- to medium-run effects of the productive public good provision generated by their structural model match the empirical responses of the key macroeconomic variables.

The effects of balanced-budget rules have been previously studied in the context of unitary economies. Stockman (2001) analyzes the potential welfare effects of the balanced-budget rule proposed in 1995 for the U.S. Federal Government. Aiyagari, Marcet, Sargent, and Seppala (2002) focus on the cost of debt service in a unitary economy, in which the government is subject to a borrowing limit. They find that the decrease of a stock of public debt increases welfare and argued for the accumulation of reserves to decrease the costs of future stabilization policies. Azzimonti, Battaglini, and Coate (2010) undertake a study of political economy of balanced-budget rules, explicitly modeling the election process. They find that borrowing limits increase welfare through the elimination of pork-barrel spending.

The rest of the paper is structured as follows. The next section describes the model's environment and the optimality conditions. Calibration is summarized in Section 2.3. In Section 2.4, the effects of temporary, adverse productivity shocks of different types on regional performance are analyzed. Additionally, the implications of public good productivity for risk sharing are considered. Section 2.5 concludes. Appendix B.1 provides additional details about balanced-budget rules in the U.S., Appendix B.2 presents a derivation of the equation for net regional asset accumulation, and Appendix B.3 contains some model results estimated under alternative assumptions about technology process specifications.

2.2 Model

This section starts with the description of the model environment, which augments [Backus et al. \(1992\)](#) to include the public-sector features of a federal state. Special attention is paid to the provision of consumption and productive public goods, as in [Turnovsky and Fisher \(1995\)](#). The model economy includes households, firms, and two levels of governance: federal and regional. Its stylized structure is presented in [Figure 2.2](#). After the environment is described, equilibrium conditions for the model economy are derived.

2.2.1 Environment

Consider a federal state that consists of two regions: Rigid and Flexible. The regional economies are identical in terms of their size, technology, and preferences, with the exception of fiscal policy. Each region is populated by a representative household and a representative firm. Labor mobility is prohibited between the regions, but there are no barriers to interregional capital mobility.¹⁰

The government in the federal state consists of two levels. The first level is represented by the Federal government, which collects capital income and labor income taxes from both regions and provides a non-rival public consumption good in return.

Regional governments represent the second level of governance. Each regional government provides a rival productive public good to the local representative firm in exchange for a consumption tax collected from the residents of its own region. Besides the productive public good, the firms employ private capital and labor to manufacture a consumption-investment good that is homogeneous across the regions.

The households in both regions have access to one-period, risk-free private and public bonds. The public bonds can be issued by both federal and regional authorities. However, region-specific borrowing limits are introduced to ensure the model's consistency with

¹⁰See [footnote 7](#) for the motivation for such a modeling choice.

the stylized facts about heterogeneous balanced-budget rules adopted by the U.S. states. Only one of the regions, Flexible, has the authority to borrow, while the Rigid region has a zero-borrowing limit. Since all types of bonds are risk-free, the asset markets are incomplete.

Households

The representative household in the Rigid region derives instantaneous utility from private and public consumption goods, C and C_G , according to an isoelastic utility function (2.1). Labor is supplied inelastically and $\gamma > 0$ and $\gamma_G > 0$ are inverses of the intertemporal elasticity of substitution for private and public consumption goods, respectively.

$$\frac{C_t^{1-\gamma}}{1-\gamma} + \frac{\overline{C}_G^{1-\gamma_G}}{1-\gamma_G}. \quad (2.1)$$

Unless otherwise stated, the Flexible region's environment is symmetric. In what follows, the Flexible variables are marked with asterisks.

Firms

The representative firm hires labor, L , from its region,¹¹ employs private capital stock, K , and uses the stock of region-specific publicly provided physical capital, K_{RG} , to produce the homogeneous consumption-investment good, Y , according to the production function (2.2). The output also depends on the total factor productivity, Z , which is affected by the realization of a technology shock, ϵ .

$$Y_t = Z_t K_t^\alpha \bar{L}^{1-\alpha} (K_{RG,t})^{\alpha_G}. \quad (2.2)$$

Finally, the technology processes of the two regions are related by the following spec-

¹¹In representative agent models with an inelastic labor supply, whether a firm hires locally or nationally does not make a difference.

ification:

$$\begin{bmatrix} Z_t \\ Z_t^* \end{bmatrix} = \begin{bmatrix} \phi_Z & \phi_{ZZ^*} \\ \phi_{Z^*Z} & \phi_{Z^*} \end{bmatrix} \begin{bmatrix} Z_{t-1} \\ Z_{t-1}^* \end{bmatrix} + \begin{bmatrix} \epsilon_t \\ \epsilon_t^* \end{bmatrix}.$$

Section 2.3 imposes more structure on the matrix Φ .

Federal Government

The Federal government collects capital and labor income taxes at uniform rates, τ_K and τ_L , from both regions, and exogenously provides the non-rival public consumption good, C_G . The government apportions the procurement of the public good equally between the regions. In the absence of any borrowing limits imposed on it, the Federal government issues one-period, risk-free bonds, B_{FG} , that pay the interest rate $R_{FG,t}$ at the beginning of period t . The federal bonds are available for purchase to households of both regions. The federal authorities also impose negative lump-sum taxes on the residents of each region, T_{FG} and T_{FG}^* .¹² The budget constraint of the Federal government takes the following form:

$$\begin{aligned} \tau_K(R_t K_t + R_t^* K_t^*) + \tau_L(W_t \bar{L} + W_t^* \bar{L}^*) + B_{FG,t+1} + B_{FG,t+1}^* + T_{FG,t} + T_{FG,t}^* & \quad (2.3) \\ = \bar{C}_G + (1 + R_{FG,t})B_{FG,t} + (1 + R_{FG,t}^*)B_{FG,t}^* & \end{aligned}$$

Regional Governments

Both regional governments collect consumption taxes at a uniform rate, τ_C , from the residents of their own region and provide a rival productive public good, I_{RG} , to the local representative firm. T_{RG} and T_{RG}^* stand for regional lump-sum taxes.

The regional governments' borrowing limits and hence their budget constraints are region-specific. Their form is based on the findings of the empirical literature that confirm

¹²The negative lump-sum taxes have an interpretation of transfers, such as welfare and social security payments.

the real (and asymmetric) effects of balanced-budget rules across different types of states on their fiscal policy. Using data from the early 1990s, [GAO \(1993\)](#) summarized the states' responses to prospective deficits. In those cases in which the deficit was estimated after the budget had been passed by the legislature, only 4% of the deficit reduction was achieved via revenue increases, while 60% was achieved by sequestration. The remaining 36% of the prospective deficits were accounted for by "adjustment of budget execution," including short-term borrowing.¹³

[Poterba \(1994, 1995\)](#) and [Bohn and Inman \(1996\)](#) confirm that increasing tax revenue is the least common response on the part of state governments to the negative shocks. States with strict balanced-budget rules are less likely to borrow and most often resort to a reduction of their public expenditures. States with less stringent rules rely on borrowing to maintain their public spending at the pre-shock level.

[Bayoumi and Eichengreen \(1995\)](#) show that the cyclical responsiveness of the states is affected negatively by the stringency of their balanced-budget rules. In this sense, the fiscal policy of the states with strict balanced-budget rules amplifies business cycle downturns, and therefore leads to destabilization, while the fiscal policy of those states with less stringent balanced-budget rules mutes economic downturns.

In the case of windfall tax revenues, the behavior of the two types of the states differs as well.¹⁴ Although both groups of the states change their expenditures little during expansions, their use of the unplanned tax revenues varies. The states with strict balanced-budget rules direct the budget surplus to finance lump-sum transfers. At the same time, the states with less stringent balanced-budget rules also use the windfall revenues to reduce their debt burdens.

These facts from the data and empirical studies motivate the construction of the

¹³Besides borrowing, "adjustment of budget execution" refers to a number of temporary measures, including the use of rainy-day funds and various accounting gimmicks, such as interfund transfers and deferrals of payments.

¹⁴See, e.g., [Poterba \(1995\)](#) and [Sorensen and Yosha \(2001\)](#).

model in which the balanced-budget rules have real effects. Thus, using [Poterba's \(1996\)](#) terminology, the present analysis contributes to the “public choice view,” as opposed to the “institutional irrelevance” hypothesis. The former treats institutional constraints as important factors of fiscal policy, while the latter suggests that such limitations can be circumvented effectively and therefore do not affect policymakers’ actions.

The government of the Rigid region has a zero-borrowing limit and the public good provision is thus determined only by current tax revenues of the region and is exogenously capped at the steady-state level, $\overline{I_{RG}}$:

$$\begin{aligned}\tau_C C_t + T_{RG,t} &= I_{RG,t}, \\ I_{RG,t} &= \min\{\tau_C C_t, \overline{I_{RG}}\}.\end{aligned}\tag{2.4}$$

The Flexible region’s government is not constrained by a borrowing limit and therefore can issue one-period, risk-free bonds, $B_{RG F}$, where $RG F$ denotes Flexible Regional Government, to maintain the provision of the productive public good independently of transitory shocks to its revenues, that is at the exogenously predetermined steady-state level. The interest rate $R_{RG F,t}$ is paid to the bondholders at the beginning of the period. The budget constraint of the Flexible government takes the following form:

$$\begin{aligned}\tau_C C_t^* + B_{RG F,t+1} + B_{RG F,t+1}^* + T_{RG,t}^* \\ = \overline{I_{RG}^*} + (1 + R_{RG F,t})B_{RG F,t} + (1 + R_{RG F,t})B_{RG F,t}^*,\end{aligned}\tag{2.5}$$

where $B_{RG F}$ and $B_{RG F}^*$ refer to the bond holdings of the representative households in the Rigid and Flexible regions, correspondingly.

2.2.2 Equilibrium Conditions

Households

The representative household in the Rigid region maximizes its utility (2.6) by optimally choosing its consumption, investment, and holdings of private and public bonds, where $\beta \in (0, 1)$ is a subjective discount factor, subject to the constraint (2.7):

$$\max_{C_t, I_t, B_{t+1}, B_{FG,t+1}, B_{RG F,t+1}} E_t \left[\sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\gamma}}{1-\gamma} + \frac{\bar{C}_G^{1-\gamma_G}}{1-\gamma_G} \right) \right] \quad (2.6)$$

s.t.

$$\begin{aligned} & (1 - \tau_K)R_t K_t + (1 - \tau_L)W_t \bar{L} \\ & + (1 + R_{PRI,t})B_t + (1 + R_{FG,t})B_{FG,t} + (1 + R_{RG F,t})B_{RG F,t} \\ = & (1 + \tau_C)C_t + I_t + B_{t+1} + B_{FG,t+1} + B_{RG F,t+1} + \frac{\eta}{2}(B_{t+1})^2 + \frac{\eta}{2}(B_{FG,t+1})^2 + \frac{\eta}{2}(B_{RG F,t+1})^2 \\ & + T_{FG,t} + T_{RG,t} + T_{\eta,t}. \end{aligned} \quad (2.7)$$

The constraint states that the household allocates its disposable labor and capital income and returns on its bond holdings among consumption spending, investment in productive private capital, and purchases of the bonds. Following [Turnovsky \(1985\)](#), households pay the bond-holding adjustment fees η to financial intermediaries. Quadratic bond-holding adjustment costs ensure the uniqueness of the macroeconomic equilibrium and stationarize the response of the economy to transitory shocks. These fees are rebated to households via T_η . Finally, the household pays lump-sum taxes to, or receives lump-sum transfers from, both levels of government, T_{FG} and T_{RG} .

The solution to the optimization problem yields the set of Euler equations for the Rigid and Flexible households, (2.8) – (2.11). In the absence of the capital controls, these yield a no-arbitrage condition that equates interest rates on all types of bonds with

returns on private capital, adjusted for depreciation and the tax on capital income.

$$(C_t)^{-\gamma} = \beta((1 - \tau_K)R_{t+1} + 1 - \delta)E_t [(C_{t+1})^{-\gamma}], \quad (2.8)$$

$$(1 + \eta B_{t+1})(C_t)^{-\gamma} = \beta(1 + R_{PRI,t+1})E_t [(C_{t+1})^{-\gamma}], \quad (2.9)$$

$$(1 + \eta B_{FG,t+1})(C_t)^{-\gamma} = \beta(1 + R_{FG,t+1})E_t [(C_{t+1})^{-\gamma}], \quad (2.10)$$

$$(1 + \eta B_{RG F,t+1})(C_t)^{-\gamma} = \beta(1 + R_{RG F,t+1})E_t [(C_{t+1})^{-\gamma}]. \quad (2.11)$$

The perfect risk-sharing condition (2.12) derived for the economy with complete financial markets states that the marginal utilities across the union regions are perfectly correlated. This expression can be rearranged to show that the ratio of the Rigid household's marginal utility to the Flexible household's marginal utility is constant over time under complete markets. The incomplete markets of this model allow to analyze how the asymmetric regional borrowing limits distort risk sharing.

$$\frac{(C_t)^{-\gamma}}{(C_{t+1})^{-\gamma}} = \frac{(C_t^*)^{-\gamma}}{(C_{t+1}^*)^{-\gamma}} \quad (2.12)$$

Finally, to satisfy the intertemporal budget constraint, the household is subject to the transversality (2.13) and no-Ponzi game (2.14) conditions. The former ensures that all capital is used by the end of time and the latter implies that the household cannot finance its consumption indefinitely by borrowing.

$$\lim_{t \rightarrow \infty} \beta^t \lambda_t K_{t+1} = 0, \quad (2.13)$$

$$\lim_{t \rightarrow \infty} \beta^t \lambda_t B_{t+1} = 0, \quad (2.14)$$

where λ refers to the shadow value of consumption.

Firms

The representative firm in the Rigid region maximizes its profits, which yields the standard optimality conditions (2.15) and (2.16) that equate the wage and the return to private capital to marginal productivities of labor and capital stock, respectively:

$$W_t = (1 - \alpha)Y_t/\bar{L}, \quad (2.15)$$

$$R_t = \alpha Y_t/K_t. \quad (2.16)$$

The law of motion for private capital stock is standard, with $\delta \in (0, 1)$ being the depreciation rate.

$$K_t = I_t + (1 - \delta)K_{t-1}. \quad (2.17)$$

Federal Government

In order to rule out the explosion of public debt, a fiscal feedback rule is introduced.¹⁵ I adopt the rule from [Erceg, Guerrieri, and Gust's \(2006\)](#) SIGMA model, which relates the budget-deficit-to-output ratio to the debt-to-output ratio. The rule for the federal debt held by residents of the Rigid region takes the following form:

$$\frac{T_{FG,t}}{Y_t} = \frac{T_{FG,t-1}}{Y_{t-1}} + \iota_{st} \left(\frac{B_{FG,t+1}}{Y_t} - \frac{B_{stst}}{Y_{stst}} \right) + \iota_{gr} \left(\frac{B_{FG,t+1}}{Y_t} - \frac{B_{FG,t}}{Y_{t-1}} \right), \quad (2.18)$$

where parameter $\iota_{gr} \in (0, 1)$ determines the speed of the debt adjustment, which increases with ι_{gr} , parameter $\iota_{st} \in (0, 1)$ determines the cyclicity of the adjustment, and the variables with the subscript *stst* refer to their steady-state values.

The adjustment rule for the federal debt held by residents of the Flexible region is symmetric.

¹⁵A discussion of the necessity of the fiscal feedback rule for determinacy of equilibrium and model stability can be found in [Aiyagari et al. \(2002\)](#).

Regional Governments

Similarly to the federal government's case, an analogous fiscal feedback rule restricts the accumulation of the regional public debt (2.19). Since only Flexible does not have a borrowing limit, only one regional rule is necessary. The rule applies to the bonds issued by the government of the Flexible region and held by households in both the Flexible and Rigid regions:

$$\frac{T_{RG,t}^*}{Y_t^*} = \frac{T_{RG,t-1}^*}{Y_{t-1}^*} + \iota_{st} \left(\frac{B_{RG F,t+1} + B_{RG F,t+1}^*}{Y_t^*} - \frac{B_{RG F stst}}{Y_{stst}^*} \right) \quad (2.19)$$

$$+ \iota_{gr} \left(\frac{B_{RG F,t+1} + B_{RG F,t+1}^*}{Y_t^*} - \frac{B_{RG F,t} + B_{RG F,t}^*}{Y_{t-1}^*} \right). \quad (2.20)$$

The law of motion for the stock of public capital, K_{RG} , is analogous to that for private capital. Parameter $\delta_G \in (0, 1)$ is the rate of depreciation of public capital stock.

$$K_{RG,t} = I_{RG,t} + (1 - \delta_G)K_{RG,t-1}. \quad (2.21)$$

Aggregation and Interregional Trade

The aggregate national accounting identity (2.22) is obtained by combining budget constraints of the households and the governments. It states that markets clear once national income is used for private consumption and investment, provision of the non-rival consumption public good, and investment in the local productive public goods.

$$Y_t + Y_t^* = C_t + C_t^* + I_t + I_t^* + \overline{C_G} + I_{RG,t} + \overline{I_{RG}^*}. \quad (2.22)$$

In a multiregional economy, trade between the regions can occur and, in general, does not have to be balanced. The trade balance is given by:

$$BOT_t = Y_t - C_t - I_t - 0.5\overline{C_G} - I_{RG,t}. \quad (2.23)$$

In the case where one region runs a trade deficit, its representative household issues private debt obligations to finance its private expenditures. Then the equation for the Rigid net regional asset accumulation takes the following form:¹⁶

$$B_{t+1} - (1 + R_{PRI,t})B_t = \frac{1}{2}(R_t K_t - R_t^* K_t^*) + \frac{1}{2}(W_t \bar{L} - W_t^* \bar{L}^*) - \frac{1}{2}(C_t - C_t^*) - \frac{1}{2}(I_t - I_t^*) - \frac{1}{2}(I_{RG,t} - \bar{I}_{RG}^*). \quad (2.24)$$

Finally, in the two-region economy, private bonds issued by one region are necessarily purchased by another, and hence the bonds are in zero net supply:

$$B_t + B_t^* = 0. \quad (2.25)$$

2.3 Calibration

The model's parameters are calibrated at an annual frequency, and their values are summarized in Table 2.2. The discount factor, β , is set to 0.9615. $\gamma = 2$ is a standard choice for intertemporal elasticity of substitution for private consumption goods. $\gamma_G = 2$ is an analogous parameter for the consumption public good.

The share of national income that accrues to private capital, α , is 0.36, while the remainder accrues to labor. The elasticity of the output with respect to public capital, α_G , implies its productivity,¹⁷ and is difficult to pin down. The original estimate of this parameter reported by [Aschauer \(1989\)](#), 0.39, exceeds the productivity of private capital. Aschauer's work spurred numerous empirical studies that generated a broad range of productivity estimates for total public expenditures and its finer components.

¹⁶By construction, the positive net regional asset position of a given region corresponds to the net positive holdings of assets issued by another region by the residents of the former region. See Appendix B.2 for details.

¹⁷[Eicher and Turnovsky \(2000\)](#) interpret low public good productivity as substantial congestion of the public goods.

The sweeping majority of the obtained estimates vary between 0.05 and 0.4, with a consensus that some categories of public expenditures increase private sector productivity more than others. Given the uncertainty about the productivity of public investment, I choose 0.2 as a baseline (medium) value and conduct robustness tests with alternative values of the productivity parameter: 0.05 (very low), 0.1 (low), and 0.3 (high).

The depreciation rate is set to 0.1 for private capital stock and 0.08 for more durable public capital. The capital income tax rate, τ_K , is set to 0.305, the labor income tax, τ_L , is 0.24, and the consumption tax rate, τ_C , is 0.1. The speed of public debt adjustment, ι_{gr} , is chosen following the SIGMA model and is equal to 0.1. The bond-holding adjustment cost, η , is set to the standard value in the literature, 0.0025.

Next, the bivariate exogenous productivity process has to be parameterized. [Baxter and Farr \(2005\)](#) characterize the task of the parameter estimation for open economies as follows:

Many researchers have attempted to estimate the parameters of [the productivity] process... It has proved impossible to estimate [its] parameters with much precision...

Having this statement in mind, I allow for two types of technology processes to capture the most probable range of the parameter estimates:

First, without interregional spillovers and high persistence of shocks, as in [Baxter \(1995\)](#):

$$\begin{bmatrix} \phi_Z & \phi_{ZZ^*} \\ \phi_{Z^*Z} & \phi_{Z^*} \end{bmatrix} = \begin{bmatrix} 0.995 & 0 \\ 0 & 0.995 \end{bmatrix}. \quad (2.26)$$

Second, with spillovers and lower persistence of own shocks, as in [Backus et al. \(1992\)](#):

$$\begin{bmatrix} \phi_Z & \phi_{ZZ^*} \\ \phi_{Z^*Z} & \phi_{Z^*} \end{bmatrix} = \begin{bmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{bmatrix}. \quad (2.27)$$

Notice that the former technology process, eq. (2.26), by abstracting from spillovers between the regions, can serve to sharpen the effects of public borrowing limits on macroeconomic dynamics.

Finally, consumption, investment, and government expenditure shares are calibrated to 62.4%, 17.9%, and 19.7% of national output, respectively.¹⁸ I calibrate the share of the consumption public good provided by the federal government and the share of productive public goods provided by the regional governments to the corresponding shares of current and capital operations budgets in the national income, 15.3% and 4.4%, respectively. This approach is adopted for a number of reasons. It is consistent with fiscal policy studies that model general government behavior. Moreover, it helps to mitigate the uncertainty regarding the attribution of different types of public expenditures to consumption and productive public goods. First, not all capital expenditures are productive. For example, [Aschauer \(1989\)](#), [Finn \(1993\)](#), and others show little productive effect of national defense expenditures and some smaller categories of government investment. Second, some authors argue that the current expenditures can be productive; for instance, [Evans and Karras \(1994\)](#) emphasize the productive role of current expenditures on education. Such arguments, combined with the fact that current expenditures on education amount to 41% of state expenditures, make it worrisome to dismiss the entire current expenditures category as completely unproductive.

2.4 Analysis of Shocks in the Union

Parameters calibrated in the previous section, together with equilibrium conditions from Section 2.2, are used to numerically solve for the unique symmetric steady state. Decision rules and dynamic responses of the endogenous variables to productivity shocks

¹⁸The average values for 1977–2000 were calculated from the NIPA Table 1.1. The national output is defined as domestic absorption consistently with the market-clearing condition (2.22).

are obtained with the first-order perturbation technique. The choice of the linear solution method is dictated by the compatibility requirements of the [Guerrieri and Iacoviello \(2015\)](#) occasionally binding constraints toolkit.

Using the numerical results, this section investigates how the asymmetric public borrowing limits affect transmission channels of productivity shocks in the fiscal union, checks the sensitivity of results to the productivity of public goods, analyzes welfare effects of the shocks, and reports moments of the simulated data.

For these purposes, this section focuses on the one-time orthogonal adverse productivity shocks that realize in both regions (Section [2.4.1](#)) or in one region only (Sections [2.4.2](#) and [2.4.3](#)). To sharpen the effects of borrowing limits on macroeconomic dynamics, Section [2.4.2](#) starts by abstracting from possible spillovers between the regions. After the intuition for the transmission of shocks is established, I allow for technology spillovers between the regions in Section [2.4.3](#). The latter brings the analysis closer to reality. Each productivity shock amounts to a negative 1%.

Up to this point, the medium productivity of public goods was assumed. Section [2.4.4](#) presents the analysis of the implications of public good productivity for risk sharing before turning attention to the analysis of numerical estimates of welfare (Section [2.4.5](#)).

2.4.1 Aggregate Shock in Absence of Spillovers

Figure [2.3](#) illustrates the dynamic response of the model economy without technology spillovers in the scenario of an aggregate adverse productivity shock.¹⁹ I start with the analysis of the public sector dynamics, which drive this model's results. On impact of the shock, all types of tax revenues (consumption, capital income, and labor income) decline in both regions as their corresponding tax base contracts (consumption expenditures, investment expenditures, and wages, respectively). However, the response of public

¹⁹The transmission of aggregate shocks in an economy with technology spillovers is qualitatively identical. The corresponding impulse responses are presented in Figure [B.1](#).

investment differs between the regions. The Rigid government constrained by the zero-borrowing limit finances its expenditures with tax revenues only, which fall during the downturn. The Flexible government has the authority to borrow and maintain the provision of the productive public good at the pre-shock level. These dynamics are captured by the time paths of the public investment and public capital stock.

The declining supply of the productive public good from the Rigid government yields interregional differentials of marginal productivities. Since the productive public good augments productivity of both private factors, the marginal productivity of capital as well as the marginal productivity of labor are affected.²⁰ Their interregional ratios are tilted in favor of Flexible, which leads to the shift of resources to the more productive jurisdiction in the union and, in turn, deteriorates risk sharing. Note that this mechanism is in contrast with standard models, such as [Backus, Kehoe, and Kydland \(1992\)](#), where resources are shifted in response to idiosyncratic rather than aggregate shocks.

Although the reduction of the public expenditures in the Rigid region increases availability of the resources for private absorption, these resources are not used for private investment locally, but instead are loaned to private and public borrowers in the rest of the union. Moreover, the Rigid region's consumption as well as private and public investments fall faster than its output due to the interregional shift of resources. The undersupply of both public and private investments in the Rigid region has a negative influence on its post-shock recovery.

Productive public good provision in the Flexible region is financed in part by its own residents, while the rest of the funding comes from the residents of Rigid. The interregional shift of resources, contrary to the Rigid region, dampens the contraction of private consumption and investment in Flexible. Additionally, the allocations in the Flexible region return to their respective steady-state levels faster.

²⁰The decline of the marginal products of labor is due to the dynamics of the total factor productivity and, with an inelastic labor supply, changes at the private and public capital margins rather than the labor margin.

The Federal government is unconstrained by a borrowing limit and provides the consumption public good in a steady fashion. The debt-financed portion of its provision is financed by the Rigid representative household. Because marginal productivity is lower in the Rigid region, its household has an incentive to invest in public bonds, instead of local private capital. In this sense, the Federal government's borrowing increases the asymmetry of allocations in the union. On the other hand, the steady provision of the consumption public good by the Federal government improves interregional risk sharing.

The Rigid representative household holds a net positive asset position in all types of bonds on impact and during the early periods after the shock. At the longer horizon, once the effect of the productivity shock weakens sufficiently and the decumulation of private capital increases the return on capital, the marginal productivity ratios reverse and the shift of resources changes its direction.

The demand for loanable funds grows as the indebtedness of both the Federal and Flexible governments and of the Flexible representative household increases. Hence, the returns on all types of bonds grow, which is consistent with the no-arbitrage condition implied by the Euler equations (2.8) – (2.11).

Remarkably, the uninterrupted flow of the productivity-augmenting public good provided by the Flexible government allows that region to utilize the shift of resources, stabilize its economy, and improve its relative performance. From the union's standpoint, the drawback of this policy is the deterioration of the interregional risk sharing.

2.4.2 Idiosyncratic Shocks in Absence of Spillovers

In the scenarios of idiosyncratic shocks, the region in which the shock is realized is hurt due to both the decreased marginal productivity of private factors and the consequential outward shift of resources. The other region is affected positively by the inward shift of resources, correspondingly. Similar to the scenario of aggregate shocks, here, the Flexible fiscal policy acts as a shock absorber and improves the relative performance of the region

that adopts it.

Shock to Rigid Region

The adjustment of the macroeconomic variables after a negative asymmetric shock to the Rigid region's economy is illustrated in Figure 2.4. Since the adverse disturbance directly affects the Rigid region, in the absence of spillovers, the Flexible region is affected positively via the shift of resources from Rigid. Interregional trade is no longer balanced in response to the marginal productivity differential between the regions. The balance of trade captures the corresponding shift of resources to the more productive region. On impact and immediately after the shock, the Rigid region runs a trade deficit, and the Flexible region holds a positive net regional asset position in private bonds against the Rigid region. The inward shift of resources increases Flexible's transitional allocations of investment, consumption, and output above their respective steady-state levels.

The behavior of the other endogenous variables follows the pattern established in the analysis of the aggregate shock scenario. The allocations of the variables diverge across the regions. The impulse responses of consumption demonstrate that the interregional risk sharing deteriorates. This deterioration is more pronounced than that in the previously discussed scenario of aggregate shocks and as compared with the scenario of an idiosyncratic shock to Flexible, as discussed next.

Shock to Flexible Region

Following an adverse productivity shock to the Flexible region, marginal productivity differentials are tilted in favor of the Rigid region, as illustrated by Figure 2.5. Hence, the latter region receives the inflow of resources from the former. This shift of resources is smaller as compared to the previous scenario, and so is the overaccumulation of capital by the Rigid region, unaffected by the shock directly.

As before, the dynamics of the regional public good supply are responsible for this

outcome. However, contrary to the previous scenario, the government of the region directly affected by the negative shock does not allow the provision of the local productive public good to contract. This enables a faster recovery of that region's marginal productivities. Hence, the interregional ratio of the marginal products of capital flips, and reverses the shift of resources substantially faster than in the scenario of an idiosyncratic shock to the Rigid region. Intuition for the dynamics of other variables is as discussed in the preceding section.

Note that in the scenario of an idiosyncratic shock to Flexible, the asymmetric borrowing limits adopted by the regions have beneficial implications for risk sharing. In such an arrangement, the absence of a borrowing limit allows the Flexible region affected by the adverse disturbance to stabilize its economy and to recover from the shock's effects faster. One can arrive at this conclusion by visually examining the allocations of consumption on Figure 2.5. Numerical support for this statement is presented in Section 2.4.5 below.

2.4.3 Shocks in Presence of Spillovers

Having identified the shock transmission mechanism for the case without technology spillovers, it is natural to consider an economy with interregional spillovers. Such a specification is arguably more realistic for the U.S., as a union with numerous interregional and interindustry links. On one hand, the choice of the technology process specification is immaterial for the dynamic response of the model economy in the scenario of aggregate shocks. Figures 2.3 and B.1 show that the time paths of macroeconomic variables are virtually identical.

On the other hand, the spillovers start playing a role in the idiosyncratic shock scenarios. A comparison of Figures 2.6 and 2.7 with Figures 2.4 and 2.5 points out that the technology spillovers ensure comovement of the endogenous variables, speed up the transition, and hence affect quantitative outcomes of the model. For example, output ex-

pansions in the regions unaffected by adverse idiosyncratic shocks directly are short-lived in the framework with spillovers. Additionally, a recession in one region leads to a downturn instead of an expansion in another, albeit a smaller one and with a lag. Also, in the region affected by the shocks indirectly, through spillovers, consumption never increases (although output does), due to the forward-looking, consumption-smoothing behavior of rational households.

The main finding from the comparison of the economy responses in the presence and in the absence of technology spillovers is as follows. By inducing comovement of the macroeconomic variables and by reducing the range of fluctuations, spillovers mitigate the effects of the asymmetric balanced-budget rules in the idiosyncratic shock scenarios. Hence, the interregional technology linkages improve interregional risk sharing, conditional on the realization of idiosyncratic shocks, though not in the scenario of aggregate disturbances. This finding is numerically supported by the analysis presented in Section 2.4.5 below.

2.4.4 Effects of Public Good Productivity

To address the uncertainty associated with the degree of public good productivity, I investigate the model's behavior under alternative parameterization of the productivity of public goods, α_G . Besides the baseline medium productivity value of 0.2, I consider high, low, and very low values of public good productivity (α_G equal to 0.3, 0.1, and 0.05, correspondingly). The highest considered value of 0.3 is closer to Aschauer's original estimate of public infrastructure productivity of 0.39, but still below the private capital productivity. The lowest value, 0.05, serves as a proxy for the productivity of significantly congested productive public goods.

The risk-sharing implications of public borrowing limits in this model are robust to α_G , ranging from low to high levels. The higher productivity of public goods is associated with worse interregional risk sharing, as it leads to: greater differences between the two types

of regions in output, wages, consumption, private and public investment, and private and public capital stock; larger fluctuations in interregional trade and all types of bond holdings; and smaller fluctuations in interest rates. Panel A of Figure 2.8 illustrates this point with the time paths for consumption, output, and interregional balance of trade after an aggregate shock in the economy with spillovers.

The analysis of the transition after idiosyncratic shocks (Panels B and C of Figure 2.8) supports that observation. When the productivity of public goods is higher, the undersupply of the public goods becomes costlier as measured by levels of macroeconomic variables or interregional differentials.

The scenario of an idiosyncratic shock to the Rigid region sharpens strongly the difference between alternative fiscal policies (Panel C of Figure 2.8). The relative loss, measured as a percentage deviation from the steady-state levels, is quite steady in the Flexible region regardless of the public good productivity. This is in contrast with dynamics in the Rigid region as represented on Panel B of Figure 2.8. The shift of resources from the Rigid to the Flexible region becomes costlier for the former region when public good productivity is higher. The undersupply of public goods negatively affects the marginal productivity of private factors and therefore brings about a larger shift of resources and greater losses of consumption and output. These results obtained for the technology process specification with spillovers qualitatively hold in the absence of spillovers (Figure B.1).

As public good productivity falls to very low, not only does the interregional consumption differential become smaller, but the relative performance of the two regions flips as well. At first glance, this result might look surprising, as it seems to contradict Barro's (1979) tax-smoothing hypothesis, which implies the optimality of public borrowing.²¹ However, there is no contradiction. Barro's analysis assumes away productive

²¹In Barro's model, public borrowing helps to maintain a constant tax rate after a realization of adverse shocks. The government debt eliminates wedges associated with the adjustment of distortionary tax rates. Hence, public debt that is brought about by

government expenditures. Once productive public goods are modeled explicitly, as in the present study, the optimality of public borrowing is determined by two counteracting forces associated with the provision of productive public goods: an enhanced private-factor productivity due to productive public expenditures, on one hand, and, on the other, decreased private investment and consumption due to the resource-withdrawal effect. Hence, in the case of sufficiently low productivity of public goods, debt financing of public expenditures is not justified, since the cost of public investment is greater than its benefit, and refraining from public borrowing improves welfare of the local representative household.

2.4.5 Welfare

This subsection starts with the analysis of the lifetime welfare in the model economy after the realization of a one-time aggregate productivity shock. Next, idiosyncratic shocks are considered. Initially, both shocks are introduced in the presence of technology spillovers. A case without spillovers is analyzed afterwards.

Aggregate Shock

Conditional on the medium productivity of the public goods, the Flexible region is better insulated against aggregate adverse shocks than the Rigid region (Table 2.3). The welfare loss amounts to 2.04% (1.54%) of the Rigid (Flexible) region's lifetime welfare.

Due to the difference of regional fiscal policies, the Rigid representative household enjoys a 0.5 percentage point lower lifetime consumption relative to the Flexible household in the aftermath of the shock. Thus, the zero-borrowing limit results in additional 32% consumption loss in the Rigid region as compared with the Flexible representative household's loss.

a budget deficit can be viewed as a byproduct of optimal fiscal policy.

The remaining columns of Panel A, Table 2.3 show that, as the public good productivity increases, the underprovision of public goods becomes costlier for the region, as measured by its representative household's loss of welfare. Consequently, as α_G decreases, the benefit of public borrowing vanishes. Both the absolute welfare loss and the consumption differential between two regions decreases.

Finally, if the public good productivity is too low, or if the goods are substantially congested, the adoption of the Flexible fiscal policy is no longer welfare improving, as compared with the Rigid policy. The intuition for this outcome was presented in Subsection 2.4.4 above.

Idiosyncratic Shocks

Panels B and C of Table 2.3 document the welfare consequences of idiosyncratic shocks to the union in the presence of technology spillovers. As discussed in Section 4.3 above, when the adverse shock is realized in one region only, both regions are affected negatively through the interregional technology linkages. The welfare loss is increasing (decreasing) in the productivity of public goods in the Rigid (Flexible) region regardless of the destination of the idiosyncratic shock. The zero-borrowing limit of the Rigid region hinders its post-shock recovery, which becomes more apparent as the public good productivity increases from low to high.

The welfare and consumption differential as well as the efficiency of risk sharing between the union members is increasing in public good productivity, conditional on an idiosyncratic shock to the Rigid region (Panel B of Table 2.3), but is decreasing if the shock hits the Flexible region (Panel C). The asymmetry of public borrowing limits generates the shift of resources, which allows Flexible to recover faster, especially if the productivity of public goods is higher. This explains the finding that the consumption differential between the regions closes faster (slower) when only the Flexible (Rigid) region is affected by the shock.

In the specification without technology spillovers, the shift of resources becomes even more pronounced, as Table B.1 reports. An idiosyncratic shock to Rigid leads to welfare improvement in Flexible, and *vice versa*, as a shock to Flexible improves the welfare of Rigid. However, due to the adoption of the Flexible fiscal policy, the corresponding regional welfare gain is larger (and the loss is smaller), conditional on the realization of idiosyncratic shocks.

The exception, as in the case with spillovers, is represented by a case with very low public good productivity. The intuition for the consumption differential tilted in favor of the Rigid household is identical to that in the instance with spillovers.

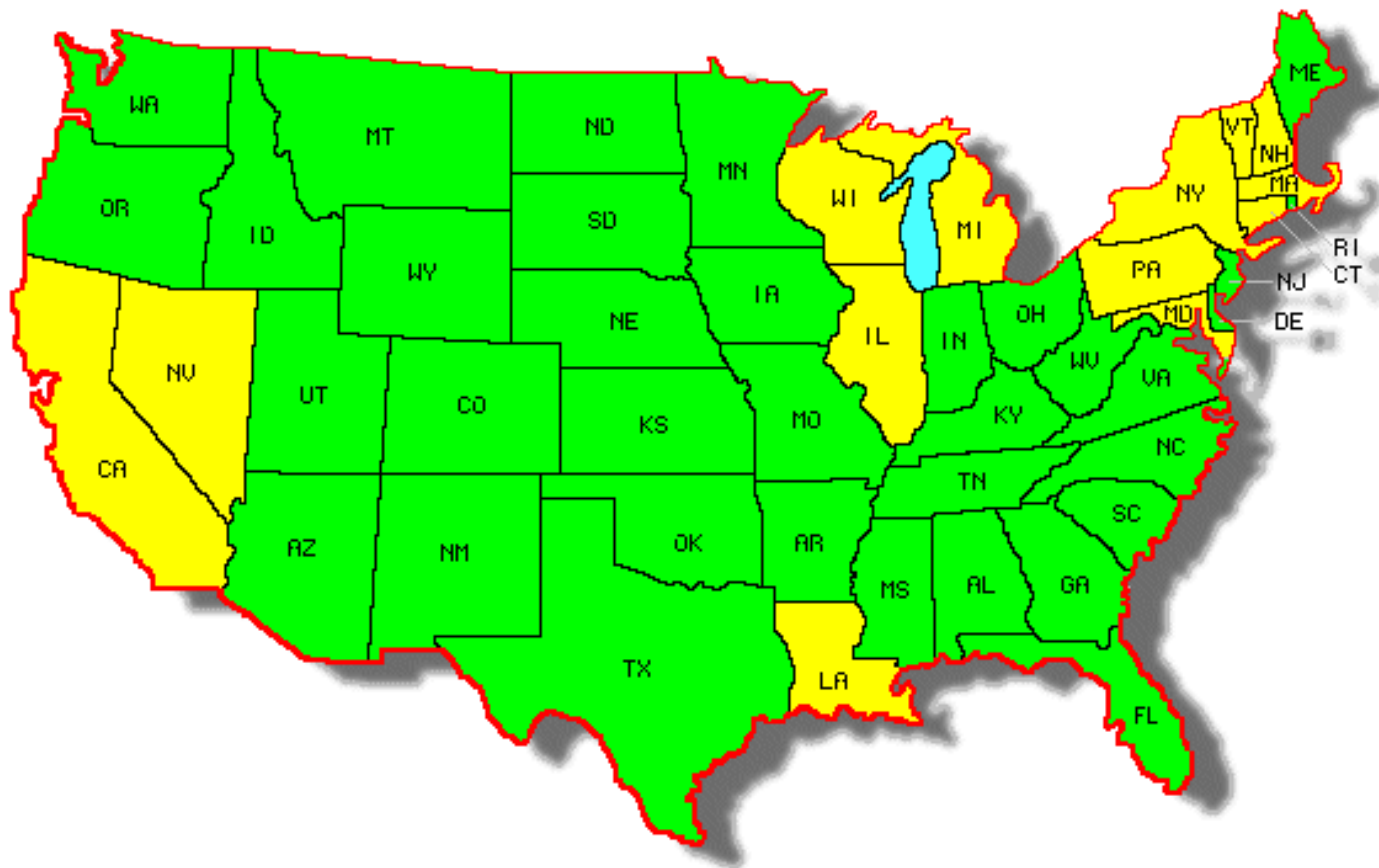
2.5 Conclusions

This chapter has employed a microfounded, dynamic market-clearing general equilibrium framework to study the question: What are the implications of the asymmetry of balanced-budget rules for the interregional risk sharing in a fiscal union? I found that the asymmetry of balanced-budget rules is detrimental for the risk sharing in the union.

The exact magnitude of the risk sharing deterioration in the fiscal union is a function of the public good productivity, specification of the technology process, and distribution of productivity shocks in the union.

The avenues for future research include the analysis of the policy interactions between the union members as well as the exploration of the need for policy intervention by the federal government in the regional tax system design.

Figure 2.1: Balanced-budget rules in the continental U.S. states.



Source: ACIR (1987).

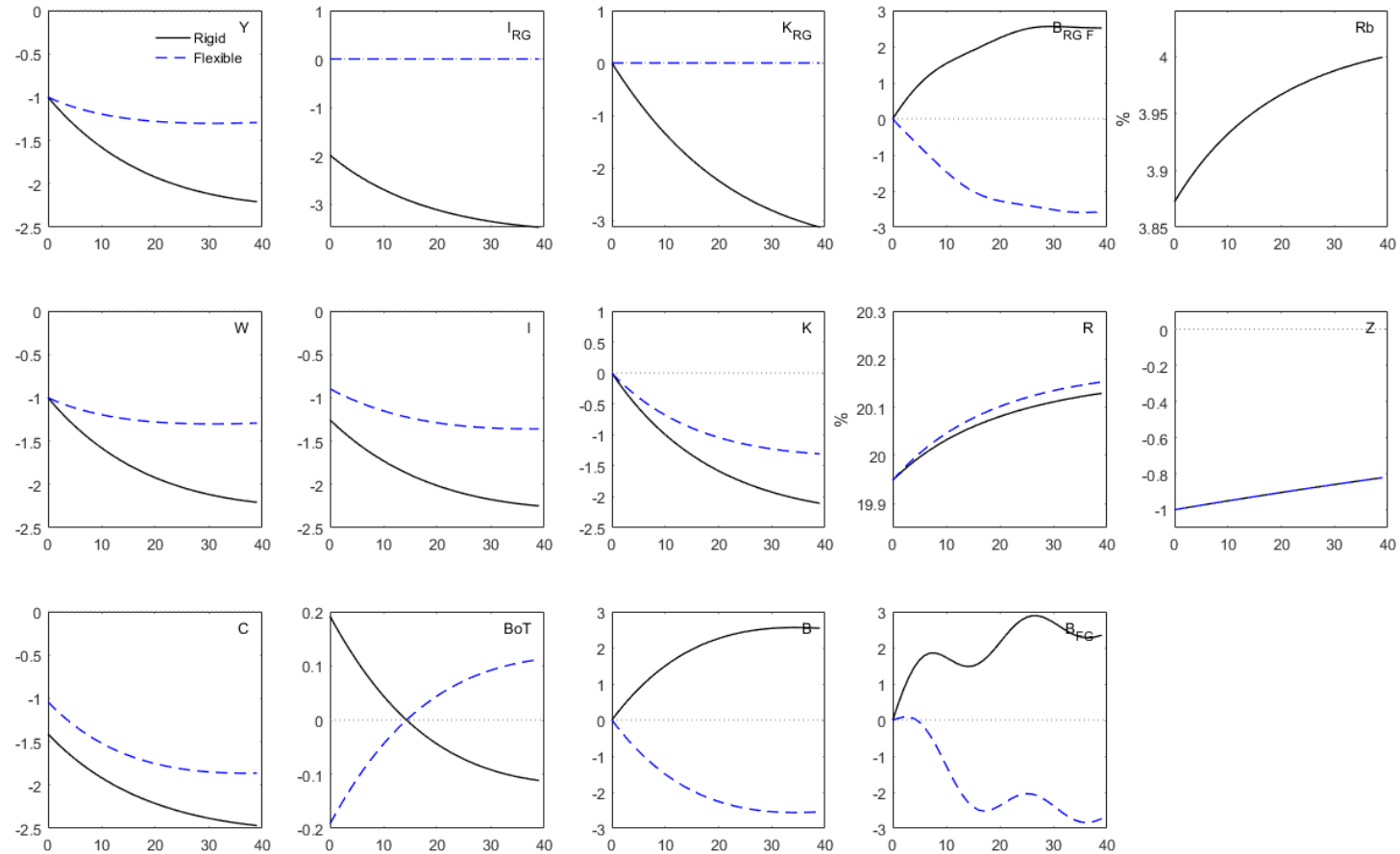
Note: The yellow (lighter) color represents states with less stringent balanced-budget rules and corresponds to the ACIR index value of 6 and below. The green (darker) color represents states with strict balanced-budget rules and corresponds to the ACIR index value of 7 and above. The breakpoint value between the two types of the states is borrowed from the fiscal federalism literature.

Figure 2.2: Structure of the model economy.

Federal Government	
Collects capital income tax and labor income tax	
Provides non-rival consumption public good to households	
No borrowing limit	
Rigid Region	Flexible Region
Household	Household
Consumes, provides labor and capital to firms	Consumes, provides labor and capital to firms
No borrowing limit	No borrowing limit
Firm	Firm
Manufactures consumption-investment good using labor and private and public capital	Manufactures consumption-investment good using labor and private and public capital
Regional Government	Regional Government
Collects consumption tax	Collects consumption tax
Provides productive public good to local firm	Provides productive public good to local firm
Zero-borrowing limit	No borrowing limit

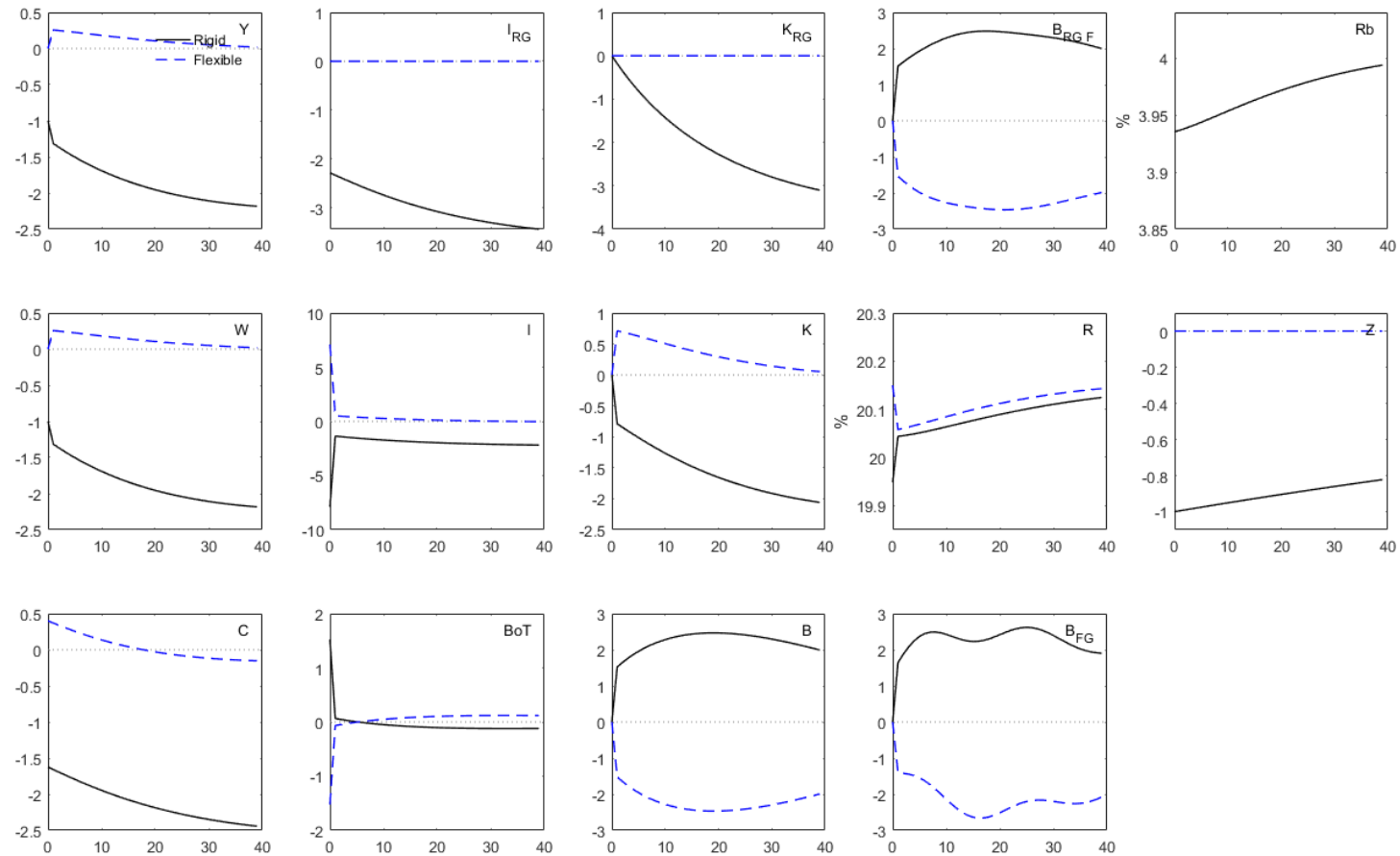
Note: “No borrowing limit” refers to the absence of an institutional limit and does not imply the agents are not subject to the no-Ponzi game condition.

Figure 2.3: Responses of the endogenous variables to the aggregate -1% productivity shock.



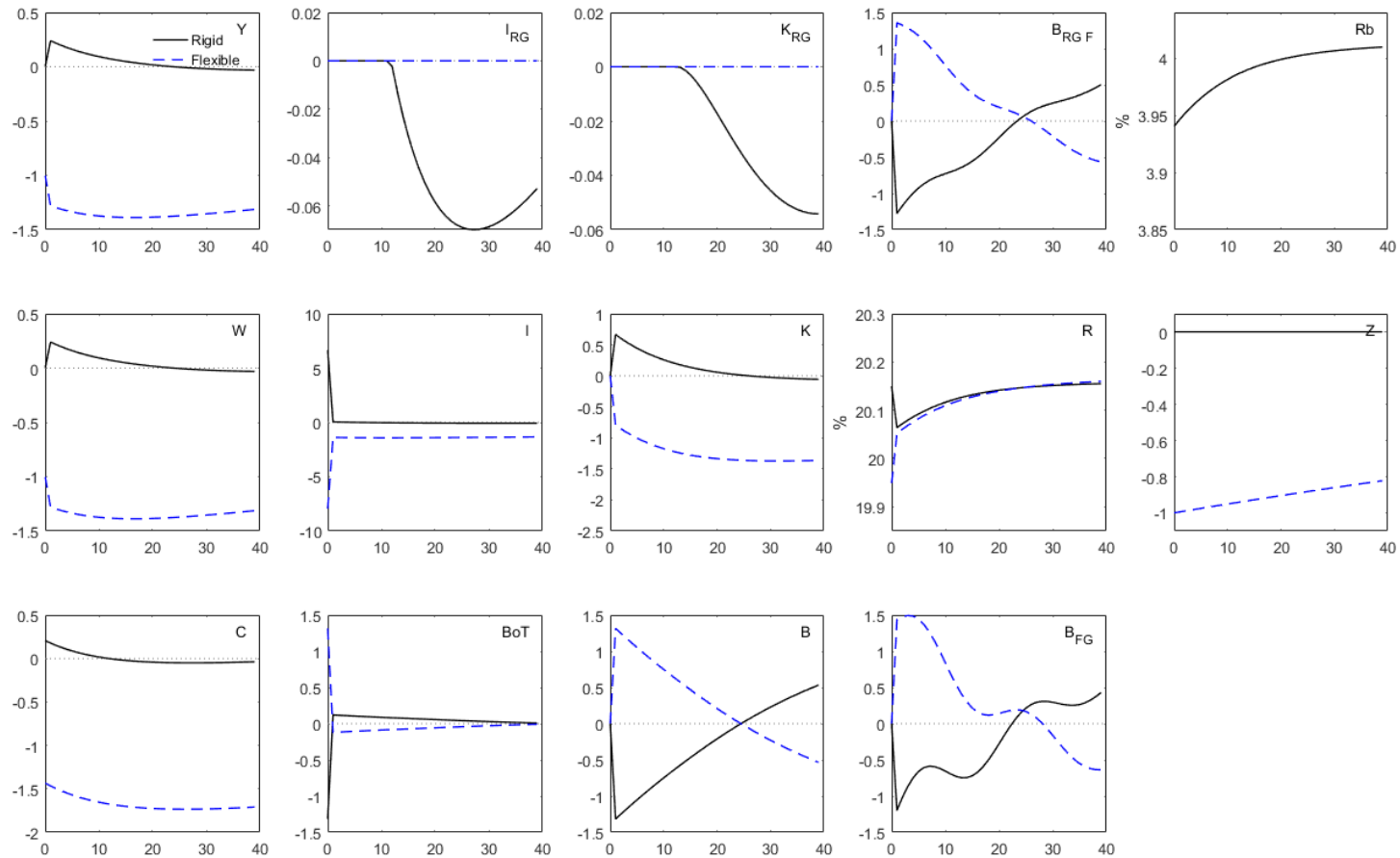
Notes: The fiscal union consists of the Rigid and Flexible regions. The technology process without spillovers is adopted. The vertical axis measures percentage deviations of the endogenous variables from their respective steady states with the exception of the balance of trade and bonds measured relative to the steady-state output as well as the interest rates measured as percentages. The horizontal axis measures periods after the shock.

Figure 2.4: Responses of the endogenous variables to the idiosyncratic -1% productivity shock to the Rigid region.



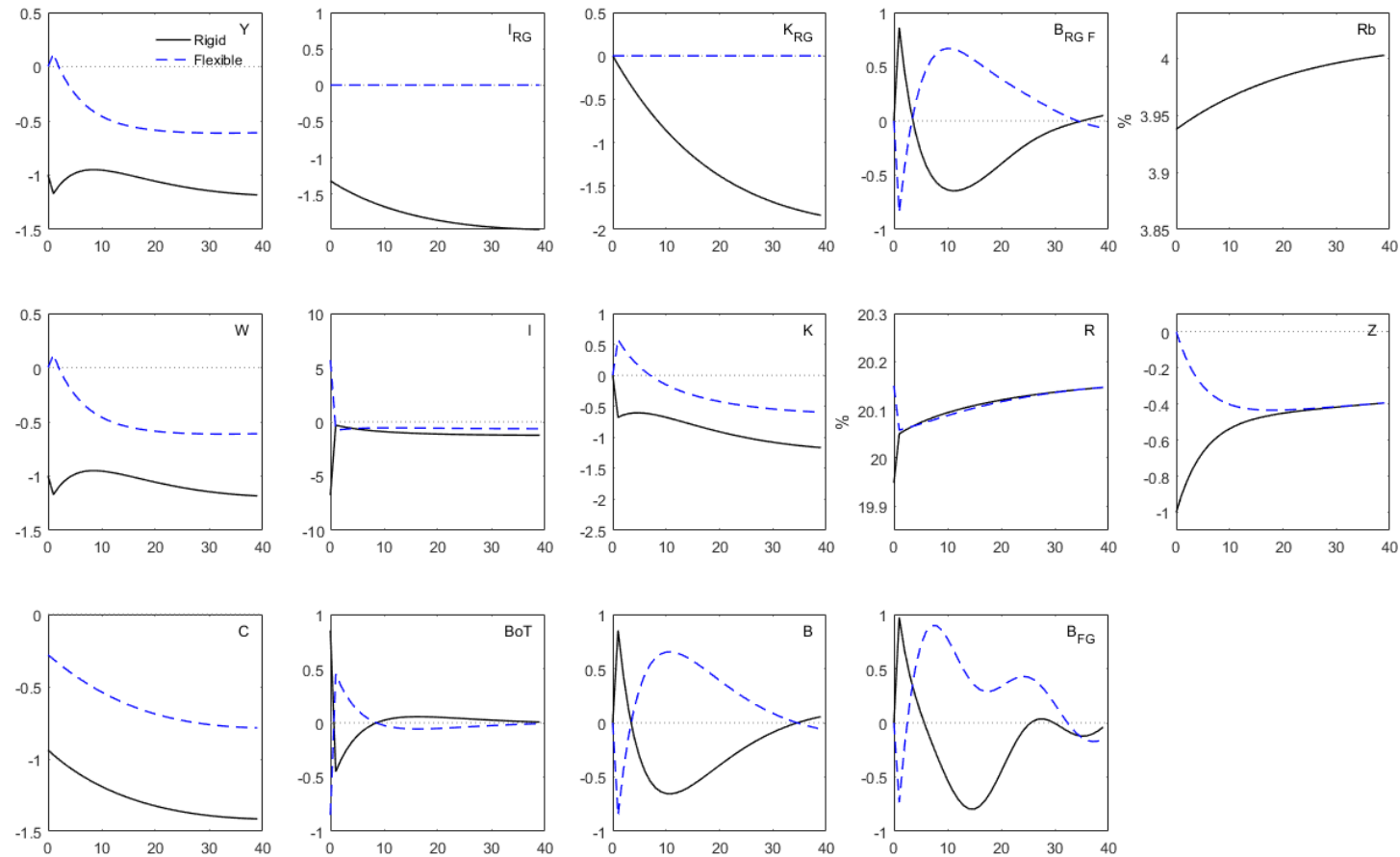
Notes: The fiscal union consists of the Rigid and Flexible regions. The technology process without spillovers is adopted. The vertical axis measures percentage deviations of the endogenous variables from their respective steady states with the exception of the balance of trade and bonds measured relative to the steady-state output as well as the interest rates measured as percentages. The horizontal axis measures periods after the shock.

Figure 2.5: Responses of the endogenous variables to the idiosyncratic -1% productivity shock to the Flexible region.



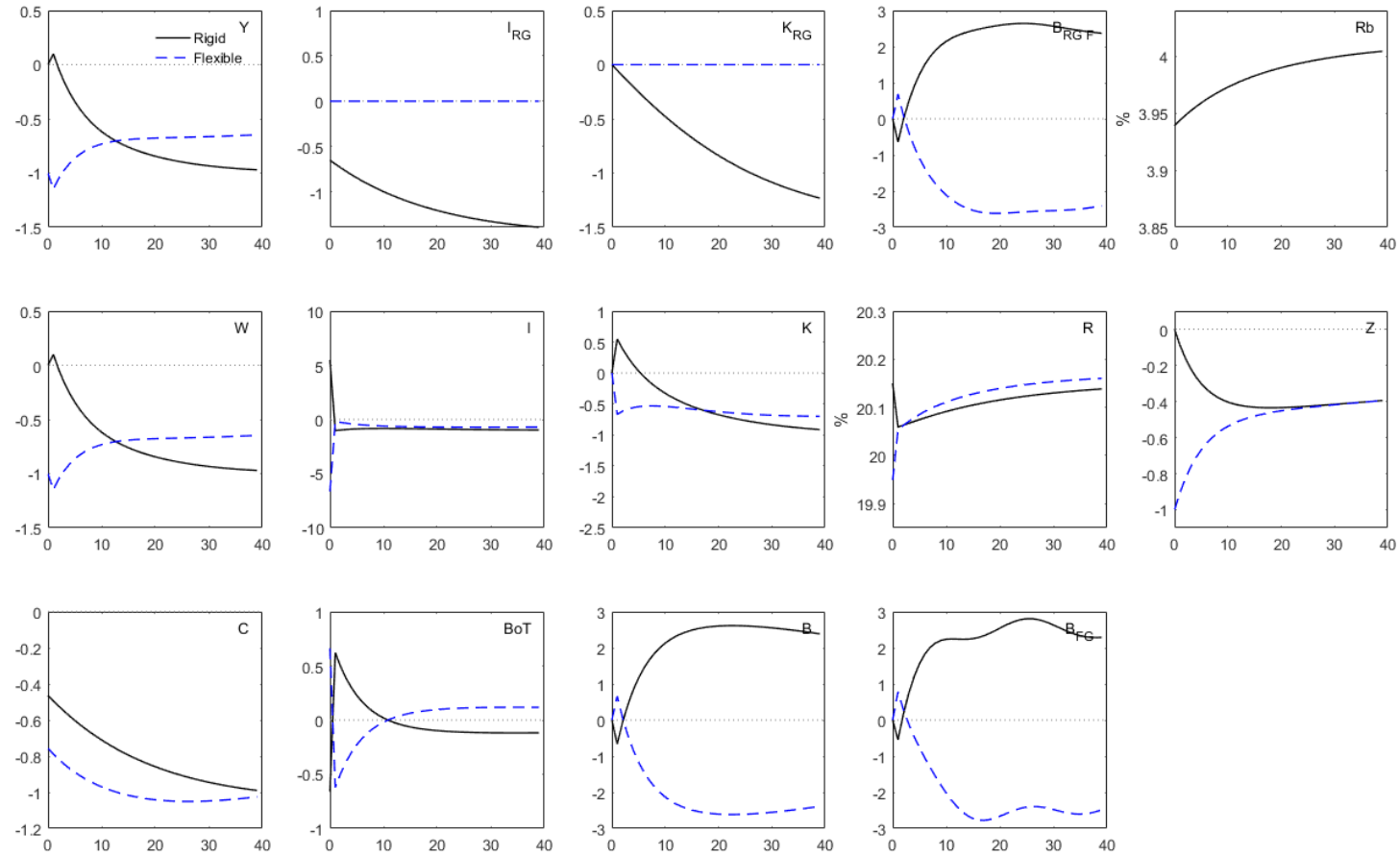
Notes: The fiscal union consists of the Rigid and Flexible regions. The technology process without spillovers is adopted. The vertical axis measures percentage deviations of the endogenous variables from their respective steady states with the exception of the balance of trade and bonds measured relative to the steady-state output as well as the interest rates measured as percentages. The horizontal axis measures periods after the shock.

Figure 2.6: Responses of the endogenous variables to the idiosyncratic -1% productivity shock to the Rigid region.



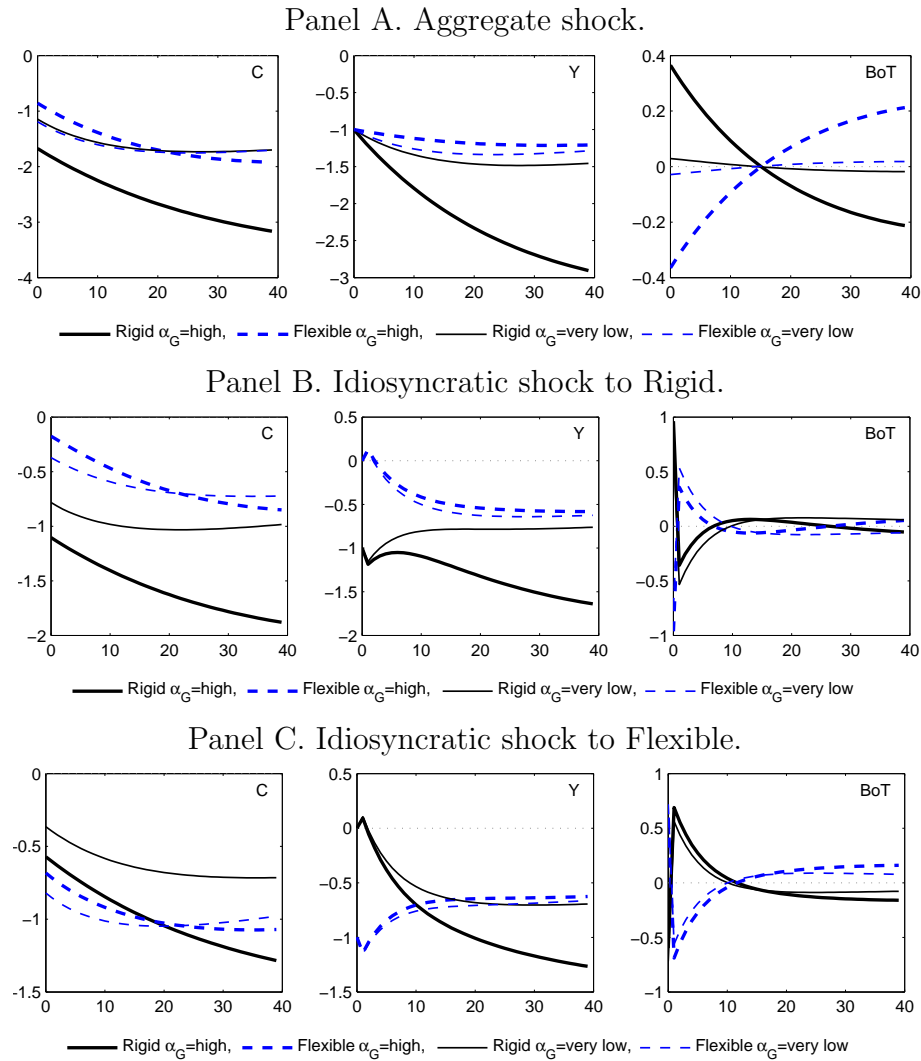
Notes: The fiscal union consists of the Rigid and Flexible regions. The technology process with spillovers is adopted. The vertical axis measures percentage deviations of the endogenous variables from their respective steady states with the exception of the balance of trade and bonds measured relative to the steady-state output as well as the interest rates measured as percentages. The horizontal axis measures periods after the shock.

Figure 2.7: Responses of the endogenous variables to the idiosyncratic -1% productivity shock to the Flexible region.



Notes: The fiscal union consists of the Rigid and Flexible regions. The technology process with spillovers is adopted. The vertical axis measures percentage deviations of the endogenous variables from their respective steady states with the exception of the balance of trade and bonds measured relative to the steady-state output as well as the interest rates measured as percentages. The horizontal axis measures periods after the shock.

Figure 2.8: Responses of output, consumption, and investment to the -1% productivity shocks under alternative assumptions about the productivity of public goods.



Notes: The fiscal union consists of the Rigid and Flexible regions. The vertical axis measures percentage deviations of the variables from their respective steady states with the exception of the balance of trade measured relative to the steady-state output. The technology process with spillovers is adopted. The horizontal axis measures periods after the shock.

Table 2.1: Functional composition of the federal and state government expenditures, 1977–2000, % of general government expenditures.

	Federal expenditures	State expenditures
Total expenditures	47.8	52.2
Consumption public goods	37.8	20.9
National defense	29.9	0.0
General public service	2.1	6.0
Health	3.2	2.6
Housing and community services	0.9	1.2
Income security	0.5	2.3
Public order and safety	1.0	7.7
Recreation and culture	0.2	1.1
Productive public goods	10.0	31.3
Education	0.7	23.8
Economic affairs	9.3	7.5

Source: U.S. National Income and Product Accounts, Section 3.

Note: The data in the table are consistent with the NIPA expenditures approach.

Namely, transfers from the federal government to state governments are included in the expenditures of the federal government and transfers from governments to individuals are not reported as a part of government expenditures.

Table 2.2: Calibrated parameters.

Parameter		Value
Preferences		
β	discount factor	0.9615
γ	inverse of intertemporal elasticity of substitution for private consumption	2
γ_G	inverse of intertemporal elasticity of substitution for public consumption	2
Technology		
α	capital income share	0.36
α_G	elasticity of output with respect to public capital	0.05, 0.1, 0.2, 0.3
δ	rate of depreciation of private capital	0.10
δ_G	rate of depreciation of public capital	0.08
Policy		
τ_K	capital income tax	0.305
τ_L	labor income tax	0.24
τ_C	consumption tax	0.10
ι_{st}	cyclicality of public debt adjustment	0.1
ι_{gr}	speed of public debt adjustment	0.001
η	bond-holding adjustment cost	0.0025

Table 2.3: Lifetime welfare dynamics under alternative assumptions about the productivity of public goods in the fiscal union, with technology spillovers.

Panel A. Aggregate shock.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in Rigid, %	1.54	1.68	2.04	2.59
Loss of lifetime welfare in Flexible, %	1.56	1.56	1.54	1.52
Rigid-Flexible loss differential, p.p.	-0.02	0.12	0.49	1.07
Rigid-Flexible loss differential as % of Flexible loss	-1.4	7.7	32.0	70.4
Panel B. Idiosyncratic shock to Rigid.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in Rigid, %	0.94	1.02	1.24	1.58
Loss of lifetime welfare in Flexible, %	0.61	0.61	0.60	0.58
Rigid-Flexible loss differential, p.p.	0.33	0.42	0.64	0.99
Rigid-Flexible loss differential as % of Flexible loss	54.0	68.6	107.6	170.1
Panel C. Idiosyncratic shock to Flexible.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in Rigid, %	0.60	0.66	0.80	1.01
Loss of lifetime welfare in Flexible, %	0.95	0.95	0.95	0.94
Flexible-Rigid loss differential, p.p.	0.35	0.30	0.15	-0.08
Flexible-Rigid loss differential as % of Rigid loss	58.3	45.2	18.8	-7.5

Notes: The fiscal union consists of the Rigid and Flexible regions. The table entries are calculated using consumption scale factors and have the interpretation of compensating variation measured in terms of private lifetime consumption.

Chapter 3

Constrained-Optimal Design of Balanced-Budget Rules in a Fiscal Union

3.1 Introduction

The second chapter of this dissertation explored the implications of balanced-budget rules' asymmetry and the heterogeneity of a public good provision for interregional risk sharing in a fiscal union. That study demonstrated that the asymmetry of balanced-budget rules is detrimental for risk sharing in the union. It further established that the degree of risk sharing is a function of the public good productivity, specification of the technology process, and distribution of productivity shocks in the union.

Such findings raise a new research question: How should the design of borrowing limits in the union be altered to improve the risk sharing and decrease the welfare cost of business fluctuations? The objective of this chapter is to address this question by means of a counterfactual policy-interaction experiment, in which the regional borrowing limits are no longer restricted to being asymmetric. Additionally, the present study tests if the welfare-maximizing outcome can be achieved without regional policy coordination and estimates the welfare cost of the current set of borrowing limits adopted by U.S. states.

My research framework modifies the one adopted in the second chapter by endowing each of the regional governments with a policy menu that contains zero-borrowing-limit

and no-borrowing-limit policies. The choice of the borrowing limits, as a corollary, implies the choice of the specific regime of the productive public goods provision.

Two types of the policy-interaction game are considered. In the first type of the game, the policy choice is made in a noncooperative fashion, as each region maximizes its own welfare while taking the other region's actions as given. To answer the question if policy coordination is needed, the outcomes of this game are compared with those of a cooperative game, in which the regional governments cooperate to maximize the joint welfare of both regions. Alternatively, the latter problem can be interpreted as a game in which the regions delegate to the Federal government their authority to set borrowing limits. Then, the Federal government maximizes the joint welfare of the regions.

The analysis of the welfare effects of the noncooperative and cooperative policies suggests that the welfare-maximizing fiscal policies are symmetric. By mirroring each other's choice of borrowing limits, regional governments minimize the shift of resources after an adverse shock.

The unique parameter that determines the specific type of the welfare-maximizing borrowing limits in the fiscal union is the productivity of public goods. When the productivity is sufficiently high, welfare is maximized and risk sharing is improved by lifting any restrictions on public borrowing by all regional governments. Otherwise, when public good productivity is very low, all members of the union should refrain from public borrowing to maximize welfare and improve consumption risk sharing. Importantly, other aspects of the economy, such as the type of technology process, or the shock type (aggregate or idiosyncratic), do not matter for the policy choice.

By comparing outcomes of a noncooperative game, when each regional government maximizes the welfare of its representative household, and a cooperative game, in which two regions cooperate to maximize the joint welfare of the households, I arrive at the conclusion that, in this economy, the welfare-maximizing outcome can be achieved without policy coordination. That is, each region's objective of its own utility maximization

is consistent with the union's objective of joint regional welfare maximization.

To answer the question, "What welfare improvement can be achieved by adopting welfare-maximizing borrowing limits?" I estimate a historical sequence of productivity shocks for 1970–1979 and 1983–2000. Next, I calculate the welfare cost of business cycle fluctuations, conditional on four possible fiscal policies adopted in the union. One policy includes the case when both regional governments eliminate public borrowing limits; another includes the opposite case, when the governments allow the issuance of public bonds; and finally, two other policies in which only one of the two regions imposes a public borrowing limit. The obtained estimates of welfare gains for the most plausible model specification amount to 0.06% of lifetime consumption or 55.5% of the cost of business cycles. When high public good productivity is considered in the economy without technology spillovers, the welfare gains raise to 0.13% of lifetime consumption, which corresponds to 74.6% of the business cycle cost.

How this work relates to the fiscal unification studies and to the analysis of the macroeconomic effects of borrowing limits is discussed in the previous chapter of this dissertation. Interregional policy interactions with borrowing limits as a policy tool have not been considered in the literature to the best of my knowledge.

Most of the existing literature devoted to macroeconomic policy interactions focuses on monetary policy. Early studies, such as [Canzoneri and Henderson \(1991\)](#) and [Turnovsky and d'Orey \(1989\)](#) analyze the interaction between money supply and interest rates, as monetary policy instruments, in the hands of authorities located in different countries. The studies of interactions between monetary and fiscal policies add government expenditures into the toolkit of the policymakers (e.g., [Frankel and Rockett \(1988\)](#) and, more recently, microfounded studies by [Benigno and Benigno \(2003\)](#) and [Beetsma and Jensen \(2005\)](#)).

In the papers that consider fiscal policy interactions only, authors focus on tax rates rather than on borrowing limits as policy instruments, for instance, [Sorensen \(2004\)](#) and

[Mendoza and Tesar \(2005\)](#). Moreover, such studies analyze level effects, while abstracting from the stochastic fluctuations, their costs, and consumption risk sharing. My approach differs from the existing literature by emphasizing the business cycle cost of the policy decisions and their risk-sharing implications. Also, the task of the identification of the welfare-maximizing borrowing limits in the union belongs to the body of constrained-optimal literature, since the tax rates and public expenditures are treated as exogenous in this study.

The rest of the paper is structured as follows. The next section describes the model's environment and the optimality conditions. Calibration is summarized in [Section 3.3](#). [Section 3.4](#) studies the model economy after the realization of one-time and historical shocks and presents results of the policy-interaction analysis. Also, it presents the estimates of the cost of business cycles as well as of counterfactual welfare improvement. [Section 3.5](#) concludes. [Appendix C.1](#) contains some model results estimated under alternative assumptions about technology process specifications.

3.2 Model

This section starts with the description of the model environment, which augments [Backus et al. \(1992\)](#) to include public sector features of a federal state. Special attention is paid to the provision of consumption and productive public goods, as in [Turnovsky and Fisher \(1995\)](#). The model economy includes households, firms, and two levels of governance: federal and regional. Its stylized structure is presented in [Figure 3.1](#). After the environment is described, equilibrium conditions for the model economy are derived and the policy-interaction games are set up.

3.2.1 Environment

Consider a federal state that consists of two regions: Region 1 and Region 2. The regional economies are identical in terms of their size, technology, and preferences, with a possible exception of fiscal policy. Each region is populated by a representative household and a representative firm. Labor mobility is prohibited between the regions, but there are no barriers to interregional capital mobility.

The government in the federal state consists of two levels. The first level is represented by the Federal government, which collects capital income and labor income taxes from both regions and provides a non-rival public consumption good in return.

Regional governments represent the second level of governance. Each regional government provides a rival productive public good to the local representative firm in exchange for a consumption tax collected from the residents of its own region. Besides the productive public good, the firms employ private capital and labor to manufacture a homogeneous across the regions consumption-investment good.

The households in both regions have access to one-period, risk-free private and public bonds. The public bonds can be issued by both federal and regional authorities. However, region-specific borrowing limits are introduced to ensure the model's consistency with the stylized facts about heterogeneous balanced-budget rules adopted by the U.S. states. The regions have an ability to borrow, if their policymakers adopted a Flexible fiscal policy. Otherwise, they conduct a Rigid fiscal policy and have a zero-borrowing limit. Since all types of bonds are risk-free, the asset markets are incomplete.

Households

The representative household in Region 1 derives instantaneous utility from private and public consumption goods, C and C_G , according to an isoelastic utility function (3.1). Labor is supplied inelastically and $\gamma > 0$ and $\gamma_G > 0$ are inverses of the intertemporal elasticity of substitution for private and public consumption goods, respectively.

$$\frac{C_t^{1-\gamma}}{1-\gamma} + \frac{\overline{C}_G^{1-\gamma_G}}{1-\gamma_G}. \quad (3.1)$$

Unless otherwise stated, the Region 2 environment is symmetric. In what follows, Region 2 variables are marked with asterisks.

Firms

The representative firm hires labor, L , from its region, employs private capital stock, K , and uses the stock of region-specific publicly provided physical capital, K_{RG} , to produce the homogeneous consumption-investment good, Y , according to the production function (3.2). The output also depends on the total factor productivity, Z , which is affected by the realization of a technology shock, ϵ .

$$Y_t = Z_t K_t^\alpha \bar{L}^{1-\alpha} (K_{RG,t})^{\alpha_G}. \quad (3.2)$$

Finally, the technology processes of the two regions are related by the following specification:

$$\begin{bmatrix} Z_t \\ Z_t^* \end{bmatrix} = \begin{bmatrix} \phi_Z & \phi_{ZZ^*} \\ \phi_{Z^*Z} & \phi_{Z^*} \end{bmatrix} \begin{bmatrix} Z_{t-1} \\ Z_{t-1}^* \end{bmatrix} + \begin{bmatrix} \epsilon_t \\ \epsilon_t^* \end{bmatrix}.$$

Federal Government

The Federal government collects capital and labor income taxes at uniform rates, τ_K and τ_L , from both regions, and exogenously provides the non-rival public consumption good, C_G . The government apportions the procurement of the public good equally between the regions. In the absence of any borrowing limits imposed on it, the Federal government issues one-period, risk-free bonds, B_{FG} , that pay the interest rate $R_{FG,t}$ at the beginning of period t . The federal bonds are available for purchase to households of both regions. The federal authorities also impose negative lump-sum taxes on the residents of each region,

T_{FG} and T_{FG}^* .¹ The budget constraint of the Federal government takes the following form:

$$\begin{aligned} \tau_K(R_t K_t + R_t^* K_t^*) + \tau_L(W_t \bar{L} + W_t^* \bar{L}^*) + B_{FG,t+1} + B_{FG,t+1}^* + T_{FG,t} + T_{FG,t}^* \quad (3.3) \\ = \bar{C}_G + (1 + R_{FG,t})B_{FG,t} + (1 + R_{FG,t})B_{FG,t}^*. \end{aligned}$$

Regional Governments

Both regional governments collect consumption taxes at a uniform rate, τ_C , from the residents of their own region and provide a rival productive public good, I_{RG} , to the local representative firm. T_{RG} and T_{RG}^* stand for regional lump-sum taxes.

The government of Region 1 has a zero-borrowing limit and the public good provision is thus determined only by current tax revenues of the region and is exogenously capped at the steady-state level, \bar{I}_{RG} :

$$\begin{aligned} \tau_C C_t + T_{RG,t} &= I_{RG,t}, \quad (3.4) \\ I_{RG,t} &= \min\{\tau_C C_t, \bar{I}_{RG}\}. \end{aligned}$$

In these case where the government adopts the Flexible fiscal policy, it is not constrained by a borrowing limit and therefore can issue one-period, risk-free bonds, B_{RG1} , where $RG1$ denotes Region 1 Government, to maintain the provision of the productive public good independently of transitory shocks to its revenues, that is at the exogenously predetermined steady-state level. The interest rate $R_{RG1,t}$ is paid to the bondholders at the beginning of the period. The budget constraint of the Region 1 government takes the following form:

$$\begin{aligned} \tau_C C_t + B_{RG1,t+1} + B_{RG1,t+1}^* + T_{RG,t} \quad (3.5) \\ = \bar{I}_{RG} + (1 + R_{RG1,t})B_{RG1,t} + (1 + R_{RG1,t})B_{RG1,t}^*, \end{aligned}$$

¹The negative lump-sum taxes have an interpretation of transfers, such as welfare and social security payments.

where B_{RG1} and B_{RG1}^* refer to the $RG1$ bond holdings of the representative households in Region 1 and Region 2, correspondingly.²

3.2.2 Equilibrium Conditions

Households

Conditional on both regions conducting the Flexible policy, the representative household in Region 1 maximizes its utility (3.6) by optimally choosing its consumption, investment, and holdings of private and public bonds, where $\beta \in (0, 1)$ is a subjective discount factor, subject to the constraint (3.7):

$$\max_{C_t, I_t, B_{t+1}, B_{FG,t+1}, B_{RG1,t+1}, B_{RG2,t+1}} E_t \left[\sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\gamma}}{1-\gamma} + \frac{\bar{C}_G^{-1-\gamma_G}}{1-\gamma_G} \right) \right] \quad (3.6)$$

s.t.

$$\begin{aligned} & (1 - \tau_K)R_t K_t + (1 - \tau_L)W_t \bar{L} \quad (3.7) \\ & +(1 + R_{PRI,t})B_t + (1 + R_{FG,t})B_{FG,t} + (1 + R_{RG1,t})B_{RG1,t} + (1 + R_{RG2,t})B_{RG2,t} \\ & = (1 + \tau_C)C_t + I_t + B_{t+1} + B_{FG,t+1} + B_{RG1,t+1} + B_{RG2,t+1} \\ & \quad + \frac{\eta}{2}(B_{t+1})^2 + \frac{\eta}{2}(B_{FG,t+1})^2 + \frac{\eta}{2}(B_{RG1,t+1})^2 + \frac{\eta}{2}(B_{RG2,t+1})^2 \\ & \quad + T_{FG,t} + T_{RG,t} + T_{\eta,t}. \end{aligned}$$

The constraint states that the household allocates its disposable labor and capital income and returns on its bond holdings among consumption spending, investment in productive private capital, and purchases of the bonds. Following [Turnovsky \(1985\)](#), households pay the bond-holding adjustment fees η to financial intermediaries. Quadratic bond-holding adjustment costs ensure the uniqueness of the macroeconomic equilibrium

²The prototypical regions of two types are plotted on [Figure 2.1](#). Some historical information about the classification of regions is presented in [Appendix B.1](#).

and stationarize the response of the economy to transitory shocks. These fees are rebated to households via T_η . If any regional government implements the Rigid policy, the corresponding terms associated with regional bonds disappear from the problem. Finally, the household pays lump-sum taxes to, or receives lump-sum transfers from, both levels of government, T_{FG} and T_{RG} .

The solution to the optimization problem yields the set of Euler equations for the households, (3.8) – (3.12). In the absence of the capital controls, these yield a no-arbitrage condition that equates interest rates on all types of bonds with returns on private capital, adjusted for depreciation and the tax on capital income.

$$(C_t)^{-\gamma} = \beta((1 - \tau_K)R_{t+1} + 1 - \delta)E_t [(C_{t+1})^{-\gamma}], \quad (3.8)$$

$$(1 + \eta B_{t+1})(C_t)^{-\gamma} = \beta(1 + R_{PRI,t+1})E_t [(C_{t+1})^{-\gamma}], \quad (3.9)$$

$$(1 + \eta B_{FG,t+1})(C_t)^{-\gamma} = \beta(1 + R_{FG,t+1})E_t [(C_{t+1})^{-\gamma}], \quad (3.10)$$

$$(1 + \eta B_{RG 1,t+1})(C_t)^{-\gamma} = \beta(1 + R_{RG 1,t+1})E_t [(C_{t+1})^{-\gamma}], \quad (3.11)$$

$$(1 + \eta B_{RG 2,t+1})(C_t)^{-\gamma} = \beta(1 + R_{RG 2,t+1})E_t [(C_{t+1})^{-\gamma}]. \quad (3.12)$$

The perfect risk-sharing condition (3.13) states that the ratio of the marginal utilities of consumption across the regions is constant over time in the economy with complete asset markets. This condition can also be rearranged to show that perfect risk sharing implies the perfect correlation of the marginal utilities of consumption across the regions. The incomplete financial markets adopted in this model allow to analyze how regional borrowing limits affect risk sharing.

$$\frac{(C_t)^{-\gamma}}{(C_{t+1})^{-\gamma}} = \frac{(C_t^*)^{-\gamma}}{(C_{t+1}^*)^{-\gamma}} \quad (3.13)$$

Finally, to satisfy the intertemporal budget constraint, the household is subject to the transversality (3.14) and no-Ponzi game (3.15) conditions. The former ensures that

all capital is used by the end of time and the latter implies that the household cannot finance its consumption indefinitely by borrowing.

$$\lim_{t \rightarrow \infty} \beta^t \lambda_t K_{t+1} = 0, \quad (3.14)$$

$$\lim_{t \rightarrow \infty} \beta^t \lambda_t B_{t+1} = 0, \quad (3.15)$$

where λ refers to the shadow value of consumption.

Firms

The representative firm in Region 1 maximizes its profits, which yields the standard optimality conditions (3.16) and (3.17) that equate the wage and the return to private capital to marginal productivities of labor and capital stock, respectively:

$$W_t = (1 - \alpha)Y_t/\bar{L}, \quad (3.16)$$

$$R_t = \alpha Y_t/K_t. \quad (3.17)$$

The law of motion for private capital stock is standard, with $\delta \in (0, 1)$ being the depreciation rate.

$$K_t = I_t + (1 - \delta)K_{t-1}. \quad (3.18)$$

Federal Government

In order to rule out the explosion of public debt, a fiscal feedback rule is introduced.³ I adopt the rule from [Erceg et al.'s \(2006\)](#) SIGMA model, which relates the budget-deficit-to-output ratio to the debt-to-output ratio. The rule for the federal debt held by residents

³A discussion of the necessity of the fiscal feedback rule for determinacy of equilibrium and model stability can be found in [Aiyagari et al. \(2002\)](#).

of Region 1 takes the following form:

$$\frac{T_{FG,t}}{Y_t} = \frac{T_{FG,t-1}}{Y_{t-1}} + \iota_{st} \left(\frac{B_{FG,t+1}}{Y_t} - \frac{B_{stst}}{Y_{stst}} \right) + \iota_{gr} \left(\frac{B_{FG,t+1}}{Y_t} - \frac{B_{FG,t}}{Y_{t-1}} \right), \quad (3.19)$$

where parameter $\iota_{gr} \in (0, 1)$ determines the speed of the debt adjustment, which increases with ι_{gr} , parameter $\iota_{st} \in (0, 1)$ determines the cyclicity of the adjustment, and the variables with the subscript *stst* refer to their steady-state values.

The adjustment rule for the federal debt held by residents of Region 2 is symmetric.

Regional Governments

Similarly to the federal government's case, an analogous fiscal feedback rule restricts the accumulation of the regional public debt (3.20). The rule applies to the bonds issued by the government of Region 1 and held by households in both regions:

$$\begin{aligned} \frac{T_{RG,t}}{Y_t} = & \frac{T_{RG,t-1}}{Y_{t-1}} + \iota_{st} \left(\frac{B_{RG1,t+1} + B_{RG1,t+1}^*}{Y_t} - \frac{B_{RG1,stst}}{Y_{stst}} \right) \\ & + \iota_{gr} \left(\frac{B_{RG1,t+1} + B_{RG1,t+1}^*}{Y_t} - \frac{B_{RG1,t} + B_{RG1,t}^*}{Y_{t-1}} \right). \end{aligned} \quad (3.20)$$

The adjustment rule for the regional debt held by residents of Region 2 is symmetric.

The law of motion for the stock of public capital, K_{RG} , is analogous to that for private capital. Parameter $\delta_G \in (0, 1)$ is the rate of depreciation of public capital stock.

$$K_{RG,t} = I_{RG,t} + (1 - \delta_G)K_{RG,t-1}. \quad (3.21)$$

Aggregation and Interregional Trade

The aggregate national accounting identity (3.22) is obtained by combining budget constraints of the households and the governments.

$$Y_t + Y_t^* = C_t + C_t^* + I_t + I_t^* + \overline{C_G} + I_{RG,t} + I_{RG,t}^*. \quad (3.22)$$

The trade balance is given by:

$$BOT_t = Y_t - C_t - I_t - 0.5\overline{C_G} - I_{RG,t}. \quad (3.23)$$

In the case where one region runs a trade deficit, its representative household issues private debt obligations to finance its private expenditures. Then the equation for the Region 1 net regional asset accumulation takes the following form:⁴

$$\begin{aligned} B_{t+1} - (1 + R_{PRI,t})B_t &= \frac{1}{2}(R_t K_t - R_t^* K_t^*) + \frac{1}{2}(W_t \overline{L} - W_t^* \overline{L}^*) \\ &\quad - \frac{1}{2}(C_t - C_t^*) - \frac{1}{2}(I_t - I_t^*) - \frac{1}{2}(I_{RG,t} - I_{RG,t}^*). \end{aligned} \quad (3.24)$$

Finally, the private bonds are in zero net supply:

$$B_t + B_t^* = 0. \quad (3.25)$$

Game Setup

Each regional government's strategy space, $\Omega_1 = \{R, F\}$, includes two types of policy that differ in their attitude to public debt and, hence, public good provision. Rigid or R represents the choice of the zero-borrowing limit and the public good provision consistent with the regional government budget constraint (3.4). Flexible or F refers to the absence of a borrowing limit and the exogenous provision of the public good, as described in the budget constraint (3.5).

Formally, the noncooperative problem of Region 1 takes the following form:

$$\max_{\Omega_1} \max_{C_t, I_t, \mathbf{B}_{t+1}} E_t \left[\sum_{t=0}^{\infty} \beta^t U(C_t, \overline{C_G}) \right], \quad (3.26)$$

⁴By construction, the positive net regional asset position of a given region corresponds to the net positive holdings of assets issued by another region by the residents of the former region. See Appendix B.2 for details.

where the outer maximand is subject to regional government budget constraints (3.4 and 3.5) and the inner is subject to the household budget constraint (3.7).⁵ The Region 2 problem is symmetric.

When regional governments cooperate to maximize their joint welfare, their strategy space, $\Omega_2 = \{RR, RF, FR, FF\}$, becomes a natural extension of the noncooperative problem strategy space. The first symbol in each strategy-space element refers to the Region 1 choice, while the second refers to the choice of Region 2. For instance, RF means that Region 1 adopts the Rigid fiscal policy and Region 2 adopts the Flexible policy. The cooperative problem takes the form:

$$\max_{\Omega_2} \left[\max_{C_t, I_t, \mathbf{B}_{t+1}} E_t \left[\sum_{t=0}^{\infty} \beta^t U(C_t, \overline{C}_G) \right] + \max_{C_t^*, I_t^*, \mathbf{B}_{t+1}^*} E_t \left[\sum_{t=0}^{\infty} \beta^t U(C_t^*, \overline{C}_G) \right] \right], \quad (3.27)$$

subject to the budget constraints of both regional governments (3.4 and 3.5). Note that the specification of this problem implies that the utilities of the individual regions have equal weight from the union standpoint.

Because any modification of balanced-budget rules requires legislative changes⁶ and is accompanied by substantial policy lags, it can hardly be considered a policy instrument operating at business cycle frequency. Therefore, regions make their policy choices only once in this model, before the start of the game, and the policymakers commit to their actions until the end of time. The policymakers' decisions become immediately known to the households.

⁵To economize on notation, vector \mathbf{B} is introduced. It combines all possible types of bonds, B, B_{RG1}, B_{RG2} , and B_{FG} .

⁶In the U.S., constitutional and/or statutory changes at the state level are required.

3.3 Calibration

The calibration of the model's parameters follows the approach of taken in the second chapter. The parameter values are calibrated at an annual frequency and are summarized in Table 2.2. The discount factor, β , is set to 0.9615. $\gamma = 2$ is a standard choice for the intertemporal elasticity of substitution for private consumption goods. $\gamma_G = 2$ is an analogous parameter for the consumption public good.

The share of national income that accrues to private capital, α , is 0.36, while the remainder accrues to labor. The elasticity of the output with respect to public capital, α_G , implies its productivity,⁷ and is difficult to pin down. Given the uncertainty about the productivity of public investment, I choose 0.2 as a baseline (medium) value and conduct robustness tests with alternative values of the productivity parameter: 0.05 (very low), 0.1 (low), and 0.3 (high).

The depreciation rate is set to 0.1 for private capital stock and 0.08 for more durable public capital. The capital income tax rate, τ_K , is set to 0.305, the labor income tax, τ_L , is 0.24, and the consumption tax rate, τ_C , is 0.1. The speed of public debt adjustment, ι_{gr} , is chosen following the SIGMA model and is equal to 0.1. The bond-holding adjustment cost, η , is set to the standard value in the literature, 0.0025.

The bivariate exogenous productivity process is modeled in two fashions to capture the most probable range of the parameter estimates. First, without interregional spillovers and a high persistence of shocks, as in [Baxter \(1995\)](#):

$$\begin{bmatrix} \phi_Z & \phi_{ZZ^*} \\ \phi_{Z^*Z} & \phi_{Z^*} \end{bmatrix} = \begin{bmatrix} 0.995 & 0 \\ 0 & 0.995 \end{bmatrix}. \quad (3.28)$$

Second, with spillovers and a lower persistence of own shocks, as in [Backus et al.](#)

⁷[Eicher and Turnovsky \(2000\)](#) interpret low public good productivity as substantial congestion of the public goods.

(1992):

$$\begin{bmatrix} \phi_Z & \phi_{ZZ^*} \\ \phi_{Z^*Z} & \phi_{Z^*} \end{bmatrix} = \begin{bmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{bmatrix}. \quad (3.29)$$

Finally, consumption, investment, and government expenditure shares are calibrated to 62.4%, 17.9%, and 19.7% of national output, respectively.⁸ I calibrate the share of the consumption public good provided by the federal government and the share of productive public goods provided by the regional governments to the corresponding shares of current and capital operations budgets in the national income, 15.3% and 4.4%, respectively.

3.4 Policy Interactions

This section studies the policy interactions of the regional governments that have the authority to adopt different fiscal policy regimes. It starts with the analysis of the model economy after the realization of one-time aggregate and idiosyncratic shocks (Subsection 3.4.1), before proceeding to the environment in which historical shocks realize (Subsection 3.4.2). Then, it continues with the estimation of welfare cost of business fluctuations given the realization of a historical sequence of shocks conditional on alternative regional borrowing limits (Subsection 3.4.3), and reports estimates of the counterfactual welfare improvement associated with the corresponding adjustment of the borrowing limits (Subsection 3.4.4).

3.4.1 One-Time Shocks

Parameters calibrated in the previous section, together with equilibrium conditions from Section 3.2, are used to numerically solve for the unique (conditional on the type of

⁸The average values for 1977–2000 were calculated from the NIPA Table 1.1. The national output is defined as domestic absorption consistently with the market-clearing condition (3.22).

adopted fiscal policy) symmetric steady state. Decision rules and dynamic responses of the endogenous variables to productivity shocks are obtained with the first-order perturbation technique. The choice of the linear solution method is dictated by the compatibility requirements of the [Guerrieri and Iacoviello \(2015\)](#) occasionally binding constraints toolkit.

Using the numerical results, this section investigates how the public borrowing limits affect welfare and risk sharing in the fiscal union in the scenario of one-time orthogonal adverse productivity shocks that realize in both regions as well as in one region only. I allow for technology process specifications both without and with spillovers between the regions.

Aggregate Shock

Consider the realization of an aggregate shock in the model economy with a medium productivity of public goods and the technology process with spillovers. Panel 3A of [Table 3.1](#) presents results of the noncooperative problem, [\(3.26\)](#). The table entries refer to the lifetime welfare loss of the representative households.

Let both regions of the union initially pursue the Rigid (zero-borrowing limit) policy. Then each region has an incentive to adopt the Flexible policy to minimize the welfare loss of its representative household after the arrival of a negative productivity shock. If only one region switches its strategy to Flexible, while the other preserves the zero-borrowing limit, the former region stabilizes its economy faster by attracting resources from the latter region, which deteriorates the risk sharing. The Flexible region would be able to provide an uninterrupted flow of the productivity-augmenting public good upon the realization of a negative shock, which also allows that region to utilize the shift of resources to its own benefit.

To eschew this negative spillover effect, the other government switches to the Flexible policy. For each individual regional government, the dominant welfare-maximizing

strategy is to remove the zero-borrowing limit. Panel 3A shows that each region has an incentive to deviate from the Rigid strategy. Hence, the Nash equilibrium in the scenario of the aggregate shocks is FF .

Finally, this outcome is consistent with the federal government's objective. Panel B of the same table presents results of the cooperative problem, (3.27). The Flexible policy pursued by each region remains the dominant strategy from the fiscal union's perspective as well. This implies that there is no conflict between the objectives of the regional and federal governments.

As corresponding panels of Table 3.1 suggest, the equilibrium strategies of this game are determined by the productivity of public goods, α_G . Conditional on the low, medium, or high productivity of public goods, union welfare is maximized by the adoption of the Flexible fiscal policy. However, if public good productivity is very low, the Rigid fiscal policy minimizes the welfare costs.

The outcomes of the policy-interaction game, conditional on low through high levels of public good productivity, can be ranked according to the minimization of the union welfare cost as follows:⁹

$$FF \succ FR = RF \succ RR.$$

In a fiscal union with symmetric borrowing limits across its members, an aggregate shock brings about identical welfare losses across all regions. When union members mirror each other's choice of public borrowing limits, the shift of resources cancels out, as the marginal productivity of private factors in each region stays equal across the regions. The symmetric policies, when both regions lift borrowing limits, FF , top the ranking, as they maximize the output of each region. By providing a steady flow of productive public goods, both regions increase the marginal productivity of their private factors.

The second set of the symmetric policies, RR , concludes the ranking, because regional output is minimized when both policymakers impose zero-borrowing limits and hence lose

⁹Note that from the regional standpoint F dominates R in this game.

an opportunity to augment the productivity of private factors.

Consequently, both asymmetric policies, RF and FR , are ranked between the two symmetric ones. Because the shift of resources takes place, the recipient of the resources does better than the other region. Although interregional risk sharing deteriorates, the boost of output in the only region that adopts the Flexible policy is sufficient to increase the union's welfare above the level achieved conditional on RR . The welfare cost of RF is equal to the cost of FR due to the symmetry of the regions.

Next, consider the very low productivity of public goods. The welfare ranking of the policies is reversed:

$$RR \succ FR = RF \succ FF.$$

In this case, debt financing of public expenditures is not justified, since the cost of public investment is greater than is its benefit, and the regions prefer to completely shut down their public borrowing. Therefore, the logic of the ranking works in reverse to minimize the waste of resources. As in the case with higher public good productivity, no conflict between objectives of the regional and federal governments emerges (Panel 1B of Table 3.1).

The comparison of these results with the results conditional on the technology process without spillovers shows that all qualitative results are preserved, while welfare costs increase modestly once the spillovers are removed (Table C.2).

Idiosyncratic Shocks

In this subsection, the adverse productivity shock is assumed to be realized in Region 1. An analysis of the effects of idiosyncratic shocks with technology spillovers and without them is presented in Tables 3.2 and C.3, correspondingly. The results are qualitatively similar to the results of the aggregate shocks analysis. The productivity of public goods remains the unique parameter that determines the welfare-maximizing fiscal policy. Conditional on the low, medium, or high productivity of public goods, the welfare ranking of

the fiscal policies from the union standpoint is as follows:

$$FF \succ FR \succ RF \succ RR.$$

The Nash equilibrium, conditional on the public good productivity, is unique. With sufficiently high productivity of public goods, $\alpha_G = \{l, m, h\}$, FF becomes the welfare-maximizing policy. Yet the union is no longer indifferent between the two asymmetric policies. The shock's impact on the marginal productivity is stronger in the region in which the shock has been realized; hence, adopting the Flexible policy and maintaining a steady provision of the public good in that region induces a larger shift of resources and closes the consumption differential between the regions to the greater extent. Therefore, FR dominates RF .

When α_G is very low, the logic works in reverse, as previously discussed, and the ranking reverses:

$$RR \succ RF \succ FR \succ FF.$$

Finally, note that the spillovers smooth the interregional differences. Put another way, without spillovers, the welfare cost of fiscal policies becomes larger for the policies ranked lower, but abstracting from spillovers is not sufficient to change the welfare ordering (Tables 3.2 and C.3).

3.4.2 Historical Shocks

Having established the intuition for policy interaction conditional on theoretical one-time shocks, the next natural step is to estimate the welfare cost of the currently adopted fiscal policy (RF) according to the model notation, and to check how the policy interactions would change, if any, once the historical productivity shock realization is taken into account.

Data and Methodology

The shock sequence is estimated from the series of Solow residuals obtained from a production function of the following form:¹⁰

$$Y_t = Z_t L^\alpha K_t^{1-\alpha}. \quad (3.30)$$

The series for output, Y , and capital, K , are in 2000 dollars and taken from [Chirinko and Wilson \(2009\)](#).¹¹ Their database covers manufacturing industries at the state level. The data were aggregated to represent model regions according to [ACIR \(1987\)](#) taxonomy, as described in Section 3.1.

Labor input, L , is represented by the total number of jobs in manufacturing by county and aggregated to U.S. state levels before aggregating them to regional levels. The original series are obtained from [BEA Table CA25](#), “Total Full-Time and Part-Time Employment by Industry.”¹²

The sample spans 1969–2000 with a three-year gap. Between 1979 and 1981, the U.S. Census Bureau did not conduct its Annual Survey of Manufacturers, and the output series were not collected. The series of the log total factor productivity were estimated with the value of α calibrated, as described in Section 3.3. Next, $\log(Z)$ series were normalized to have the mean value of one.

Using the normalized productivity series, I retrieve two alternative historical shock

¹⁰ Using the production function without public capital to retrieve the shocks, while the structural model has a technology has public capital as an input, is not the first-best approach and is driven by regional public capital data’s limited availability. However, similar discrepancies are not uncommon in the literature. For example, [Backus et al. \(1992\)](#) omit physical capital in the estimation of their production function parameters, although it is present in the production function included in their structural model. [Glick and Rogoff \(1995\)](#) omit either capital or labor in alternative versions of their production function estimation. Yet results of their model, conditional on the use of alternative parameterization, are similar.

¹¹ Accessed 2015/06/16.

¹² Accessed 2015/05/27.

sequences according to the alternative parameterization of the technology process specified in Section 3.3. One sequence is obtained using the matrix of VAR coefficients with non-zero off-diagonal elements, as estimated by Backus et al. (1992), equation (3.29). The other sequence is estimated without spillovers, following Baxter (1995), equation (3.28). Due to the lag structure of the technology process, the sample shrinks by one observation and the resulting shock sequence of each region contains 27 observations. Each shock sequence was de-trended with an HP filter to retrieve a cyclical component consistent with the model's stationary steady state.

The historical shock sequences obtained with different technology process specifications are closely correlated with slightly higher variability of the shocks in the Rigid region: $\sigma_{\epsilon^R} = 0.0073 > \sigma_{\epsilon^F} = 0.0066$.¹³

Welfare Ranking of Policies

As in the scenario of one-time shocks, the productivity of public goods determines the welfare ranking of the fiscal policies. The policy *RF* currently adopted in the U.S. is neither the best nor the worst possible fiscal policy. Tables 3.3 and C.4 present welfare loss estimates with spillovers and without them, correspondingly, in a noncooperative (Panel A) and cooperative (Panel B) setting.

The productivity of public goods remains the unique parameter that determines the welfare-maximizing fiscal policy. Conditional on $\alpha_G = \{l, m, h\}$, Panels 2B – 4B,

$$FF \succ FR \succ RF \succ RR.$$

The best and the worst policies are ranked as in the previous section. If no technology spillovers between the regions are allowed, *FR* strictly dominates *RF* due to the unequal

¹³The statistics presented for the shocks were obtained with a technology process consistent with the Backus et al. (1992) specification. For the technology process without spillovers, as in Baxter (1995), the volatility of shocks is almost identical: $\sigma_{\epsilon^R} = 0.0072 > \sigma_{\epsilon^F} = 0.0067$.

variances of the historical shocks realization in the regions. As in the one-time shock scenarios, spillovers comove the macroeconomic variables and mitigate the interregional differences. Therefore, the welfare benefit of FR becomes just marginally higher than that of RF once technology spillovers are modeled.

Conditional on $\alpha_G = v.l.$, Panel 1B,

$$RR \succ RF \succ FR \succ FF.$$

Again, the intuition from the previous section is preserved, and the logic works in reverse to minimize the waste of resources.

Finally, regardless of the public good productivity, a conflict between the objectives of the regional and federal governments does not emerge.

3.4.3 Cost of Business Cycles

To obtain the estimates of the cost of business cycles and union welfare improvement, the retrieved sequence of historical productivity shocks is fed into the model.

The welfare cost of business cycle fluctuations in a union that adopts the symmetric Flexible policy, FF , conditional on the low, medium, or high productivity of public goods, is consistent with Lucas' (2003) estimate that amounts to 0.05% of lifetime consumption (policy FF in Panel B of Table 3.3).¹⁴

Once the union with at least low productivity of public goods deviates from fiscal policy FF , the cost of business cycles increases. The exact magnitude depends on the productivity of public goods, fiscal policy, and technology process. For example, for the U.S. as a fiscal union with medium public good productivity that adopted the asymmetric regional fiscal policy, RF , the welfare costs are estimated in the range of 0.11%–0.12% of lifetime consumption. The exact value depends on the technology process specification

¹⁴Lucas estimates the cost of business cycles for a unitary economy model without a public sector.

(Panels 3B of Tables 3.3 and C.4). Alternatively, the welfare cost can be as high as 0.28% of lifetime consumption when public goods are highly productive, there are technology spillovers across the regions, and both regions refrain from public borrowing (Panel 4B of Table C.4).

The minimal cost of business cycles, 0.043% of lifetime consumption, is achieved in the case of congested public goods, when both regions adopt the Rigid policy in the environment with technology spillovers, as Panels 1B of Tables 3.3 and C.4 illustrate.

3.4.4 Counterfactual Welfare Improvement

Although the model predicts that both regions should find it beneficial to adopt the Flexible policy, the current fiscal policy pursued by the U.S. is asymmetric, RF . Panel A of Table 3.4 presents estimates of the welfare improvement that would have been achieved had the union with sufficiently high productivity of public goods changed its fiscal policy from RF to the welfare-maximizing FF . The union welfare gains range from 0.01% to 0.15% of lifetime consumption, or from 22% to 75% of the cost of business cycle fluctuations. The gains from the policy change increase with α_G , as the opportunities to augment the marginal productivity of private factors are realized. Also, the welfare improvement is marginally larger in the absence of spillovers.

Conditional on the very low productivity of public goods, welfare improvement is achieved by switching to RR , that is by shutting down borrowing by both regional governments. However, the welfare gain is negligibly small in this scenario, as Panel B of Table 3.4 reports. The estimates range from 0.002% to 0.003% of permanent consumption, depending on the technology process specification.

3.5 Conclusions

The objective of this chapter was to study how the design of borrowing limits in the fiscal union should be altered to improve risk sharing and welfare. I show that it is possible to increase efficiency and improve interregional consumption risk sharing by adopting symmetric borrowing limits, which would minimize the shift of resources between the regions.¹⁵

The policy implication of the present study is that the unique parameter that should be taken into account by designers of regional borrowing limits is public good productivity. When the productivity is sufficiently high, welfare is maximized and risk sharing is improved by lifting any restrictions on public borrowing by all regional governments. Otherwise, when public good productivity is very low, all members of the union should refrain from public borrowing to maximize welfare and improve consumption risk sharing. Importantly, other aspects of the economy, such as the type of technology process, or the shock type (aggregate or idiosyncratic), do not matter for the policy choice.

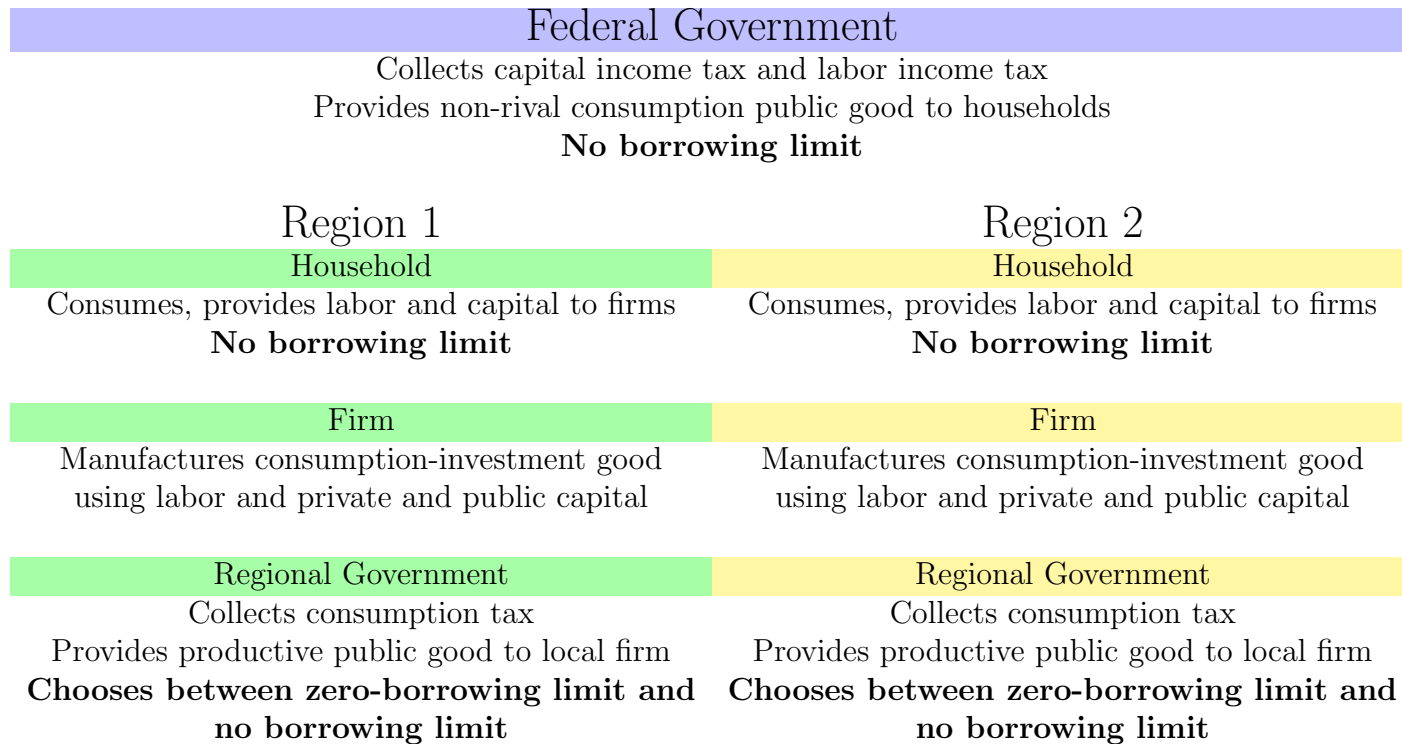
Moreover, welfare gains associated with switching the fiscal union's policy from the currently adopted asymmetric one to a symmetric welfare-maximizing policy have been estimated. Based on the realization of a sequence of historical productivity shocks between 1970 and 2000, the welfare improvement amounts to 55.5% of the cost of business cycle fluctuations in the most plausible model specification.

According to this study's findings, there is no need for fiscal policy coordination between the regions, as a conflict between their individual utility maximization and the objective of joint regional welfare maximization does not emerge. On the other hand, the current balanced-budget rules adopted by the U.S. states correspond to the model's asymmetric *FR* policy, rather than a symmetric one. This contradiction could be due to other political economy considerations, such as voters' political preferences regarding

¹⁵The shift of resources is minimized, conditional on the realization of asymmetric shocks, and eliminated if aggregate disturbances are realized.

ideology, size of the state, and so forth, which are beyond the scope of this analysis.

Figure 3.1: Structure of the model economy.



Note: “No borrowing limit” refers to the absence of an institutional limit and does not imply the agents are not subject to the no-Ponzi game condition.

Table 3.1: Lifetime welfare loss of the representative households after the realization of the aggregate -1% productivity shock, %.

<i>$\alpha_G = \text{very low}$</i>							
Panel 1A. Noncooperative policy.			Panel 1B. Cooperative policy.				
		RG 2					
		R	F				
RG 1	R	1.54, 1.54	1.54, 1.57	RG 1	R	3.08	3.10
	F	1.57, 1.54	1.57, 1.57		F	3.10	3.14
<i>$\alpha_G = \text{low}$</i>							
Panel 2A. Noncooperative policy.			Panel 2B. Cooperative policy.				
		RG 2					
		R	F				
RG 1	R	1.67, 1.67	1.68, 1.56	RG 1	R	3.34	3.24
	F	1.56, 1.68	1.57, 1.57		F	3.24	3.14
<i>$\alpha_G = \text{medium}$</i>							
Panel 3A. Noncooperative policy.			Panel 3B. Cooperative policy.				
		RG 2					
		R	F				
RG 1	R	2.01, 2.01	2.04, 1.54	RG 1	R	4.02	3.58
	F	1.54, 2.04	1.57, 1.57		F	3.58	3.14
<i>$\alpha_G = \text{high}$</i>							
Panel 4A. Noncooperative policy.			Panel 4B. Cooperative policy.				
		RG 2					
		R	F				
RG 1	R	2.51, 2.51	2.59, 1.52	RG 1	R	5.02	4.11
	F	1.52, 2.59	1.57, 1.57		F	4.11	3.14

Notes: The technology process with spillovers is adopted. F (R) stands for the Flexible (Rigid) fiscal policy.

Table 3.2: Lifetime welfare loss of the representative households after the realization of the idiosyncratic -1% productivity shock in Region 1, %.

$\alpha_G = \textit{very low}$						
Panel 1A. Noncooperative policy.			Panel 1B. Cooperative policy.			
RG 2			RG 2			
			RG 1			
			F			
			R			
RG 1	R	0.94, 0.60	0.94, 0.61	R	1.54	1.55
	F	0.95, 0.60	0.96, 0.61	F	1.55	1.57

$\alpha_G = \textit{low}$						
Panel 2A. Noncooperative policy.			Panel 2B. Cooperative policy.			
RG 2			RG 2			
			RG 1			
			F			
			R			
RG 1	R	1.02, 0.65	1.02, 0.61	R	1.67	1.63
	F	0.95, 0.66	0.96, 0.61	F	1.61	1.57

$\alpha_G = \textit{medium}$						
Panel 3A. Noncooperative policy.			Panel 3B. Cooperative policy.			
RG 2			RG 2			
			RG 1			
			F			
			R			
RG 1	R	1.23, 0.78	1.24, 0.60	R	2.01	1.84
	F	0.95, 0.80	0.96, 0.61	F	1.75	1.57

$\alpha_G = \textit{high}$						
Panel 4A. Noncooperative policy.			Panel 4B. Cooperative policy.			
RG 2			RG 2			
			RG 1			
			F			
			R			
RG 1	R	1.55, 0.96	1.58, 0.58	R	2.51	2.16
	F	0.94, 1.01	0.96, 0.61	F	1.95	1.57

Notes: The technology process with spillovers is adopted. F (R) stands for the Flexible (Rigid) fiscal policy.

Table 3.3: Lifetime welfare loss of the representative households after the realization of the historical productivity shock sequence, %.

$\alpha_G = \textit{very low}$							
Panel 1A. Noncooperative policy.			Panel 1B. Cooperative policy.				
RG 2			RG 2				
		R	F			R	F
RG 1	R	0.022, 0.021	0.022, 0.024	RG 1	R	0.043	0.046
	F	0.025, 0.020	0.025, 0.024		F	0.045	0.049
$\alpha_G = \textit{low}$							
Panel 2A. Noncooperative policy.			Panel 2B. Cooperative policy.				
RG 2			RG 2				
		R	F			R	F
RG 1	R	0.040, 0.037	0.041, 0.022	RG 1	R	0.08	0.06
	F	0.024, 0.039	0.025, 0.024		F	0.06	0.05
$\alpha_G = \textit{medium}$							
Panel 3A. Noncooperative policy.			Panel 3B. Cooperative policy.				
RG 2			RG 2				
		R	F			R	F
RG 1	R	0.083, 0.079	0.090, 0.020	RG 1	R	0.16	0.11
	F	0.022, 0.087	0.025, 0.024		F	0.11	0.05
$\alpha_G = \textit{high}$							
Panel 4A. Noncooperative policy.			Panel 4B. Cooperative policy.				
RG 2			RG 2				
		R	F			R	F
RG 1	R	0.143, 0.137	0.165, 0.016	RG 1	R	0.28	0.18
	F	0.018, 0.159	0.025, 0.024		F	0.18	0.05

Notes: The productivity shocks are obtained from the estimation of the bivariate technology process with spillovers. F (R) stands for the Flexible (Rigid) fiscal policy.

Table 3.4: Estimates of the counterfactual welfare improvement.

Panel A. Union-wide welfare improvement after switching from RF to FF .				
α_G	% of lifetime consumption		% of business cycle cost	
	spillovers	no spillovers	spillovers	no spillovers
low	0.01	0.02	22.2	24.2
med	0.06	0.07	55.5	57.6
high	0.13	0.15	72.9	74.6

Panel B. Union-wide welfare improvement after switching from RF to RR .				
α_G	% of lifetime consumption		% of business cycle cost	
	spillovers	no spillovers	spillovers	no spillovers
v low	0.003	0.002	6.5	4.3

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Appendix A

Appendix to Chapter 1

A.1 Net Regional Asset Accumulation

This appendix derives the expression for net regional asset accumulation for the θ^C region.

Aggregate accounting implies the following laws of motion for net regional assets in the θ^C and θ^L regions:

$$B_{t+1} - (1 + R_{PRI,t})B_t = R_t K_t + W_t \bar{L} - C_t - I_t - I_{RG,t} - \frac{1}{2}C_{G,t}, \quad (\text{A.1})$$

$$B_{t+1}^* - (1 + R_{PRI,t})B_t^* = R_t^* K_t^* + W_t^* \bar{L}^* - C_t^* - I_t^* - I_{RG,t}^* - \frac{1}{2}C_{G,t}^*. \quad (\text{A.2})$$

The right-hand side of each of the laws of motion is a regional equivalent of the System of National Accounts' definition of national savings for a sovereign state: national income less domestic absorption. If the regional savings are positive (negative), the region runs a trade surplus (deficit) and holds a positive (negative) net regional asset position.

Subtracting the latter equation from the former yields:

$$\begin{aligned} B_{t+1} - (1 + R_{PRI,t})B_t - B_{t+1}^* + (1 + R_{PRI,t})B_t^* & \quad (\text{A.3}) \\ & = (R_t K_t - R_t^* K_t^*) + (W_t \bar{L} - W_t^* \bar{L}^*) \\ & - (C_t - C_t^*) - (I_t - I_t^*) - (I_{RG,t} - I_{RG,t}^*) - \left(\frac{1}{2}C_{G,t} - \frac{1}{2}C_{G,t}^* \right). \end{aligned}$$

Using the fact that private bonds are in zero net supply, $B_t + B_t^* = 0$, and due to the

Federal government apportioning procurement of the consumption public good equally between the regions, one can rewrite (A.3) as

$$\begin{aligned}
 B_{t+1} - (1 + R_{PRI,t})B_t &= \frac{1}{2} (R_t K_t - R_t^* K_t^*) + \frac{1}{2} (W_t \bar{L} - W_t^* \bar{L}^*) \\
 &\quad - \frac{1}{2} (C_t - C_t^*) - \frac{1}{2} (I_t - I_t^*) - \frac{1}{2} (I_{RG,t} - I_{RG}^*).
 \end{aligned}
 \tag{A.4}$$

This equation relates the θ^C region's net regional asset accumulation to the interest income and differentials between the two regions' capital income, labor income, private absorption, and public absorption.

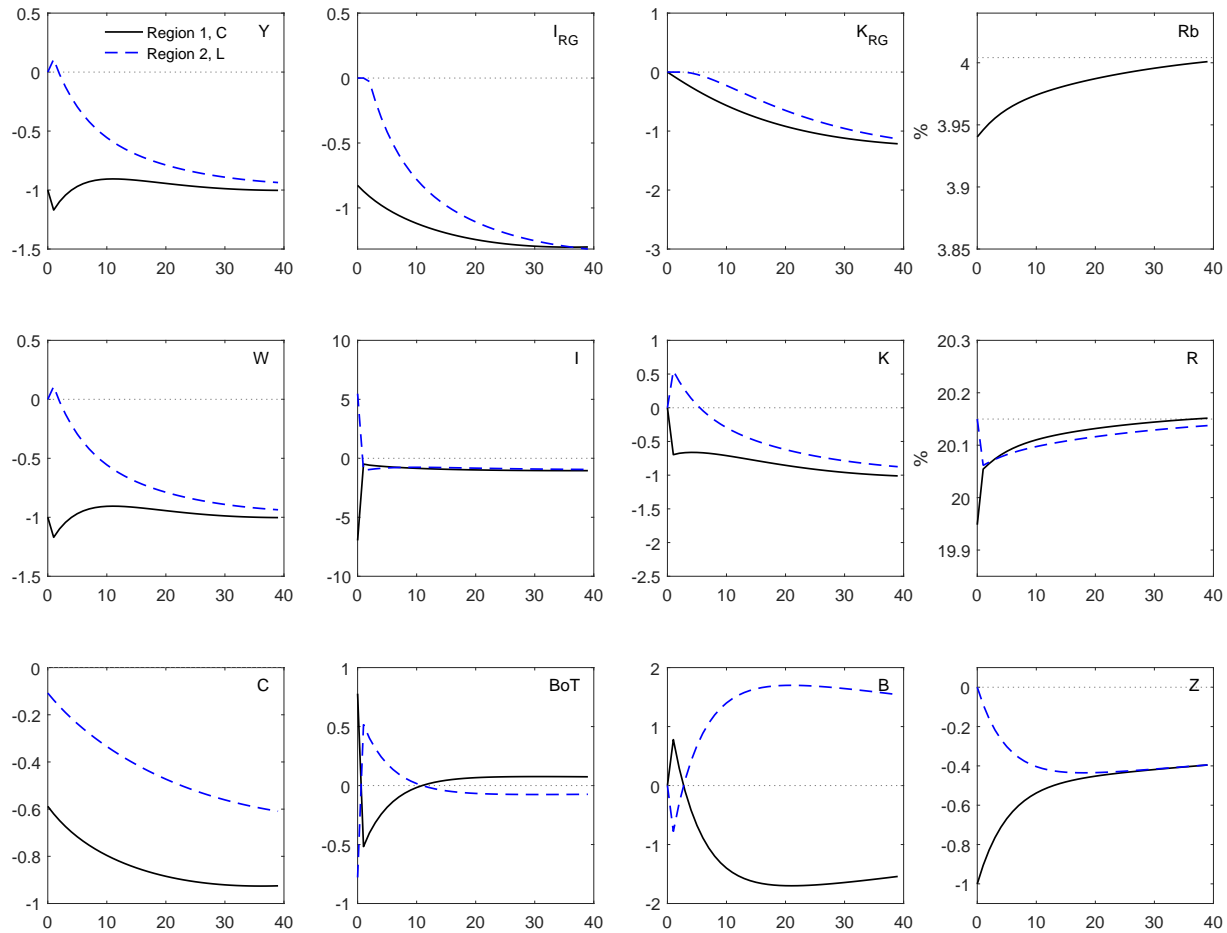
A.2 Some Results Conditional on Alternative Technology Process Specification

Table A.1: Lifetime welfare dynamics under alternative assumptions about the productivity of public goods in the fiscal union, without technology spillovers.

Panel A. Aggregate shock.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in the θ^C region, %	1.03	1.08	1.20	1.34
Loss of lifetime welfare in the θ^L region, %	1.02	1.10	1.31	1.61
$\theta^C - \theta^L$ loss differential, p.p.	0.005	-0.03	-0.12	-0.27
$\theta^C - \theta^L$ loss differential as % of the θ^C region loss	0.04	-2.4	-9.7	-20.4
Panel B. Idiosyncratic shock to the θ^C region.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in the θ^C region, %	1.33	1.43	1.67	2.03
Loss of lifetime welfare in the θ^L region, %	-0.31	-0.33	-0.39	-0.47
$\theta^C - \theta^L$ loss differential, p.p.	1.64	1.76	2.06	2.50
$\theta^C - \theta^L$ loss differential as % of the θ^L region loss	-528	-528	-530	-532
Panel C. Idiosyncratic shock to the θ^L region.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in the θ^C region, %	-0.31	-0.34	-0.39	-0.48
Loss of lifetime welfare in the θ^L region, %	1.33	1.43	1.69	2.06
$\theta^L - \theta^C$ loss differential, p.p.	1.64	1.76	2.09	2.54
$\theta^L - \theta^C$ loss differential as % of the θ^C region loss	-525	-526	-528	-532

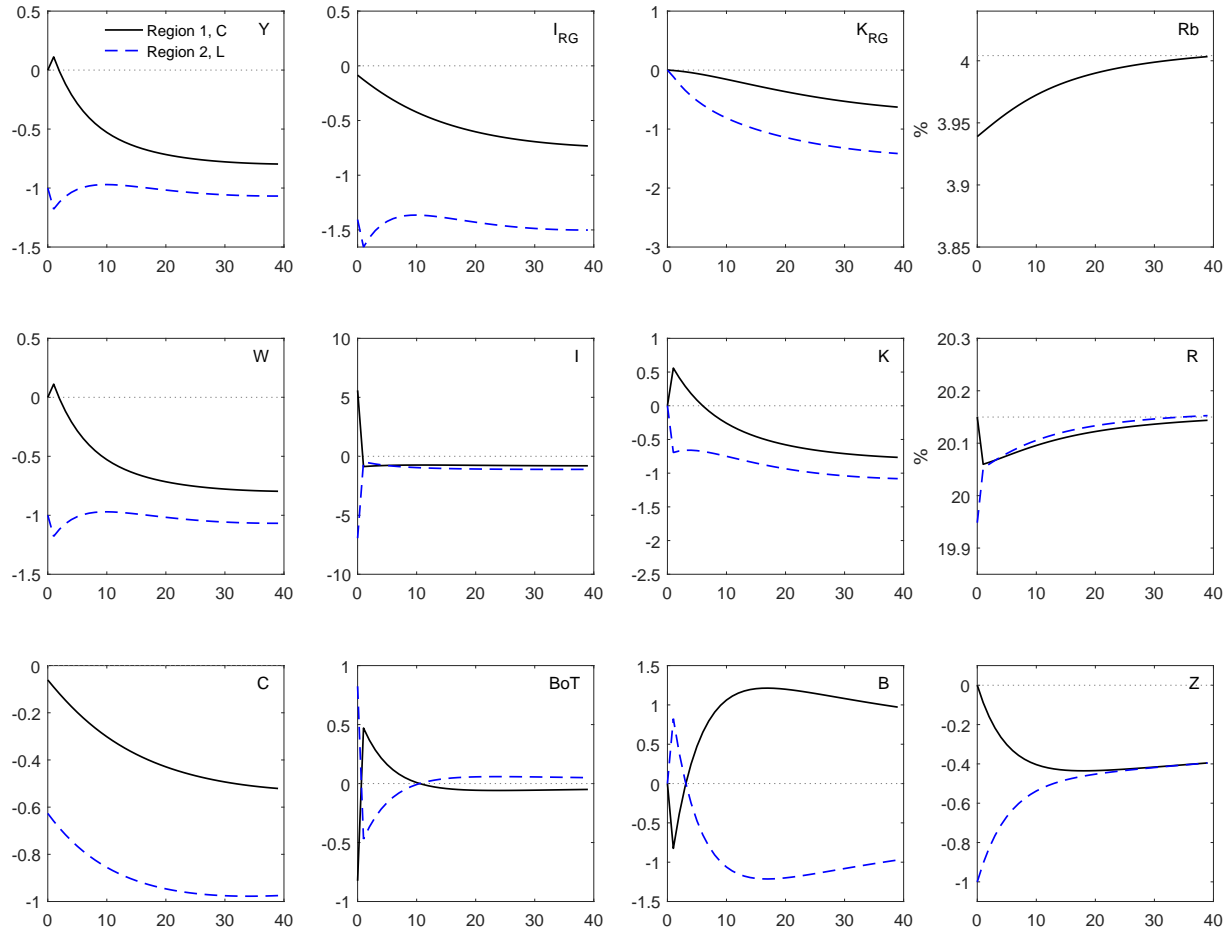
Notes: The fiscal union consists of the θ^L and θ^C regions. The table entries are calculated using consumption scale factors and have the interpretation of compensating variation measured in terms of private lifetime consumption.

Figure A.1: Response of the endogenous variables to the idiosyncratic -1% productivity shock to the θ^C region.



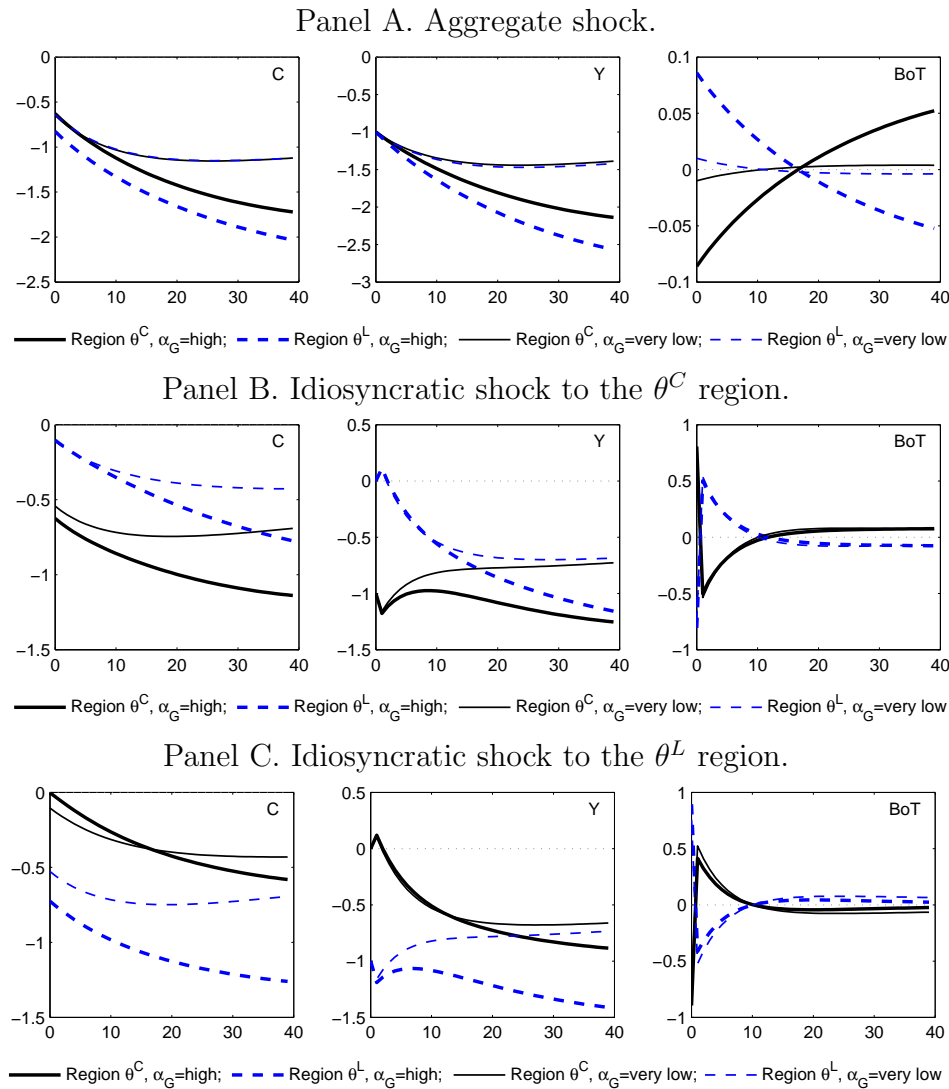
Notes: The fiscal union consists of the θ^C region and the θ^L region. The technology process with spillovers is adopted. The vertical axis measures percentage deviations of the endogenous variables from their respective steady states with the exception of the balance of trade and bonds measured relative to the steady-state output as well as the interest rate measured as percentages. The horizontal axis measures periods after the shock.

Figure A.2: Response of the endogenous variables to the idiosyncratic -1% productivity shock to the θ^L region.



Notes: The fiscal union consists of the θ^C region and the θ^L region. The technology process with spillovers is adopted. The vertical axis measures percentage deviations of the endogenous variables from their respective steady states with the exception of the balance of trade and bonds measured relative to the steady-state output as well as the interest rate measured as percentages. The horizontal axis measures periods after the shock.

Figure A.3: Responses of output, consumption, and investment to the -1% productivity shocks under alternative assumptions about the productivity of public goods.



Notes: The fiscal union consists of the θ^C and θ^L regions. The vertical axis measures percentage deviations of the variables from their respective steady states with the exception of the balance of trade measured relative to the steady-state output. The technology process without spillovers is adopted. The horizontal axis measures periods after the shock.

Appendix B

Appendix to Chapter 2

B.1 Some Additional Characteristics of Balanced-Budget Rules

Federal Government

Although the U.S. federal government has faced a debt ceiling since 1917, when the Second Liberty Bond Act was passed, the ceiling serves primarily as a tool for partisan negotiations in the U.S. Congress and does not effectively constrain borrowing by the federal government. During the period this study considers, 1977–2000, the debt limit was lifted 32 times.¹ The debt ceiling was not raised in a timely manner only once, in 1995, due to a conflict between President Clinton and the Republican–controlled Congress, which ultimately led to a government shutdown. Between 2001 and 2015, the debt ceiling was increased 14 times, and in the 3 instances when the debt limit was not increased in a timely manner, it was suspended.

State Governments

Unlike the federal government, which has never defaulted on its debt obligations, sub-national governments have not always avoided bankruptcies. Nine of 25 U.S. state governments and several cities delayed or ceased interest and principal payments on their

¹The rationale for focusing on the 1977–2000 period is data driven and presented in footnote 4.

bonds during and in the aftermath of the 1837 recession.² This resulted in the loss of investor confidence, lengthy periods of debt repayment by the bankrupt states, and the imposition of unpopular excise and property taxes for that purpose. As a result, some states imposed constitutional and statutory requirements to balance budgets and limitations on issuance of municipal bonds in order to improve fiscal discipline.³ Nonetheless, the measures taken after the 1837 recession did not prevent another municipal debt crisis, which was brought about by the 65-month-long Great Depression of 1873. However, states joining the Union, as well as existing members, chose to adopt some form of borrowing limitations. Presently, only one state, Vermont, does not have a legal requirement to balance its budget.

One of the characteristics of balanced-budget rules is the types of funds or budgets that are considered subject to the rule. Forty-nine states impose borrowing restrictions on their current operations budgets (also called general funds). Technically, 25 states do require that their capital budgets are balanced, but all of these states allow long-term revenue bond proceeds to be included in the budget revenue (U.S. General Accounting Office [GAO \(1993\)](#)). Such treatment of the capital budget balance is likely an artifact of the early attempts to circumvent borrowing limits, when revenue bonds (guaranteed by the revenue flow from the operation of an erected capital structure but not by the full faith and credit of the state) were first introduced by the State of Washington in 1897. The attempt was successful because such bonds were exempted from the borrowing limits by the courts, which ruled that the limits did not apply to obligations that are not guaranteed by the state taxpayers.

Note that this separation of current and capital operation budgets is consistent with [Bassetto and Sargent \(2006\)](#), who make a case for it from an intergenerational point of

²The list of insolvent states in [Kiewiet and Szakaly \(1996\)](#) includes the 10th bankrupt state, Florida, which joined the Union in 1845.

³Restrictions were imposed on the only type of bonds available at the time – guaranteed – also referred to as full-faith and credit or general obligation bonds that are secured with all available to the government means to repay the principal and interest.

view. They employ an overlapping generations model with productive and consumption public goods to show that exempting the capital operations budget from the balanced-budget requirement increases efficiency. In their model, once a balanced-budget rule is imposed, public goods would be underprovided. Due to the availability of public borrowing, older generations are able to shift the cost of public investment to future generations, who will benefit from it the most.

The balanced-budget rules adopted are state-specific and vary in terms of their stringency. The stringency of the regulations is determined by the stage of the budget process at which the budget must be balanced and by the legal provision for debt carry-over from one budget period to the next. Some states require budgets to be balanced at the beginning of the budget period, while others require them to be balanced at the end. In the former case, the governor must submit a balanced budget and/or the state legislature has to pass it. Hence, the start-of-the-period balanced-budget requirement does not rule out deficits occurring after the enactment of the budget. Those states having budgets that must be balanced at the end of the budget period have to take measures to balance their budgets if expenditures increase, or revenues decline unexpectedly, or both. Such unforeseen deficits typically occur during recessions.

B.2 Net Regional Asset Accumulation

This appendix derives the expression for net regional asset accumulation for the Rigid region.

Aggregate accounting implies the following laws of motion for net regional assets in the Rigid and Flexible regions:

$$B_{t+1} - (1 + R_{PRI,t})B_t = R_t K_t + W_t \bar{L} - C_t - I_t - I_{RG,t} - \frac{1}{2} \bar{C}_G, \quad (\text{B.1})$$

$$B_{t+1}^* - (1 + R_{PRI,t})B_t^* = R_t^* K_t^* + W_t^* \bar{L}^* - C_t^* - I_t^* - \bar{I}_{RG}^* - \frac{1}{2} \bar{C}_G. \quad (\text{B.2})$$

The last term in each equation is due to the Federal government apportioning procurement of the consumption public good equally between the regions. The right-hand side of each of the laws of motion is a regional equivalent of the System of National Accounts' definition of national savings for a sovereign state: national income less domestic absorption. If the regional savings are positive (negative), the region runs a trade surplus (deficit) and holds a positive (negative) net regional asset position.

Subtracting the latter equation from the former yields:

$$\begin{aligned} B_{t+1} - (1 + R_{PRI,t})B_t - B_{t+1}^* + (1 + R_{PRI,t})B_t^* & \quad (B.3) \\ = (R_t K_t - R_t^* K_t^*) + (W_t \bar{L} - W_t^* \bar{L}^*) - (C_t - C_t^*) - (I_t - I_t^*) - (I_{RG,t} - \bar{I}_{RG}^*). \end{aligned}$$

Using the fact that private bonds are in zero net supply, $B_t + B_t^* = 0$, one can rewrite (B.3) as

$$\begin{aligned} B_{t+1} - (1 + R_{PRI,t})B_t & = \frac{1}{2} (R_t K_t - R_t^* K_t^*) + \frac{1}{2} (W_t \bar{L} - W_t^* \bar{L}^*) & (B.4) \\ - \frac{1}{2} (C_t - C_t^*) - \frac{1}{2} (I_t - I_t^*) - \frac{1}{2} (I_{RG,t} - \bar{I}_{RG}^*). \end{aligned}$$

This equation relates the Rigid region's net regional asset accumulation to the interest income and differentials between the two regions' capital income, labor income, private absorption, and public absorption.

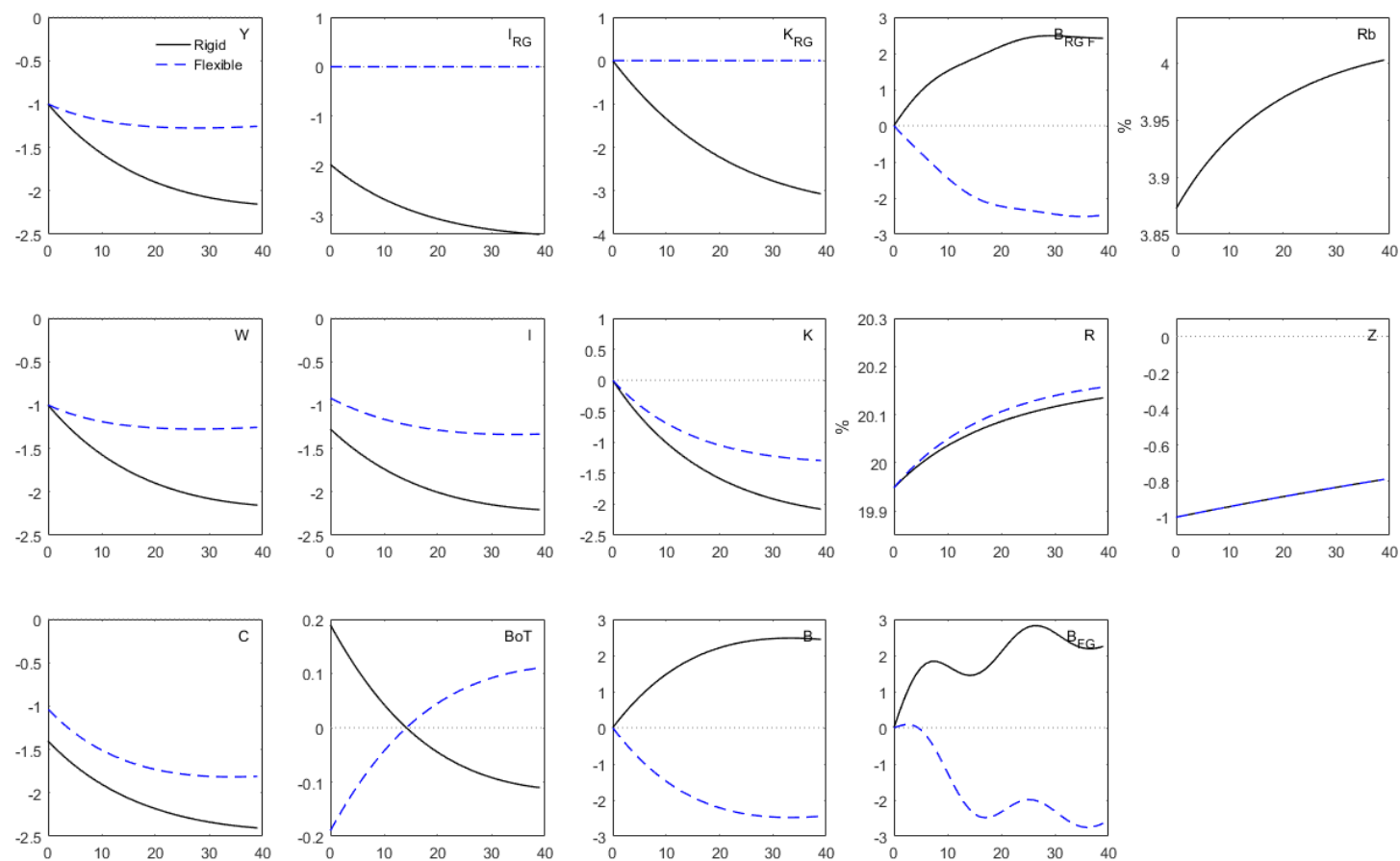
B.3 Some Results Conditional on Alternative Technology Process Specification

Table B.1: Lifetime welfare dynamics under alternative assumptions about the productivity of public goods in the fiscal union, without technology spillovers.

Panel A. Aggregate shock.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in Rigid, %	1.57	1.71	2.08	2.64
Loss of lifetime welfare in Flexible, %	1.60	1.59	1.58	1.55
Rigid-Flexible loss differential, p.p.	-0.02	0.12	0.50	1.09
Rigid-Flexible loss differential as % of Flexible loss	-1.40	7.7	32.0	70.3
Panel B. Idiosyncratic shock to Rigid.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in Rigid, %	1.60	1.74	2.12	2.69
Loss of lifetime welfare in Flexible, %	-0.03	-0.04	-0.05	-0.08
Rigid-Flexible loss differential, p.p.	1.63	1.78	2.17	2.77
Rigid-Flexible loss differential as % of Flexible loss	-5041	-4648	-4016	-3525
Panel C. Idiosyncratic shock to Flexible.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in Rigid, %	-0.03	-0.03	-0.02	-0.02
Loss of lifetime welfare in Flexible, %	1.63	1.63	1.63	1.63
Flexible-Rigid loss differential, p.p.	1.66	1.66	1.66	1.66
Flexible-Rigid loss differential as % of Rigid loss	-5898	-6135	-6828	-8143

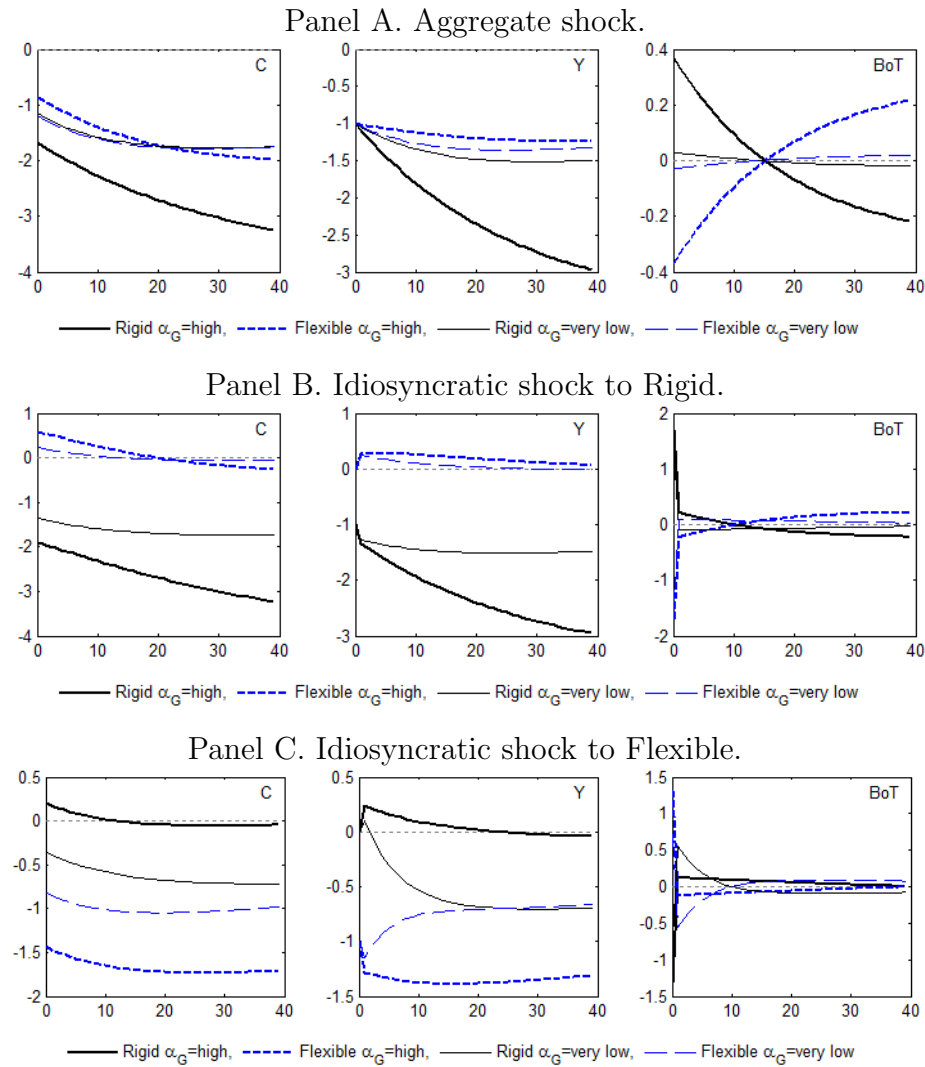
Notes: The fiscal union consists of the Rigid and Flexible regions. The table entries are calculated using consumption scale factors and have the interpretation of compensating variation measured in terms of private lifetime consumption.

Figure B.1: Responses of the endogenous variables to the aggregate -1% productivity shock.



Notes: The fiscal union consists of the Rigid and Flexible regions. The technology process with spillovers is adopted. The vertical axis measures percentage deviations of the endogenous variables from their respective steady states with the exception of the balance of trade and bonds measured relative to the steady-state output as well as the interest rates measured as percentages. The horizontal axis measures periods after the shock.

Figure B.2: Responses of output, consumption, and investment to the -1% productivity shocks under alternative assumptions about the productivity of public goods.



Notes: The fiscal union consists of the Rigid and Flexible regions. The vertical axis measures percentage deviations of the variables from their respective steady states with the exception of the balance of trade measured relative to the steady-state output. The technology process without spillovers is adopted. The horizontal axis measures periods after the shock.

Appendix C

Appendix to Chapter 3

C.1 Some Results Conditional on Alternative Technology Process Specification

Table C.1: Lifetime welfare dynamics under alternative assumptions about the productivity of public goods in the fiscal union, without technology spillovers.

Panel A. Aggregate shock.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in Rigid, %	1.57	1.71	2.08	2.64
Loss of lifetime welfare in Flexible, %	1.60	1.59	1.58	1.55
Rigid-Flexible loss differential, p.p.	-0.02	0.12	0.50	1.09
Rigid-Flexible loss differential as % of Flexible loss	-1.40	7.7	32.0	70.3
Panel B. Idiosyncratic shock to Rigid.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in Rigid, %	1.60	1.74	2.12	2.69
Loss of lifetime welfare in Flexible, %	-0.03	-0.04	-0.05	-0.08
Rigid-Flexible loss differential, p.p.	1.63	1.78	2.17	2.77
Rigid-Flexible loss differential as % of Flexible loss	-5041	-4648	-4016	-3525
Panel C. Idiosyncratic shock to Flexible.				
Elasticity of output with respect to public capital	v low	low	med	high
Loss of lifetime welfare in Rigid, %	-0.03	-0.03	-0.02	-0.02
Loss of lifetime welfare in Flexible, %	1.63	1.63	1.63	1.63
Flexible-Rigid loss differential, p.p.	1.66	1.66	1.66	1.66
Flexible-Rigid loss differential as % of Rigid loss	-5898	-6135	-6828	-8143

Notes: The fiscal union consists of the Rigid and Flexible regions. The table entries are calculated using consumption scale factors and have the interpretation of compensating variation measured in terms of private lifetime consumption.

Table C.2: Lifetime welfare loss of the representative households after the realization of the aggregate -1% productivity shock, %.

$\alpha_G = \textit{very low}$						
Panel 1A. Noncooperative policy.			Panel 1B. Cooperative policy.			
RG 2			RG 2			
			RG 1			
			RG 2			
			RG 1			
			RG 2			
			RG 1			
			RG 2			
RG 1	R	1.57, 1.57	1.58, 1.60	RG 1	R	3.14 3.17
	F	1.60, 1.58	1.60, 1.60		F	3.17 3.20
$\alpha_G = \textit{low}$						
Panel 2A. Noncooperative policy.			Panel 2B. Cooperative policy.			
RG 2			RG 2			
			RG 1			
			RG 2			
			RG 1			
			RG 2			
			RG 1			
			RG 2			
RG 1	R	1.70, 1.70	1.71, 1.59	RG 1	R	3.40 3.30
	F	1.59, 1.71	1.60, 1.60		F	3.30 3.20
$\alpha_G = \textit{medium}$						
Panel 3A. Noncooperative policy.			Panel 3B. Cooperative policy.			
RG 2			RG 2			
			RG 1			
			RG 2			
			RG 1			
			RG 2			
			RG 1			
			RG 2			
RG 1	R	2.05, 2.05	2.08, 1.58	RG 1	R	4.10 3.66
	F	1.58, 2.08	1.60, 1.60		F	3.66 3.20
$\alpha_G = \textit{high}$						
Panel 4A. Noncooperative policy.			Panel 4B. Cooperative policy.			
RG 2			RG 2			
			RG 1			
			RG 2			
			RG 1			
			RG 2			
			RG 1			
			RG 2			
RG 1	R	2.57, 2.57	2.64, 1.55	RG 1	R	5.14 4.19
	F	1.55, 2.64	1.60, 1.60		F	4.19 3.20

Notes: The technology process with spillovers is adopted. F (R) stands for the Flexible (Rigid) fiscal policy.

Table C.3: Lifetime welfare loss of the representative households after the realization of the idiosyncratic -1% productivity shock in Region 1, %.

$\alpha_G = \textit{very low}$							
Panel 1A. Noncooperative policy.			Panel 1B. Cooperative policy.				
RG 2			RG 2				
		R	F			R	F
RG 1	R	1.601, -0.032	1.60, -0.03	RG 1	R	1.569	1.57
	F	1.63, -0.03	1.63, -0.03		F	1.60	1.60
$\alpha_G = \textit{low}$							
Panel 2A. Noncooperative policy.			Panel 2B. Cooperative policy.				
RG 2			RG 2				
		R	F			R	F
RG 1	R	1.74, -0.04	1.74, -0.04	RG 1	R	1.70	1.70
	F	1.629, -0.027	1.629, -0.028		F	1.602	1.601
$\alpha_G = \textit{medium}$							
Panel 3A. Noncooperative policy.			Panel 3B. Cooperative policy.				
RG 2			RG 2				
		R	F			R	F
RG 1	R	2.12, -0.04	2.12, -0.05	RG 1	R	2.08	2.07
	F	1.63, -0.02	1.63, -0.03		F	1.61	1.60
$\alpha_G = \textit{high}$							
Panel 4A. Noncooperative policy.			Panel 4B. Cooperative policy.				
RG 2			RG 2				
		R	F			R	F
RG 1	R	2.69, -0.02	2.69, -0.08	RG 1	R	2.67	2.61
	F	1.63, -0.02	1.63, -0.03		F	1.61	1.60

Notes: The technology process without spillovers is adopted. F (R) stands for the Flexible (Rigid) fiscal policy.

Table C.4: Lifetime welfare loss of the representative households after the realization of the historical productivity shock sequence, %.

$\alpha_G = \textit{very low}$							
Panel 1A. Noncooperative policy.			Panel 1B. Cooperative policy.				
		RG 2				RG 2	
		R	F			R	F
RG 1	R	0.026, 0.018	0.026, 0.020	RG 1	R	0.044	0.046
	F	0.030, 0.018	0.030, 0.020		F	0.047	0.050
$\alpha_G = \textit{low}$							
Panel 2A. Noncooperative policy.			Panel 2B. Cooperative policy.				
		RG 2				RG 2	
		R	F			R	F
RG 1	R	0.046, 0.032	0.047, 0.019	RG 1	R	0.08	0.07
	F	0.029, 0.035	0.030, 0.020		F	0.06	0.05
$\alpha_G = \textit{medium}$							
Panel 3A. Noncooperative policy.			Panel 3B. Cooperative policy.				
		RG 2				RG 2	
		R	F			R	F
RG 1	R	0.091, 0.066	0.102, 0.016	RG 1	R	0.16	0.12
	F	0.026, 0.080	0.030, 0.020		F	0.11	0.05
$\alpha_G = \textit{high}$							
Panel 4A. Noncooperative policy.			Panel 4B. Cooperative policy.				
		RG 2				RG 2	
		R	F			R	F
RG 1	R	0.099, 0.086	0.184, 0.013	RG 1	R	0.19	0.20
	F	0.023, 0.148	0.030, 0.020		F	0.17	0.05

Notes: The productivity shocks are obtained from the estimation of the bivariate technology process without spillovers. F (R) stands for the Flexible (Rigid) fiscal policy.