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Introduction

This thesis contains three chapters, each dealing with a specific macroeconomic topic. While these topics are quite diverse, covering aspects such as international portfolio holdings, the banking sector, crisis transmission and fiscal policy, there are still several links between the individual chapters.

The first two chapters both analyze aspects of international macroeconomics, focusing on trade in goods and financial assets. More specifically, the first chapter examines how bilateral trade flows and trade openness influence a country's foreign asset holdings, and thus risk sharing. The second chapter also takes up linkages via goods and financial trade, however, it investigates the effects of a decline in trade flows and the value of foreign asset holdings on macroeconomic activity in the domestic economy.

The second and third chapter also share a common theme. Both study business cycle fluctuations and, in particular, the factors contributing to macroeconomic volatility. In the second chapter, these forces originate in the rest of the world, whereas in the third chapter internal forces - in particular fiscal policy - contribute to macroeconomic fluctuations.

CHAPTER 1.[1] The first chapter analyzes the relationship between bilateral trade, trade openness, and asset holdings theoretically, using a three-country model, as well as empirically, providing evidence for the influence of both bilateral trade and trade openness on bilateral asset holdings. The three-country model set-up enables

[1]This chapter is based on the paper "Bilateral Trade Flows, Openness, and Asset Holdings" (Peter, forthcoming).

me to disentangle the effects of bilateral trade flows and trade openness on bilateral portfolio patterns. The change to a three-country model is crucial as bilateral trade flows and openness are inseparably intertwined in the two-country case, which makes it impossible to analyze the individual effects.

The analysis shows that bilateral trade and trade openness both have independent effects on bilateral asset holdings. Higher bilateral trade as well as higher trade openness lead to a higher bilateral foreign asset position. Furthermore, the model shows an interaction effect between these two factors, where increasing trade openness reduces the influence of bilateral trade flows on asset holdings. These theoretical findings are supported by empirical evidence using a data set on the geographical composition of international portfolio holdings.

CHAPTER 2.[2] The next chapter explores the relative importance of the trade and financial channel in spreading the financial crisis of 2007-2009 to Germany. Specifically, we calibrate a DSGE model of a small open economy with a banking sector to Germany. The model economy is integrated with the rest of the world through trade in goods and through the banking sector trading foreign assets. We then use this model to investigate the transmission via the collapse of export demand and through the declined value of U.S. securities in possession of the German banking system.

The model is successful in predicting 95% of the observed decline in real output in the beginning of 2009. The trade channel is responsible for 70% of this movement, while the financial channel explains the remaining 30%. However, transmission via the financial channel triggers a longer-lasting recession than the trade channel, thereby prolonging the crisis in Germany.

CHAPTER 3.[3] The third chapter investigates the role of news about fiscal policy, and in particular the anticipation of tax rate changes for macroeconomic fluctuations. While recent macroeconomic research has started to analyze the effects of anticipated, or news, shocks on business cycle fluctuations, most empirical studies have focused on news about future productivity, but have paid little attention to fiscal news (see e.g.

[2]This chapter is based on joint work with Zeno Enders, “The International Transmission of the Financial Crisis - A German Perspective” (Enders and Peter, 2011).

[3]This chapter is based on joint work with Benjamin Born and Johannes Pfeifer, “Fiscal News and Macroeconomic Volatility” (Born et al., 2011).

Forni et al., 2011; Fujiwara et al., 2011; Khan and Tsoukalas, 2011; Schmitt-Grohé and Uribe, 2010). However, fiscal news hold the potential for explaining aggregate fluctuations. First, fiscal measures are usually publicly debated long before they become enacted or effective. Second, surprise fiscal policy shocks have long been discussed as a potential prominent driver of the business cycle (see e.g. Baxter and King, 1993; Cardia et al., 2003; Jones, 2002; McGrattan, 1994). This chapter adds upon the previous literature by explicitly analyzing the business cycle variance contribution of fiscal news. For this purpose, we employ an estimated New Keynesian DSGE model featuring several real and nominal rigidities as well as various shocks identified as important drivers of the business cycle.

While fiscal policy accounts for 12 to 20 percent of output variance at business cycle frequencies, the anticipated component hardly matters for explaining fluctuations of real variables. Anticipated capital tax shocks do explain a sizable part of inflation and interest rate fluctuations, accounting for between 5 and 15 percent of total variance. Consistent with earlier studies, we find that, in total, news shocks account for 20 percent of output variance, driven by news about stationary TFP and non-stationary investment-specific technology.

Chapter 1

Bilateral Trade Flows, Openness, and Asset Holdings

1.1 Introduction

In recent years, cross-border asset holdings have risen strongly. But despite increasing international financial integration, equity and bond holdings still differ widely across countries. This stands in contrast to economic theory, which predicts that in a fully integrated frictionless world cross-border portfolios should be identical across countries (see e.g. Lucas, 1982), leading to the question which factors determine the size and geographical composition of these varying portfolios. The factors can be grouped along two lines, size of foreign asset position and geographical composition, and have been studied extensively in the literature. The size of the foreign asset position is determined, inter alia, by trade openness. Countries that are more open to trade, measured as total exports plus imports, hold larger foreign asset positions (see e.g. Aizenman and Noy, 2009; Heathcote and Perri, 2009; Lane, 2000).[1] On the other hand, bilateral trade is one of the factors that govern the geographical composition of the foreign asset position.[2] Both Lane and Milesi-Ferretti (2008) and Aviat and Coeurdacier (2007) report that bilateral trade flows have a positive impact

[1]Other factors that influence the aggregate foreign asset position are economic size and financial development (see Heathcote and Perri, 2009; Lane, 2000; Lane and Milesi-Ferretti, 2004).
[2]Other factors are, e.g., informational and cultural linkages.

on bilateral asset holdings. However, these studies have either focused solely on trade openness and the size of foreign asset positions or on bilateral trade patterns and the composition of foreign asset positions, but have not looked at the combination of both.

In this chapter, I take up this issue and analyze the relationship between bilateral trade, trade openness, and asset holdings theoretically, using a three-country model, as well as empirically, providing evidence for the influence of both bilateral trade and trade openness on bilateral asset holdings. To study the effects of trade openness and bilateral trade flows in a unified framework, I build a three-country/three-good general equilibrium model consisting of simple endowment economies with home bias in consumption due to households preferring the home good over foreign goods.[3] The change to a three-country model is crucial as bilateral trade flows and openness are inseparably intertwined in the two-country case. As a result higher openness can only be obtained by higher bilateral trade, since there are no other trading partners. Conversely, increasing the bilateral trade between the two countries inevitably raises their trade openness. Hence, it is impossible to analyze the individual effects of bilateral and total trade on the foreign portfolio share. This has the consequence that in a two-country set-up the focus has to be either on the effect of trade openness or the effect of bilateral trade. In contrast, with three countries both effects can be studied in a unified framework. I can vary bilateral trade flows while holding the openness of a country constant. That way it is possible to distinguish explicitly between the influence of bilateral trade flows and the influence of openness on the geographical composition of the foreign asset position. In addition, I can identify possible interaction effects between bilateral trade and trade openness.

In order to keep the theoretical model simple and tractable, I follow Lucas (1982), Obstfeld and Rogoff (2001), Kollmann (2006), and Heathcote and Perri (2009) in assuming complete financial markets and full risk-sharing. That way it is possible to first characterize the optimal social planner consumption allocation and then identify the asset allocation that replicates this optimal consumption allocation in a

[3]Home bias in consumption is commonly used in the vast literature analyzing portfolio home bias. Consumption home bias is either introduced through preferences (see e.g. Coeurdacier et al., 2007; Kollmann, 2006) or through trade costs (see e.g. Coeurdacier, 2009; Obstfeld and Rogoff, 2001).

decentralized setting, where only a restricted set of assets is available.

Turning to the results, first, they show that bilateral trade and trade openness both have independent effects on bilateral asset holdings. Holding either one constant, while varying the other one, gives a distinct pattern for the bilateral foreign asset position. The sign of the effect of bilateral trade flows, but also of trade openness, depends on the elasticity of substitution between consumption goods. The elasticity of substitution in combination with the trade pattern drives the responses of international relative prices to endowment shocks and, through this, determines the portfolio allocation. For relatively small values of the elasticity of substitution, higher trade flows between two countries lead, ceteris paribus, to higher asset holdings between these two countries. For higher values of the elasticity of substitution, the opposite pattern emerges: higher trade flows lead to smaller asset holdings of the trade partner's stock. Kollmann (2006) also stresses the importance of the elasticity of substitution in his two-country model. But in using a three-country set-up, I am able to show that bilateral trade flows have an independent effect even when holding openness constant.

Second, my results indicate that, ceteris paribus, bilateral investment positions are larger for higher degrees of openness. In this case, stronger terms-of-trade reactions in response to endowment shocks rationalize higher asset holdings, given terms-of-trade effects on consumption expenditures. This particular feature of the model emerges for parameter constellations where home and foreign goods are complements.

Third, I find an interaction effect between bilateral trade and openness. Comparing the influence of bilateral trade flows on asset holdings for different values of openness shows that the effect of bilateral trade flows on equity holdings is smaller for higher trade openness. Intuitively, equity shares of the trading partner are less important for risk sharing if there is a lot of trade with other countries.

Furthermore, I provide empirical evidence that both bilateral trade flows as well as total trade flows influence bilateral asset holdings positively and significantly. For this purpose, I employ a gravity model to estimate the influence of bilateral trade and trade openness on bilateral asset holdings.[4] The basis for this analysis is

[4]Gravity models are traditionally used in the international trade literature, but are now also widely used to explain international investment patterns of equity holdings (e.g. Aviat and Coeurdacier, 2007; Lane and Milesi-Ferretti, 2008; Portes and Rey, 2005; Sarisoy Guerin, 2006), bank lending (e.g. Rose and Spiegel, 2004) and foreign direct investment (e.g., Mody et al., 2002).

the Coordinated Portfolio Investment Survey (CPIS) of the International Monetary Fund (IMF), which provides the geographical composition of security investments of up to 74 source countries.[5] I include both bilateral and total trade flows in my analysis of bilateral investment patterns. While bilateral trade flows have been found to be a major determinant of bilateral cross-border asset holdings (see Aviat and Coeurdacier, 2007; Lane and Milesi-Ferretti, 2008), total trade flows as a measure for trade openness have only been used to explain aggregate foreign asset positions.

The rest of the chapter is organized as follows: Section 2 presents the three-country stochastic general equilibrium model and its solution. In section 3, the resulting optimal portfolios for differing trade patterns are analyzed. Section 4 covers the empirical analysis of bilateral asset holdings, while section 5 concludes.

1.2 A Three-Country Model

1.2.1 Model Set-Up

I use a two-period variant of the model by Kollmann (2006) and extend it to a three-country set-up. The three countries are indexed by $i = 1, 2, 3$ and each is exogenously endowed with a distinct national good, Y_i. The economies are linked internationally by trade in goods and equities and exist for two periods ($t = 0, 1$).[6] In the first period ($t = 0$), only equity shares, which are claims to the future endowment of a particular country, are traded. In period $t = 1$, the endowment process is realized and the representative household trades goods, settles the equity claims, and consumes. The only source of uncertainty in this model is the stochastic endowment process, which is symmetric across countries. I assume $\mathrm{E}_0[Y_i] = 1$, for $i = 1, 2, 3$, where E_0 is the conditional expectation operator given information at date $t = 0$.

[5]Source country residents hold security investments, which are issued by destination country residents, and report these holdings in the CPIS.

[6]Variables without a time subscript correspond to period $t = 1$.

Preferences

Each country i is inhabited by a representative household, who has the following utility function

$$U(C^i) = \mathrm{E}_0 \left[\frac{(C^i)^{1-\rho} - 1}{1-\rho} \right], \quad \rho > 0, \tag{1.1}$$

where ρ represents the relative risk aversion parameter and C^i is the aggregate consumption index:

$$C^i = \left[(\alpha_1^i)^{\frac{1}{\theta}} (c_1^i)^{\frac{\theta-1}{\theta}} + (\alpha_2^i)^{\frac{1}{\theta}} (c_2^i)^{\frac{\theta-1}{\theta}} + (\alpha_3^i)^{\frac{1}{\theta}} (c_3^i)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \quad \text{for } i = 1, 2, 3. \tag{1.2}$$

Here, c_j^i denotes consumption in country i of good j and α_j^i is the corresponding weight parameter for that particular good. Note that $\sum_{j=1}^{3} \alpha_j^i = 1$ and country i has a home bias in consumption if $\frac{1}{3} < \alpha_i^i \leq 1$. The elasticity of substitution between any two goods is θ.[7]

Introducing p_j as the price of good j, the consumption based price index for country i is

$$P_i = \left(\alpha_1^i + \alpha_2^i (p_2)^{1-\theta} + \alpha_3^i (p_3)^{1-\theta} \right)^{\frac{1}{1-\theta}} \quad \text{for } i = 1, 2, 3. \tag{1.3}$$

Note that good 1 is chosen as the numéraire and, thus, p_1 is set to unity. Hence, the prices p_2 and p_3 can be interpreted as the terms-of-trade of country 1 vis-à-vis countries 2 and 3, respectively.

Financial Markets

There is international trade in equity shares, S_j^i, which are claims of country i to a fraction of the future endowment of country j. Each share of stock j entitles the owner to a dividend payment. The size of this payment is determined by the value of country j's endowment, $p_j Y_j$.

The supply of equity shares is normalized to unity such that market clearing in the asset market requires

$$S_j^1 + S_j^2 + S_j^3 = 1 \quad \text{for } j = 1, 2, 3. \tag{1.4}$$

[7] Assuming $\theta = 1$, aggregate consumption is of Cobb-Douglas type and α_j^i represents the expenditure share spent for consumption of good j in country i.

At the beginning of period 0, country i has zero foreign assets, $S^i_{j,0} = 0$ ($i \neq j$), and holds all local shares, $S^i_{i,0} = 1$. With $q_{j,0}$ being the price of stock j in period 0, the budget constraint of country i for period 0 takes the following form:

$$q_{1,0}S^i_1 + q_{2,0}S^i_2 + q_{3,0}S^i_3 = q_{i,0} \quad \text{for } i = 1, 2, 3. \tag{1.5}$$

In the rest of the chapter, the portfolio of country i will be the triple (S^i_1, S^i_2, S^i_3).

Household Maximization

In period 1, after uncertainty has been realized and dividends have been distributed, the representative household in country i decides on consumption, c^i_j, taking as given his portfolio of equity shares. The budget constraint for period 1 is

$$c^i_1 + p_2c^i_2 + p_3c^i_3 = S^i_1Y_1 + S^i_2p_2Y_2 + S^i_3p_3Y_3 \quad \text{for } i = 1, 2, 3, \tag{1.6}$$

i.e., consumption expenditures equal portfolio income. Maximizing the utility of country i's representative household, equation (1.1), subject to the budget constraint for period 1 yields the following first-order conditions for consumption:

$$\left(C^i\right)^{\frac{1}{\theta}-\rho}\left(\frac{c^i_1}{\alpha^i_1}\right)^{-\frac{1}{\theta}} = \lambda^i, \tag{1.7}$$

$$\left(C^i\right)^{\frac{1}{\theta}-\rho}\left(\frac{c^i_2}{\alpha^i_2}\right)^{-\frac{1}{\theta}} = \lambda^i p_2, \tag{1.8}$$

$$\left(C^i\right)^{\frac{1}{\theta}-\rho}\left(\frac{c^i_3}{\alpha^i_3}\right)^{-\frac{1}{\theta}} = \lambda^i p_3, \tag{1.9}$$

where λ^i is the Lagrange multiplier on the period 1 budget constraint of country i. After characterizing how the household income is optimally allocated across consumption goods, the next step is to explore the income side, i.e., the equity portfolio allocation.

In period 0, no production or consumption takes place, but the representative household decides on the amount of equity shares he wants to hold. When deciding on the asset portfolio the agent takes into account his consumption plan for period

1 and that his financial income is uncertain. Let λ_0^i be the Lagrange multiplier on the budget constraint of period 0 in country i. The representative agent of country i maximizes his utility, equation (1.1), subject to the budget constraints for periods 0 and 1, equations (1.5) and (1.6). This gives the following first order conditions for equity shares:

$$\lambda_0^i q_{1,0} = \mathrm{E}_0 \left[\left(C^i\right)^{\frac{1}{\theta}-\rho} \left(\frac{c_1^i}{\alpha_1^i}\right)^{-\frac{1}{\theta}} Y_1 \right], \tag{1.10}$$

$$\lambda_0^i q_{2,0} = \mathrm{E}_0 \left[\left(C^i\right)^{\frac{1}{\theta}-\rho} \left(\frac{c_1^i}{\alpha_1^i}\right)^{-\frac{1}{\theta}} p_2 Y_2 \right], \tag{1.11}$$

$$\lambda_0^i q_{3,0} = \mathrm{E}_0 \left[\left(C^i\right)^{\frac{1}{\theta}-\rho} \left(\frac{c_1^i}{\alpha_1^i}\right)^{-\frac{1}{\theta}} p_3 Y_3 \right]. \tag{1.12}$$

These equations show that the demand for equity shares depends on the purchase price in period 0 and the asset return in period 1.

Equilibrium in the Decentralized Economy

Having characterized the set-up of the economy and the household maximization, the next step is to define the equilibrium in the decentralized economy. The equilibrium in the decentralized economy is given by a set of quantities c_1^i, c_2^i, c_3^i, S_1^i, S_2^i, S_3^i, $i = 1, 2, 3$, and prices p_2, p_3, $q_{1,0}$, $q_{2,0}$, $q_{3,0}$, such that

1. the FOCs for consumption, equations (1.7)-(1.9),
2. the FOCs for equity shares, equations (1.10)-(1.12), and
3. the budget constraint, equation (1.6), hold and
4. asset markets, equation (1.4), and goods markets, $c_j^1 + c_j^2 + c_j^3 = Y_j$, $j = 1, 2, 3$, clear.

1.2.2 Equilibrium with Full Risk-Sharing

As in Lucas (1982), Obstfeld and Rogoff (2001), Kollmann (2006), and Heathcote and Perri (2009), I focus on equilibria with full risk-sharing, i.e., Pareto efficient equilibria. Therefore, I first solve the central planner's problem to obtain the efficient consumption allocation. In a next step, I characterize the asset portfolio in a decentralized economy that supports the efficient consumption allocation. In the decentralized economy, the number of assets is restricted to three equities. Coeurdacier and Gourinchas (2009) show that such a portfolio can replicate the full risk-sharing allocation up to first order, if the number of shocks equals the number of assets and the asset pay-offs react to shocks. While the first condition is fulfilled in my model with three endowment shocks and three assets, I will later encounter some model calibrations for which the second condition is not fulfilled.

Efficient Consumption Allocation

The efficient allocation is attained through a social planner maximizing the sum of the countries' utility functions, where the planner problem is static since consumption only takes place in period 1:[8]

$$\max_{\{c_j^1,\, c_j^2,\, c_j^3\}} \frac{(C^1)^{1-\rho} - 1}{1-\rho} + \frac{(C^2)^{1-\rho} - 1}{1-\rho} + \frac{(C^3)^{1-\rho} - 1}{1-\rho} \tag{1.13}$$

subject to the resource constraints

$$c_j^1 + c_j^2 + c_j^3 = Y_j \quad \text{for } j = 1, 2, 3, \tag{1.14}$$

and C^1, C^2, C^3 given by equation (1.2).

The first order conditions for consumption of good j are

$$\left(C^1\right)^{\frac{1}{\theta}-\rho} \left(\frac{c_j^1}{\alpha_j^1}\right)^{-\frac{1}{\theta}} = \left(C^2\right)^{\frac{1}{\theta}-\rho} \left(\frac{c_j^2}{\alpha_j^2}\right)^{-\frac{1}{\theta}}, \tag{1.15}$$

$$\left(C^1\right)^{\frac{1}{\theta}-\rho} \left(\frac{c_j^1}{\alpha_j^1}\right)^{-\frac{1}{\theta}} = \left(C^3\right)^{\frac{1}{\theta}-\rho} \left(\frac{c_j^3}{\alpha_j^3}\right)^{-\frac{1}{\theta}}. \tag{1.16}$$

These conditions imply that the marginal utilities from consuming good j are perfectly positively correlated across countries. From the risk-sharing conditions, equations

[8] The social planner assigns an equal weight to each country, since the endowment processes are symmetric across countries.

(1.15) and (1.16), and the resource constraints, I can compute the efficient consumption allocation, c_1^i, c_2^i, c_3^i, for $i = 1, 2, 3$.

To analyze how the efficient consumption allocation responds to endowment shocks, it is convenient to define $\mu_j^i \equiv c_j^i / Y_j$. This share μ_j^i is the efficient share of good j that is consumed by country i and shows whether consumption changes proportionally to an endowment shock or not.

The response of the consumption allocation depends on the relationship between the elasticity of substitution, θ, and the risk aversion parameter, ρ. For this response, I can distinguish between three cases. In the first case, $\frac{1}{\rho} = \theta$, all consumption shares remain unchanged after an endowment shock. The linearized risk-sharing conditions (see Appendix A) imply that consumption of good j has to increase proportionally to a positive endowment shock to good j, while consumption of the other two goods does not change.

In the second case, $\frac{1}{\rho} > \theta$, consumption shares in country i increase for a positive endowment shock in country i and fall for a positive endowment shock in one of the other countries. In this case, the three goods are complements. Therefore, a country experiencing a positive endowment shock consumes proportionally more of all goods. In the third case, $\frac{1}{\rho} < \theta$, the three goods are substitutes and consumption shares in a country fall for a shock to the home good and increase for a shock to the foreign good.[9]

Decentralizing the Efficient Allocation

Having computed the efficient consumption allocation from the social planner solution, I can now identify the portfolio allocation that supports this efficient consumption allocation. To this end, I have to find a set of prices and portfolios, p_2, p_3, S_1^i, S_2^i, S_3^i, for $i = 1, 2, 3$, that together with the efficient consumption allocation, c_1^i, c_2^i, c_3^i, for $i = 1, 2, 3$, constitutes an equilibrium.

Substituting the efficient consumption allocation into the first order conditions for consumption, equations (1.7)-(1.9), yields the relative prices p_2 and p_3 that pertain

[9]For the consumption share reactions, home bias plays an important role. Without home bias in consumption, consumption shares would be constant regardless of the relationship between $\frac{1}{\rho}$ and θ.

to the efficient consumption allocation:

$$p_2 = \left(\frac{\alpha_1^i}{\alpha_2^i}\frac{c_2^i}{c_1^i}\right)^{-\frac{1}{\theta}}, \tag{1.17}$$

$$p_3 = \left(\frac{\alpha_1^i}{\alpha_3^i}\frac{c_3^i}{c_1^i}\right)^{-\frac{1}{\theta}} \quad \text{for } i = 1, 2, 3. \tag{1.18}$$

The next step is to find the portfolio allocation, S_1^i, S_2^i, S_3^i, for $i = 1, 2, 3$, that supports the efficient allocation. Since the budget constraint of each country has to hold for the portfolio allocation, I can use these constraints to compute the optimal equity shares. However, to find this portfolio, I have to resort to a linear approximation since the first order conditions are nonlinear. This is done in the next section.

1.2.3 Linear Approximation

The model equations are linearized around a symmetric equilibrium where endowments and prices are equal and trade is balanced. Here, $\hat{x} = \frac{x-\bar{x}}{\bar{x}}$ denotes percentage deviations from the symmetric equilibrium, $\bar{x}$.

Linearizing the period 1 budget constraint for country 1, equation (1.6), and using the definition for consumption shares, μ_j^i, leads to:

$$\bar{\mu}_1^1(\hat{\mu}_1^1+\hat{Y}_1)+\bar{\mu}_2^1(\hat{\mu}_2^1+\hat{p}_2+\hat{Y}_2)+\bar{\mu}_3^1(\hat{\mu}_3^1+\hat{p}_3+\hat{Y}_3) = S_1^1\hat{Y}_1+S_2^1(\hat{p}_2+\hat{Y}_2)+S_3^1(\hat{p}_3+\hat{Y}_3). \tag{1.19}$$

This expression shows that the change in total consumption expenditures in response to an endowment shock has to be accounted for by a reaction of the portfolio income. Rearranging equation (1.19) yields:

$$\bar{\mu}_1^1\hat{\mu}_1^1 + \bar{\mu}_2^1\hat{\mu}_2^1 + \bar{\mu}_3^1\hat{\mu}_3^1 = (S_1^1 - \bar{\mu}_1^1)\hat{Y}_1 + (S_2^1 - \bar{\mu}_2^1)(\hat{p}_2 + \hat{Y}_2) + (S_3^1 - \bar{\mu}_3^1)(\hat{p}_3 + \hat{Y}_3). \tag{1.20}$$

On the left hand side, I have isolated the change in consumption expenditures in response to an endowment shock that is due to changes of consumption shares. These are changes of the efficient consumption allocation that are not proportional to an endowment shock. The right hand side shows the change in total expenditures that is due to changes of relative prices. It shows the change in portfolio income. In order to analyze the implications of relative price and consumption share responses (discussed above) for the portfolio allocation, I examine how endowment shocks affect relative prices.

The terms-of-trade of country 1 correspond to the relative prices p_2 and p_3. Linearizing equations (1.17) and (1.18) and again using the definition for consumption shares yields:

$$\hat{p}_2 = -\frac{1}{\theta}\left(\hat{\mu}_2^i + \hat{Y}_2 - \hat{\mu}_1^i - \hat{Y}_1\right), \tag{1.21}$$

$$\hat{p}_3 = -\frac{1}{\theta}\left(\hat{\mu}_3^i + \hat{Y}_3 - \hat{\mu}_1^i - \hat{Y}_1\right) \quad \text{for } i = 1, 2, 3. \tag{1.22}$$

With the assumption of efficient risk-sharing, the terms-of-trade of country 1 always worsen in response to a positive home endowment shock (see Corsetti et al., 2008). The terms-of-trade of country 2 and country 3 behave in the same way and fall in response to a positive endowment shock to good 2 and good 3, respectively. Equations (1.21) and (1.22) further show that the terms-of-trade between two countries can also change in response to an endowment shock in the third country. For example, assume a higher endowment in country 3, $\hat{Y}_3 > 0$, while $\hat{Y}_1 = \hat{Y}_2 = 0$. If consumption shares of good 1 and good 2 do not respond in an identical way to this endowment shock, i.e., $\hat{\mu}_1^i \neq \hat{\mu}_2^i$, the terms-of-trade between country 1 and 2 change, $\hat{p}_2 \neq 0$.

1.2.4 Equity Portfolios

In a next step, I solve for equity shares that replicate the efficient consumption allocation. That means, I compute the portfolio of country 1, S_1^1, S_2^1, S_3^1, such that its budget constraint, equation (1.20), holds for arbitrary realizations of $\hat{Y}_1$, $\hat{Y}_2$, $\hat{Y}_3$.

Country 1's portfolio then has the following form:

$$S_1^1 = \alpha_1^1 + \Delta_1^1 - \frac{\Gamma_{p2}^1 \left(\Delta_1^2(\Gamma_{p3}^3 + 1) - \Delta_1^3 \Gamma_{p3}^2\right) + \Gamma_{p3}^1 \left(\Delta_1^3(\Gamma_{p2}^2 + 1) - \Delta_1^2 \Gamma_{p2}^3\right)}{(\Gamma_{p2}^2 + 1)(\Gamma_{p3}^3 + 1) - \Gamma_{p2}^3 \Gamma_{p3}^2}, \quad (1.23)$$

$$S_2^1 = \alpha_2^1 + \frac{\Delta_1^2(\Gamma_{p3}^3 + 1) - \Delta_1^3 \Gamma_{p3}^2}{(\Gamma_{p2}^2 + 1)(\Gamma_{p3}^3 + 1) - \Gamma_{p2}^3 \Gamma_{p3}^2}, \quad (1.24)$$

$$S_3^1 = \alpha_3^1 + \frac{\Delta_1^3(\Gamma_{p2}^2 + 1) - \Delta_1^2 \Gamma_{p2}^3}{(\Gamma_{p2}^2 + 1)(\Gamma_{p3}^3 + 1) - \Gamma_{p2}^3 \Gamma_{p3}^2}, \quad (1.25)$$

where Δ_1^i summarizes the response of consumption shares in country 1 to an endowment shock in country i and $\Gamma_{p_j}^i$ shows the response of p_j to an endowment shock in country i.[10] The portfolios of the other countries can be derived in a similar manner.

However, there are two cases where it is not possible to derive a unique portfolio of equilibrium asset shares. In the first case, portfolio holdings are indeterminate and, thus, infinitely many portfolios exist. This case occurs for two parameter combinations. If the elasticity of substitution is equal to one, $\theta = 1$, and either the utility function is logarithmic, $\rho = 1$, or preferences do not exhibit home bias, $\alpha_j^i = 1/3$, consumption shares are constant in response to an endowment shock ($\Delta_1^i = 0$) and the terms-of-trade fully offset endowment shocks ($\Gamma_{p2}^2 = \Gamma_{p3}^3 = -1$, see appendix A). Thus, terms-of-trade changes fully insure against output fluctuations and financial autarky is efficient (see Cole and Obstfeld, 1991).

In the second case, for some parameter combinations, the given asset structure cannot replicate the efficient allocation since asset pay-offs are unaffected by endowment shocks ($\Gamma_{p2}^2 - 1 = \Gamma_{p3}^3 - 1 = \Gamma_{p2}^3 = \Gamma_{p3}^2 = 0$). The equity pay-offs are not state-contingent and it is not possible to generate a pay-off structure that replicates the one for Arrow-Debreu securities. In this case, it it not possible to derive equilibrium asset shares.

Apart from the two cases just discussed, equations (1.23)-(1.25) specify the equity portfolio of country 1. The equity shares generate the financial income for arbitrary realizations of endowment shocks that induce the households to consume according to the efficient consumption allocation. Therefore, they incorporate the responses of consumption shares and relative prices to endowment shocks, as these indicate

[10] For the calculation of Δ_1^i and $\Gamma_{p_j}^i$ see appendix A.

how the efficient consumption allocation and the dividends look like for different endowment realizations.

The first term in S_j^1 indicates the level of asset holdings, if consumption shares are constant for all endowment realizations. In this case, the asset share of stock j corresponds to the share agent 1 consumes of good j (at the point of linearization), which is equal to the preference weight for good j. Thus, financial income from these asset holdings suffices for consumption expenditures for good j. If, however, not only relative prices but also consumption shares react to endowment shocks, equity shares have to be higher or lower than the consumption weight. Higher asset holdings of a stock, whose dividend is higher relative to the other stocks, would induce the representative agent of country 1 to consume a higher output share as prescribed by efficient risk-sharing. However, I cannot state general conclusions about the consumption share and terms-of-trade responses and their co-movement, since they specifically depend on the chosen parameters.

1.3 Results from a Calibrated Model

1.3.1 Calibration

My model is parsimonious in the number of parameters. The parameter for risk aversion is set to $\rho = 2$, a standard value in the literature (see e.g. Backus et al., 1994). The parameter for the elasticity of substitution between home and imported goods, θ, plays a key role for the division of the portfolio between home and foreign assets, but also for the effect of bilateral trade flows on the portfolio. However, there is no consensus on the value of θ with estimates being highly dependent on the data used. Studies using disaggregated sectoral data usually find higher estimates of $3 - 6$ (e.g. Baier and Bergstrand, 2001; Hummels, 2001), while studies using macro data find lower estimates of $0.23 - 2$. The estimates of Enders and Müller (2009) and Lubik and Schorfheide (2006) are at the lower end with values of 0.23 and 0.3, respectively, while Corsetti et al. (2008) find a value of 0.85 and Backus et al. (1994) use one of 1.5. Therefore, I will in a first step analyze how the equilibrium portfolio depends on θ, $\theta \in [0, 5]$, given a specific trade pattern. This helps to build intuition for the portfolio composition, facilitates comparison with two-country models, and motivates the choice for $\theta = 0.3$, when analyzing the influence of bilateral trade flows.

In a second step, I will analyze how the portfolio depends on bilateral trade flows. For this purpose, I consider varying values for the consumption preference parameters that govern trade flows. The values of the α_j^is are chosen to pin down the import share in country 1, $\alpha_j^1 + \alpha_k^1, j \neq k$, at 30% of GDP. The exact specifications for α_j^is depend on the prespecified trade pattern and will be discussed in subsequent sections.

1.3.2 The Portfolios' Dependence on the Elasticity of Substitution

In this section, I study how the substitution elasticity, θ, affects the portfolio allocation given two specific trade patterns. In what follows, I interpret country 3 as the rest of the world and focus mostly on the bilateral relationship between country 1 and 2 from the viewpoint of country 1. The two trade patterns analyzed include one case, where all countries have symmetric preferences regarding the foreign goods, and one case, where country 1 and 2 have asymmetric preferences regarding the respective foreign goods. In case 1, the symmetry across the three countries implies that trade flows between all countries are identical (see table 1.1, case 1).

In the second case, country 1 and 2 are symmetric and import a higher share from country 3, i.e., the rest of the world, than from the other trading partner. Table 1.1 (case 2) gives the specification for the consumption preference parameters. Note that country 3 has symmetric preferences for good 1 and 2, and that the import share of country 3 has to be increased to ensure consistency of the trade matrix.[11]

Symmetric Preferences

Figure 1.1 shows the portfolio of country 1 as a function of the elasticity of substitution, θ. Since all countries are symmetric the portfolio allocation is identical in all three countries. In addition, due to the symmetric preference structure, asset holdings of stocks 2 and 3 are identical. As mentioned, θ plays a key role for

[11] In case 1, bilateral and overall trade is balanced in steady state due to the symmetry across countries. For better comparability, I assume bilaterally balanced trade in case 2 as well. This assumption facilitates interpretation as bilateral net foreign asset position are balanced. However, relaxing the assumption of bilateral balanced trade would not materially affect the results.

Table 1.1: Trade Flow Matrix

		Case 1: Sym. Pref.			Case 2: Asym. Pref.		
Import Country i		1	2	3	1	2	3
Export Country j	1	0.7	0.15	0.15	0.7	0.1	0.2
	2	0.15	0.7	0.15	0.1	0.7	0.2
	3	0.15	0.15	0.7	0.2	0.2	0.6

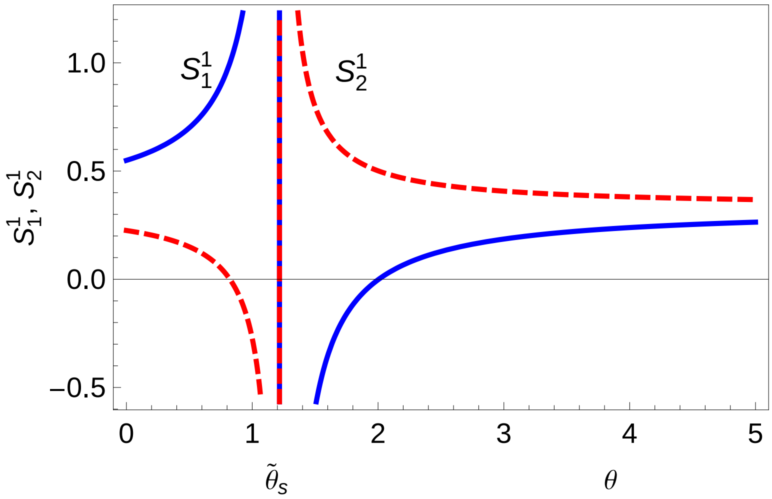
Notes: The table reports the share α_j^i that country i imports from export country j in steady state for symmetric and asymmetric preferences regarding the two foreign goods.

the composition of the portfolio. There exists a critical value of θ, $\tilde{\theta}_s = 1.22$, for which dividends are unaffected by endowment shocks and the efficient consumption allocation cannot be supported under the existing asset structure. For values of θ smaller than this threshold, the portfolio of country 1 exhibits home bias, while for values higher than $\tilde{\theta}_s$ the portfolio mainly contains foreign shares. For values of θ near the threshold point, the portfolio exhibits extreme home or foreign bias. The portfolio responds very sensitively to parameter changes in this region (see Coeurdacier and Gourinchas, 2009).

The composition of the portfolio depends on the way an asset can hedge consumption risk relative to the other assets. This is determined by the relative value of a stock compared to the other stocks and by the co-movement between the shock responses of a stock's dividend and consumption shares. These shock responses and thus the hedging abilities of the individual assets change with θ.

As shown in the last section, consumption shares in country 1 fall in response to a positive endowment shock to one of the foreign goods, if $\theta < 1/2$ (since $\rho = 2$), and rise otherwise. Similarly, the response of dividends depends on θ. Consider the response of stock 2's dividend to an increase of good 2 endowment. The ensuing terms-of-trade decrease has a a negative effect on stock 2's dividend (value effect), while the endowment increase has a positive effect on stock 2's dividend (volume effect). For $\theta < \tilde{\theta}_s$, the value effect dominates, since terms-of-trade fall more strongly for lower θ. Thus, the dividend of stock 2 falls. However, for $\theta > \tilde{\theta}_s$, the volume effect dominates and the dividend of stock 2 increases.

Figure 1.1: Equity Portfolio of Country 1 with Symmetric Preferences



Notes: The figure shows the shares country 1 holds of stock 1 (S_1^1, solid line) and of stock 2 (S_2^1, dashed line) as a function of the elasticity of substitution θ. For symmetric preferences $S_2^1 = S_3^1$. The asset structure cannot replicate the efficient consumption allocation for $\theta = \tilde{\theta}_s = 1.22$.

From these considerations, we can differentiate three different regions of θ for the portfolio composition: For $\theta < 1/2$, consumption shares and the dividend value of stock 2 co-move positively, however the relative value of stock 1 is higher than of stock 2 and the home stock prevails in the portfolio. If $1/2 < \theta < \tilde{\theta}_s$ holds, the relative hedging ability of stock 2 falls, since consumption shares and the dividend value of stock 2 now co-move negatively, and the share of the home asset in the portfolio rises.[12] Once $\theta > \tilde{\theta}_s$, the dividend of stock 2 rises after an endowment shock in country 2 and holdings of stock 2 can hedge consumption risk (consumption shares in country 1 are positively correlated with an endowment shock to good 2) relatively better than holdings of stock 1. The portfolio now contains a higher proportion of foreign shares than of home shares.

In summary, if consumption shares and the relative dividend value of the home asset

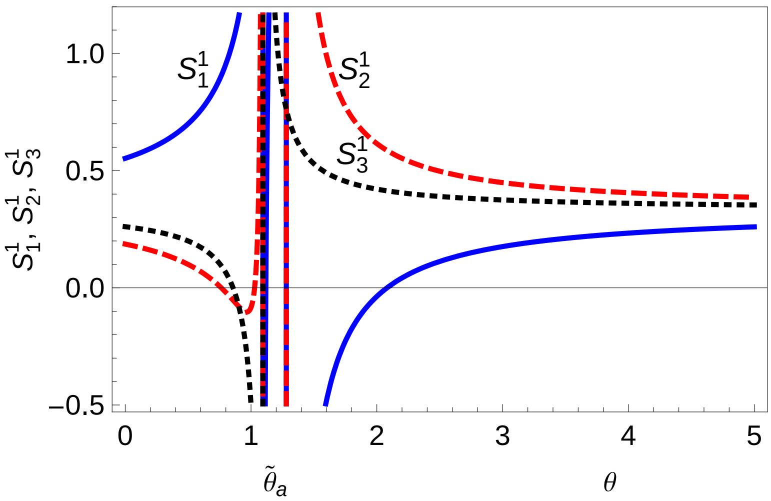
[12]For values of θ near $\tilde{\theta}_s$, country 1 goes short in assets of country 2 and 3. In this case, country 1 would want to hold a larger share of its own stock than it initially has in period 0 to ensure full risk-sharing. This is financed by selling claims to the endowment of good 2 and 3. Country 2 and 3 behave in a similar way, such that all countries hold a leveraged position of their own stock, i.e., more than 100%. After the endowment is distributed, each countries buys the respective amounts of foreign good endowment from the other countries and subsequently hands it back to them, thus, serving the claims it has shorted.

co-move positively, the portfolio exhibits home bias, while a negative co-movement leads to foreign bias. This confirms results from standard two-country models (see Kollmann, 2006). Coeurdacier (2009) also finds a foreign bias for a high substitution elasticity. In his model, the covariance between the home real exchange rate and home equity returns matters for the composition of the portfolio. A positive covariance leads to a home bias, while for a negative covariance the foreign share in the portfolio prevails.

Asymmetric Preferences

Next, I assume the trade pattern outlined in table 1.1 for asymmetric preferences (case 2). Figure 1.2 displays the portfolio of country 1 as a function of θ. In comparison to the case with symmetric preferences, asset holdings of stock 2 and 3 differ and asset holdings of stock 1 and 2 cannot support the efficient consumption allocation for two values of θ. However, the composition of the portfolio still changes with θ. For $\theta < \tilde{\theta}_{a1} = 1.10$, the portfolio contains mainly the local asset, while for $\theta > \tilde{\theta}_{a2} = 1.28$ foreign assets prevail. Between $\tilde{\theta}_{a1}$ and $\tilde{\theta}_{a2}$ portfolio holdings show strongly leveraged positions and are hard to interpret.

Figure 1.2: Equity Portfolio of Country 1 with Asymmetric Preferences



Notes: The figure shows the shares country 1 holds of stock 1 (S_1^1, solid line), of stock 2 (S_2^1, dashed line) and of stock 3 (S_3^1, dotted line) as a function of the elasticity of substitution θ. The asset structure cannot replicate the efficient consumption allocation for $\theta = \tilde{\theta}_{a1} = 1.10$ and $\theta = \tilde{\theta}_{a2} = 1.28$.

In this setting, it is interesting to compare the two foreign shares, S_2^1 and S_3^1. When $\theta < \tilde{\theta}_a$, asset holdings of stock 3 are higher than holdings of stock 2 except for values of θ that are close to $\tilde{\theta}_a$, while for $\theta > \tilde{\theta}_a$ the opposite emerges. Trade flows between country 1 and 3 are assumed to be higher than between country 1 and 2 ($\alpha_3^1 = 0.2 > \alpha_2^1 = 0.1$). Hence, these results show a (mostly) positive influence of bilateral trade flows on asset holdings for $\theta < \tilde{\theta}_a$, while for $\theta > \tilde{\theta}_a$ the influence is negative. For the analysis in the next section, these results imply a value for θ that is sufficiently small in order to generate the empirically identified positive effect of bilateral trade on bilateral asset holdings (Aviat and Coeurdacier, 2007; Lane and Milesi-Ferretti, 2008). The results also suggest that the influence of bilateral trade flows is closely related to the portfolio composition regarding home and foreign assets.

1.3.3 How Bilateral Trade Flows Affect the Foreign Portfolio Share

One major advantage of the three country model developed in this chapter is that it enables me to analyze the effects of bilateral trade flows on asset holdings independently of trade openness. Let us focus on country 1's equity holdings of stock 2. An increase in the parameter α_2^1 leads to a rise in trade flows between country 1 and 2. At the same time, the import share of country 1, $\alpha_2^1 + \alpha_3^1$, is assumed to stay constant due to the presence of country 3. Of course, trade flows between country 1 and country 3 decrease, when α_2^1 increases.

I fix the import share at 30% of output and assume that country 1 trades less with country 2 than with the rest of the world, i.e., $\alpha_2^1 \in (0, 0.15)$. Furthermore, the substitution elasticity, θ, is set to 0.3 as the results in section 1.3.2 imply that a relatively low value of θ is necessary to generate the empirically identified positive effect of bilateral trade on bilateral equity holdings (see the evidence in section 1.4.2; Aviat and Coeurdacier, 2007; Lane and Milesi-Ferretti, 2008).[13]

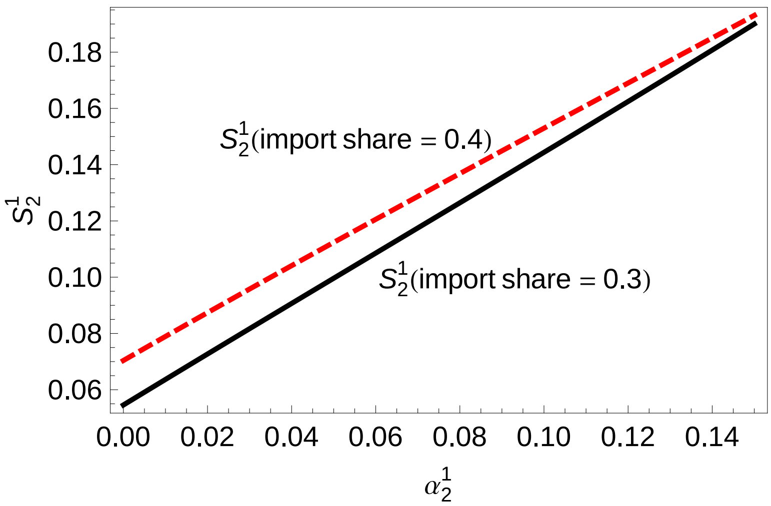
Figure 1.3 displays the share of stock 2 in country 1's portfolio as a function of α_2^1 (solid line). It shows that bilateral trade flows have a positive effect on asset holdings. Importantly, this effect is independent of the general openness to trade.

[13] Note that a value of, e.g., $\theta = 0.8$ would also generate a positive effect of bilateral trade flows on bilateral asset holdings. However, foreign asset holdings are mainly negative in this case.

When country 1 and 2 trade more with each other, the ability of stock 2 to hedge consumption risk increases and country 1 holds more of stock 2.

Consider for example the effects of a negative endowment shock to good 2. One effect is the increase of stock 2's dividend. In response to a negative endowment shock terms-of-trades increase. In addition, the terms-of-trade increase dominates the negative effect from the endowment decrease, since the value of θ is sufficiently low. Another effect of the negative endowment shock is the increase of consumption expenditures as both terms-of-trade and consumption shares increase. On the one hand, the increase in the dividend of stock 2 is stronger for higher imports from country 2 (α_2^1 increases), since the rise in the terms-of-trade is stronger in this case. This by itself would lead to lower asset holdings. On the other hand, consumption expenditures react more strongly to the endowment shock if imports from country 2 are higher, thus calling for higher asset holdings of stock 2. Since the latter effect is more pronounced, shares of stock 2 are higher for higher α_2^1.

Figure 1.3: Country 1 Holdings of Stock 2 for Increasing Trade Flows



Notes: The figure shows S_2^1 for a bilateral import share α_2^1 between 0 and 0.15. The total import share is 0.3 (solid line) and 0.4 (dashed line), such that $\alpha_3^1 = 0.3 - \alpha_2^1$ and $\alpha_3^1 = 0.4 - \alpha_2^1$, respectively. The elasticity of substitution is set to $\theta = 0.3$.

Furthermore, I am interested in the effect of trade openness on asset shares controlling for the effect of bilateral trade flows. To this end, I choose a higher import share of 40% and repeat the experiment of computing the portfolio share of stock 2 as a function of α_2^1. Figure 1.3 plots the graphs for the two experiments. The solid line depicts holdings of stock 2 for an import share of 30% and the dashed line shows holdings of stock 2 for an import share of 40%. Comparing the asset holdings for the two import shares shows that openness exerts an independent effect on bilateral investment patterns. Although bilateral trade flows are the same, bilateral asset holdings vary with the degree of trade openness. The influence of openness is positive as country 1 holds a higher share of stock 2 for an import share of 40% than for one of 30%. The explanation runs along similar lines as for the effect of α_2^1 on S_2^1. Consumption expenditures and the dividend of stock 2 fall more strongly in response to a positive endowment shock to good 2, if trade openness is higher. The dividend of stock 2 falls more strongly, since the relative price of good 2 in terms of good 1 falls more strongly due to consumption of good 1 being higher. If consumption expenditures would be constant, this stronger response of stock 2 dividends would mean that the agent would need to hold a lower share of stock 2 to generate the same amount of financial income. However, consumption expenditures also react more strongly to an endowment shock if trade openness is higher. This response calls for a higher financial income and outweighs the dividend effect. Hence, S_2^1 is higher for higher trade openness.

Given this comparison between asset holdings for different import shares, I can analyze possible interaction effects between bilateral trade flows and trade openness. An interaction effect would show up through an influence of openness on the effect bilateral trade has on stock holdings. For my calibration, I find a negative interaction effect, where higher trade openness has a dampening effect on the influence of bilateral trade flows on S_2^1. In other words, the slope of S_2^1 is smaller for $\alpha_2^1 + \alpha_3^1 = 0.4$ in comparison to $\alpha_2^1 + \alpha_3^1 = 0.3$. This negative interaction effect can be explained through the stronger dividend response of stock 2 when trade openness is higher. S_2^1 increases with higher bilateral trade flows, since consumption expenditures react more strongly to an endowment shock for increasing α_2^1 and dominate the negative effect of the dividend response. The dividend moves more strongly for increasing α_2^1, which would lead to lower asset holdings assumed consumption expenditures are constant. This dividend increase for increasing α_2^1 is stronger for a higher import share. Thus, the positive effect of the consumption expenditure response on S_2^1 is less pronounced for a higher import share, leading to the smaller slope of S_2^1 for the case of a 40% import share.

This negative interaction effect shows up for relatively small and relatively high values of θ, whereas for intermediate values of θ, higher trade openness leads to a stronger influence of bilateral trade on bilateral asset holdings. Thus, in those parameter regions, in which consumption shares and dividend values co-move positively (see discussion in section 1.3.2), the interaction effect is negative. The interaction effect for intermediate and high values of θ is driven by the dividend response along the lines of the presented case for small values of θ.

1.4 Empirical Evidence

1.4.1 Data and Econometric Specification

In this section, I provide empirical evidence on the effects of bilateral and total trade flows on the bilateral foreign asset position. For this analysis, I use a data-set that breaks international security holdings down by the residence of the security issuer, the *Coordinated Portfolio Investment Survey* (CPIS) provided by the IMF. The CPIS reports data on year-end cross-border security holdings, where security holdings include holdings of equity and long- and short-term debt securities. The empirical analysis is not confined to the narrow definition of equities as "claims on the residual values of incorporated enterprises" (see CPIS Data: Notes and Definitions), but also includes debt securities that offer an unconditional right to a fixed money income. This ensures that the empirical measure of assets adequately matches the broad definition of equities used in the theoretical model. There, equity shares represent total claims to national output. Bond holdings can also have equity type characteristics. For example, if the endowment realization is lower than the promised fixed payment, the bond holder only receives the residual resource flow.[14]

Annual data starting in 2001 is available for up to 74 source and 236 destination countries and territories. Although I could in principle employ panel data methods, the low time-variation (high correlation over time) in bilateral asset holdings leads

[14]See also Heathcote and Perri (2009) who make a similar point.

me to consider only cross-sections without losing too much sample information. To estimate my model, I use the 2001 cross-section, which was also used by Lane and Milesi-Ferretti (2008),[15] and the 2007 cross-section, which is the latest available year and has the broadest country coverage.[16]

Specifically, my econometric analysis is based on the following gravity model:[17]

$$\log(assets_{ij}) = d_j + \beta_1 \log(biltrade_{ij}) + \beta Z_{ij} + \gamma_1 \log(tottrade_i) + \gamma C_i + \epsilon_{ij} \ , \quad (1.26)$$

where $assets_{ij}$ is the level of portfolio investment in host country j by source country i, $biltrade_{ij}$ measures trade between source country i and host country j, $tottrade_i$ is total trade - that is, openness - of source country i, all three measured in millions of US Dollars, d_j is a host country dummy, and ϵ_{ij} is an error term.[18] I also include a set of bilaterally varying control variables, Z_{ij}, and a set of controls for source country characteristics, C_i. While Lane and Milesi-Ferretti (2008) employ a double fixed effects specification with host and source country dummies, I cannot use source country dummies as they would absorb the effect of total trade.

I follow the literature and specify the dependent variable in natural logarithms.[19] In addition, I exclude source and host countries that mainly act as financial offshore centers.[20] The reasons why these countries hold cross-border asset holdings might differ systematically from other source countries since financial offshore centers are mostly intermediaries (see the discussion in Lane and Milesi-Ferretti, 2008). Similarly, the motives why source countries hold assets of financial offshore centers might be different as well.

[15] For a detailed discussion of the shortcomings of the CPIS data regarding country coverage and asset reporting, see Lane and Milesi-Ferretti (2008).

[16] The data for 2008 is only preliminary.

[17] For a complete list of data sources and variable definitions, see appendix B.

[18] The empirical specification corresponds to the theoretical setup in the sense that the empirical setup also focuses on the the bilateral relationship and the third country or rest of the world only appears through the source country characteristics.

[19] While this forces me to exclude all observations that are equal to zero, Lane and Milesi-Ferretti (2008) argue that this specification is justified on the grounds that the main focus is on variables explaining the specific magnitude of investments. Including zero observations would put a higher emphasis on regressors explaining the difference between zero and non-zero asset holdings. A way to include zero observations would be to add a small "epsilon" to the dependent variable before taking logs, i.e., $\log(assets + \varepsilon)$.

[20] See appendix C for a list of excluded countries.

The set of bilaterally varying control variables, Z_{ij}, consists of variables that have been previously found to influence bilateral investment patterns. First, these include the geographical distance and the time-zone difference between two countries, which could possibly have a negative impact on information flows and communication.[21] Second, I include dummies for common language, past colonial relationship, and currency unions, which are measures for cultural and financial proximity that could help overcome information barriers. Furthermore, I include a dummy for the existence of a tax treaty and control for a possible diversification motive by including the correlation between GDP growth rates of source and host country.

The source country control variables, C_i, include country specific characteristics that influence a source country's propensity to hold outward investments. The factors I control for are the size of the source country (measured by population) and economic and financial development (measured by GDP per capita and stock market capitalization). Richer countries and those with a more developed financial market might have higher incentives to invest in securities of other countries (Lane and Milesi-Ferretti, 2004). Besides these three factors, the bilateral portfolio composition could also be affected by the source country's financial openness. Therefore, I include a measure for de jure financial openness, the Chinn-Ito index that measures capital account openness (Chinn and Ito, 2008), and a measure for de facto financial openness, the ratio of gross capital flows to GDP (see e.g. Kose et al., 2006).

1.4.2 Estimation Results

The first two columns of table 1.2 present OLS estimates for the 2001 cross-section not including (column 1) and including (column 2) total trade as a regressor, respectively. The results show that bilateral trade and total trade both have a significant positive impact on bilateral asset holdings, even when controlling for informational frictions and source country characteristics. Once I include total trade in the regression, the influence of bilateral trade decreases slightly. The effect of total trade is similar in magnitude to the effect of bilateral trade. Other significant factors

[21] While the negative impact of distance on trade in goods can be justified by transportation costs, this does not apply to "weightless" equities. Distance is thus interpreted as a barrier to information flows. The time difference between countries hinders communication directly (see Aviat and Coeurdacier, 2007; Portes and Rey, 2005; Stein and Daude, 2007).

are bilateral distance (with the expected negative influence), common language, and being in a currency union (both raising bilateral asset holdings). Economic and financial development both seem to have a positive influence on a country's bilateral investment: GDP per capita and stock market capitalization both have significant positive coefficients. A country's population, apart from the role it plays in GDP per capita, is not significant in itself. Including total trade in the regression leads to marginally smaller coefficients for the regressors that control for source country characteristics. Including measures for financial openness does not change the results significantly (table 1.2, column 3). The coefficient for total trade is slightly smaller, but still sizeable and significant. Both financial openness measures influence bilateral asset holdings positively and significantly.

Using the cross-section for 2007 changes the OLS estimates only slightly, as columns 1 and 2 of table 1.3 show. However, some differences are noteworthy. First, there are more observations. Interestingly, only a small share of the higher amount of non-zero observations are due to the additional countries reporting to the CPIS in 2007.[22] One potential explanation for the higher number of observations might be an increasing worldwide financial integration. Second, the effects of some regressors have become stronger, while others have become smaller. The coefficient for total trade is slightly smaller than in 2001. The effect of the currency union is stronger in 2007, which might be driven by the European Monetary Union. The coefficient for the time zone difference is now significant. However, it is positive and very small, making an interpretation difficult. The coefficient of per capita GDP is higher, while the one for stock market capitalization is smaller.

However, in the 2007 cross-section, the effect of total trade is not robust to including measures for financial openness. The coefficient of total trade becomes insignificant (table 1.3, column 3). Thus, the effect of total trade on bilateral asset holdings might not be as robust as the effect of bilateral trade. Considering that the results without financial openness show a smaller coefficient for total trade as well, a possible conclusion might be that the effect of total trade has decreased with increasing financial linkages.

[22] Countries that report their security holdings for the first time after 2001 include Pakistan (2002), Barbados (2003), Kuwait (2003), Mexico (2003), Gibraltar (2004), India (2004), and Latvia (2006). The number in parentheses is the first year these countries report their data in the CPIS.

The theoretical model shows an interaction effect between bilateral and total trade flows, where total trade has a dampening effect on the influence of bilateral trade on bilateral asset holdings. In column 4 of table 1.2 and table 1.3, respectively, I include as an interaction term the product of the log of bilateral trade and the log of total trade in the baseline regression.[23] The coefficient of the interaction term is significantly positive. Thus, both trade measures reinforce each other. Higher total trade increases the influence bilateral trade has on asset holdings. The data does not support the theoretically implied negative interaction effect.

Aviat and Coeurdacier (2007) point to an endogeneity problem that renders OLS estimates biased and inconsistent. Not only does trade in goods affect asset holdings, the reverse is also possible. Therefore, I use instrumental variables to check the robustness of the results. The possibly endogenous regressors that I instrument are bilateral and total trade, the correlation of GDP growth rates, GDP per capita, and stock market capitalization. As instruments I use variables that are known to be correlated with trade: the product of the land area of the two countries, a common border dummy, a dummy for being in a free-trade-agreement, a dummy for the number of landlocked countries in the country pair[24], and a dummy for a common colonial ruler after 1945.[25] I also use the colonial dummy as an instrument (excluding this dummy as an independent regressor). Furthermore, I include lagged GDP per capita, lagged stock market capitalization, and the lagged correlation of GDP growth rates in my list of instruments.

Column 5 of table 1.2 and column 5 of table 1.3 show the results for the IV estimation. The results are mostly unchanged in comparison to the OLS estimates. All regressors that were significant before are still significant with similarly sized coefficients. One exception applies to the IV results for 2007. In line with the results for the regression variant including financial openness measures, total trade does not have an economically or statistically significant effect anymore.

[23] Including such an interaction term in the regression with the two financial openness measures does not change the results.

[24] Takes values 0, 1 or 2.

[25] The dummy takes the value 1, if the two countries were colonies after 1945 and had the same colonial ruler, e.g., Singapore and Sri Lanka.

1.5 Conclusion

Using a three-country stochastic general equilibrium model, I have shown in this chapter that bilateral trade and trade openness both have an independent and positive effect on bilateral cross-country asset holdings. To my knowledge, this is the first attempt to analyze these two effects in a unified framework as the separation of the effects of bilateral trade and trade openness is impossible in a two-country model.

My model showed that bilateral trade flows can have a positive impact on the bilateral foreign asset position. This means that two countries that trade more with each other also hold higher shares of each other's equities. The reason is that the equities of the trade partners provide a better hedge for output risks. Similarly, higher trade openness leads to higher bilateral asset holdings. Furthermore, I have identified an interaction effect between the two trade measures. Higher trade openness dampens the effect bilateral trade flows have on bilateral asset holdings.

My empirical findings mostly supported the theoretical results. Analyzing the geographically categorized asset holdings of 74 countries showed that bilateral and total trade both have a positive effect on bilateral portfolio holdings. Nevertheless, the influence of total trade is less robust and seems to fall over time. While I found empirical evidence for the positive effects of bilateral and total trade on asset holdings, the negative interaction in the theoretical model is not supported by the data. In the empirical exercise, the two trade measures reinforce each other.

It would be interesting to relax some of the simplifying assumptions in future work. One example would be to analyze whether the results change in a framework with incomplete markets.

Appendix to Chapter 1

A Derivation of Consumption and Terms-of-Trade Responses to Endowment Shocks

In this appendix, I derive the responses of consumption shares and the terms-of-trade to endowment shocks. The model is linearized around a symmetric equilibrium, where endowments and prices are equal and trade is balanced. $\hat{x}$ denotes percentage deviations from the symmetric equilibrium $\bar{x}$.

In a first step, I linearize the risk-sharing conditions, equations (1.15) and (1.16):

$$\left(\frac{1}{\theta} - \rho\right)\hat{C}^1 - \frac{1}{\theta}\hat{c}_j^1 = \left(\frac{1}{\theta} - \rho\right)\hat{C}^2 - \frac{1}{\theta}\hat{c}_j^2, \tag{1.27}$$

$$\left(\frac{1}{\theta} - \rho\right)\hat{C}^1 - \frac{1}{\theta}\hat{c}_j^1 = \left(\frac{1}{\theta} - \rho\right)\hat{C}^3 - \frac{1}{\theta}\hat{c}_j^3 \quad \text{for } j = 1, 2, 3. \tag{1.28}$$

If $\frac{1}{\rho} = \theta$, these equations become $\hat{c}_j^1 = \hat{c}_j^2$ and $\hat{c}_j^1 = \hat{c}_j^3$.

Using the definition $\mu_j^i \equiv c_j^i / Y_j$, the linearized risk sharing conditions, and the resource constraints (equation (1.14)), I can show that endowment shocks affect consumption shares μ_1^1 and μ_2^2 in the following way:

$$\hat{\mu}_1^1 = \Sigma_1 \hat{Y}_1 + \Sigma_2 \hat{Y}_2 + \Sigma_3 \hat{Y}_3, \tag{1.29}$$

$$\hat{\mu}_2^2 = \Psi_1 \hat{Y}_1 + \Psi_2 \hat{Y}_2 + \Psi_3 \hat{Y}_3, \tag{1.30}$$

where Σ_i and Ψ_i are functions of the structural parameters θ, ρ and α_i^j. For all other consumption shares, the following holds: $\hat{\mu}_j^i = \gamma_j^i \hat{\mu}_1^1 + \chi_j^i \hat{\mu}_2^2$, where γ_j^i and χ_j^i are combinations of $\bar{\mu}_j^i$s.[26] The signs of Σ_i and Ψ_i are driven by the relationship between ρ and θ. If $\theta = \frac{1}{\rho}$, consumption shares remain constant, i.e., $\Sigma_i = \Psi_i = 0$. In this case, full risk-sharing implies $\hat{c}_j^1 = \hat{c}_j^2$ and $\hat{c}_j^1 = \hat{c}_j^3$, which means, that consumption of good j has to change by the same amount in all countries. Thus, consumption of good j increases proportionally to an increase of good j endowment in all three

[26]E.g.

$$\gamma_2^1 = \frac{\bar{\mu}_2^3}{\bar{\mu}_1^3(1 - \bar{\mu}_2^2) + \bar{\mu}_1^2\bar{\mu}_2^3} \quad \text{and} \quad \chi_2^1 = \frac{\bar{\mu}_1^2\bar{\mu}_2^3 - \bar{\mu}_2^2\bar{\mu}_1^3}{\bar{\mu}_1^3(1 - \bar{\mu}_2^2) + \bar{\mu}_1^2\bar{\mu}_2^3}.$$

countries, while consumption of the other two goods does not change.

If, $\frac{1}{\rho} \neq \theta$, the response of consumption shares depends on whether $\frac{1}{\rho}$ or θ are higher, which determines whether the goods are complements or substitutes (see Kollmann, 2006). The three goods are complements, when higher consumption of one good increases the marginal utilities of the other goods. For $\frac{1}{\rho} > \theta$, the goods are complements and consumption shares of a country increase for a positive endowment shock in the same country, while they fall for a positive endowment shock in one of the other countries. In contrast, for $\frac{1}{\rho} < \theta$, the three goods are substitutes and consumption shares in a country fall for a positive shock to the home good and increase for a shock to the foreign good.

In a second step, I substitute the consumption share responses in the linearized equations for relative prices, (1.21) and (1.22). The relative price responses can then be summarized in the following way:

$$\hat{p}_2 = \Gamma^1_{p2} Y_1 + \Gamma^2_{p2} Y_2 + \Gamma^3_{p2} Y_3, \tag{1.31}$$

$$\hat{p}_3 = \Gamma^1_{p3} Y_1 + \Gamma^2_{p3} Y_2 + \Gamma^3_{p3} Y_3, \tag{1.32}$$

where

$$\begin{aligned}
\Gamma^1_{pj} &= -\frac{1}{\theta}\Big((\gamma^1_2 - 1)\Sigma_1 + \chi^1_2 \Psi_1 - 1\Big) \quad \text{for } j = 2,3, \\
\Gamma^i_{pi} &= -\frac{1}{\theta}\Big((\gamma^1_2 - 1)\Sigma_i + \chi^1_2 \Psi_i + 1\Big) \quad \text{for } i = 2,3, \\
\Gamma^i_{pj} &= -\frac{1}{\theta}\Big((\gamma^1_2 - 1)\Sigma_i + \chi^1_2 \Psi_i\Big) \quad \text{for } i \neq j,\ i = 2,3,\ j = 2,3.
\end{aligned}$$

Substituting the foregoing equations into the budget constraint, equation (1.20), and using the assumption $\bar{\mu}^i_j = \alpha^i_j$ (see Kollmann, 2006) results in:

$$\begin{aligned}
&\hat{Y}_1 \left\{\Delta^1_1 - (S^1_1 - \alpha^1_1) - (S^1_2 - \alpha^1_2)\Gamma^1_{p2} - (S^1_3 - \alpha^1_3)\Gamma^1_{p3}\right\} \\
&\quad + \hat{Y}_2 \left\{\Delta^2_1 - (S^1_2 - \alpha^1_2)(\Gamma^2_{p2} + 1) - (S^1_3 - \alpha^1_3)\Gamma^2_{p3}\right\} \\
&\quad + \hat{Y}_3 \left\{\Delta^3_1 - (S^1_2 - \alpha^1_2)\Gamma^3_{p2} - (S^1_3 - \alpha^1_3)(\Gamma^3_{p3} + 1)\right\} \\
&\quad = 0\ ,
\end{aligned} \tag{1.33}$$

where $\Delta_1^i = (\alpha_1^1 + \alpha_2^1\gamma_2^1 + \alpha_3^1\gamma_3^1)\Sigma_i + (\alpha_2^1\chi_2^1 + \alpha_3^1\chi_3^1)\Psi_i$. I solve this equation for S_1^1, S_2^1, S_3^1 such that it holds for arbitrary realizations of $\hat{Y}_1$, $\hat{Y}_2$, $\hat{Y}_3$, which yields equations (1.23)-(1.25) in the main text.

B Data: Definitions and Sources

- **Bilateral Portfolio Asset Holdings**: Portfolio investment assets (equity securities, long-term and short-term debt securities) held by source country residents and issued by destination country residents. Asset holdings are end of 2001 (2007) holdings measured in millions of current US dollars. *Source*: Coordinated Portfolio Investment Survey, International Monetary Fund, `http://www.imf.org/external/np/sta/pi/datarsl.htm`.

- **Bilateral Trade**: Sum of exports and imports between source and host country. Annual data averaged over the period 1997-2001 and 1997-2007, respectively, in millions of current US dollars. *Source*: Direction of Trade Statistics, International Monetary Fund.

- **Total Trade**: Sum of exports and imports of the source country for a given year. Annual data averaged over the period 1997-2001 and 1997-2007, respectively, in millions of current US dollars. *Source*: Direction of Trade Statistics, International Monetary Fund.

- **Distance**: Great-circle distance in miles between the approximate geographic centers of source and host country taken from the CIA "World Factbook" (`https://www.cia.gov/library/publications/the-world-factbook/index.html`). *Source*: Rose and Spiegel (2004); Subramanian and Wei (2007).

- **Common Language Dummy**: Dummy variable, that is 1 if source and host country have the same language. Constructed using country-specific information from the CIA "World Factbook". *Source*: Rose and Spiegel (2004); Subramanian and Wei (2007).

- **Colony Dummy**: Dummy variable, that is 1 if source and host country have ever been in a colonial relationship. Constructed using country-specific information from the CIA "World Factbook". *Source*: Rose and Spiegel (2004); Subramanian and Wei (2007).

- **Time Difference**: Absolute value of the time difference between source and host country (ranging from 0 to 12). *Source*: `http://timeanddate.com`.

- **Tax Treaty Dummy**: Dummy variable, that is 1 if the source and host country have a double taxation treaty prior to 1999. *Source*: Treaty data from `http://www.unctad.org`.

- **Population**: Source country population in thousands. *Source*: World Development Indicators, World Bank.

- **GDP per capita**: Source country GDP in current US dollars per capita. *Source*: World Development Indicators, World Bank.

- **GDP growth rate correlation**: Correlation between the annual nominal GDP growth rates of source country i and host country j using growth rates from 1981-2000. For the IV-estimation I use the correlation between growth rates for the period 1981-1990 as the lagged variable. *Source*: Calculations based on World Development Indicators, World Bank.

- **Stock Market Capitalization**: Market capitalization of the companies, listed on the source country's stock exchange in millions of current US dollars. *Source*: World Development Indicators, World Bank.

- **Capital Account Openness (de jure financial openness)**: Chinn-Ito index measuring the source country's degree of capital account openness based on the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER). *Source*: Chinn and Ito (2008).

- **Financial Openness (de facto)**: Source country's gross capital flows (sum of capital inflows and outflows) in percent of GDP. *Source*: International Financial Statistics, International Monetary Fund.

C List of Excluded Offshore Financial Centers

The following list contains the countries and territories I have excluded in my empirical analysis. These countries and territories are classified as offshore financial centers by the IMF (see Zorome, 2007). If a country or territory is an offshore financial center according to the IMF, but was not excluded by Lane and Milesi-Ferretti (2008), I follow Lane and Milesi-Ferretti (2008) and do not exclude that country either.

Andorra, Anguilla, Antigua and Barbuda, Aruba, the Bahamas, Bahrain, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands, Cook Islands, Cyprus, Dominica, Gibraltar, Grenada, Guernsey, Isle of Man, Jersey, Lebanon, Liechtenstein, Luxembourg, Macao SAR, Malta, Marshall Islands, Mauritius, Monaco, Montserrat, Nauru, Netherlands Antilles, Niue, Palau, Panama, Samoa, Seychelles, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Turks and Caicos Islands, Vanuatu.

D Tables

Table 1.2: Regression Results for 2001

	(1)	(2)	(3)	(4)	(5)
Dependent variable	Log(assets)	Log(assets)	Log(assets)	Log(assets)	Log(assets)
Estimation method	OLS	OLS	OLS	OLS	IV
Log bilateral trade	0.46	0.36	0.38	0.38	0.28
	(8.95)***	(6.51)***	(7.13)***	(7.29)***	(1.69)*
Log total trade		0.42	0.27	0.50	0.75
		(5.02)***	(2.86)***	(5.93)***	(4.04)***
Log distance	-0.41	-0.45	-0.41	-0.38	-0.48
	(-4.00)***	(-4.41)***	(-4.23)***	(-3.88)***	(-2.58)***
Common language dummy	0.76	0.84	0.78	0.81	0.94
	(6.56)***	(7.32)***	(6.89)***	(7.09)***	(6.88)***
Colony dummy	0.23	0.29	0.25	0.25	
	(1.19)	(1.49)	(1.29)	(1.30)	
Currency union dummy	1.25	1.20	0.88	1.19	1.12
	(8.44)***	(8.25)***	(6.33)***	(8.26)***	(7.22)***
Time zone difference	0.03	0.02	0.02	0.01	0.01
	(1.26)	(0.71)	(0.85)	(0.40)	(0.43)
Correlation in growth rates	0.15	0.15	0.21	0.12	0.30
	(1.00)	(1.01)	(1.41)	(0.83)	(1.21)
Tax treaty dummy	-0.02	-0.07	-0.05	-0.01	-0.11
	(-0.19)	(-0.77)	(-0.59)	(-0.15)	(-1.24)
Log GDP per capita	1.35	1.14	0.86	1.02	0.88
	(13.83)***	(10.82)***	(7.62)***	(9.49)***	(7.40)***
Log market capitalization	0.28	0.23	0.22	0.24	0.25
	(4.82)***	(3.97)***	(3.49)***	(4.15)***	(3.36)***
Log Population	0.15	-0.00	0.17	-0.09	-0.19
	(2.06)**	(-0.05)	(1.89)*	(-1.17)	(-2.09)**
De jure financial openness			0.43		
			(7.99)***		
De facto financial openness			0.46		
			(6.21)***		
Log bilateral trade*log total trade				0.10	
				(6.85)***	
N	1725	1725	1645	1725	1725
Adjusted $\bar{R}^2$	0.77	0.77	0.78	0.78	0.77

Notes: Asset holdings are end of 2001 holdings measured in millions of U.S. dollars. Regressions include fixed host country effects. t-statistics are reported in parentheses. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively. De jure financial openness is measured by capital account openness and de facto financial openness by gross capital flows in percent of GDP.

Table 1.3: Regression Results for 2007

	(1)	(2)	(3)	(4)	(5)
Dependent variable	Log(assets)	Log(assets)	Log(assets)	Log(assets)	Log(assets)
Estimation method	OLS	OLS	OLS	OLS	IV
Log bilateral trade	0.49	0.43	0.45	0.48	0.69
	(10.69)***	(8.27)***	(8.49)***	(9.64)***	(4.68)***
Log total trade		0.23	0.06	0.24	-0.03
		(2.98)***	(0.70)	(3.12)***	(-0.18)
Log distance	-0.41	-0.44	-0.42	-0.41	-0.21
	(-4.72)***	(-5.01)***	(-4.75)***	(-4.77)***	(-1.29)
Common language dummy	0.88	0.91	0.81	0.83	0.73
	(8.08)***	(8.26)***	(7.38)***	(7.64)***	(5.34)***
Colony dummy	-0.09	-0.02	0.00	-0.04	
	(-0.43)	(-0.10)	(0.02)	(-0.20)	
Currency union dummy	1.47	1.43	1.33	1.36	1.50
	(10.46)***	(10.19)***	(9.63)***	(9.65)***	(9.68)***
Time zone difference	0.06	0.05	0.06	0.06	0.06
	(3.12)***	(2.72)***	(2.83)***	(2.88)***	(2.99)***
Correlation in growth rates	0.06	0.07	0.04	0.05	0.05
	(0.48)	(0.55)	(0.31)	(0.40)	(0.23)
Tax treaty dummy	0.02	0.01	0.11	0.11	-0.00
	(0.22)	(0.10)	(1.29)	(1.31)	(-0.01)
Log GDP per capita	1.50	1.37	1.33	1.16	1.34
	(19.25)***	(15.85)***	(13.65)***	(12.96)***	(13.56)***
Log market capitalization	0.14	0.11	0.11	0.22	0.16
	(3.47)***	(2.63)***	(2.30)**	(4.64)***	(3.40)***
Log Population	0.15	0.07	0.33	-0.10	-0.02
	(2.59)***	(1.10)	(4.07)***	(-1.51)	(-0.27)
De jure financial openness			0.24		
			(4.82)***		
De facto financial openness			0.32		
			(6.57)***		
Log bilateral trade*log total trade				0.12	
				(8.73)***	
N	2417	2417	2388	2417	2417
Adjusted $\bar{R}^2$	0.74	0.74	0.75	0.75	0.74

Notes: Asset holdings are end of 2007 holdings measured in millions of U.S. dollars. Regressions include fixed host country effects. t-statistics are reported in parentheses. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively. De jure financial openness is measured by capital account openness and de facto financial openness by gross capital flows in percent of GDP.

Chapter 2

The International Transmission of the Financial Crisis - A German Perspective

2.1 Introduction

The recent (2007-2009) financial crisis that started in a small segment of the U.S. financial market spread rapidly around the world, infecting in particular the large and globalized banking systems of advanced economies. It soon spilled over to the real economy, leading to a massive collapse in global trade and a synchronized global recession.[1]

In this chapter, we take two aspects of the crisis - the trade collapse and bank capital losses, both representing a particular transmission channel - and study how they shaped the crisis transmission to economically and financially integrated economies. For this purpose, we use a quantitative international business cycle model featuring a banking sector. The model economy is a small open economy integrated with the rest of the world through trade in goods and through the banking sector trading foreign assets. Global shocks are thus transmitted to the economy via a trade or a financial channel. In the first case, following a trade shock, foreign demand for home goods falters, leading to a decline in exports and output. In the second case, a financial

[1] According to the April 2009 *World Economic Outlook*, real GDP in advanced economies contracted by an unprecedented 7.5% in the fourth quarter of 2008. Subsequently, real world trade declined by 15% in the first quarter of 2009 (Bems et al., 2010).

shock in form of losses on foreign assets destroys part of the banking sector's capital. The banks have to use their own funds for financing loans and foreign asset holdings and consequently restrict lending, leading to declining investment and output.

Empirically, we focus the analysis on the example of Germany. As one of the largest export nations in the world, the German economy was hit especially hard by the trade collapse, while the globally operating part of the German banking system also took its toll in the financial crisis, experiencing high capital losses. Using our calibrated model, we are able to assess whether the trade or the financial channel was more important in transmitting the global crisis to Germany.

To be clear, we do not model or analyze how the financial crisis lead to the collapse of global trade or how it originated and infected banks' balance sheets. Instead we take the two shocks as given, analyze how the economy reacted to them, and assess which of them led to a greater share in the output decline.

The model fitted to German data is able to generate the main experiences of the German economy during the financial crisis. In particular, the calibrated model can capture about 95% of the observed output decline. Regarding the two channels, it turns out that the trade channel accounts for 70% of the explained GDP movement, while the transmission via the financial channel is responsible for 30%. Although the German banking system is of a globalized nature and held considerable amounts of U.S. securities (described in more detail in the next section), Germany's strong trade linkages make it even more vulnerable to disruptions in foreign demand. However, transmission via the trade channel leads to a relatively short recession. The financial channel, in contrast, has longer-lasting effects and is therefore crucial in accounting for the fact that German output in the last quarter of 2010 was still below the level it had two years ago.

Our analysis is related to the literature studying the international transmission of financial shocks via a global banking sector. Using a one-good two-country model, Kollmann et al. (2011) show how a banking sector subject to a bank capital requirement can transmit a loan default shock originating in one country. In comparison to their paper, we study a two-good model. This allows a more detailed analysis of the trade transmission channel, besides analyzing shock transmission via the banking sector. Another difference is that we refrain from explicitly modeling the foreign economy and instead model a small open economy.

Other contributions with global banking sectors include Ueda (2010), who shows how financial constraints and the net worth of creditors contribute to business cycle synchronization, and Olivero (2010), who models an imperfectly competitive banking sector, but does not consider financial shocks. Analyzing a model with financial constraints, Mendoza and Quadrini (2010) show how financial contagion can spread across countries through shocks to bank equity. However, they do not consider how business cycles affect this transmission.

Eickmeier et al. (2011) study the transmission of U.S. financial shocks to a set of advanced economies using a factor augmented VAR. They find that the recent negative shock was large compared to previous financial shocks. While they are not able to cleanly disentangle how the financial shock was transmitted via the different channels, they can show that both trade and financial channel contributed to the transmission.

Related to our research question, the recent literature assessing the cross-country incidence of the 2007-2009 financial crisis also investigates the transmission via trade and financial channels.[2] These studies analyze whether the cross-country variation in crisis incidence - measured by the severity and duration of output decline as well as business cycle correlation - can be attributed to pre-crisis indicators. Our approach differs from this empirical literature in two aspects. First, we focus on the transmission to one particular country, while the studies of the aforementioned literature analyze cross-country differences. Second, our transmission analysis is model based, explicitly modeling the two transmission channels.

Several studies find that advanced economies were hit harder by the crisis (Claessens et al., 2010; Lane and Milesi-Ferretti, 2011; Rose and Spiegel, 2011) and that the financial channel was relatively more important for the crisis transmission than the trade channel. The results of Ólafsson and Pétursson (2010) show that the financial channel - represented by relatively large banking sectors and strong global financial linkages - together with the macro channel - represented by inflation, current account deficits, and a leveraged private sector - plays an important role for the propagation

[2]Other transmission channels include e.g. a global increase in risk aversion and reliance on foreign finance (Lane and Milesi-Ferretti, 2011) as well as a macro channel represented by macroeconomic vulnerabilities and imbalances and an institutional channel (Ólafsson and Pétursson, 2010).

of the crisis across countries, whereas there is little evidence for transmission via the trade channel. Likewise, considering business-cycle correlations, the financial channel was more important for the diffusion of the U.S. based crisis shock to OECD countries, whereas non-OECD countries were mainly affected through the trade channel (Imbs, 2010).[3] Claessens et al. (2010) find that fewer of the impact measures they use - decline duration, severity and relative adversity - were affected by trade measures and that countries were hit through the financial channel earlier than through the trade channel. Lane and Milesi-Ferretti (2011) come to similar results, where real variables like trade openness are correlated with output declines to a lesser extent than financial factors.

On the other hand, Rose and Spiegel (2011) identify few consistent results linking pre-crisis indicators and crisis intensity. Furthermore, considering the transmission to financial variables like credit default swap premia, bank stock prices or equity portfolios, there is little direct evidence that U.S. exposure or external exposure via trade or financial openness led to higher contagion (Bekaert et al., 2011; Kamin and DeMarco, 2010). Transmission via the financial channel, however, played a role for the comovement of a country's stock market returns with those of the U.S. (Didier et al., 2010)

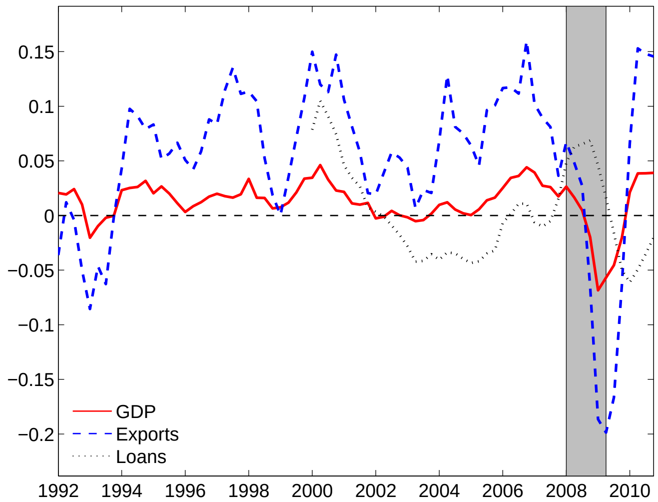
The rest of this chapter is organized as follows. The next section presents evidence on how the German economy was affected by the recent financial crisis. Section 3 describes the model setup and its calibration. Section 4 discusses the results, while section 5 concludes.

2.2 The German Economy during the 2007-2009 Financial Crisis

This section presents how the German economy was affected by the 2007-2009 financial crisis. In line with the two transmission channels presented in the introduction, we focus on the behavior of trade and the developments in the financial

[3]For the crisis transmission to emerging markets, Blanchard et al. (2010) and Berkmen et al. (2009) both find that the financial channel dominated the trade channel. In the former study, the financial channel is represented by capital outflows, while in the latter the financial channel is represented inter alia by bank lending linkages to advanced economies.

Figure 2.1: Growth Rates of GDP, Exports, and Loans.



Notes: The figure shows year-on-year (y-o-y) growth rates of GDP (solid line), exports (dashed line), and loans to non-financial corporations (dotted line). The sample period for GDP and exports is 1992Q1-2010Q4, while the data for loans starts 2000Q1. The shaded area indicates the latest CEPR recession for the Euro Area.

sector. The main aspects are captured in figure 2.1, which shows year-on-year (y-o-y) growth rates for GDP, exports, and loans to non-financial corporations for the period 1992Q1-2010Q4. The shaded area indicates the latest Euro Area recession (according to CEPR). Figure 2.1 shows the unprecedented nature of the recent recession considering the post reunification period.[4] In 2009 German GDP fell annualized by 4.7%, with a growth rate of −6.9% in the first quarter of 2009 (compared to the same quarter in 2008). By the end of 2010, it still had not returned to its pre-crisis level. Exports experienced a similarly drastic downturn, falling by almost 20% in the first two quarters of 2009. In a previous episode of negative export growth, during the recession following the reunification boom, the decline was less than half of the recent decline. The behavior of loan growth also shows a pronounced fall, although it declines a few quarters later than GDP and export growth.

The massive decline of German exports goes hand in hand with the major slump

[4] Although not strictly comparable due to methodological differences, the growth decline was also the largest considering the entire period after the second world war (see Statistisches Bundesamt, 2009).

in global trade hitting the world by the end of 2008 and the beginning of 2009. The global trade collapse was considerably larger than the accompanying world output decline,[5] which has sparked an ample search for the underlying reasons. The key factor explaining the massive trade collapse is suspected to be a deterioration in global demand, explaining 60% to 80% of the trade collapse (Behrens et al., 2010; Cheung and Guichard, 2009; Mauro et al., 2010). In particular, using a trade-weighted demand measure, the trade collapse does not seem so extraordinary as suggested by traditional measures (Bussière et al., 2011).[6] The German economy as one of the leading export nations was particularly exposed to the collapse in world demand.

To capture how global demand has affected German exports, we construct a measure for "global demand" including industrial production of the largest German trading partners (see appendix A for details). The left panel of figure 2.2 shows a close relationship of "global demand" and German export growth, with the trough of demand preceding the trough of exports by about one quarter. A striking detail of the latest collapse is the massive dimension of both demand and export decline. Both series fell by about 20%.

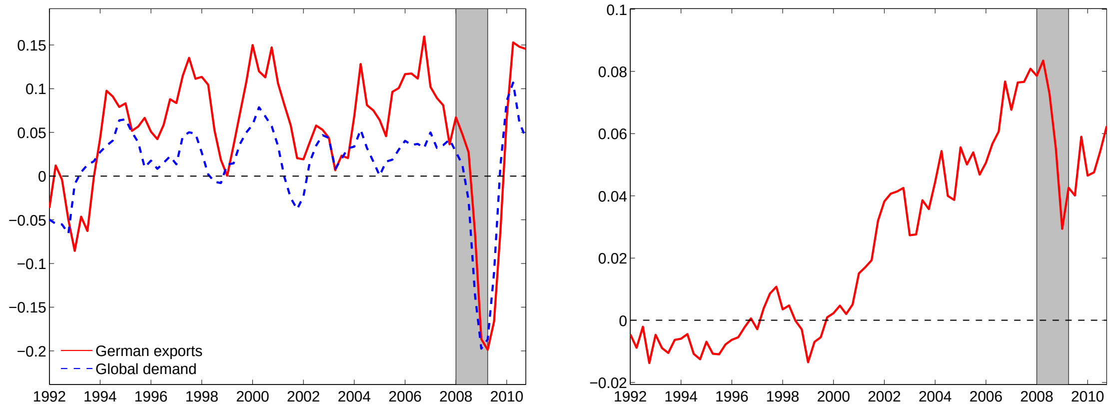
The right panel of figure 2.2 shows net exports scaled by GDP. Net exports have been positive since the beginning of 2000 and grew continuously. However, during the crisis they declined strongly from about 8% of GDP to less than 3% of GDP.

Next, we turn to the developments in the banking sector. The German banking sector was hit hard by the financial crisis. Laeven and Valencia (2010) identify a systemic banking crisis in Germany, starting in 2008. They base their identification on various banking policy intervention measures of which at least three had to take place to define a banking crisis. For Germany the following interventions occurred: extensive liquidity support, significant guarantees on liabilities and a significant bank nationalization (Hypo Real Estate in 2008). The estimations of Laeven and Valencia (2010) show that total assets of failed and government assisted banks in Germany

[5] Real world GDP fell by 7.9 % (annualized) in the first quarter of 2009, while real world trade contracted by 15% in the same period (Bems et al., 2010).

[6] Other factors contributing to the trade deterioration include tighter conditions for trade finance (Ahn, 2010; Amiti and Weinstein, 2009; Chor and Manova, 2010; Coulibaly et al., 2011), increased vertical supply integration (Behrens et al., 2010; Levchenko et al., 2010), the concentration of the demand decline on export intensive goods and durables (Bems et al., 2010; Eaton et al., 2011), or inventory adjustment (Alessandria et al., 2010).

Figure 2.2: German Exports, Global Demand, and Net Exports.



Notes: The left panel compares y-o-y growth of German exports (solid line) and of a measure for global demand (dashed line). Global demand is represented by a weighted average of industrial production of the 20 largest German trading partners. The right panel displays net exports as a ratio to GDP.

amounted to 7% and 29% of total banking assets, respectively. In comparison, U.S. banks that failed or received government assistance accounted for 24% of total banking assets, while, e.g., in France a total of 78% of assets in the banking system belonged to banks that either failed or received government assistance.

The banking sector faced massive writedowns on its loans and securities holdings, draining the capital position and leading inter alia to failure or the need for some kind of assistance. The IMF (2010) estimates that German banks faced cumulative writedowns on their total loans and securities portfolio of 314 billion U.S. dollars during the financial crisis. For the securities holdings alone this amounts to an implied cumulative loss rate of 11.2%.

These substantial losses led to strains on banks' balance sheets, forcing them to deleverage their capital position. One way to accomplish this was to restrict lending, thereby transmitting the financial shock to the real economy. Figure 2.1 shows that the loan volume to non-financial corporations declined. However, the decreasing loan volume could either be an expression of bank-sided factors that led banks to restrict their loan supply or it could stem from the demand side, with firms demanding lesser loans during times of faltering GDP growth. We will explore the role played by bank-sided factors in the reduction of the loan volume next.

Although the German central bank did not find signs for a broad credit crunch (Bundesbank, 2009, 2010), there is some evidence for negative loan supply shocks and bank-sided factors having had a dampening effect on loan growth. Busch et al. (2010) analyze the dynamics of loans to non-financial corporations in Germany using a Bayesian VAR with sign restrictions and find high negative loan-supply shocks at the end of 2008 and in the beginning of 2009. Specifically, the loan-supply shocks had a lagged effect on loan volumes, which might be a possible explanation for the lagged decline of loan growth in figure 2.1.[7] Similarly, Hristov et al. (2011) find that for Euro Area members including Germany, loan-volume changes and part of the decline in GDP growth resulted from adverse loan-supply shocks. In particular, in Germany the adverse effects developed during 2009 and the beginning of 2010.[8] Looking at consumer loans, Puri et al. (2011) show that banks with a high exposure to U.S. toxic assets restricted loans more strongly than banks without this exposure. In line with this are the results by Rottmann and Wollmershäuser (2010) demonstrating that large firms, who mostly rely on those banks hit hardest by the crisis (state-owned "Landesbanken" and commercial banks), faced a heightening unwillingness of banks to grant credit.

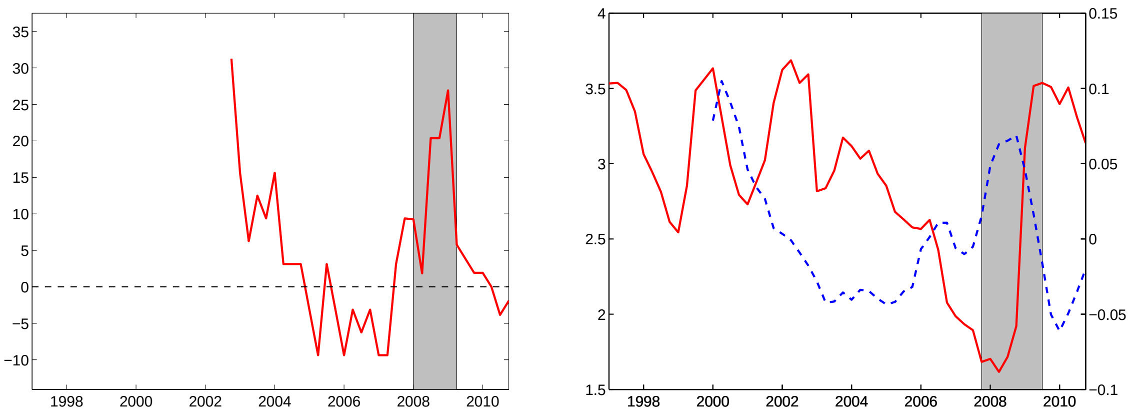
Figure 2.3 displays how credit standards (left panel) and the spread between loan and deposit rates (right panel) have reacted during the financial crisis. A high proportion of German banks considerably tightened credit standards starting in the second half of 2008, after a four-year long period of easing credit standards. At the same time the spread between loan and deposit rates widened strongly, increasing from an all-time low in early 2008 by approximately 2 percentage points (figure 2.3, right panel, solid line, left axis). To depict the negative relation between loan-rate spread and loan growth, the right panel of figure 2.3 also includes loan growth (dashed line, right axis). During times of high loan-rate spreads, loan growth was very small or negative and vice versa. Notably, in the beginning of the crisis period the spread was very low, while loans to non-financial corporations boomed, although they did not reach the high growth rates of the early 2000s.

The German banking sector operates on a global scale with claims on non-residents

[7] Explanations involve e.g. slow re-negotiations of credit lines.

[8] Similar results for bank-side factors affecting loan supply comes from Aiyar (2011), who finds that banks in the UK substantially decreased domestic lending after a shock to foreign funding.

Figure 2.3: Change of Credit Standards, Loan Deposit Rate Spread and Loan Growth.



Notes: The left panel presents the results of the bank lending survey regarding overall credit standards. Banks were asked how their credit standards have changed over the last three months. The graph shows the difference between the weighted sums of answers to "credit standards were tightened" and answers to "credit standards were eased" (each in percent of total answers given). A positive value means that a higher proportion of banks has tightened credit standards. The right panel contrasts the spread between the loan and deposit rates measured in percentage points (solid line, left axis) with y-o-y growth of loans to non-financial corporations (dashed line, right axis).

amounting to over 100% of GDP, making it vulnerable to adverse financial developments in the rest of the world. In particular, Germany was the seventh largest holder of U.S. long-term corporate asset-backed securities, holding a total amount of 42 billion U.S. dollars right before the crisis in June 2007 (Department of the Treasury, 2008). Of these, 80% constituted of mortgage-backed securities. Lane and Milesi-Ferretti, 2011 observe that several industrial countries with heavily affected financial institutions held large amounts of asset-backed securities. Figure 2.4 shows the development of foreign claims on non-residents by German banks from 2003 to 2010. Foreign claims on all countries increased until an all-time high of 134% of GDP in the third quarter of 2007 and have since been mostly declining (figure 2.4, left panel). A similar picture emerges considering y-o-y growth of one segment of foreign claims, namely securities from the U.S. (figure 2.4, right panel). These assets fell substantially during the crisis years.

In this section, we have analyzed the impact of the 2007-2009 financial crisis on the German economy, with a special focus on the effects on exports and the banking sector. As a next step, we integrate the export developments and bank losses into a

Figure 2.4: Foreign Claims by German Banks.

Notes: The left panel shows claims on non-residents (all countries) as a ratio to GDP. The right panel shows claims on non-residents (U.S. securities), y-o-y growth.

small open economy model that is connected to the rest of the world via trade in goods and securities. This enables us to study the transmission of the financial crisis via trade and financial channel. In particular, we can assess the relative importance of the two transmission channels.

2.3 The Model

We use a small open economy variant of the model proposed in Kollmann et al. (2011). The economy is inhabited by a representative worker, an entrepreneur, and a bank. There are two goods, a home intermediate good produced by the entrepreneur and a foreign intermediate good produced in the rest of world. Both intermediate goods are combined into a final good that is used for consumption by the three agents and for investment by the entrepreneur. The bank intermediates funds between the worker, the entrepreneur and the rest of the world by collecting deposits from the worker, making loans to the entrepreneur and trading foreign assets with the rest of the world. Hence, the economy is connected to the rest of the world through two channels, trade in intermediate goods (the trade channel) and trade in foreign assets (the financial channel). These two channels, and in particular the underlying trade and financial shock, will be the focus of the crisis transmission assessment.

2.3.1 The Worker

The worker's utility depends on consumption of the final good C_t, bank deposits D_{t+1} and hours worked N_t:

$$U_t = E_t \sum_{s=0}^{\infty} \beta^s \left[\frac{\left(C_{t+s} - \psi_w C_{t+s-1}\right)^{1-\sigma_w} - 1}{1 - \sigma_w} + \Psi^D \frac{\left(D_{t+1+s}\right)^{1-\sigma_w} - 1}{1 - \sigma_w} - \Psi^N N_{t+s} \right], \tag{2.1}$$

where β is the subjective discount factor, $\sigma_w > 0$ governs the worker's intertemporal elasticity of substitution, and Ψ^D, $\Psi^N > 0$ are preference parameters. The worker has habits in consumption with ψ_w measuring the degree of internal habit persistence. In addition to paying interest, deposits provide liquidity services to the worker. This is one way to model a positive spread between loan and deposit rates and to ensure that workers hold deposits, whereas entrepreneurs borrow from the bank.[9]

The budget constraint of the representative worker in terms of the final good, which is used as the numéraire, is

$$C_t + p_t^a D_{t+1} = p_t^a W_t N_t + p_t^a D_t R_{t-1}^D. \tag{2.2}$$

The household earns income from supplying labor to the entrepreneur and from interest payments on deposits held with the bank. The wage rate W_t is measured in terms of the home intermediate good. Thus, labor income in terms of the final good is $p_t^a W_t N_t$, where p_t^a is the relative price of the home intermediate good in terms of the final good. R_{t-1}^D is the gross interest rate on deposits made last period, D_t, measured in terms of the home intermediate good as well. The worker either consumes his income or saves in new deposits D_{t+1}.

Maximizing the worker's utility subject to his budget constraint yields the following

[9] Another way to model such a setup would be to assume that the worker has a smaller subjective discount factor than entrepreneur and banker, i.e. that the worker is more patient than the other two agents (see Kollmann et al., 2011; Van den Heuvel, 2008).

first-order conditions:

$$(C_t - \psi_w C_{t-1})^{-\sigma_w} - \psi_w \beta \left(C_{t+1} - \psi_w C_t\right)^{-\sigma_w} = \lambda_{w,t}, \tag{2.3}$$

$$\Psi^D \left(\frac{D_{t+1}^{-\sigma_w}}{\lambda_{w,t}}\right) + \beta E_t \left[p_{t+1}^a R_t^D \left(\frac{\lambda_{w,t+1}}{\lambda_{w,t}}\right)\right] = p_t^a, \tag{2.4}$$

$$\lambda_{w,t} p_t^a W_t = \Psi^N, \tag{2.5}$$

where $\lambda_{w,t}$ is the multiplier on the budget constraint. Equation (2.3) shows how consumption habits affect the optimizing behavior of the worker. The Euler equation (2.4) differs from a standard Euler equation through the additional term representing the liquidity services provided by deposits. The third first-order condition shows the trade-off between consumption and labor.

2.3.2 The Entrepreneur and Final Good Production

The entrepreneur produces the home intermediate good a_t by combining capital and labor provided by the worker via a Cobb-Douglas production function:

$$Y_t = z_t (K_t)^\alpha (N_t)^{1-\alpha}, \tag{2.6}$$

where α is the capital share and z_t is total factor productivity following an $AR(1)$ process:

$$\log(z_t) = \rho_z \log(z_{t-1}) + \varepsilon_{z,t}. \tag{2.7}$$

The capital stock, owned by the entrepreneur, depreciates with rate δ and increases through gross investment I_t:

$$K_{t+1} = (1-\delta)\, K_t + I_t. \tag{2.8}$$

The entrepreneur uses the final good for investment. However, the final good cannot be transformed costlessly into capital. Instead, to produce investment I_t the amount of final goods needed is

$$\xi(I_t) = I_t + 0.5\Xi \left(\frac{I_t}{\overline{I}} - 1\right)^2, \ \Xi > 0. \tag{2.9}$$

To finance his operations, the entrepreneur borrows one-period loans L_t from the bank, on which he has to pay the gross loan rate R^L_{t-1}. Thus, the entrepreneur's budget constraint is

$$p^a_t L_t R^L_{t-1} + \xi(I_t) + p^a_t W_t N_t + d^E_t = p^a_t L_{t+1} + p^a_t Y_t, \tag{2.10}$$

where d^E_t is the entrepreneur's dividend income. The entrepreneur derives utility from consuming his dividend income according to the following utility function:

$$U_t = E_t \sum_{s=0}^{\infty} \beta^s \left[\frac{\left(d^E_{t+s} - \psi_E d^E_{t+s-1}\right)^{1-\sigma_E} - 1}{1-\sigma_E} \right]. \tag{2.11}$$

The entrepreneur's risk aversion differs from the worker's risk aversion. Below we will fix σ_E to be lower than σ_w, making the entrepreneur less risk averse than the worker. However, as mentioned earlier, the subjective discount factor β is the same for all agents. Like the worker, the entrepreneur has habits in consumption, governed by ψ_E. The first-order conditions corresponding to the maximization of the entrepreneur's utility (2.11), taking into account the constraints (2.8) and (2.10), are:

$$\left(d^E_t - \psi_E d^E_{t-1}\right)^{-\sigma_E} - \psi_E \beta \left(d^E_{t+1} - \psi_E d^E_t\right)^{-\sigma_E} = \lambda_{E,t}, \tag{2.12}$$

$$\beta E_t \left[\frac{p^a_{t+1}}{p^a_t} \left(\frac{\lambda_{E,t+1}}{\lambda_{E,t}} \right) R^L_t \right] = 1, \tag{2.13}$$

$$\beta E_t \left[\left(\frac{\lambda_{E,t+1}}{\lambda_{E,t}} \right) \left(p^a_{t+1} \alpha z_{t+1} \left(\frac{K_{t+1}}{N_{t+1}} \right)^{\alpha-1} + \xi'(I_{t+1})(1-\delta) \right) \right] = \xi'(I_t), \tag{2.14}$$

$$(1-\alpha) z_t \left(\frac{K_t}{N_t} \right)^{\alpha} = W_t. \tag{2.15}$$

The final good F_t used for consumption and investment is bundled from home and foreign intermediate goods, a_t and b_t, via the CES-aggregator

$$F_t = \left(\omega^{\frac{1}{\theta}} (a_t)^{\frac{\theta-1}{\theta}} + (1-\omega)^{\frac{1}{\theta}} (b_t)^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}}, \tag{2.16}$$

where θ is the elasticity of substitution between home and foreign goods and $0 \leq \omega \leq 1$ is the share of the home intermediate good used for the final good in case of equal prices. $\omega > 0.5$ corresponds to a home bias in consumption and investment. A cost-minimization argument yields the demand functions for a_t and b_t:

$$a_t = \omega \left(p_t^a\right)^{-\theta} F_t, \tag{2.17}$$

$$b_t = (1-\omega) \left(p_t^b\right)^{-\theta} F_t, \tag{2.18}$$

with p_t^b denoting the relative price of foreign intermediate goods in terms of the final good.

2.3.3 The Bank

The bank collects deposits from the worker, makes loans to the entrepreneur, and trades foreign assets with the rest of the world. Foreign assets A_{t+1} are denominated in foreign currency.[10] The home currency value of foreign assets is therefore $p_t A_{t+1}$, where $p_t = p_t^b / p_t^a$ are the terms-of-trade defined as the ratio of import to export prices.

As in Kollmann et al. (2011), the bank faces a capital requirement. This means that the bank's capital in period t, $L_{t+1} + p_t A_{t+1} - D_{t+1}$, should not fall below a fraction γ of the bank's assets, $L_{t+1} + p_t A_{t+1}$. When the bank does not meet the capital requirement and capital falls short of the required fraction γ, the bank incurs costs.[11] These costs depend on the amount of capital exceeding/falling short of the requirement, i.e. the excess capital x_t, defined as $x_t = (1-\gamma)(L_{t+1} + p_t A_{t+1}) - D_{t+1}$. The cost function $\phi(x_t)$ has the form

$$\phi(x_t) = \phi_1 x_t + \frac{\phi_2}{2}(x_t)^2. \tag{2.19}$$

If capital falls short of the requirement and excess capital is negative, costs are positive, whereas holding more capital then required leads to a reduction in operation costs, discussed next.

[10] Actually, more than half of the claims by German banks on non-residents are denominated in Euro. However, here we focus on a financial shock originating in the U.S. financial market and on average around 90% of German banks' claims on the U.S. are denominated in U.S. dollar.

[11] We assume that in this case the bank needs funds for its efforts to meet the capital requirement, while a high capital buffer eases operations.

All bank operations - collecting deposits from workers, handing out loans to entrepreneurs, and holding foreign assets - lead to linear operation costs Γ_D, Γ_L, and Γ_A. The bank's budget constraint is:

$$p_t^a \left(L_{t+1} + D_t R_{t-1}^D + \Gamma_D D_{t+1} + \Gamma_L L_{t+1} + \Gamma_A (A_{t+1}) + \phi(x_t) + \frac{\chi_A}{2} \left(A_{t+1} - \bar{A} \right)^2 \right)$$
$$+ p_t^b A_{t+1} + d_t^B = p_t^a \left(L_t R_{t-1}^L + D_{t+1} \right) + p_t^b A_t R_t^A Q_t. \tag{2.20}$$

Here, d_t^B is the banker's dividend income. To induce stationarity we assume that the foreign assets are subject to quadratic portfolio adjustment costs (see Schmitt-Grohé and Uribe, 2003). Specifically, deviations of foreign asset holdings from their steady-state value $\bar{A}$ are costly.

The foreign asset pays a risky return, where R_{t+1}^A is the expected gross return of foreign assets accumulated in period t. The return is exogenous and follows an $AR(1)$-process:

$$\log(R_t^A) = (1 - \rho_R) \log(\bar{R^A}) + \rho_R \log(R_{t-1}^A) + \varepsilon_{R,t}. \tag{2.21}$$

In addition, foreign assets are subject to an unpredictable i.i.d. valuation shock Q_t. With this structure we split the return of the foreign asset into returns under normal circumstances and into a valuation shock that represents more fundamental re-evaluations, such as those massive writeoffs experienced during the current financial crisis. Subsequently, the valuation shock will represent the foreign financial shock, when we assess the crisis transmission.

The banker consumes his dividend income and maximizes his utility function

$$U_t = E_t \sum_{s=0}^{\infty} \beta^s \left[\frac{\left(d_{t+s}^B \right)^{1-\sigma_B} - 1}{1 - \sigma_B} \right] \tag{2.22}$$

subject to the budget constraint (2.20). The corresponding first-order conditions are:

$$\beta E_t \left[\frac{p_{t+1}^a}{p_t^a} \left(\frac{d_{t+1}^B}{d_t^B} \right)^{-\sigma_B} R_t^D \right] = 1 - \Gamma_D + \phi'(x_t). \tag{2.23}$$

$$\beta E_t \left[\frac{p^a_{t+1}}{p^a_t} \left(\frac{d^B_{t+1}}{d^B_t} \right)^{-\sigma_B} R^L_t \right] = 1 + \Gamma_L + \phi'(x_t)(1-\gamma), \tag{2.24}$$

$$\beta E_t \left[\frac{p^b_{t+1}}{p^b_t} \left(\frac{d^B_{t+1}}{d^B_t} \right)^{-\sigma_B} R^A_{t+1} Q_{t+1} \right] = 1 + \frac{\Gamma_A}{p_t} + \phi'(x_t)(1-\gamma) + \frac{\chi_A}{p_t} \left(A_{t+1} - \bar{A} \right), \tag{2.25}$$

2.3.4 Market Clearing and Definitions

We assume that the costs incurred by the bank are paid in terms of the home intermediate good. The bank has to buy these resources from the entrepreneur. Thus, market clearing for the home intermediate good requires

$$Y_t = a_t + a^*_t + \phi(x_t) + \Gamma_D D_{t+1} + \Gamma_L L_{t+1} + \Gamma_A A_{t+1} + \frac{\chi_A}{2} \left(A_{t+1} - \bar{A} \right)^2, \tag{2.26}$$

where a^*_t is the amount of the home intermediate good exported to the rest of the world. The demand from the rest of the world for home intermediate goods is specified as (see e.g. Justiniano and Preston, 2010):

$$a^*_t = (1-\omega) \left(p^{*a}_t \right)^{-\theta} Y^*_t. \tag{2.27}$$

The foreign demand depends on the relative price for the home intermediate good in the rest of the world p^{*a}_t, which is inversely related to the terms-of-trade, and on foreign demand Y^*_t, which follows an $AR(1)$ process

$$\log(Y^*_t) = \rho_Y \log(Y^*_{t-1}) + \varepsilon_{Y,t}. \tag{2.28}$$

Net exports scaled by GDP are

$$nx_t = \frac{a^*_t - p_t b_t}{Y_t}. \tag{2.29}$$

Finally, market clearing for the final good requires that the production of final goods equals the sum of aggregate consumption, which is the sum of worker, entrepreneur and banker consumption, and the amount used for investment:

$$F_t = C_t + d_t^E + d_t^B + \xi(I_t). \tag{2.30}$$

2.3.5 Calibration

The model is calibrated to match properties of the German economy. A period in the model corresponds to one quarter. We set the parameter ω such that trade openness in the model, $1-\omega$, matches the average trade openness of Germany during the sample period, which runs from the first quarter of 1991 to the fourth quarter of 2010. The substitution elasticity between home and foreign goods θ is fixed at 1.5, a standard value in the literature (see Backus et al., 1994).

The capital share in production α is set to 0.3, which corresponds to the average capital share in Germany over the sample period. Physical capital depreciates with a rate of $\delta = 0.025$ per quarter. We use the investment adjustment cost parameter Ξ to match the relative volatility of investment of the model, i.e. the standard deviation of investment relative to the standard deviation of GDP, with the empirical counterpart of 2.55 (see table 2.1). To calculate the relative investment volatility of the model, we simulate the model including the three shock processes as described below.

The approximate capital ratio of German banks, i.e. the ratio of bank equity to total bank assets (not risk-weighted) over the period 1998-2010 was 5%. Thus, we set the required bank capital ratio to this value, $\gamma = 0.05$. The steady state deposit and loan rates are set to their respective averages over the period 1997-2010, 2.69% p.a. and 5.60% p.a. Thus, the spread is 2.91% in steady state. We assume that the bank incurs equal costs for handling domestic deposits, loans or foreign assets, $\Gamma_D = \Gamma_L = \Gamma_A$=0.0035. Assuming equal operating costs, the bank's first order conditions for loans and foreign assets, (2.24) and (2.25), imply that in steady state the interest rate on foreign assets R^A has to be equal to the loan rate.[12] Similar to Davis (2010), the parameter governing portfolio adjustment costs is set to a small value, $\chi_A = 0.005$.

[12]The foreign asset return series used to match the process for foreign asset returns gives an average quarterly return of 1.37% over the sample period. This is roughly the same as the quarterly loan rate of 1.4%.

The loan rate also determines the subjective discount factor $\beta = 0.9862$, which follows from the Euler equation of the entrepreneur (equation (2.13)). We follow Kollmann et al. (2011) and assume log utility for the worker and the banker, $\sigma_w = \sigma_B = 1$, and almost risk-neutral entrepreneurs, i.e. $\sigma_E = 0.01$. As in Gerali et al. (2010), entrepreneurs and workers have the same consumption habits of $\psi_E = \psi_w = 0.85$.

Excess capital in steady state is zero. We also need to fix the parameters of the excess capital cost function, ϕ_1 and ϕ_2. Given the bank's costs for handling deposits, loans, and foreign assets, any of the bank's Euler equations in steady state yields ϕ_1. For the curvature of the excess cost function, we follow Kollmann et al. (2011) and set $\phi_2 = 0.25/Y$.

The loans to physical capital ratio is set such that the ratio of loans to annual GDP in steady state matches the mean of the empirical counterpart for Germany during the sample period, which is 86%. Together with the assumption about excess capital in steady state being zero, this pins down the preference parameters of the worker, $\Psi^D = 0.05$ and $\Psi^N = 2.35$. Our calibration entails that the worker has the highest consumption share, 72.84% of GDP, while the entrepreneur's and banker's consumption shares are considerably lower, 5.98% and 0.35% of GDP, respectively.

We also fix the ratio of loans to foreign assets in steady state. Empirically, the ratio of foreign securities to domestic loans is approximately 30%. Setting $A/L = 0.3$, the model's net foreign asset position (NFA) to GDP is 25.64%, which corresponds to the empirical NFA/GDP ratio of Germany for 2007.[13]

The foreign demand process is approximated using a series constructed with industrial production of Germany's 20 biggest trading partners (see figure 2.2). A detailed description of the data is provided in appendix A. The global demand series has an autocorrelation of 0.9 and a standard deviation of 4.78%. Thus, we set $\rho_Y = 0.9$ and $E\left(\varepsilon_{Y,t}\right)^2 = (0.0208)^2$. The $AR(1)$ process for TFP is matched to linearly detrended German log TFP. Based on this measure, we set $\rho_z = 0.9$ and $E\left(\varepsilon_{z,t}\right)^2 = (0.0076)^2$; the unconditional standard deviation of German TFP is 1.74%. For the return of the foreign assets we combine data on stock and corporate debt returns. This series has an autocorrelation of 0.15 and a standard deviation of 4.60%.

[13]Here we have used the NFA position from the updated and extended version of the External Wealth of Nations Mark II database constructed in Lane and Milesi-Ferretti (2007).

We also match the empirical correlations between the three data series. The correlation between TFP and foreign demand is 0.82, $Corr\left(\varepsilon_{z,t}, \varepsilon_{Y^*,t}\right) = 0.82$. In contrast, the correlations between the returns to foreign assets and home TFP as well as foreign demand are not significantly different from zero.

2.4 Results

The model is solved using a first-order approximation. First, we use the model to examine whether it is able to capture features of German business cycles by comparing empirical moments of the data with theoretical moments of the model. In a second step, we compute impulse response functions to analyze the transmission of trade and financial shocks in our model and study whether the model is able to generate the experiences of the German economy during the financial crisis as described in section 2.2.

2.4.1 Business Cycle Statistics

As a first step, we compare the business cycle properties of our model with those of the data. For this purpose, we calculate second moments of HP-filtered German data for the period 1991Q1-2010Q4 and HP-filtered theoretical moments of the model. In this exercise, we include three of the four shocks of our model: TFP, trade and foreign asset returns. The valuation shock does not play a role under normal circumstances. Hence, we only include the shock process for "normal" foreign asset returns. The three shocks are set to the fitted $AR(1)$ processes described in the previous section.

Table 2.1 presents the moments of the data (column 1), of the model with all shocks (column 2), as well as of the model including TFP, trade and foreign asset return shocks separately (columns 3-5). The model is able capture most features of German business cycles, in particular considering that we only targeted the relative volatility of investment, when calibrating the model. GDP volatility generated by the model including all shocks is somewhat higher than its counterpart in the data, 1.76% vs. 1.37%. However, the relative volatilities of the other variables and their correlations with GDP are matched quite closely. As in the data, aggregate consumption is less volatile than GDP. Loans show a higher relative volatility than deposits in the

Table 2.1: Business Cycle Statistics of German Data and the Model

	Data	Model			
		All	TFP	Trade	Return
	(1)	(2)	(3)	(4)	(5)
Standard deviation (in %)					
GDP	1.37	1.76	1.44	0.18	0.80
Relative standard deviations					
Consumption	0.60	0.74	0.59	0.74	1.24
Investment	2.55	2.55	2.39	0.99	3.45
Employment	0.47	0.81	0.46	1.46	1.43
Deposits	0.99	0.56	0.26	1.68	0.95
Loans	1.25	0.69	0.39	0.71	1.37
Loan deposit rate spread	0.27	0.21	0.03	0.28	0.45
Net Exports	0.66	0.50	0.11	2.94	0.81
Correlation with GDP					
Consumption	0.43	0.62	0.77	-0.67	0.69
Investment	0.86	0.85	0.94	0.33	0.64
Employment	0.54	0.89	0.98	1.00	1.00
Deposits	-0.14	0.16	0.26	-0.11	0.01
Loans	0.27	-0.13	0.04	-0.09	-0.21
Loan deposit rate spread	-0.59	-0.44	-0.99	0.81	-0.98
Net Exports	0.59	0.37	0.13	0.96	-0.26

Notes: This table compares empirical and theoretical moments. Empirical statistics are computed using German data running from 1991Q1 to 2010Q4, except for data on loan deposit rate spreads that starts 1997Q1. For data sources see appendix A. Theoretical statistics are generated by the model variants including all three shocks together and the three shocks separately. All variables are HP-filtered and except for the loan deposit rate spread logged before applying the HP-filter.

model, but are even more volatile in the data. The model predicts a relative standard deviation of the loan deposit rate spread that is very close to the data. Similarly, the relative volatility of net exports is captured quite well.

As in the data, investment is more procyclical than consumption. While the model is able to generate the negative correlation between the interest rate spread and GDP as well as the procyclicality of net exports, it is not able to fully account for the correlations of deposits and loans with GDP.

Considering the three shocks separately shows that the model including only the TFP shock predicts a GDP volatility that is close to the actual GDP volatility. In addition, the relative standard deviations of consumption and employment are matched almost exactly. However, the relative volatilities of the financial variables and net exports are strongly underpredicted. This shows the importance of including the trade and financial shocks to account for German business cycle moments.

The trade shock contributes relatively little to output fluctuations. However, it is the only shock predicting a countercyclical correlation of deposits as in the data. On the other hand, the trade shock by itself generates a counterfactual negative correlation of consumption and a counterfactual positive correlation of the interest rate spread with output.

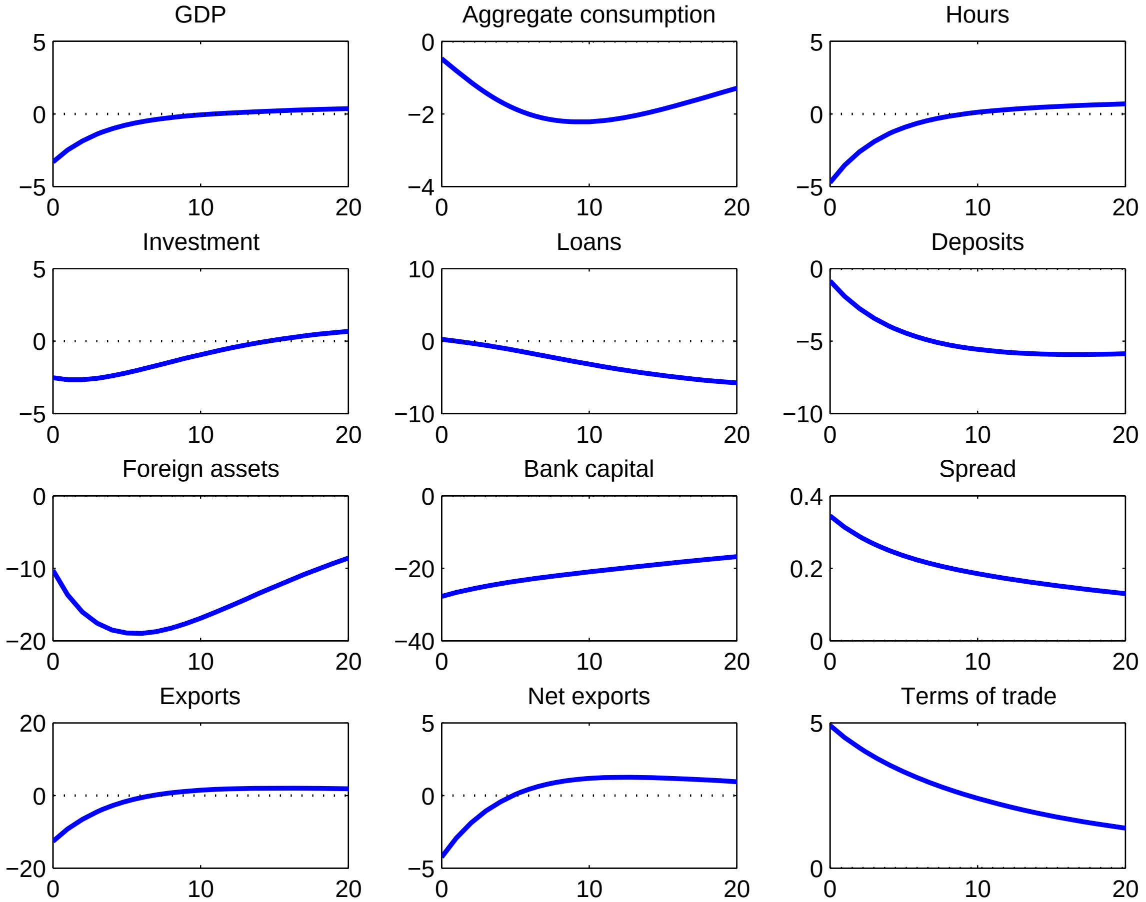
Finally, including only the shock to foreign asset returns leads to a very close match of the relative standard deviation of loans and deposits in the model to their respective counterparts in the data. In this case, loans are more volatile than output and deposits are almost as volatile as output. However, the relative volatilities of all other variables are overpredicted by this model variant.

Having shown that the proposed model captures the properties of German business cycles statistics quite well, we can now continue to analyze how the latest financial crisis was transmitted to the German economy.

2.4.2 Crisis Transmission

In this section, we analyze the crisis transmission to the German economy, focusing on two particular shocks representing the transmission via the trade and the financial channel. The foreign demand shock, subsequently called trade shock, represents developments in global trade, while the valuation shock, or financial shock, represents the massive value loss of foreign asset holdings. The magnitudes of the shocks are chosen to match the observed declines in trade and asset values. The financial shock is set to 11%, matching the estimated losses on securities incurred by German banks (see section 2.2). Hence, foreign assets are hit by a one time valuation shock Q_t of

Figure 2.5: Impulse Responses to Simultaneous Trade and Financial Shocks.



Notes: The variables are expressed in percentage deviations from steady state, the spread is expressed in percentage points p.a.

−11%. The trade shock is set to −20%, based on the global demand measure that fell by approximately 20% in the beginning of 2009 (see figure 2.2). The autocorrelation of the trade shock is set to 0.8, which is different compared to the previous section. With this we intend to capture the extraordinary duration of the compressed demand.[14]

In a first step, we study whether our model economy is able to capture characteristics of the German economy during the financial crisis when hit simultaneously by both trade and financial shocks. Next, we turn to a comparison of the effects of the two

[14] After the 20% decrease of the global demand measure, it recovers fairly quickly, corresponding to an autocorrelation coefficient of 0.8 in the periods after the trough.

shocks, assessing their relative importance in the crisis transmission.

Figure 2.5 presents the impulse responses to a simultaneous negative trade and financial shock. On impact, GDP falls by 3.31%, with continuing negative growth for about 14 quarters. Investment and hours fall on impact by 2.5% and 4.7%, respectively. Aggregate consumption declines in a hump-shaped manner, with an impact response of −0.47% and a maximum response of −2.22% after 10 quarters.

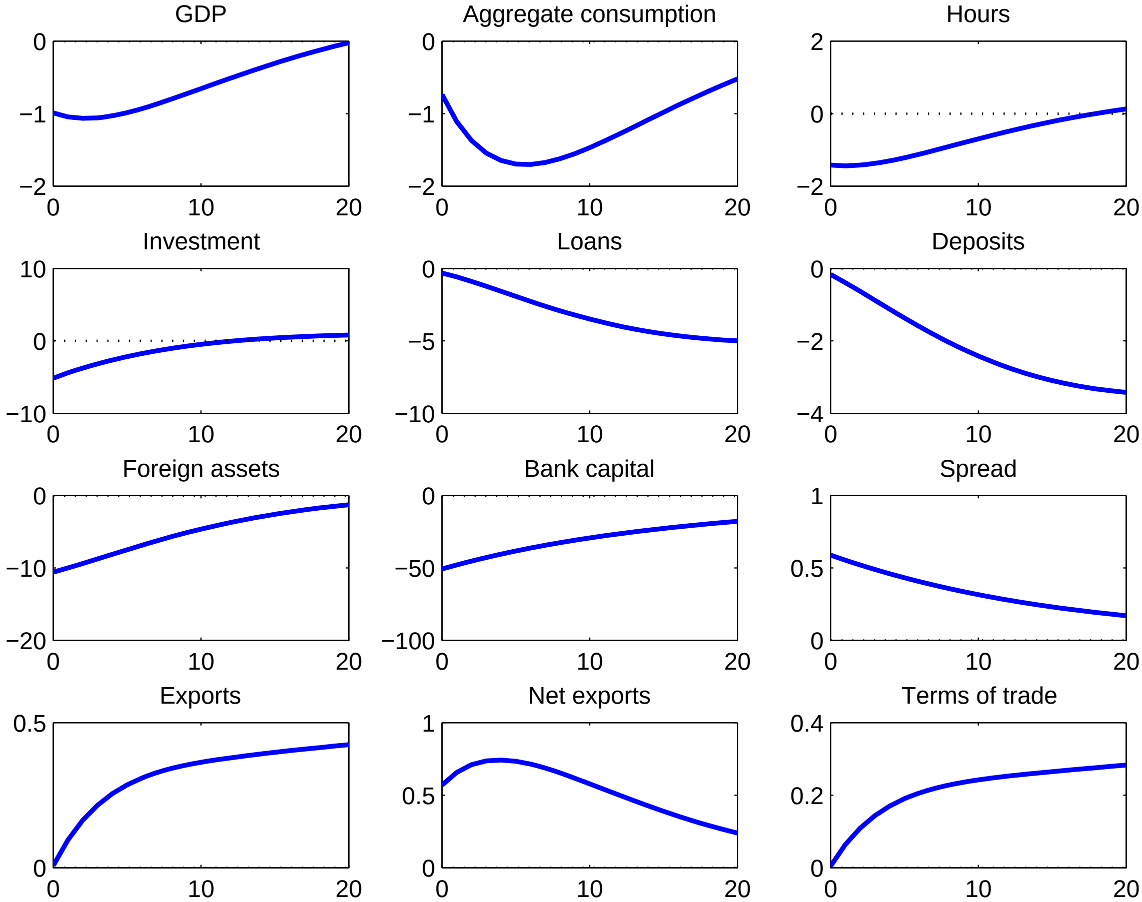
The financial shock destroys part of the bank's balance sheet. Bank capital declines by 27.7% and recovers very slowly. This leads to an increase of the loan-deposit interest rate spread by 0.34 percentage points on impact. Since it is costly to deviate from the capital requirement, the bank adjusts its balance sheet. The value of foreign assets in home currency falls by 10.26% on impact and declines by another 10% during the next 2 years. Subsequently, loans and deposits decrease as well. Whereas deposits fall by 0.84% on impact, loans stay constant for the first two quarters before declining. Thus, the lagged loan decrease in the model is roughly consistent with the observed behavior of loan volume growth (see figure 2.1). The negative trade shock leads to decreasing foreign demand and exports decline by 12.63%. They fall more strongly than imports, leading to a decrease of net exports.

Thus, by including both shocks, we can capture many features characterizing the German economy during the financial crisis. In particular, the model responses show a decline in macroeconomic activity, with output, consumption, investment, and hours decreasing on impact. The model is particularly successful in explaining the decline of German GDP. Output fell by 3.5% in the first quarter of 2009, compared to 3.31% in the model.[15] Also the fall in exports, important for the trade channel, is predicted well: 12.63% vs. around 11% in the data for 2009Q1. The model is somewhat less successful for the other components of GDP. Consumption is predicted to fall by half a percent on impact. In the data, consumption falls indeed by 0.55%, but only in the fourth quarter of 2009 and starts to recover soon after. The investment decline is underpredicted with 2.5% vs. 8% in the data.

Since the main focus of this chapter is the comparison of the shock transmission via the trade and the financial channel, we now consider the financial and trade shocks separately. Both shocks have the same magnitude as before. Figures 2.6 and 2.7 show

[15] We compare the size of the initial response to the quarter-on-quarter growth of the respective variables in the first quarter of 2009.

Figure 2.6: Impulse Responses to a Financial Shock.

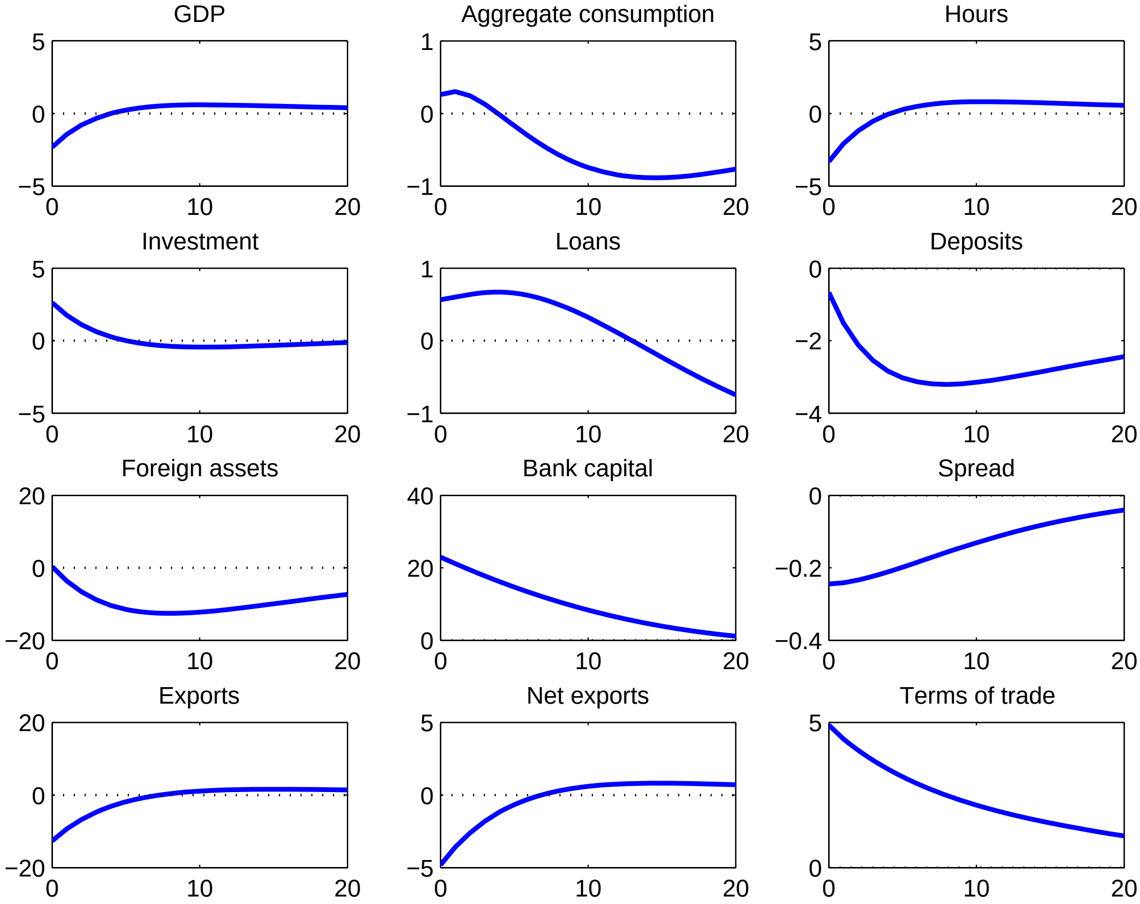


Notes: The variables are expressed in percentage deviations from steady state, the spread is expressed in percentage points p.a.

the responses to a financial and a trade shock, respectively. Both shocks lead to a decline in output, hours and investment. However, the responses of other variables, in particular bank capital and exports, differ.

In the case of the financial shock, the deteriorating value of foreign assets leads to a decline in bank capital. This sets off an increase in the loan deposit rate spread by about 0.6 percentage points and a fall of loans as well as deposits. A higher loan rate discourages loan demand from the entrepreneur, while a lower deposit rate induces the worker to save less. Exports increase slightly by less than 0.5% over four years. At the same time imports fall, leading to higher net exports.

Figure 2.7: Impulse Responses to a Trade Shock.



Notes: The variables are expressed in percentage deviations from steady state, the spread is expressed in percentage points p.a.

In contrast, bank capital increases in the case of the trade shock. This is driven by a positive response of loans during the first 3 years. Loans increase due to higher demand by entrepreneurs following a fall of the loan rate. The lower loan rate also induces higher investment. Deposits and foreign assets on the other hand decline. The value of foreign assets in home currency actually increases on impact, driven by the increase of the terms-of-trade. However, foreign assets valued in foreign currency fall on impact.

The initial increase of aggregate consumption following a trade shock is mainly driven by an increase of entrepreneur consumption. Banker consumption also increases, but its share in aggregate consumption is very low. On the other hand, consumption of workers, which constitutes the largest part of aggregate consumption, falls.

Comparing the output responses for the two shocks shows that the initial impact is higher in case of the trade shock. While output declines by around 1% following a financial shock, it declines by 2.3% following a trade shock. Thus, using the same measure as before, the quarter-on-quarter growth in the first quarter of 2009, shows that the trade shock explains more than twice as much of the actual GDP decline than the financial shock, 66% vs. 28%.[16] However, output needs a longer time to recover from the financial shock compared to the trade shock. In the case of the financial shock, the response of output is negative for about 5 years, while the GDP response becomes positive after less than 2 years, when hit by the trade shock.[17] Given that German output in the last quarter of 2010 was still below its level two years before, the financial shock plays an important role for the tepid recovery.

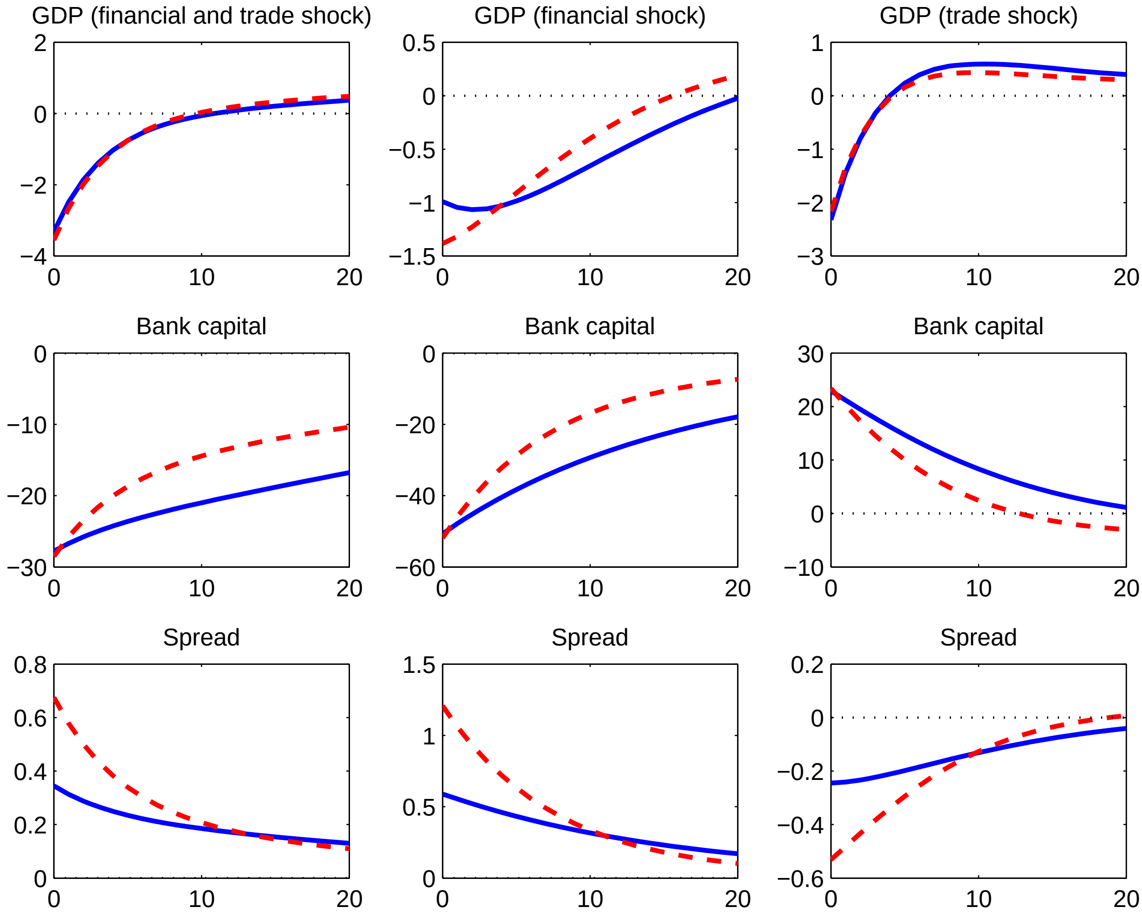
So far, the parameter for the bank capital cost function was set at $\phi_2 = 0.25/Y$. However, in times of uncertainty about the health of banks' balance sheets, the costs for falling short of the bank capital requirement might be much higher because of "overcautious" markets. Therefore in a next step, we explore the implications of higher costs for the bank to violate the bank capital requirement, i.e. we double ϕ_2 to $= 0.5/Y$. Figure 2.8 shows how output, bank capital, and the loan-deposit spread react in this case.

Increasing the costs associated with the bank capital requirement affects the dynamics of bank capital and the interest rate spread, but has a smaller effect on the dynamics of output. In all three model variants, the higher bank costs lead to higher initial responses of the loan deposit rate spread, which is almost twice as large as in the baseline case. The higher bank capital costs make it more expensive for the bank to deviate from the capital requirement and, thus, bank capital reverts back to its steady state much faster than in the baseline case. In the model variant with just the financial shock, this leads to a stronger initial output drop, but faster recovery. Initially, the adjustment has to be harder, but in later periods loans fall less in the

[16] Put differently, the trade shock accounts for 70% of the explained GDP drop, with the remaining 30% being due to the financial shock.

[17] This is in line with evidence by Claessens et al. (2011), who find that recessions associated with financial disruption episodes tend to be longer than other recessions.

Figure 2.8: Impulse Responses to Financial and Trade Shocks with Different Bank Capital Costs.



Notes: The figure compares responses for $\phi_2 = 0.25/Y$ (solid line) with responses for $\phi_2 = 0.5/Y$ (dashed line). The variables are expressed in percentage deviations from steady state, the spread is expressed in percentage points p.a.

higher bank capital cost case.

In the other two model variants, with both shocks and just the trade shock, the impact of increasing capital costs on the shock transmission is more muted than in the variant with just the financial shock.

The shares of the GDP decline explained by the two shocks change somewhat relative to the low-cost specification. Now, the trade shock explains 61% and the financial shock 39% of the explained GDP decline.

2.5 Conclusion

In this chapter, we have analyzed how the recent financial crisis was transmitted to the German economy. For this purpose, we have employed a quantitative business cycle model featuring trade with the rest of the world as well as a globally operating banking sector. Calibrated to German data the model can account for key features of regular German business cycles as well as of the recent financial crisis. It is able to capture 95% of the output decline observed in Germany in the beginning of 2009. Analyzing the relative importance of the two transmission channels shows that the trade channel played a stronger role in accounting for the output drop than the financial channel. In particular, it explains twice as much of the output decline as the financial channel. However, since the financial channel triggers a longer-lasting recession than the trade channel, it is mainly responsible for the duration of the crisis.

Appendix to Chapter 2

A Data Construction and Data Sources

- **GDP, its components, and employment:** We use quarterly German data from the ECB for GDP, gross fixed capital formation, consumption of households and non-profit institutions serving households, exports and imports of goods and services, and total employment. The data runs from 1991Q1 to 2010Q4.

- **Loans, deposits, and interest rates:** We use data on loans and deposits from the Bundesbank. The data on loans to domestic non-financial corporations starts in 1999. For the business cycle statistics calculation, we use a data series on loans to domestic enterprises and households, which is available for the entire sample period starting in 1991. Deposits include deposits from domestic enterprises, households and non-profit institutions. For the interest rate spread, we combine data on deposit and loan rates from the Bundesbank (1997-2003) and the ECB (from 2003 onwards).
  Deposit rate: average rate on savings deposits with higher rates of returns, with agreed notice of 3 months and a duration of up to and including 1 year (Bundesbank); annualized agreed rate on deposits with agreed maturity up to 1 year from households and non-profit institutions serving households (ECB).
  Loan rate: effective interest rate on long-term fixed-rate loans to enterprises and self-employed persons of 500000 and up to 5 million Euro (Bundesbank); annualized agreed rate on loans other than revolving loans and overdrafts, convenience and extended credit card debt to nonfinancial corporations with a maturity of at least 1 and up to 5 years of up to and including 1 million Euro (ECB).

- **Claims on non-residents by German banks:** For claims on non-residents by German banks we use data from the Bundesbank, which is available starting in the second quarter of 2002.

- **Change of credit standards:** The bank lending survey conducted by the

Eurosystem provides a measure for the change of credit standards.[18] For this survey 86 (now 124) banks in Euro Area including 17 (since 2008 30) German banks are asked a set of qualitative questions. These questions ask whether credit standards changed over the last three months and what factors affected loan supply as well as loan demand. The data series is available starting in the fourth quarter of 2002.

- **Global demand process:** To construct the global demand process, we use data for industrial production of the 20 most important German trading partners, as resembled by their average trade weights in total German trade over the period 1991-2010.[19] These 20 countries accounted for 81% of total German trade. For the global demand measure, we compute the geometric average of individual country data using the respective trade weights (see Harrison and Oomen, 2010). The data for industrial production comes from the IMF's IFS database.

- **Foreign asset returns:** We construct the return process for foreign assets using data on stock prices and the value of corporate debt. For the former, we use data of the S&P 500 total return index (from DataStream), while for the latter we use the Bank of America Merrill Lynch U.S. Corp Master Total Return Index Value that tracks investment grade rated corporate debt, taken from the FRED database. The two series are deflated with the U.S. GDP deflator and weighted by the average share of equity and corporate debt in German long-term portfolio holdings of U.S. securities. The data for German holdings of long-term portfolio holdings of U.S. securities is taken from various reports on foreign portfolio holdings of U.S. securities published by the Department of the Treasury together with the Federal Reserve Bank of New York and the Board of Governors of the Federal Reserve System.

- **TFP process:** To construct the TFP measure, we use data on the gross stock of fixed assets from the German Federal Statistical Office,[20] as well as real GDP

[18] For a detailed description of the survey and its purpose see ECB (2003).

[19] The trade weights of the main trading partners have remained relatively stable over the last twenty years, such using average trade weights does not lead to big distortions.

[20] We interpolate quarterly data from the annual stock series using cubic splines.

and total employment data from the OECD Economic Outlook database. The capital share is set to 30%, as in the model.

Chapter 3

Fiscal News and Macroeconomic Volatility

3.1 Introduction

This chapter analyzes the role of news about fiscal policy, and in particular the anticipation of tax rate changes, for business cycle fluctuations. Recent macroeconomic research has increasingly shifted from explaining business cycle fluctuations through contemporaneous shocks to explaining them by anticipated, or news, shocks. Rational agents, anticipating future changes will already react today to these news (see e.g. Beaudry and Portier, 2004, 2006; Jaimovich and Rebelo, 2009; Schmitt-Grohé and Uribe, 2010). However, most empirical studies on the effects of anticipated shocks on business cycles have focused on news about future productivity (see e.g. Forni et al., 2011; Fujiwara et al., 2011; Khan and Tsoukalas, 2011).[1]

This is remarkable for two reasons. First, fiscal measures are usually publicly debated well in advance and often known before becoming effective, i.e. there are considerable decision and implementation lags. A tax bill typically takes about one year from the U.S. President's initial proposal to the law's enactment and another year until the tax change becomes effective (Mertens and Ravn, 2011; Yang, 2005). As a recent example, consider the *Patient Protection and Affordable Care Act*

[1] There is a prominent literature branch dealing with the importance of fiscal foresight. However, its focus has mostly been on analyzing single tax events (House and Shapiro, 2006; Parker, 1999; Poterba, 1988) or tracing out the consequences for econometric analyses (Leeper et al., 2011; Yang, 2005).

("Obamacare"), whose core contents were debated for almost one year and whose financing provisions will only phase in gradually over time. Second, surprise fiscal policy shocks have long been discussed as a potential prominent driver of the business cycle (see e.g. Baxter and King, 1993; Cardia et al., 2003; Jones, 2002; McGrattan, 1994). McGrattan (1994) for example attributes one third of the U.S. business cycle variance to distortionary taxation, while McGrattan (2011) argues that changes in business taxation can explain one third of the output drop during the Great Depression.[2] This potential importance of fiscal policy shocks, combined with the fact that many fiscal policy measures are known well in advance, makes fiscal news a natural candidate for explaining aggregate fluctuations.

We add upon the previous literature by explicitly analyzing the business cycle variance contribution of fiscal news. For this purpose, we employ a New Keynesian DSGE model featuring several real and nominal rigidities as well as various shocks identified as important drivers of the business cycle and augment it with a government sector financed through distortionary labor and capital taxes. Our main focus lies on the effects of fiscal news, but we also control for anticipation in technology, investment-specific productivity, and the wage markup. The model is estimated by full information (Bayesian) methods using quarterly U.S. data from 1955 to 2006. Model-based estimation allows us to circumvent the issue of non-invertibility typically encountered when estimating structural VARs in the presence of anticipation effects (Fernández-Villaverde et al., 2007; Hansen and Sargent, 1991; Leeper et al., 2011).[3]

Computing forecast error variance decompositions, we find that while fiscal policy accounts for 12 to 20 percent of output variance at business cycle frequencies, fiscal news generally only plays a very limited role. Its contribution to output variance ranges around 3 percent.

With a variance share of 10 percent at the 5 year forecast horizon, government

[2]Although Forni et al. (2009) find that unanticipated tax shocks contribute little to macroeconomic fluctuations of the Euro area, this could in principle be the result of ignoring fiscal foresight.

[3]Non-invertibility means that the DGSE-model has a VARMA representation that cannot be inverted to yield a finite-order VAR in the observables. Hence, the true innovations do not perfectly map into the VAR residuals, meaning that the structural shocks cannot be recovered using a VAR. Non-invertibility arises, e.g. when the information set of an econometrician estimating the VAR is smaller than that of the forward-looking agents. For alternative ways to mitigate this problem, see e.g. Sims (2009), Giannone and Reichlin (2006), and Forni et al. (2011).

spending is the fiscal variable with the largest effect on output variance. However, this contribution only comes from surprise shocks, with anticipated spending shocks explaining virtually nothing. Contemporaneous and anticipated capital tax shocks each contribute $2-3$ percent to output fluctuations. However, they are considerably more important for explaining inflation and interest rate fluctuations. Depending on the forecast horizon, surprise capital tax shocks contribute roughly 30 percent to their variance. Anticipated capital tax shocks are responsible for 5 to 15 percent. The effect of contemporaneous and anticipated labor taxes, on the other hand, is negligible.

In line with previous studies that do not consider news shocks (e.g. Smets and Wouters, 2007), we find that the main drivers of the output variance are preference and wage markup shocks. News shocks explain on average 20 percent of the variance of output, with the main effect coming from news about TFP and investment-specific productivity. This result conforms well with i) VAR evidence (Barsky and Sims, 2011), ii) evidence coming from a factor model (Forni et al., 2011), and iii) other DSGE-based estimates of the importance of news shocks, who all find a similar fraction of output fluctuations explained by anticipated shocks.

The two papers most closely related to ours are recent contributions by Mertens and Ravn (forthcoming) and Schmitt-Grohé and Uribe (2010). The former use a VAR to analyze the business cycle contribution of narratively identified anticipated and unanticipated tax shocks.[4] They find that both types of tax shocks together explain 20 to 25 percent of output variance, with anticipation accounting for the majority. Schmitt-Grohé and Uribe (2010) evaluate the role of news about TFP, investment-specific technology, wage markup, and government spending shocks in an estimated RBC model with various real rigidities. In their setup, news shocks account for 41 percent of output fluctuations. But while they find government spending shocks to explain 10 percent, evenly distributed across surprise, one and two year anticipated shocks, they do not consider foresight about the financing side of the government budget constraint.

Our paper is also related to other DSGE-based papers focusing on the effects of

[4] Mertens and Ravn (forthcoming) classify the Romer and Romer (2010) tax shocks according to the time passed between the presidential signing of a bill and the tax changes becoming effective into anticipated and contemporaneous shocks.

anticipated technology shocks. Davis (2007), using a New Keynesian model, estimates news shocks to be responsible for 50 percent of output fluctuations. Fujiwara et al. (2011) extend the New Keynesian model of Smets and Wouters (2007) and Christiano et al. (2005) to include news about TFP. They estimate news shocks to explain 9 percent of output variance in the unconditional variance decomposition. The paper of Khan and Tsoukalas (2011) uses the same basic New-Keynesian model framework, but additionally allows for news about investment-specific technology growth. In their estimated model, both types of news shocks together account for less than 10 percent. Finally, Auray et al. (2009) estimate a New Keynesian model with an additional durables sector, featuring news about TFP in both sectors. They find that technology news in the non-durables sector explain 52% of output variance.

The outline of the chapter is the following. Section 2.2 introduces the DSGE-model with fiscal foresight, while section 2.3 presents the estimation approach and results. In section 2.4, we compute variance decompositions and impulse responses. Section 2.5 concludes.

3.2 A DSGE-Model with Fiscal Foresight

We use a medium-scale DSGE-model featuring various real and nominal frictions as well as a variety of shocks that have been identified as important drivers of the business cycle (see e.g. Justiniano et al., 2010a; Smets and Wouters, 2007). We incorporate both contemporaneous and anticipated elements into the shock processes as in Schmitt-Grohé and Uribe (2010) and allow for non-stationary shocks. We first discuss the information structure of the shock processes in the next section before describing the model in detail.

3.2.1 Shock Structure

Our model features 10 sources of stochastic fluctuations. On the government side, we include shocks to labor and capital tax rates τ_n and τ_k, a shock to government spending g, and a monetary policy shock ξ^R. The technology shocks considered are shocks to stationary neutral productivity z_t, non-stationary productivity X_t, stationary investment-specific productivity z_t^I, and non-stationary investment-specific productivity A_t. In addition, the model includes a preference shock ξ_t^{pref} and a wage markup shock μ_t^w.

The monetary policy shock and the preference shock are assumed to only contain a contemporaneous, unanticipated component. For the other shocks, we follow the framework proposed by Schmitt-Grohé and Uribe (2010) and allow for both contemporaneous shocks and shocks that are anticipated 4 and 8 periods in advance. Anticipation horizons of 4 and 8 quarters fulfill the aim of capturing longer anticipation horizons while keeping the state space at a manageable level. This is crucial as each additional anticipation horizon is an additional state variable. While specifically choosing 4 and 8 quarters of anticipation might be seen as arbitrary, this assumption can be rationalized by the workings of the political system. Four quarters of anticipation are close to the average length of a tax bill from the President's proposal announcement to enactment (Yang, 2005). Eight quarters serves as a plausible upper bound for the anticipation of shocks to tax rates as Congressional elections take place every two years. We think this makes it very unlikely that people are able to correctly predict both the reigning majority and the tax laws being implemented by the next Congress. The same, of course, applies to spending bills. For reasons of symmetry, we then assume this anticipation structure for all shock processes.

The general structure for shock $\epsilon^i,\ i \in \left\{\tau^n, \tau^k, g, z, x, z^I, a, w\right\}$ is given by

$$\epsilon^i = \varepsilon^0_{i,t} + \varepsilon^4_{i,t-4} + \varepsilon^8_{i,t-8}\ , \tag{3.1}$$

where $\varepsilon^j_{i,t-j},\ j \in \{0, 4, 8\}$ denotes a shock to variable i that becomes known in period $t - j$ and hits the economy j periods later. For example, $\varepsilon^4_{\tau^n,t-4}$ denotes a four period anticipated shock to the labor tax rate that becomes known at time $t-4$ and becomes effective at time t. The shocks are assumed to have mean 0, standard deviation σ_i^j, to be serially uncorrelated, and to be uncorrelated across anticipation horizons, i.e. $E(\varepsilon^j_{i,t-j}) = 0$ and $E(\varepsilon^k_{i,t}\varepsilon^l_{i,t-j}) = (\sigma_i^k)^2$ for $j = 0,\ k = l$, and 0 otherwise. Moreover, they are uncorrelated across shock types $i_m, i_n \in i$, $E(\varepsilon^k_{i_m,t}\varepsilon^l_{i_n,t-j}) = 0\ \forall j, k, l$ and $i_m \neq i_n$, .

The assumed information structure implies that agents foresee future shocks to the extent of already known but not yet realized shocks $\varepsilon^m_{i,t-j},\ m > j$. The forward-looking behavior of rational optimizing agents results in them reacting to anticipated shocks even before they are realized. By imposing a structural model on the data, this anticipatory behavior enables the econometrician to achieve identification. However, it is exactly this foresight that makes identifying the shocks with a VAR impossible. The econometrician attempting to do this only uses current and past values of the observables and thus has a smaller information set than the agents. In particular, he is missing the anticipated but not yet realized shocks as states in his VAR.[5] To remedy this issue, structural estimation has been advocated (Blanchard et al., 2009). We will pursue this avenue in Section 3.3 by using Bayesian methods to estimate the proposed model.

3.2.2 Conceptualizing Tax Shocks

The tax shocks considered in the present work do not necessarily stem from actual changes in the labor and capital tax rates. Rather, they are interpreted as the probability weighted effect of tax actions under legislative debate or due to judicative decisions. They are the product of the likelihood of a tax change and the size of this effect, as perceived by rational agents forming expectations about the future path of taxes. Hence, our definition is wider than the one considered by Mertens and Ravn (forthcoming), who restrict their attention to the shocks directly deriving from the legislative process. Shocks deriving from e.g. the SEC suing against the legality of a tax shelter would be excluded from their definition but not from ours.[6] Note that news shocks are distinct from pure uncertainty about future taxes. While the former are associated with an anticipated change in the mean of the tax rate, tax uncertainty shocks can be conceptualized as mean-preserving spreads.[7]

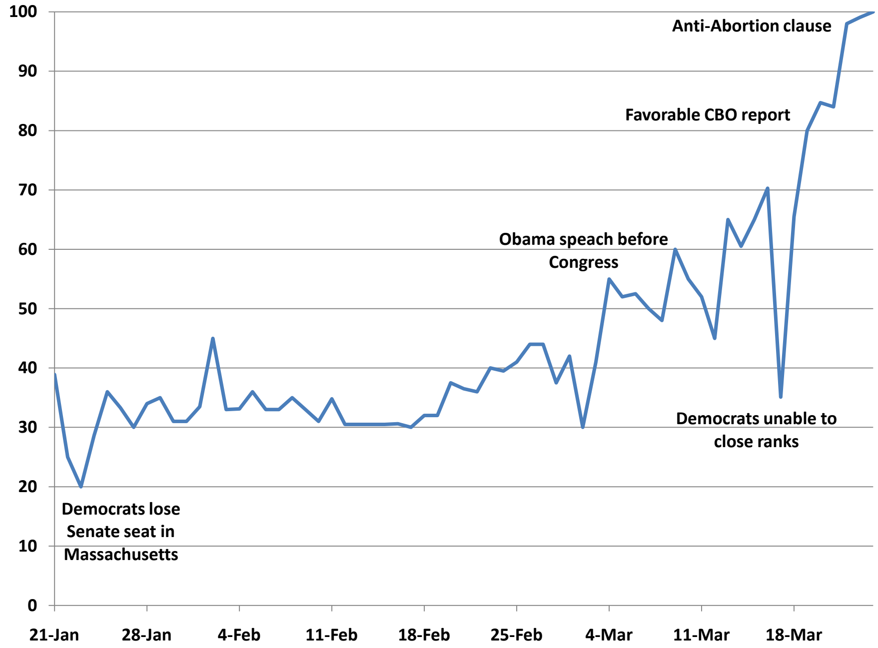
To fix ideas, consider the *Patient Protection and Affordable Care Act* of 2010 as an example. On June 9, 2009, a first draft of the health care bill was released. At that time, people at the latest could anticipate that taxes were going to rise in order to finance the bill, if it ever passed. However, both the size and the likelihood of

[5]Sims (2009) shows that in some cases it may be possible to recover the shocks using a structural VAR. By including enough lags and forward-looking variables, it may be possible to move the non-invertible root(s) close enough to unity so that the discrepancy between true structural errors and the estimated ones becomes small.

[6]This notion of tax shocks is consistent with concept of "policy expectations" in McGrattan (2011).

[7]For an analysis of uncertainty about fiscal policy in the context of a New Keynesian model, see Born and Pfeifer (2011); Fernández-Villaverde et al. (2011).

Figure 3.1: Intrade Daily Closing Prices: “Will 'Obamacare' health care reform become law in the United States?”



Notes: This contract will settle (expire) at 100 ($10.00) if a health care reform bill is passed into law before midnight ET 30 Jun 2010. It will settle (expire) at 0 ($0.00) if a health care reform bill is not passed into law.

such a change was largely unknown. The first point of uncertainty changed on July 13, 2009, when the Congressional Budget Office published official cost estimates: If passed, marginal income tax rates were going to increase by 22 percentage points for households between 100% and 400% of the poverty level. Taking these costs as given, households were experiencing tax shocks with changes in the likelihood of the passage of the bill. Intrade bets on the passage of the bill show that some people were constantly reevaluating this likelihood. Figure 3.1 presents the closing prices of an Intrade betting contract that paid 100, if a health care reform bill was passed into law before mid-2010 and 0 if a health care reform bill was not passed. Hence, the closing price is a direct measure of the likelihood of a bill becoming law. There is a large variance in the probability of passing the bill that varies with the ebb and flow of the political process. These changes potentially act like a huge sequence of tax shocks for households. If one considers only the change in the likelihood from the time directly after the Massachusetts Senate election in January to the final vote of the bill, this amounts in expectations to a tax shock of $0.7 \times 22\% = 15.4\%$ during one quarter.[8]

3.2.3 The Model

The model economy includes five sectors: the household sector with a large representative household, the labor market featuring a continuum of monopolistically competitive unions selling differentiated labor services to intermediate firms, the firm sector including a continuum of intermediate goods firms producing intermediate goods and a final good firm bundling the intermediate goods, and the government sector responsible for fiscal and monetary policy.

Household Sector

The economy is populated by a large representative household with a continuum of members. Household preferences are defined over per capita consumption C_t and per capita labor effort L_t, where each member consumes the same amount and works the same number of hours.[9] We follow Schmitt-Grohé and Uribe (2006) and assume that household members supply their labor uniformly to a continuum of unions $j \in [0, 1]$. The unions are monopolistically competitive and supply differentiated labor services $l_t(j)$ to intermediate goods firms. Overall, total labor supply of the representative household is given by the integral over all labor markets j, i.e. $L_t = \int_0^1 l_t(j)dj$. We will discuss the labor market structure in detail below.

Following Jaimovich and Rebelo (2009), we assume a preference specification that allows to control the size of the wealth effect, but additionally assume habits in

[8] Unfortunately, due to the non-availability of data for the relative price of investment, our sample does not cover this series of events.

[9] Due to the symmetric equilibrium, the decisions of the household members are identical. Hence, we suppress the subscript denoting individual members.

consumption:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \xi_t^{pref} \frac{\left(C_t - \phi_c C_{t-1} - \gamma \frac{L_t^{1+\sigma_l}}{1+\sigma_l} S_t\right)^{1-\sigma_c} - 1}{1-\sigma_c}. \tag{3.2}$$

Here, the parameter $\phi_c \in [0,1]$ measures the degree of internal habit persistence, $\sigma_c \geq 0$ governs the intertemporal elasticity of substitution, $\sigma_l \geq 0$ is related to the Frisch elasticity of labor supply, and $\gamma \geq 0$ measures the relative disutility of labor effort.[10] The term

$$S_t = (C_t - \phi_c C_{t-1})^{\sigma_s} S_{t-1}^{1-\sigma_s} \tag{3.3}$$

makes the preferences non-separable in both consumption and work effort. This preference specification introduces the parameter $\sigma_s \in (0,1]$ that allows to govern the magnitude of the wealth effect on the labor supply. As special cases, the specification nests the preference class discussed by King et al. (1988), i.e. $\sigma_s = 1$, and the preferences proposed by Greenwood et al. (1988), i.e. $\sigma_s = 0$, where the latter case implies a zero wealth elasticity of labor supply. We assume the preference shock ξ_t^{pref} to follow an $AR(1)$-process in logs:

$$\log \xi_t^{pref} = \rho_{pref} \log \xi_{t-1}^{pref} + \varepsilon_t^{pref}. \tag{3.4}$$

The household faces the budget constraint

$$\begin{aligned} C_t + z_t^I A_t I_t + \frac{B_{t+1}}{P_t} = & (1-\tau_t^n) \int_0^1 W_t(j) l_t(j) dj + \left(1-\tau_t^k\right) R_t^K u_t K_t + \Phi_t + T_t \\ & + \left(1-\tau_t^k\right) \Xi_t + \left(1-\tau_t^k\right)(R_{t-1}-1)\frac{B_t}{P_t} + \frac{B_t}{P_t}. \end{aligned} \tag{3.5}$$

Besides labor income from supplying differentiated labor services $l_t(j)$ at the real wage $W_t(j)$, the household has capital income from renting out capital services $u_t K_t$ at the rental rate R_t^K, from receiving firm profits Ξ_t, and from investing in bonds B_{t+1}, which are in zero net supply. Both forms of income are taxed at their

[10] In a recent paper, Nutahara (2010) shows that it is important to distinguish between internal and external habits in a model with news shocks. He finds that internal habits are able to generate news-driven business cycles, whereas external habits are not.

respective tax rates τ_t^n and τ_t^k. Only net returns of bonds are taxed, such that the term $\left(1-\tau_t^k\right)(R_{t-1}-1)\frac{B_t}{P_t}+\frac{B_t}{P_t}$ is the after-tax return. In addition, the government pays lump sum transfers.

The household spends its income on consumption C_t and investment $z_t^I A_t I_t$, where I_t denotes gross investment at the price of capital goods. We assume that the relative price of investment in terms of the consumption good is subject to two shocks, a stationary investment-specific productivity shock z_t^I and non-stationary investment-specific technological progress A_t (see Greenwood et al., 1997, 2000). The relative price of investment is equal to the technical rate of transformation between investment and consumption goods. Changes in this price do not affect the productivity of already installed capital, but do affect newly installed capital and become embodied in it. For the non-stationary investment-specific technology process, we assume a random walk with drift in its logarithm

$$\log A_t = \log A_{t-1} + \log \mu_t^a. \tag{3.6}$$

The drift term μ_t^a is subject to contemporaneous and anticipated shocks according to

$$\log\left(\frac{\mu_t^a}{\mu^a}\right) = \rho_a \log\left(\frac{\mu_{t-1}^a}{\mu^a}\right) + \varepsilon_{a,t}^0 + \varepsilon_{a,t-4}^4 + \varepsilon_{a,t-8}^8. \tag{3.7}$$

The stationary investment-specific technology shock z_t^I follows an $AR(1)$-process

$$\log z_t^I = \rho_{z^I} \log z_{t-1}^I + \varepsilon_{z^I,t}^0 + \varepsilon_{z^I,t-4}^4 + \varepsilon_{z^I,t-8}^8. \tag{3.8}$$

Depreciation allowances are an important feature of the U.S. tax code, therefore, we also include them in our model. They are captured by the term Φ_t in equation (3.5) and have the form $\Phi_t = \tau_t^k \sum_{s=1}^{\infty} \delta_\tau (1-\delta_\tau)^{s-1} z_{t-s}^I A_{t-s} I_{t-s}$, where δ_τ is the depreciation rate for tax purposes.[11] Since depreciation allowances provide new investment with a tax shield at historical costs, they may be important in capturing the dynamics of investment following shocks (Christiano et al., forthcoming; Yang, 2005).

[11] Following Auerbach (1989), we allow the depreciation rate for tax purposes to differ from the physical rate.

The household members own the capital stock K_t, whose law of motion is given by

$$K_{t+1} = \left[1 - \left(\delta_0 + \delta_1 \left(u_t - 1\right) + \frac{\delta_2}{2} \left(u_t - 1\right)^2\right)\right] K_t + \left[1 - \frac{\kappa}{2} \left(\frac{I_t}{I_{t-1}} - \mu^I\right)^2\right] I_t. \quad (3.9)$$

Household members do not simply rent out capital, but capital services $u_t K_t$, where u_t denotes capital utilization. Thus, they decide about the intensity with which the existing capital stock is used. However, using capital with an intensity that is higher than normal is not costless, but leads to higher depreciation of the capital stock. This is captured by the increasing and convex function $\delta\left(u_t\right) = \delta_0 + \delta_1 \left(u_t - 1\right) + \delta_2/2 \left(u_t - 1\right)^2$, with $\delta_0, \delta_1, \delta_2 > 0$. Without loss of generality, capital utilization in steady state is normalized to 1. Following Christiano et al. (2005), we assume the presence of investment adjustment costs $S\left(I_t/I_{t-1}\right) = \kappa/2 \left(I_t/I_{t-1} - \mu^I\right)^2$ to dampen the volatility of investment over the business cycle. $\kappa > 0$ is a parameter governing the curvature of the investment adjustment costs and μ^I is the steady state growth rate of investment, which is equal to the steady state growth rate of capital. This specification assures that the investment adjustment costs are minimized and equal to 0 along the balanced growth path, i.e. $S = S' = 0$ and $S'' > 0$, where the primes denote derivatives.

The household maximizes its utility, equation (3.2), by choosing C_t, L_t, S_t, B_{t+1}, K_{t+1}, u_t, and I_t, subject to the budget constraint (3.5), the law of motion for capital (3.9), and the resource constraint for aggregate labor given by (3.10) below.

Labor Market

The labor market is characterized by differentiated labor services and staggered wage setting. To model these features without letting idiosyncratic wage risk affect the household members, and thus making aggregation intractable, we assume a continuum of unions j, $j \in [0, 1]$. The household members supply their labor $l_t\left(j\right)$ equally to the unions, which are monopolistically competitive and supply differentiated labor $l_t\left(j\right)$ to intermediate firms at wage $W_t\left(j\right)$. Every period, a union j is able to re-optimize its wage with probability $\left(1 - \theta_w\right)$, $0 < \theta_w < 1$. A union j that is not able to re-optimize indexes its nominal wage to the price level according to $W_t\left(j\right) P_t = \left(\Pi_{t-1}\right)^{\chi_w} \bar{\Pi}^{1-\chi_w} \mu_t^y W_{t-1}\left(j\right) P_{t-1}$, where the parameter $\chi_w \in [0, 1]$ measures the degree of indexing, $\bar{\Pi}$ is steady state gross inflation, and μ_t^y is the gross growth rate of output (see e.g. Smets and Wouters, 2003). Thus, in the absence of price adjustment the wage still partly adapts to changes in productivity and inflation (Christiano et al., 2008), thereby assuring that no current wage contract will deviate arbitrarily far from the current optimal wage.

Household members supply the amount of labor services that is demanded at the current wage. Unions that can reset their wages choose the real wage that maximizes the expected utility of its members, taking into account the demand for its labor services $l_t(j) = (W_t(j)/W_t)^{-\eta_{w,t}} L_t^{comp}$, where L_t^{comp} is the aggregate demand for composite labor services, the respective resource constraint

$$L_t = L_t^{comp} \int_0^1 \left(\frac{W_t(j)}{W_t} \right)^{-\eta_{w,t}} dj, \tag{3.10}$$

and the aggregate wage level $W_t = \left(\int_0^1 W_t(j)^{1-\eta_{w,t}} dj \right)^{\frac{1}{1-\eta_{w,t}}}$. The time-varying substitution elasticity $\eta_{w,t}$ allows us to include a wage markup shock $\mu_t^w = (\eta_{w,t} - 1)^{-1}$ that follows

$$\log \left(\frac{\mu_t^w}{\mu^w} \right) = \rho_w \log \left(\frac{\mu_{t-1}^w}{\mu^w} \right) + \varepsilon_{w,t}^0 + \varepsilon_{w,t-4}^4 + \varepsilon_{w,t-8}^8. \tag{3.11}$$

Including a wage markup shock is motivated by the finding that this shock is important for explaining output fluctuations (see e.g. Schmitt-Grohé and Uribe, 2010; Smets and Wouters, 2007).

Firm Sector

A continuum of monopolistically competitive intermediate goods firms i, $i \in [0, 1]$, produces differentiated intermediate goods Y_{it} via a Cobb-Douglas production function, using capital services $u_{it}K_{it}$ and a composite labor bundle L_{it}^{comp}

$$Y_{it} = z_t \left(u_{it} K_{it} \right)^{\alpha} \left(X_t L_{it}^{comp} \right)^{1-\alpha} - \psi X_t^Y, \tag{3.12}$$

where α is the capital share, z_t is a stationary TFP shock, X_t is a non-stationary labor augmenting productivity process, and X_t^Y is the trend of output defined in

Appendix B. The fixed cost of production ψ is set such that profits are 0 in steady state and there is no entry or exit (Christiano et al., 2005). The composite labor bundle is aggregated from differentiated labor inputs $L_{it}(j)$ with a Dixit-Stiglitz aggregator $l_{it}^{comp} = [\int_0^1 l_{it}(j)^{\frac{\eta_{w,t}-1}{\eta_{w,t}}} dj]^{\frac{\eta_{w,t}}{\eta_{w,t}-1}}$.

For the non-stationary labor augmenting productivity process X_t, we assume a random walk with drift in its logarithm

$$\log X_t = \log X_{t-1} + \log \mu_t^x. \tag{3.13}$$

The drift term μ_t^x is subject to contemporaneous and anticipated shocks according to

$$\log\left(\frac{\mu_t^x}{\mu^x}\right) = \rho_x \log\left(\frac{\mu_{t-1}^x}{\mu^x}\right) + \varepsilon_{x,t}^0 + \varepsilon_{x,t-4}^4 + \varepsilon_{x,t-8}^8. \tag{3.14}$$

Hence, in the deterministic steady state, the natural logarithm of the non-stationary component of the neutral technology shock grows with rate μ^x. The stationary technology shock z_t follows an $AR(1)$-process with persistence ρ_z

$$\log z_t = \rho_z \log z_{t-1} + \varepsilon_{z,t}^0 + \varepsilon_{z,t-4}^4 + \varepsilon_{z,t-8}^8. \tag{3.15}$$

We assume staggered price setting a la Calvo (1983) and Yun (1996). Each period, an intermediate firm i can re-optimize its price with probability $(1-\theta_p)$, $0 < \theta_p < 1$. If a firm i cannot re-optimize the price, it is indexed to inflation $\Pi_t = \frac{P_t}{P_{t-1}}$ according to $P_{it+1} = (\Pi_t)^{\chi_p} (\bar{\Pi})^{1-\chi_p} P_{it}$, where $\chi_p \in [0,1]$ governs the degree of indexation. The intermediate firms maximize their discounted stream of profits subject to the demand from the final good producer, equation (3.17) below, applying the discount factor of their owners, the household members.

The intermediate goods are bundled by a competitive final good firm to a final good Y_t using a Dixit-Stiglitz aggregation technology with substitution elasticity η_p

$$Y_t = \left(\int_0^1 Y_{it}^{\frac{\eta_p-1}{\eta_p}} di\right)^{\frac{\eta_p}{\eta_p-1}}. \tag{3.16}$$

Expenditure minimization yields the optimal demand for intermediate good i as

$$Y_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\eta_p} Y_t \quad \forall\, i. \tag{3.17}$$

Government Sector

Government expenditures are financed by taxing profits and the return to capital services at the rate τ_t^k and labor income at the rate τ_t^n. Following McGrattan (1994) and Mertens and Ravn (forthcoming), we model average tax rates as $AR(2)$-processes

$$\tau_t^n = \left(1 - \rho_1^n - \rho_2^n\right)\tau^n + \rho_1^n \tau_{t-1}^n + \rho_2^n \tau_{t-2}^n + \varepsilon_{\tau^n,t}^0 + \varepsilon_{\tau^n,t-4}^4 + \varepsilon_{\tau^n,t-8}^8, \tag{3.18}$$

$$\tau_t^k = \left(1 - \rho_1^k - \rho_2^k\right)\tau^k + \rho_1^k \tau_{t-1}^k + \rho_2^k \tau_{t-2}^k + \varepsilon_{\tau^k,t}^0 + \varepsilon_{\tau^k,t-4}^4 + \varepsilon_{\tau^k,t-8}^8, \tag{3.19}$$

where $\tau^k, \tau^n \in [0, 1)$ are parameters determining the unconditional mean. We are aware that using average effective tax rates for capital and labor income may be problematic for several reasons. First, the U.S. tax code does not allow for a clean division between labor and capital taxation, which are theoretical constructs.[12] Second, using average effective tax rates may be particularly problematic for progressive labor income taxes, where marginal tax rates rather than effective tax rates influence peoples' behavior. Nevertheless, due to data availability issues[13] and comparability with the existing literature, we follow the path set forward by Mendoza et al. (1994), Jones (2002), and Leeper et al. (2010) and construct average effective tax rates for capital and labor income. While this is clearly a simplifying assumption, it can be justified on grounds that dynamics of marginal and average tax rates are very similar (Mendoza et al., 1994).

Government spending G_t, which may be thought of as entering the utility function additively separable, displays a stochastic trend X_t^G. Log deviations of government spending from its trend are assumed to follow an $AR(1)$-process

$$\log\left(\frac{g_t}{\bar{g}}\right) = \rho_g \log\left(\frac{g_{t-1}}{\bar{g}}\right) + \epsilon_{g,t}^0 + \epsilon_{g,t-4}^4 + \epsilon_{g,t-8}^8, \tag{3.20}$$

[12] For example, the personal income tax applies to both sources of income.

[13] In principle, it would be desirable to e.g. use the Barro and Sahasakul (1983) average marginal tax rates as extended by Barro and Redlick (2011). However, they are only available at annual frequency.

where $g_t = \frac{G_t}{X_t^G}$ denotes detrended government spending and ρ_g is the persistence parameter.

The stochastic trend in G_t is assumed to be cointegrated with the trend in output. This assures that the output share of government spending G_t/Y_t is stationary, while at the same time allowing the trend in G_t to be smoother than the one in Y_t. In particular,

$$X_t^G = \left(X_{t-1}^G\right)^{\rho_{xg}} \left(X_{t-1}^Y\right)^{1-\rho_{xg}}. \tag{3.21}$$

Lump sum transfers T_t are used to balance the budget. Thus, the government budget constraint is given by[14]

$$G_t + T_t = \tau_t^n W_t L_t^{comp} + \tau_t^k \left(R_t^K u_t K_t + \Xi_t\right) - \Phi_t. \tag{3.22}$$

We close the model by assuming that the central bank follows a Taylor rule that reacts to inflation and output growth:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left(\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\phi_{R_\Pi}} \left(\frac{Y_t}{Y_{t-1}} \frac{1}{\mu^y}\right)^{\phi_{R_Y}}\right)^{1-\rho_R} \exp\left(\xi_t^R\right), \tag{3.23}$$

where ρ_R is a smoothing parameter introduced to capture the empirical evidence of gradual movements in interest rates (see e.g. Clarida et al., 2000). The parameters ϕ_{R_Y} and ϕ_{R_Π} capture the responsiveness of the nominal interest rate to deviations of inflation and output growth from their steady state values. We assume that the central bank responds to changes in output rather than its level as this conforms better with empirical evidence and avoids the need to define a measure of trend growth that the central bank can observe (see Lubik and Schorfheide, 2007). ξ_t^R is the i.i.d. monetary policy shock.

3.3 Model Estimation

We use a Bayesian approach as described in An and Schorfheide (2007) and Fernández-Villaverde (2010). Specifically, we use the Kalman filter to obtain the

[14]Note that private bonds are in zero net supply.

likelihood from the state-space representation of the model solution and the *Tailored Randomized Block Metropolis-Hastings (TaRB-MH)* algorithm (Chib and Ramamurthy, 2010) to maximize the posterior likelihood.[15]

3.3.1 Data

We use quarterly U.S. data from 1955:Q1 until 2006:Q4 and include twelve observable time series: the growth rates of per capita GDP, consumption, investment, wages and government expenditure, all in real terms, the logarithm of the level of per capita hours worked, the growth rates of the relative price of investment and of total factor productivity, the log difference of the GDP deflator, and the federal funds rate. Since our main objective are the effects of tax shocks, we also include capital and labor tax rates.[16] Figure 3.2 displays the evolution of the tax rates and the government spending to GDP ratio over our sample. All three series show a large persistence. Tests against the null hypothesis of a unit root in both tax rates are borderline significant, while they cannot reject the null of a unit root in the government spending to GDP ratio. As there are theoretical reasons to believe that both the tax rates and the government spending to GDP ratio do not contain unit roots, we treat them as stationary. However, to account for the relatively persistent deviations from the unconditional mean, we allow the trend in G_t to be smoother than the one in Y_t.[17]

3.3.2 Fixed Parameters

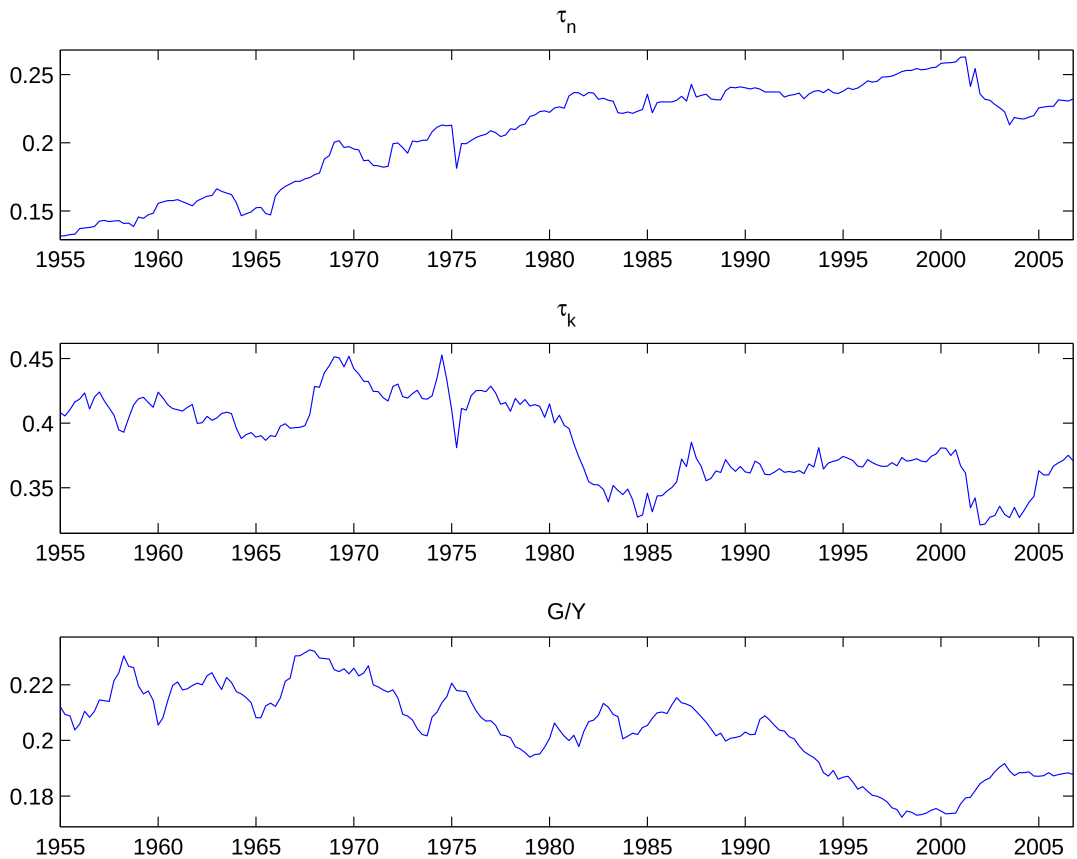
Prior to estimation, we fix a number of parameters to match sample means (see Table 3.1). The curvature of the utility function σ_c is set to 2. This value is consistent with most DSGE models. The discount factor β is fixed at 0.99. We set the parameter

[15] We used a t-distribution with 10 degrees of freedom as proposal density. The posterior distribution was computed from a 10,000 draw Monte Carlo Markov Chain, where the first 2,500 draws were discarded as burn-in draws.

[16] Detailed data sources and the observation equation that describes how the empirical time series are matched to the corresponding model variables can be found in Appendices D and C.

[17] We think that the government spending to GDP ratio actually displays mean reversion. Since the end of our sample in 2006Q4, it has returned to about 20.5 in 2010 and is thus close to its unconditional mean.

Figure 3.2: Evolution of the Tax Rates and the Spending to GDP Ratio.



Notes: The top panel shows the evolution of the labor tax rate series (τ_n), the middle panel the evolution of the capital tax rate series (τ_k), and the bottom panel the evolution of the spending to GDP ratio (G/Y).

that governs the disutility of labor effort γ such that labor effort in steady state is 20%. We assume an annual physical depreciation rate of 10%, which corresponds to a δ_0 of 0.025 per quarter. Following Auerbach (1989) and Mertens and Ravn (2011), we set the depreciation rate for tax purposes δ_τ to twice the rate of physical depreciation, i.e. 0.05. The depreciation parameter δ_1 is fixed to set the steady state capacity utilization to 1 (Christiano et al., 2005). The parameter α is 0.2935, which matches the capital share in output over our sample, and the fixed cost parameter ψ is set to ensure zero profits in steady state. We assume a steady state price and wage markup of 11% and thus set η_p and η_w to 10.

Table 3.1: Parameters Fixed Prior to Estimation

Parameter	Value	Target/Motivation (matched to quarterly data)
σ_c	2	Common in RBC models
γ	0.0216	Set labor effort in steady state to 20%
β	0.99	Common in RBC models
δ_0	0.025	Annual physical depreciation of 10%
δ_1	0.0486	Set capacity utilization $u = 1$ in steady state
δ_τ	0.05	Twice the rate of physical depreciation δ_0 (Auerbach, 1989)
α	0.2935	Match capital share in output
ψ	0.0432	Set profits to zero
η_p	10	Set price markup to 11% in steady state
η_w	10	Set wage markup to 11% in steady state
μ^y	1.0045	Match average sample growth rate of per capita output
μ^a	0.9957	Match average sample growth rate of relative price of investment
τ^n	0.1984	Match average sample labor tax rate
τ^k	0.3880	Match average sample capital tax rate
G/Y	0.2031	Match average sample mean
$\bar{\Pi}$	1.0089	Match average sample mean

The steady state gross growth rates of per capita output μ^y and of the relative price of investment μ^a are set to their sample means of $1 + 0.45\%$ and $1 - 0.43\%$. The parameters τ^k and τ^n, which determine the unconditional mean of the tax rates, equal the post-war sample means of 0.388 and 0.1984. We set the steady state ratio of government spending to output G/Y to 0.2031, which also corresponds to the sample mean. The steady state inflation rate corresponds to the average sample mean of 1.0089, i.e. annual inflation of 3.6%

3.3.3 Priors

Tables 3.2 and 3.3 present the prior distributions. Where available, we use prior values that are standard in the literature (e.g. Smets and Wouters, 2007) and independent of the underlying data. The autoregressive parameters of the tax processes, ρ_1^n, ρ_2^n, ρ_1^k, ρ_2^k, are essentially left unrestricted, but we impose stability of the $AR(2)$-

processes.[18] The other autoregressive parameters, $\rho_i,\ i \in \left\{pref, g, z, x, z^I, a, w\right\}$, are assumed to follow a beta distribution with mean 0.5 and standard deviation 0.2. We assume the standard deviations of the shocks to follow inverse-gamma distributions with prior means 0.1 and standard deviations 2. For the parameters of the Taylor-rule, ϕ_{R_Π} and ϕ_{R_Y}, we impose gamma distributions with a prior mean of 1.5 and 0.5, respectively, while the interest rate smoothing parameter ρ_R has the same prior distribution as the persistence parameters of the shock processes. The habit parameter ϕ_c is assumed to be beta distributed with a prior mean of 0.7, which is standard in the literature. Following Justiniano et al. (2010b), the parameter determining the Frisch elasticity of labor supply σ_l is assumed to follow a gamma distribution with a prior mean of 2 and a standard deviation of 0.75. The prior distribution for the parameter governing the wealth elasticity of labor supply σ_s is a beta distribution with mean 0.5 and standard deviation 0.2. We impose an inverse-gamma distribution with prior mean of 0.5 and standard deviation of 0.15 for δ_2/δ_1, the elasticity of marginal depreciation with respect to capacity utilization. The parameters governing the indexation of prices and wages, χ_p and χ_w, each are beta distributed with mean 0.5 and standard deviation 0.2. For the Calvo parameters θ_w and θ_p we assume a beta distribution with a prior mean of 0.5, which corresponds to price and wage contracts having an average length of half a year (Smets and Wouters, 2007). Finally, we follow the literature (e.g. Justiniano et al., 2010a; Smets and Wouters, 2007) and impose a gamma prior with mean 4 for the parameter controlling investment adjustment costs κ.

3.3.4 Posterior Distribution

The last four columns of Tables 3.2 and 3.3 display the mean, the standard deviation and the 90%-posterior intervals for each of the estimated parameters. Most estimated parameters and shock processes are in line with previous studies on the determinants of business cycle fluctuations, both with those using only contemporaneous shocks (e.g. Justiniano et al., 2010a; Smets and Wouters, 2007) as well as those including

[18] Specifically, we impose a uniform prior for each of the corresponding autoregressive roots over the stability region $(-1, +1)$. Let ξ_1 and ξ_2 be the roots of such an $AR(2)$-process. The autoregressive parameters corresponding to these roots can be recovered from: $\rho_1 = \xi_1 + \xi_2$ and $\rho_2 = -\xi_1\xi_2$.

contemporaneous and anticipated shocks (Fujiwara et al., 2011; Khan and Tsoukalas, 2011; Schmitt-Grohé and Uribe, 2010).

However, some estimates deserve further comment. We find a considerable degree of internal habits with $\phi_c = 0.86$, which is right between the estimates obtained by Smets and Wouters (2007) and Schmitt-Grohé and Uribe (2010). The posterior mean of the parameter governing the wealth elasticity ($\sigma_s = 0.1$) implies a relatively low wealth elasticity of labor supply and, thus, preferences that are close to the ones proposed by Greenwood et al. (1988).[19] Schmitt-Grohé and Uribe (2010) find an even lower wealth elasticity of almost zero. Khan and Tsoukalas (2011), on the other hand, estimate the wealth elasticity of labor to be quite high at 0.85. A possible explanation for these differing estimates is the inclusion of government spending as an observable. Increases in government spending may entail positive consumption responses (Blanchard and Perotti, 2002; Galí et al., 2007), a behavior which can be explained by a New-Keynesian model with a low wealth elasticity (Monacelli and Perotti, 2008). Even in studies finding a negative consumption response (see e.g. Ramey, 2011), this negative response tends to be relatively small or hardly distinguishable from 0, also suggesting the presence of a low wealth effect. Including government spending as an observable restricts the parameter governing the wealth elasticity to a low value. In our model, this happens although the consumption response to a government spending shock is estimated to be negative. On the other hand, without the observable government spending as in Khan and Tsoukalas (2011), this parameter remains mostly unrestricted with regard to the effects of government spending on consumption.[20]

Turning to the nominal rigidities in our model, we find that prices are on average adjusted about every three quarters, while the Calvo parameter for wages implies a high degree of wage stickiness. The degree of price indexation is low ($\chi_p = 0.06$) and in a similar range as in Justiniano et al. (2011). Wages, on the other hand, are indexed to inflation with a higher proportion than prices ($\chi_w = 0.6$), which corresponds well with the estimates in Smets and Wouters (2007).

[19] Note, however, that in the presence of habits, even a value of $\sigma_s = 0$ still implies the presence of a wealth effect, see Monacelli and Perotti (2008).

[20] A small wealth effect also helps in explaining the empirical behavior of labor market variables (Galí et al., 2011).

The parameters of the Taylor rule are in line with previous estimates (e.g. Clarida et al., 2000). They imply a high degree of interest rate smoothing ($\rho_R = 0.86$), a strong response to inflation ($\phi_{R_\Pi} = 2.96$), and a moderate value for the standard deviation of the monetary policy shock ($\sigma_R = 0.251\%$).

With the exception of the non-stationary technology shock, all shocks are estimated to be highly persistent, with $AR(1)$-coefficients ranging from 0.94 for the government spending shock to 0.99 for the preference, the stationary technology, and the non-stationary investment-specific technology shock. The non-stationary productivity component has a relatively low serial correlation of 0.34, a value commonly found in the literature (e.g. Justiniano et al., 2011).

The contemporaneous shock as well as the 4 quarter anticipated non-stationary technology shock have relatively low standard deviations of 0.04% and 0.03%, respectively, whereas the two year anticipated shock is the most important one with a standard deviation of 0.6%. A similar pattern emerges for the stationary technology shock. In this case, however, the standard deviation of the unanticipated component has a similar size as the 8 quarter anticipated component, 0.74% and 0.73%, whereas the 4 quarter anticipated shock is less important with a standard deviation of 0.18%.

Examining investment-specific technology shows that investment-specific growth displays the same pattern as neutral technology growth. The shock with the longest anticipation horizon is the most important one, having the highest standard deviation ($\sigma_a^8 = 0.14\%$), albeit in this case it is only slightly higher than the one for the contemporaneous shock ($\sigma_a^0 = 0.11$). The 4 quarter anticipated shock, on the other hand, is negligible ($\sigma_a^4 = 0.04\%$). In contrast, for stationary investment-specific technology anticipation does not play a role, the standard deviations are less than 0.05%, while the unanticipated stationary shock component has a higher standard deviation than the unanticipated non-stationary investment-specific technology shock ($\sigma_{z^I}^0 = 0.31\%$).

Another shock, where the anticipated shock components are negligible, is the wage markup shock. While the standard deviation of the unanticipated shock is relatively high, the anticipated shocks have very low standard deviations that are below 0.04%. In contrast, the surprise wage markup shock has a high standard deviation of almost 46%, which is consistent with evidence from Smets and Wouters (2007) and Galí et al.

(2011), who showed this shock to be the most important driver of business cycles.[21]

Next, we direct our focus to the fiscal policy shock processes. Both tax processes show a very high persistence, with the roots of the autoregressive processes implying autoregressive parameters of $\rho_1^n = 0.770$, $\rho_2^n = 0.228$, $\rho_1^k = 1.604$, and $\rho_2^k = -0.605$, respectively.[22] The posterior estimates suggest that for government spending and labor taxes fiscal foresight is rather limited. The unanticipated government spending shock has a volatility of 3%, a value also found by Leeper et al. (2010). The volatilities of the anticipated shock components, on the other hand, are rather small, $\sigma_g^4 = 0.03\%$ and $\sigma_g^8 = 0.04\%$. A similar pattern emerges for the labor tax process τ_t^n. The shock with the largest volatility is the unanticipated component $\varepsilon^0_{\tau^n,t}$ with 0.48%, while the anticipated components have a similar size as the anticipated government spending shocks. Only for the capital tax rate, news shocks display a higher standard deviation. Particularly, compared to the shocks to the labor tax process, the shocks $\varepsilon^i_{\tau^k,t-i}$ to the capital tax process τ_t^k display a much higher volatility. The unanticipated component $\varepsilon^0_{\tau^k,t}$ has the highest standard deviation of 0.92%, while the anticipated components have smaller, but still sizeable standard deviation, $\sigma^4_{\tau^k} = 0.46\%$ and $\sigma^8_{\tau^k} = 0.65\%$.

Table 3.4 compares empirical moments of the data to the corresponding moments from the model. Overall, the model is able to replicate the sample moments fairly well.

3.4 Business Cycle Effects of Fiscal News

We are now in a position to analyze the dynamic effects of fiscal news. Given the estimated deep parameters of the model, we compute forecast error variance decompositions to trace out the shocks' contributions to business cycle volatility. To better understand the dynamic effects of news shocks, we then analyze their transmission into the economy in Section 3.4.2.

[21] Note that the shock applies to the net markup so a 46% shock increases the markup from 11% to about 16%. Chari et al. (2009) point out that wage markup shocks cannot be distinguished from labor supply shocks. For policy makers this distinction matters, since both shocks entail different policy implications (Galí et al., 2011). However, as we are not interested in optimal policy, it is not important to identify the two shocks separately.

[22] The high persistence of the labor tax rate has, for example, been documented in Cardia et al. (2003).

3.4.1 Variance Decomposition

Results

We use our estimated model to analyze the quantitative importance of the different anticipated and surprise shocks for explaining business cycles. To this end, we compute conditional and unconditional forecast error variance decompositions for the growth rates of output, consumption, investment, hours, wages, the Federal funds rate, and inflation (see Table 3.5).[23]

Overall, we find that news shocks on average explain between 10 and 30 percent of the variance of the variables considered. However, fiscal foresight only plays a very limited role. Of the three types of fiscal foresight we consider, only the anticipated capital tax shock has a sizeable variance contribution. While news about future capital taxes contribute only 2 percent to output growth variance, they matter for inflation and interest rate variability, explaining more than 10 percent of the variability of inflation and interest rates at forecast horizons longer than three years. This makes them the third largest source of inflation and interest rate volatility, only behind preference and unanticipated capital tax shocks. Together, surprise and anticipated capital tax shocks explain around 40 to 50 percent of inflation and interest rate fluctuations. In contrast, news about labor tax and government spending shocks explain at most 0.01 percent of the variance of any of the seven variables considered.

More important than fiscal foresight are the surprise components of the fiscal variables. As already noted, besides the preference shock, the surprise capital tax shock is the most important factor for the variance of the Federal funds rate and inflation. Moreover, it accounts for 2 to 3 percent of output fluctuations. While the surprise government spending shock ε_g^0 accounts for almost 10 percent of the output growth variance at the five year horizon and even more at shorter horizons, it hardly contributes anything to the other variables' fluctuations.

Whereas fiscal foresight seems to be of only minor importance for the fluctuations of output, consumption, and investment, other news shocks contribute significantly to their variance. The news shocks that matter most are news about stationary

[23] For ease of exposition we have combined the two anticipated shock components into one and left out three anticipated shocks (stationary investment-specific, wage markup, and government spending) that each contributed less than 0.01 percent to the variance of the variables.

technology, which account for 8 to 12 percent of the variance of output and consumption. News about non-stationary technology mostly affects the volatility of wages, predominantly at long horizons. At the five year horizon, it is the single most important factor affecting wage volatility. News about non-stationary investment-specific technology explain around 8 percent of the variance of investment at all horizons and about the same amount of the variance of hours (at the five year horizon). In contrast, the news components of stationary investment-specific technology and the wage markup shock account for at most 0.01 percent of the variance of any variable we consider.

In general, the importance of news shocks increases at longer forecast horizons. E.g., anticipated shocks account for a larger share of output volatility at the five year horizon (21%) than at the one year horizon (11%).

Turning to the surprise shocks, we find the most important drivers of business cycles to be wage markup, preference, and unanticipated technology shocks. At business cycle frequencies, these shocks combined explain about 60 to 70 percent of the fluctuations of real variables. E.g., at the 20 period forecast horizon, these three shocks account for 31, 21, and 16 percent of output volatility, respectively. Inflation and interest rate variability are mostly explained by preference and capital tax shocks, whereas wage fluctuations are mainly driven by technology shocks, especially anticipated non-stationary technology shocks. Lastly, the monetary policy shock plays a minor role in accounting for macroeconomic fluctuations, a result similar to Smets and Wouters (2007). It explains around 15 percent of the Federal funds rate volatility, but only at the short term, i.e. horizons of about one year, and has much smaller contributions for the other variables.

Discussion

Using a DSGE-based estimation approach to determine the importance of news about fiscal policy, we find that fiscal foresight only plays a minor role in explaining business cycle fluctuations. Specifically, using full information Bayesian estimation and accounting for different kinds of shocks, we find tax shocks and, in particular, news about taxes to explain less than 3 percent of output growth fluctuations. This compares to about 25 percent in the VAR study of Mertens and Ravn (forthcoming), indicating that the rigid anticipation structure and the strict exogeneity assumption in the latter paper may be problematic (see also Leeper et al., 2011).

Our estimates also attribute less than one third of output fluctuations to surprise tax shocks, which was found by McGrattan (1994). However, her paper only featured TFP, government spending, and tax rate shocks. In contrast, our analysis features a richer set of shocks commonly thought to be essential for explaining business cycles (Chari et al., 2007; Smets and Wouters, 2007).

Regarding the evidence on the effects of news shocks on the business cycles, our result of 10 to 30 percent of the variance of output growth being attributable to anticipated shocks squares well with the evidence found by Forni et al. (2011) and Barsky and Sims (2011). Using a factor model, Forni et al. (2011) find that around 20 percent of output volatility is explained by technology and 10 percent by news about technology, while Barsky and Sims (2011), in a VAR, attribute 10 to 40 percent to news shocks.

Fujiwara et al. (2011) and Khan and Tsoukalas (2011), using an estimated DSGE model with nominal rigidities, find a technology news contribution to output variance of 8.5 and 1.6 percent, respectively, which is lower than our own estimates. On the other hand, Schmitt-Grohé and Uribe (2010) find that news about technology account for as much as 41 percent of output variance. Part of this higher number can be attributed to the absence of nominal rigidities in their model (Khan and Tsoukalas, 2011). Overall and consistent with these studies, news shocks contribute a higher share to the unconditional variance of nominal variables (wages, inflation, interest rate) than to the variance of real variables (output, consumption, investment, hours). However, allowing anticipation not only for TFP but also for other shocks, leads to a higher relative contribution of news shocks. Whereas the contribution of anticipated shocks in the study by Fujiwara et al. (2011) ranges from 4 percent (to the variance of investment) to 15 percent (to inflation volatility), we find contributions of anticipated shocks (combining all shocks) between 19 percent (investment and consumption volatility) and 52 percent (variance of wages).

Turning to the role of unanticipated shocks, we see that while the investment-specific technology shock has been identified as an important driver of business cycles by previous studies (Davis, 2007; Fisher, 2006; Justiniano et al., 2010a), it is of lesser importance in our case and contributes a smaller fraction to fluctuations than TFP shocks. The contributions of non-stationary investment-specific productivity vary between 5 and 15 percent, whereas stationary investment-specific technology explains hardly 1 percent. The difference to the previous studies finding the high contribution of investment-specific technology stems from our decision to include the relative price of investment as an observable. Recent studies including the relative price of investment as an observable find similarly small contributions of investment-specific technology (Justiniano et al., 2011; Schmitt-Grohé and Uribe, 2010).[24] However, we have to stress that both the stationary as well as the non-stationary investment-specific productivity shock pertain to the relative price of investment and are accordingly mapped to this observable.[25] Thus, our stationary investment-specific technology shock is not directly comparable to the stationary investment-specific technology shock in Schmitt-Grohé and Uribe (2010). This could explain the starkly differing results regarding the effects of this particular shock for output and investment fluctuations, 30 to 60 percent in their case vs. less than 1 percent in our case.

3.4.2 Impulse Responses

In order to better understand what drives the results of the previous section, we analyze the impulse responses to stationary TFP shocks and to capital tax rate shocks. We choose to focus on these shocks as they are the technology and fiscal policy shock, respectively, where the anticipated component contributes most to business cycle variance.[26]

Figure 3.3 shows the impulse responses to an unanticipated (solid line) and an eight period anticipated (dashed line) one percentage point cut of the capital tax rate.[27] The top left panel shows the impulse response for the capital tax rate that is

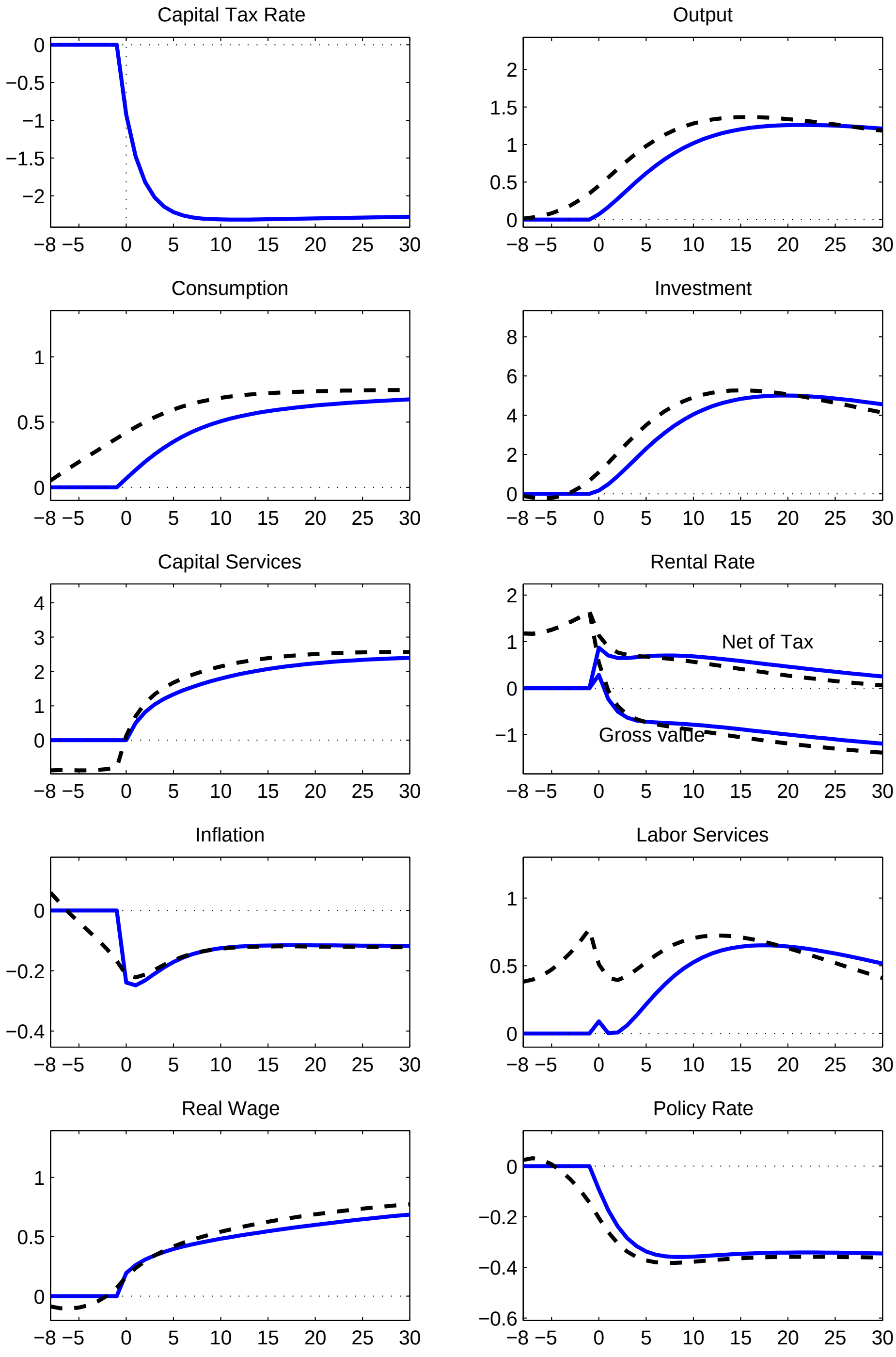
[24]Models that do not use the relative price of investment as an observable variable usually imply wrong moments for this series (Justiniano et al., 2011). When this problem is eliminated, the variance contribution of investment-specific technology shocks tends to disappear.

[25]The observation equation in Appendix C shows the exact mapping.

[26]Although we find the preference and wage markup shocks to be the most important drivers of business cycles, we omit analyzing their impulse responses as their importance and behavior is already well understood (see e.g. Galí et al., 2011; Smets and Wouters, 2007). The impulse responses to a government spending news shock are very similar to the ones in Ramey (2011), albeit the negative response of private consumption is more persistent in our setup.

[27]For the surprise shock, this roughly corresponds to a one standard deviation shock as $\sigma^0_{\tau^k} = 0.923\%$.

Figure 3.3: Impulse Responses to Unanticipated and Anticipated Capital Tax Shocks



Notes: solid line: impulse responses to an unanticipated 1 percentage point cut of the capital tax rate τ^k; dashed line: impulse responses to an eight period anticipated 1 percentage point cut of the capital tax rate τ^k that becomes known at $t = -8$ and effective at $t = 0$. All impulse responses are semi-elasticities and measured in percent. Inflation and the policy rate are measured as gross rates so that the responses can be interpreted as percentage point changes.

shocked. The actual response of the exogenous capital tax rate is the same after the surprise and anticipated tax shock, because the only difference between the two cases is the time at which the tax change that happens at $t = 0$ is known. But the other variables react differently, because with anticipation the future realization of the tax rate is already known at $t = -8$ and agents immediately start to optimally respond to this information.

First, consider the solid line representing the impulse responses to a surprise 1 percentage point decrease in the capital tax rate. This tax cut acts expansionary and leads to an increase in output, investment, and consumption on impact. The effect is quite large due to the strong estimated persistence of the shock process. Consistent with the evidence of high multipliers for tax rates (Mountford and Uhlig, 2009; Romer and Romer, 2010), an initial 1 percentage point decrease in the capital tax rate leads to a peak output response of 1.25 percent. Labor and capital services increase in a hump shaped manner after the realization. For capital services, this is driven by the higher after-tax rental rate that can be earned after the tax cut. Note that the gross value of the rental rate decreases, reflecting the decreased tax wedge. The increase in capital services also raises the marginal product of labor, leading to an initial jump in the real wage as a fraction of unions is able to reset wages in the current period and to a further rise over time when additional unions are able to reset their nominal wages. The initial increase of the real wage is amplified by an overshooting of the nominal wage, which is indexed to past inflation, due to a drop in inflation. Current inflation falls due to the positive supply side effect of the tax decrease. This positive effect on inflation is also the reason why the policy rate falls considerably, accommodating the expansion and further fueling investment and consumption.

Although the impulse responses for the eight period anticipated tax shock look very similar, there are two major differences. First, agents have more time to adjust and already react during the anticipation phase. Hence, the impulse responses are now more drawn out. Reacting immediately to an anticipated tax shock is optimal for the agents, because the estimated degrees of consumption habits, capital adjustment costs, capital utilization, and nominal rigidities imply that large abrupt changes in

For the eight period anticipated shock, $\sigma^8_{\tau^k} = 0.645\%$, so that we have re-scaled the size of this shock to make both shocks comparable. Note that the impulse responses are semi-elasticities, i.e. they are measured in percent of the steady state values of the corresponding variables.

important choice variables are welfare reducing and must be avoided. As a result of these more gradual and hence more resource-saving responses, the peak responses of all variables are now higher than for the case of a comparable surprise tax cut and generally occur earlier relative to the shock realization at t=0. Note that relative to the announcement of the shocks, i.e. the point in time where the horizon for the forecast error variance decomposition starts,[28] the peak responses generally occur later for the news shocks. This peak response at later horizons for news shocks explains why their importance in the forecast error variance decomposition tends to be larger at later horizons.

Second, in contrast to the unanticipated shock, agents now substitute labor services for capital services, leading to an immediate increase in the former and a decrease in the latter. Only when the tax shock realizes, there is a jump in capital services. The higher production resulting from the increase in labor services and the resources saved through the initially lower depreciation resulting from the weaker capital use allows to increase consumption during the anticipation phase. The net result of this substitution of labor for capital services with the simultaneous increase in consumption and investment expenditures is a slight inflationary pressure in the first period. As a response, the central bank somewhat tightens its policy. However, the negative supply side effect of the input substitution subsides with the subsequent further increase in labor supply. This increase is driven by the household's desire to increase the physical capital stock through investment while also keeping up consumption. As a result, inflationary pressures abate and give room to an accommodating policy stance.

Note that physical investment in the capital stock slightly decreases initially. This behavior is due to the depreciation allowances, whose present value for new investment decreases with the future tax bill from which it is deducted. But, in contrast to the results of Mertens and Ravn (2011), this incentive to disinvest is rather mild. Hence, in our estimated model, the announcement of a tax cut is insufficient to generate the investment-driven slump during the anticipation phase of a tax cut found in their model. This difference can be explained by the different estimation procedures used. Mertens and Ravn (2011) rely on an impulse response matching technique, where the empirical impulse responses were derived from a VAR using a

[28] I.e. t=-8 for the anticipated shock and t=0 for the surprise shock.

narrative identification scheme. The impulse responses to be matched by the model were only the ones to anticipated and unanticipated labor and capital tax shocks. In contrast, our estimation uses full information techniques and thus tries to match all moments given the full set of exogenous driving forces of the model. While the crucial investment adjustment cost and capital utilization cost parameters are actually estimated to generate a drop in investment as in Mertens and Ravn (2011), it is the monetary policy response that dampens this drop. When setting the output coefficient in the Taylor rule to 0 and the inflation response to 2, the investment response becomes stronger and leads to an initial drop in output with a subsequent boom. This indicates the importance of controlling for the stance of monetary policy when tracing out the effects of fiscal shocks.[29]

Figure 3.4 displays the impulse responses to one standard deviation surprise (solid line) and anticipated (dashed line) stationary TFP shocks.[30] The result of a surprise increase in total factor productivity is a prolonged boom driven by both consumption and investment. Consistent with a typical supply side shock, inflation decreases considerably with the central bank lowering the policy rate by 20 basis points in response. This in turn leads to an increase in the real wage and a subsequent increase in the labor services used.

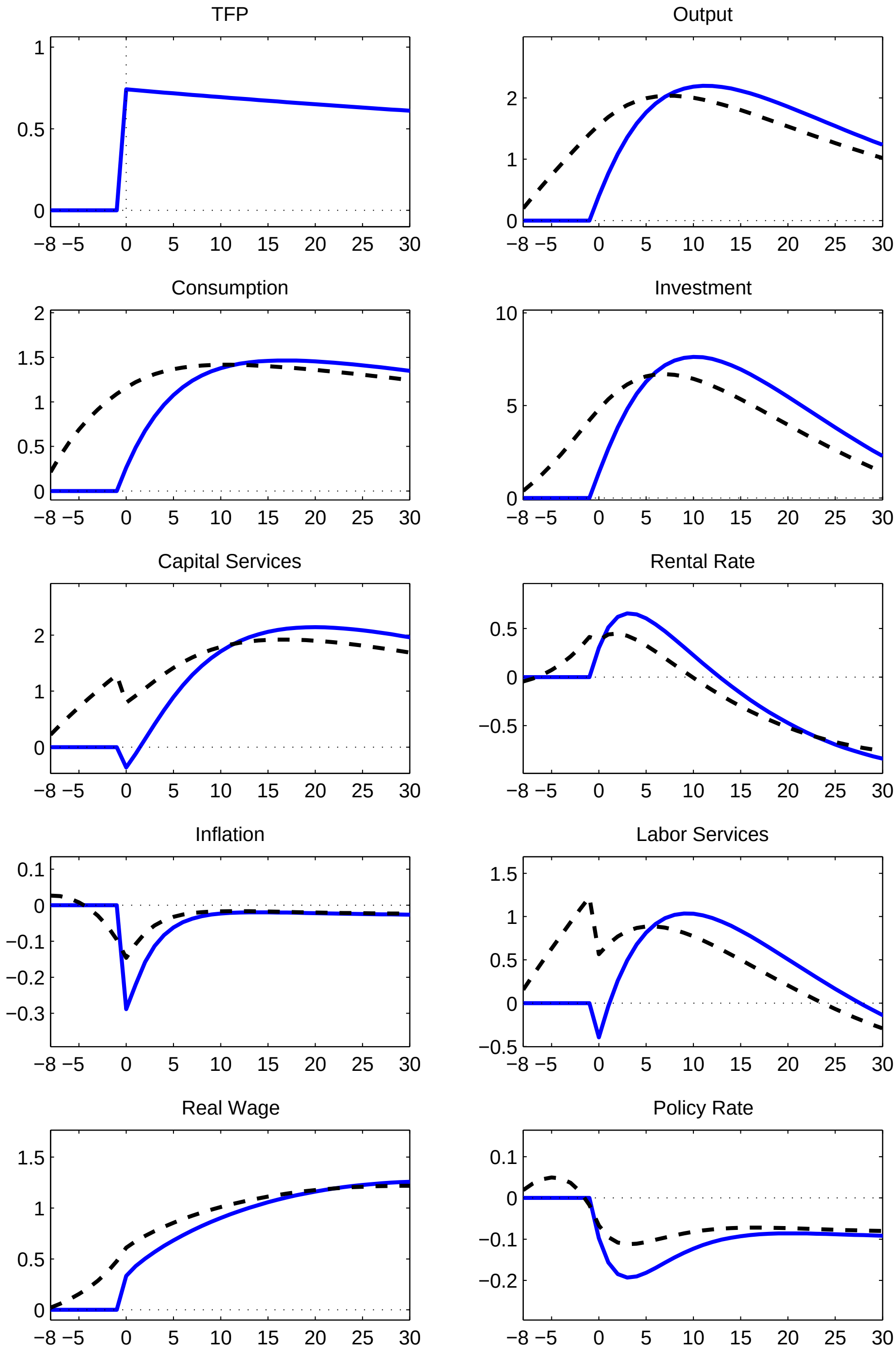
For the eight period anticipated increase in technology, we observe an immediate increase in output, investment, and consumption during the anticipation phase due to the entailed wealth effect. This boom occurs already before the technology has actually increased and is fueled by a rise in both capital and labor services.[31] In this regard, the response differs from the response to an anticipated capital tax shock, where a substitution of capital services for labor services is observed. The reason for the difference is that, for the anticipated TFP shock, agents have a stronger incentive to increase investment during the anticipation phase. In contrast, for the anticipated capital tax shock, investment falls slightly on announcement due to the decrease in the present value of the depreciation allowances.

[29] On this issue, see also Leeper (2010).

[30] We scaled the news shock by 1.03 to have exactly the same standard deviation as the surprise shock.

[31] This observation is consistent with Jaimovich and Rebelo (2009), who show theoretically that a low estimated wealth elasticity of labor supply facilitates positive comovement of output, consumption, and hours in response to TFP news.

Figure 3.4: Impulse Responses to Unanticipated and Anticipated Stationary TFP Shocks



Notes: solid line: impulse responses to an unanticipated one standard deviation increase in stationary TFP z; dashed line: impulse responses to an eight period anticipated one standard deviation increase in stationary TFP z that becomes known at $t = -8$ and effective at $t = 0$. All impulse responses are semi-elasticities and measured in percent. Inflation and the policy rate are measured as gross rates so that the responses can be interpreted as percentage point changes.

Lastly, to better understand the contribution of capital tax and stationary TFP shocks to business cycle variance, it is worth comparing the relative size and persistence of the impulse responses of output, inflation, and the nominal interest rate to these shocks. As can be seen from the the upper right panels of Figures 3.3 and 3.4, the peak response of output to an average TFP shock is about 80% higher than to an average capital tax shock, although the latter is somewhat more persistent.[32] This difference in the size of the output responses explains why stationary TFP shocks are more important for the volatility of output than capital tax shocks. In contrast, both the inflation and the policy rate responses to capital tax shocks have higher peaks and show more persistence. In particular, the average surprise TFP shock leads to a peak reduction in the nominal interest rate of -0.2%, while the average surprise tax shock leads to a drop of -0.4%. As this larger response is also more persistent, the difference in response sizes explains why capital taxes are rather important for the variance of inflation and the nominal interest rate, while they are less important for explaining output variance.

3.5 Conclusion

In this chapter, we analyzed the contribution of fiscal foresight about labor and capital tax rates and government spending to business cycle volatility in an estimated New Keynesian DSGE model. Computing forecast error variance decompositions, we found that fiscal foresight only plays a limited role for business cycle fluctuations. Its variance contribution was mostly confined to inflation and interest rate fluctuations, where anticipated capital tax shocks were responsible for between 5 and 15 percent of the total variance.

Our results show that accounting for fiscal foresight does not qualitatively alter the importance of traditional business cycle factors like technology, wage markup, and preference shocks (see e.g. Smets and Wouters, 2007).

Structural estimation always runs the risk of misspecifying the underlying model structure. Hence, future work should test whether the results obtained here are robust

[32]Note also that the average anticipated capital tax shock is roughly 40% smaller than the one depicted due to re-scaling.

against the specification of different fiscal rules where taxes respond to debt and possibly output as in Leeper et al. (2010) and Forni et al. (2009). Similarly, it might be worthwhile to explore the effects of a more detailed modeling of the U.S. tax code as suggested by McGrattan (2011). However, given the need for non-linear modeling and filtering required in this case and the typically large state space of models with anticipation effects, estimating the effects of fiscal news in such a model will be an extremely challenging computational task. Finally, the role of the information structure assumed in the present work should be further scrutinized as the particular choice of information structures may matter (Leeper and Walker, 2011).

Appendix to Chapter 3

A Tables

Table 3.2: Prior and Posterior Distributions of Preference and Technology Parameters

Parameter	Prior distribution			Posterior distribution			
	Distribution	Mean	Std. Dev.	Mean	Std. Dev.	5 Percent	95 Percent
ϕ_c	Beta	0.7	0.1	0.858	0.014	0.834	0.880
σ_l	Gamma	2	0.75	3.410	0.452	2.704	4.132
σ_s	Beta	0.5	0.2	0.101	0.023	0.069	0.137
κ	Gamma	4	1.5	4.860	0.425	4.128	5.526
δ_2/δ_1	Inverse-Gamma	0.5	0.15	0.280	0.023	0.243	0.316
χ_w	Beta	0.5	0.2	0.590	0.069	0.486	0.704
χ_p	Beta	0.5	0.2	0.059	0.024	0.022	0.098
θ_w	Beta	0.5	0.2	0.938	0.006	0.927	0.948
θ_p	Beta	0.5	0.2	0.662	0.009	0.646	0.676

Table 3.3: Prior and Posterior Distributions of the Shock Processes

Parameter	Prior distribution			Posterior distribution			
	Distribution	Mean	Std. Dev.	Mean	Std. Dev.	5 Percent	95 Percent
				Preference Shock			
ρ_{pref}	Beta	0.5	0.2	0.991	0.003	0.987	0.996
σ_{pref}	Inverse-Gamma	0.1	2	40.383	11.382	22.511	57.325
				Wage Markup Shock			
ρ_w	Beta	0.5	0.2	0.976	0.006	0.967	0.986
σ_w^0	Inverse-Gamma	0.1	2	45.692	7.160	34.538	58.147
σ_w^4	Inverse-Gamma	0.1	2	0.037	0.018	0.020	0.058
σ_w^8	Inverse-Gamma	0.1	2	0.032	0.017	0.023	0.045

Prior and Posterior Distributions of the Shock Processes - Continued

Parameter	Prior distribution			Posterior distribution			
	Distribution	Mean	Std. Dev.	Mean	Std. Dev.	5 Percent	95 Percent
				Stationary Technology Shock			
ρ_z	Beta	0.5	0.2	0.994	0.004	0.989	0.999
σ_z^0	Inverse-Gamma	0.1	2	0.738	0.043	0.663	0.806
σ_z^4	Inverse-Gamma	0.1	2	0.178	0.161	0.024	0.394
σ_z^8	Inverse-Gamma	0.1	2	0.730	0.047	0.648	0.804
				Non-stationary Technology Shock			
ρ_x	Beta	0.5	0.2	0.336	0.059	0.245	0.438
σ_x^0	Inverse-Gamma	0.1	2	0.040	0.024	0.024	0.061
σ_x^4	Inverse-Gamma	0.1	2	0.034	0.015	0.021	0.047
σ_x^8	Inverse-Gamma	0.1	2	0.601	0.028	0.554	0.645
				Stationary Investment-Specific Productivity Shock			
ρ_{z^I}	Beta	0.5	0.2	0.968	0.019	0.942	0.992
$\sigma_{z^I}^0$	Inverse-Gamma	0.1	2	0.313	0.021	0.274	0.342
$\sigma_{z^I}^4$	Inverse-Gamma	0.1	2	0.034	0.015	0.025	0.053
$\sigma_{z^I}^8$	Inverse-Gamma	0.1	2	0.037	0.017	0.023	0.053
				Non-stationary Investment-Specific Productivity Shock			
ρ_a	Beta	0.5	0.2	0.986	0.0062	0.9766	0.996
σ_a^0	Inverse-Gamma	0.1	2	0.114	0.011	0.095	0.130
σ_a^4	Inverse-Gamma	0.1	2	0.036	0.013	0.020	0.056
σ_a^8	Inverse-Gamma	0.1	2	0.139	0.013	0.117	0.160
				Taylor Rule and Monetary Policy Shock			
ρ_R	Beta	0.5	0.2	0.865	0.009	0.851	0.879
ϕ_{R_Π}	Gamma	1.5	3	2.958	0.107	2.779	3.126
ϕ_{R_Y}	Gamma	0.5	3	0.314	0.050	0.235	0.402
σ_R	Inverse-Gamma	0.1	2	0.251	0.011	0.234	0.268

Prior and Posterior Distributions of the Shock Processes - Continued

Parameter	Prior distribution			Posterior distribution			
	Distribution	Mean	Std. Dev.	Mean	Std. Dev.	5 Percent	95 Percent
			Government Spending Shock				
ρ_g	Beta	0.5	0.2	0.940	0.017	0.912	0.968
ρ_{xg}	Beta	0.5	0.2	0.912	0.102	0.864	0.984
σ_g^0	Inverse-Gamma	0.1	2	3.024	0.124	2.815	3.217
σ_g^4	Inverse-Gamma	0.1	2	0.033	0.012	0.025	0.044
σ_g^8	Inverse-Gamma	0.1	2	0.038	0.023	0.025	0.058
			Labor Tax Shock				
ξ_{n1}	Uniform	0	0.577	-0.228	0.046	-0.313	-0.164
ξ_{n2}	Uniform	0	0.577	0.998	0.001	0.997	0.999
$\sigma_{\tau^n}^0$	Inverse-Gamma	0.1	2	0.476	0.019	0.441	0.503
$\sigma_{\tau^n}^4$	Inverse-Gamma	0.1	2	0.037	0.018	0.024	0.051
$\sigma_{\tau^n}^8$	Inverse-Gamma	0.1	2	0.032	0.015	0.023	0.044
			Capital Tax Shock				
ξ_{k1}	Uniform	0	0.577	0.605	0.147	0.574	0.999
ξ_{k2}	Uniform	0	0.577	0.999	0.144	0.634	0.999
$\sigma_{\tau^k}^0$	Inverse-Gamma	0.1	2	0.923	0.045	0.856	0.997
$\sigma_{\tau^k}^4$	Inverse-Gamma	0.1	2	0.460	0.044	0.386	0.531
$\sigma_{\tau^k}^8$	Inverse-Gamma	0.1	2	0.645	0.046	0.571	0.721

Table 3.4: Model and Data Moments

	Model	Data	Model	Data	Model	Data
	$\rho(x_t, y_t)$		$\sigma(x_t)$		$\rho(x_t, x_{t-1})$	
$\Delta \log (Y_t)$	1	1.00	0.02	0.01	0.88	0.28
$\Delta \log (C_t)$	0.631	0.50	0.01	0.01	0.88	0.21
$\Delta \log (A_t I_t)$	0.89	0.69	0.09	0.02	0.96	0.52
$\Delta \log (A_t)$	-0.1792	-0.13	0.01	0.00	0.91	0.49
$\Delta \log (TFP_t)$	0.1669	0.09	0.01	0.01	0.05	0.18
$\log (R_t)$	0.1453	-0.19	0.11	0.01	1.00	0.96
$\log (\Pi_t)$	0.0575	-0.29	0.04	0.01	0.99	0.85

Notes: Time Series x_t are the growth rates of output ($\Delta \log (Y_t)$), consumption ($\Delta \log (C_t)$), investment ($\Delta \log (A_t I_t)$), investment-specific technology ($\Delta \log (A_t)$), TFP ($\Delta \log (TFP_t)$), the level of the net nominal interest rate ($\log (R_t)$), and the level of net inflation ($\log (\Pi_t)$).

Table 3.5: Variance Decomposition of Shocks (in %)

	Pref./Wage Markup		Technology							Policy					
	ξ^{pref}	ε_w^0	ε_z^0	$\varepsilon_z^{4,8}$	ε_x^0	$\varepsilon_x^{4,8}$	$\varepsilon_{z^I}^0$	ε_a^0	$\varepsilon_a^{4,8}$	ξ^R	ε_g^0	$\varepsilon_{\tau^n}^0$	$\varepsilon_{\tau^n}^{4,8}$	$\varepsilon_{\tau^k}^0$	$\varepsilon_{\tau^k}^{4,8}$
4 Periods															
GDP	5.00	35.26	24.03	7.98	0.01	0.65	0.27	1.96	2.09	1.48	18.43	0.46	0.00	2.11	0.25
Cons.	18.93	44.73	16.30	11.58	0.02	2.99	0.07	0.87	0.84	0.31	0.05	1.06	0.01	1.49	0.76
Invest.	37.59	17.99	20.53	3.63	0.00	0.00	0.41	7.75	7.91	2.08	0.04	0.09	0.00	1.86	0.12
Hours	3.29	48.73	4.29	7.96	0.03	0.84	0.07	9.48	5.61	4.11	8.91	0.66	0.00	0.13	5.89
Wages	7.39	2.65	50.01	3.35	0.65	0.09	0.12	8.72	5.51	1.71	0.18	0.05	0.00	17.58	1.99
FFR	16.46	2.39	17.85	1.10	0.00	0.20	0.01	5.62	9.99	15.01	0.75	0.00	0.00	29.51	1.11
Infl.	19.15	6.82	25.09	0.53	0.00	0.08	0.03	4.24	8.05	2.04	0.17	0.03	0.00	31.75	2.02
8 Periods															
GDP	11.18	35.13	20.52	9.54	0.01	0.68	0.26	1.83	2.75	1.04	12.76	0.44	0.00	2.96	0.90
Cons.	15.94	46.39	16.20	12.43	0.02	3.16	0.08	0.79	0.74	0.26	0.04	1.10	0.01	1.76	1.08
Invest.	41.33	18.32	15.61	5.40	0.00	0.03	0.35	6.19	7.88	1.29	0.02	0.09	0.00	2.76	0.72
Hours	8.78	52.59	6.56	9.78	0.01	0.98	0.13	6.64	5.49	1.78	2.87	0.68	0.00	0.61	3.09
Wages	6.53	2.41	44.66	11.78	0.53	0.52	0.12	7.65	4.77	1.52	0.16	0.05	0.00	15.14	4.15
FFR	21.19	3.23	12.88	0.86	0.00	0.22	0.01	4.50	10.55	5.54	0.42	0.00	0.00	35.54	5.06
Infl.	22.27	7.10	17.80	1.90	0.00	0.07	0.02	3.01	6.82	1.39	0.15	0.03	0.00	31.29	8.14
20 Periods															
GDP	21.15	30.89	16.43	9.13	0.01	0.98	0.21	1.58	3.44	0.87	9.89	0.39	0.00	2.89	2.12
Cons.	19.72	44.09	14.88	11.98	0.02	3.14	0.08	0.72	0.84	0.23	0.04	1.06	0.01	1.80	1.37
Invest.	45.16	16.75	12.51	5.79	0.00	0.17	0.28	5.04	8.13	1.07	0.03	0.09	0.00	2.73	2.24
Hours	22.63	50.14	4.20	4.30	0.00	0.25	0.12	5.14	8.29	0.49	0.71	0.67	0.01	1.52	1.52
Wages	6.16	2.26	18.65	8.87	0.20	48.45	0.06	3.00	2.22	0.64	0.06	0.02	0.00	6.08	3.31
FFR	31.49	4.15	5.45	1.94	0.00	0.12	0.00	1.64	5.08	1.53	0.17	0.00	0.00	30.96	17.48
Infl.	31.97	6.27	9.91	3.44	0.00	0.04	0.01	1.74	3.85	0.76	0.10	0.02	0.00	25.83	16.06
Uncond. Variance															
GDP	23.57	26.88	12.88	7.67	0.01	0.73	0.19	5.61	11.02	0.66	6.83	0.28	0.00	2.09	1.58
Cons.	24.27	37.52	12.06	9.74	0.01	2.45	0.07	3.75	6.54	0.20	0.04	0.83	0.00	1.43	1.08
Invest.	44.46	15.95	9.61	5.26	0.00	0.14	0.22	7.14	12.98	0.73	0.02	0.07	0.00	1.85	1.56
Hours	46.58	16.62	2.83	2.68	0.00	0.09	0.06	9.97	18.68	0.11	0.15	0.96	0.01	0.67	0.59
Wages	19.01	4.34	13.37	6.78	0.14	32.83	0.05	6.53	9.74	0.45	0.05	0.02	0.00	4.26	2.42
FFR	31.89	1.64	0.42	0.27	0.00	0.01	0.00	1.46	2.76	0.06	0.01	0.01	0.00	35.25	26.22
Infl.	31.43	1.69	1.00	0.43	0.00	0.00	0.00	1.34	2.53	0.07	0.01	0.01	0.00	35.33	26.16

Notes: Variance decompositions are performed at the posterior mean. ε_i^0 represents contemporaneous shock components; $\varepsilon_i^{4,8}$ represents the sum of the 4 and 8 quarter anticipated shock components. For ease of exposition, we leave out anticipated stationary investment-specific, wage-markup, and government spending shocks, since these shocks contribute less then 0.01% to the variances of the variables.

B Stationary Equilibrium

In order to derive a state-space representation of the model, the model presented in the main text is solved by using a first-order perturbation method. However, due to the two integrated processes A_t and X_t, which grow with rates

$$\mu_t^a = \frac{A_t}{A_{t-1}}, \quad \mu_t^x = \frac{X_t}{X_{t-1}}, \tag{3.24}$$

the model has to be detrended first in order to induce stationarity and to have a well-defined steady state. Y_t, C_t and W_t inherit the trend $X_t^Y = A^{\frac{\alpha}{\alpha-1}} X_t$, which corresponds to a growth rate of

$$\mu_t^y = (\mu_t^a)^{\frac{\alpha}{\alpha-1}} \mu_t^x. \tag{3.25}$$

K_t and I_t inherit the trend $X_t^K = A^{\frac{1}{\alpha-1}} X_t$ and thus grow with

$$\mu_t^k = \mu_t^I = (\mu_t^a)^{\frac{1}{\alpha-1}} \mu_t^x. \tag{3.26}$$

G_t inherits $X_t^G = \left(X_{t-1}^G\right)^{\rho_{xg}} \left(X_{t-1}^Y\right)^{1-\rho_{xg}}$ due to the assumed cointegrated trend with output. It hence grows with rate

$$x_t^g = \frac{(x_{t-1}^g)^{\rho_{x_g}}}{\mu_t^y}. \tag{3.27}$$

The detrending is performed by dividing the trending model variables by their respective trend. For the estimation of our structural model, these stationary model variables are matched to the data presented in appendix D.

C Observation Equation

The observation equation describes how the empirical times series are matched to the corresponding model variables:[33]

$$OBS_t = \begin{bmatrix} \Delta \log (Y_t) \\ \Delta \log (C_t) \\ \Delta \log \left(z_t^I A_t I_t\right) \\ \log (L_t) \\ \Delta \log (G_t) \\ \Delta \log \left(z_t^I A_t\right) \\ \Delta \log \left(\tau_t^k\right) \\ \Delta \log (\tau_t^n) \\ \Delta \log (TFP_t) \\ \Delta \log (W_t) \\ \Delta \log (R_t) \\ \Delta \log (\Pi_t) \end{bmatrix} \times 100 = - \begin{bmatrix} \log (\mu^y) \\ \log (\mu^y) \\ \log (\mu^y) \\ \log \left(\bar{L}\right) \\ \log (\mu^y) \\ \log (\mu^a) \\ \log \left(\tau^k\right) \\ \log (\tau^n) \\ (1-\alpha) \log (\mu^x) \\ \log (\mu^y) \\ \log (R) \\ \log \left(\bar{\Pi}\right) \end{bmatrix} + \begin{bmatrix} \hat{y}_t - \hat{y}_{t-1} + \hat{\mu}_t^y \\ \hat{c}_t - \hat{c}_{t-1} + \hat{\mu}_t^y \\ \hat{i}_t - \hat{i}_{t-1} + \hat{z}_t^I - \hat{z}_{t-1}^I + \hat{\mu}_t^y \\ \hat{L}_t \\ \hat{g}_t - \hat{g}_{t-1} + \hat{x}_t^g - \hat{x}_{t-1}^g + \hat{\mu}_t^y \\ \hat{\mu}_t^a + \hat{z}_t^I - \hat{z}_{t-1}^I \\ \hat{\tau}_t^k \\ \hat{\tau}_t^n \\ \hat{z}_t - \hat{z}_{t-1} + (1-\alpha)\hat{\mu}_t^x \\ \hat{w}_t + \hat{w}_{t-1} + \hat{\mu}^y \\ \hat{R}_t \\ \hat{\Pi}_t \end{bmatrix},$$

where Δ denotes the temporal difference operator, $\bar{L}$ denotes the steady state of hours worked, μ^y is the steady state growth rate of output[34], μ^a is the steady state growth rate of the relative price of investment, τ^k and τ^n are the steady state tax rates, $TFP_t = z_t X_t^{1-\alpha}$ is total factor productivity, and R is the steady state interest rate. The hats above the variables denote log deviations from steady state.

[33]The equation for L_t follows from

$$\log L_t = \log \left(L_t \frac{\bar{L}}{\bar{L}} \right) \approx \hat{L}_t + \log \bar{L}.$$

The equation for government spending follows from

$$\log \frac{G_t}{G_{t-1}} = \log \frac{g_t X_t^g}{g_{t-1} X_{t-1}^g} = \log \frac{g_t x_t^g X_t^Y}{g_{t-1} x_{t-1}^g X_{t-1}^Y} = \log \frac{g_t x_t^g}{g_{t-1} x_{t-1}^g} \mu_t^y.$$

Note that the presence of x^g also implies that there is no perfect linear restriction between the GDP components following from the resource constraint. Hence, we do not need to add additional measurement error.

[34]This is also the growth rate of the individual components of GDP along the balanced growth path.

D Data Construction

Unless otherwise noted, all data are from the Bureau of Economic Analysis (BEA)'s NIPA Tables and available in quarterly frequency from 1955Q1 until 2006Q4.

- **Capital and labor tax rates**: Our approach to calculate average tax rates closely follows Mendoza et al. (1994), Jones (2002), and Leeper et al. (2010). We first compute the average personal income tax rate

$$\tau^p = \frac{IT}{W + PRI/2 + CI},$$

where IT is personal current tax revenues (Table 3.1 line 3), W is wage and salary accruals (Table 1.12 line 3), PRI is proprietor's income (Table 1.12 line 9), and $CI \equiv PRI/2 + RI + CP + NI$ is capital income. Here, RI is rental income (Table 1.12 line 12), CP is corporate profits (Table 1.12 line 13), and NI denotes the net interest income (Table 1.12 line 18).

The average labor and capital income tax rates can then be computed as

$$\tau^n = \frac{\tau^p(W + PRI/2) + CSI}{EC + PRI/2},$$

where CSI denotes contributions for government social insurance (Table 3.1 line 7), and EC is compensation of employees (Table 1.12 line 2), and

$$\tau^k = \frac{\tau^p CI + CT + PT}{CI + PT},$$

where CT is taxes on corporate income (Table 3.1 line 5), and PT is property taxes (Table 3.3 line 8).

- **Government spending**: Government spending is the sum of government consumption (Table 3.1 line 16) and government investment (Table 3.1 line 35) divided by the GDP deflator (Table 1.1.4 line 1) and the civilian noninstitutional population (BLS, Series LNU00000000Q).

- **Total factor productivity (TFP)**: The construction of TFP closely follows

Beaudry and Lucke (2010), i.e.

$$TFP_t = \frac{Y_t}{K^{\alpha} H^{1-\alpha}}.$$

To construct K, we use data on capital services for the private non-farm business sector (Bureau of Labor Statistics (BLS), Historical Multifactor Productivity Tables),[35] multiply it by the total capacity utilization rate (Federal Reserve System, Statistical Release G.17 - Industrial Production and Capacity Utilization), and divide it by the civilian noninstitutional population above 16 years of age (BLS, Series LNU00000000Q). Real GDP per capita Y is nominal GDP (Table 1.1.5 line 1) divided by the GDP deflator (line 1 in Table 1.1.4) and the population, and per capita hours H are non-farm business hours worked (BLS, Series PRS85006033) divided by the population. The capital share α is set at 0.2935, the mean over the sample compiled by the BLS (Bureau of Labor Statistics (BLS), Historical Multifactor Productivity Tables).

- **Relative price of investment**: The relative price of investment is taken from Schmitt-Grohé and Uribe (2011). They base their calculations on Fisher (2006).

- **Output**: Nominal GDP (Table 1.1.5 line 1) divided by the GDP deflator (Table 1.1.4 line 1) and the civilian noninstitutional population (BLS, Series LNU00000000Q).

- **Investment**: Sum of Residential fixed investment (Table 1.1.5 line 12) and nonresidential fixed investment (Table 1.1.5 line 9) divided by the GDP deflator (Table 1.1.4 line 1) and the civilian noninstitutional population (BLS, Series LNU00000000Q).

- **Consumption**: Sum of personal consumption expenditures for nondurable goods (Table 1.1.5 line 5) and services (Table 1.1.5 line 6) divided by the GDP deflator (Table 1.1.4 line 1) and the civilian noninstitutional population (BLS, Series LNU00000000Q).

[35] Quarterly data is interpolated from the annual series using cubic spline interpolation.

- **Real wage**: Hourly compensation in the nonfarm business sector (BLS, Series PRS85006103) divided by the GDP deflator (Table 1.1.4 line 1).
- **Inflation**: Computed as the log-difference of the GDP deflator (Table 1.1.4 line 1).
- **Nominal interest rate**: Geometric mean of the effective Federal Funds Rate (St.Louis FED - FRED Database, Series FEDFUNDS).
- **Hours worked**: Nonfarm business hours worked (BLS, Series PRS85006033) divided by the civilian noninstitutional population (BLS, Series LNU00000000Q)

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