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International Fiscal Policy Spillovers, Asset Prices, and Business Cycles: Essays on Applied Macroeconomics

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Contents

List of Figures

List of Tables

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Örök szeretettel és hálával édesanyámnak.

Preface

This dissertation consists of three chapters, each of them representing a self-contained research project. Thematically, Chapter 1 is not related to the rest of the dissertation, whereas Chapter 2 and 3 are closely linked. Nevertheless these chapters share a common theme: the importance of financial markets in economics. A decade ago, we witnessed the most recent financial crisis, which triggered severe economic recessions. Since then, causes and consequences of such financial crisis are a topic of high relevance not only in the academic discussion, but also in the political discourse. On the one hand, we need a profound understanding of the working mechanisms of financial markets, which includes the pricesetting in such markets. On the other hand, we need countermeasures - a such could be policy coordination in common economic markets - to mitigate or even prevent such crisis. This dissertation treats questions related to this broad topic and discusses them in the following three chapters.
In Chapter 1 we quantify cross-country spillovers in the European Union stemming from fiscal policy reforms or large, onetime, exogenous shocks - typical of crisis - using a multi-country CGE-OLG model. The model is calibrated in detail for 14 member countries of the European Union and two stylized "Rest-of-the-world" countries. Moreover, we evaluate possible benefits from coordination of fiscal policies at the EU-level. The financial market, or capital market, serves as transmission channel of cross-country spillovers and the severity of shocks to capital markets influences the magnitude of spillovers. Large shocks that affect the capital stock of a country generate significantly larger spillovers than fiscal policy reforms. Furthermore, our simulations suggest that the respective type of fiscal policy response to a shock matters, indicating that coordination of fiscal policy at the EU-level could have benefits, at least under certain conditions.
The focus in Chapter 2 is on asset pricing. An extensively discussed issue in asset pricing is the fact that standard asset pricing models are weak in explaining empirically observed moments of asset returns using reasonable parameter assumptions. In this chapter we challenge the model assumptions on investment behavior in a classical asset pricing model. We propose a new modification of preference structure, that describes the investment behavior of agents, apply it to a standard asset pricing model, and aim to rationalize historical asset returns on different types of assets. Compared to standard modelling assumptions, our specification features a richer set of behavioral aspects, such as a form of loss aversion and habit formation. Our model is able to rationalize empirically observed first moments of equity and riskless bonds and hence the corresponding interest rate spread. These results indicate an improvement on existing studies in the related literature.
In Chapter 3 we apply the preference structure proposed in Chapter 2 to a real business cycle model. Again, we are particularly interested in the asset pricing implications of our modification, since the standard real business cycle model struggles with explaining financial data. As a sideline, reasonable asset pricing implications would serve as a robustness test of our specification proposed in Chapter 2. Using our specification, we find that the model is able to rationalize a large set of financial data while maintaining adequately accurate predictions with respect to business cyle statistics.
Finally, a note on the authorship of the following chapters. I am the sole author of the Chapters 2 and

3, but Chapter 1 is co-authored with Thomas Davoine and Michael Reiter. This Chapter is based on the existing research report Davoine et al. (2016). For more details on this project see footnote 2 in Chapter 1. Therefore I want to clarify the respective contributions. Literature research, calibration, and simulations were predominantly my responsibility. For the analytic derivation and implementation of the model we were able to rely on previous research carried out at the IHS, with contributions from Thomas Davoine. Both of us contributed, to equal parts, to the implementation of the multi-country extension of the model and to the discussion of results. Michael Reiter served as supervisor in this project and provided us with valuable feedback on earlier drafts. Except for Section 1.3, the Chapter was written by me.

Chapter 1

Measuring Long-run Fiscal Policy Spillovers and Coordination Effects: A Quantitative Assessment for Europe

1.1 Introduction

Since the last financial crisis and subsequent sovereign debt crisis, policy makers have renewed their interest in policy coordination in the European Union (EU). Calling for reinforcement of economic policy coordination for instance, the European Commission recommended the creation of a "European Semester" to better synchronize the assessment of fiscal and structural policies of EU member states (European Commission, 2010). For many, increased fiscal policy harmonization should be the next step for countries with a unified monetary policy and basic public debt management rules, such as countries of the Eurozone.

According to Alesina and Wacziarg (1999), the optimal degree of fiscal policy coordination includes a trade-off. Heterogeneous preferences across nations and country-specific constraints are in conflict with the capability for managing policy spillovers. National policy makers have to decide to which extent country specific policy opportunities should be sacrificed for building a framework which counterbalances policy spillovers.

The current framework of European economic governance implements coordination mainly as a set of rules whose purpose is to prevent or at least mitigate the risk of fiscal shocks and ensure long-term sustainability of public finances (e.g. SGP).[1] The current governance system proceeds from the hypothesis that spillovers are the result of a response to an idiosyncratic shock (e.g. demand or supply shock). The aim of the response is to stabilize the economy, or the shock itself. The response itself is implemented as a fiscal policy decision. This is the variable under control of the policy maker.

Thus the main questions which we want to consider in this chapter are the following: Are cross-country spillovers large enough to justify coordination? Is the advantage in coordinating fiscal policies always visible?[2]

[1]The Stability and Growth Pact (SGP) is an agreement between the member states of the EU whose aim is to ensure fiscal stability in the EU. For instance countries are committed to respect a government budget deficit limit (maximum 3% of GDP) and a public debt limit (maximum 60% of GDP) in fiscal policy implementation.

[2]This chapter is based on a work package of the research project FIRSTRUN (Fiscal Rules and Strategies under Externalities and Uncertainties) funded by the Horizon 2020 Framework Programme of the European Union (Project ID 649261) contracted to the Institute for Advanced Studies (IHS) and is a shorter version of the delivered research report Davoine et al. (2016) available online `http://www.firstrun.eu/files/2016/08/D1.6_Spillover_effects.pdf`. The declaration on authorship in the Preface of this dissertation refers to both, this chapter and the research report.

The literature on spillovers and policy coordination provides ambiguous findings. There is a large theoretical literature on the advantages and disadvantages of fiscal policy coordination in a monetary union, focusing mainly on strategic issues of the distinct agents.[3]

In comparison, the concrete quantification of spillovers received relatively little attention in the literature. Nevertheless there are a few studies using econometric as well as simulation-based approaches to quantify spillovers from fiscal policy actions.

Beetsma et al. (2006) find that spillovers are economically relevant and that the magnitude of the spillovers depends on the size of the originating country and the distance of the trade partner. Auerbach and Gorodnichenko (2013) consider spillovers transmitted through trade linkages. They find that spillovers on output are stronger during recessions than during expansions. However, the estimated multipliers are not significant if the economy is in a state of expansion. Hebous and Zimmermann (2013) likewise argue in favor of fiscal policy coordination based on qualitative arguments. They find that the positive effects on output are larger for the case of an area-wide fiscal shock compared to a domestic shock of similar size.[4]

Besides these econometric estimations, model-based simulation approaches also exist in the literature. Gros and Hobza (2001) condense the results of four different established macroeconomic models that are regularly used for policy analysis.[5] They argue that spillovers tend to be quantitatively small and the sign of the impact is not clear. Given the minor importance of spillovers, fiscal policy coordination is not favorable.

Corsetti et al. (2010) find that a combination of a tax increase and a spending decrease can reinforce spillovers, but overall spillovers tend to be moderate in size. Cwik and Wieland (2011) use the model by Taylor (1993) to quantify spillover effects of a fiscal stimulus in one country and conclude that spillovers are small. More recent literature has emerged, taking effects of monetary policy developments into account. Benes et al. (2013) find larger spillovers than previous studies on conventional monetary policy, once they take the zero lower bound on the interest rate into account, and conclude that fiscal policy coordination could be useful. Boersch-Supan et al. (2006) quantify spillovers due to differences in the speed of population ageing and argue that capital mobility across countries may have an important role.

To evaluate long-run spillovers and to compare different forms of fiscal policy coordination between countries of the EU we develop a multi-country overlapping generations model with an integrated capital market. Compared to existing general equilibrium studies, our approach has various benefits. Consistent with empirical evidence, we include capital-skill complementarities in the production function.[6] Because spillovers are channeled through the integrated capital market and education levels differ across countries, spillovers will then have different impacts across countries. Further, we model the labor market in detail (including involuntary unemployment, intensive and extensive margins and a pension system), as labor supply varies with fiscal policy and thus plays a role in cross-country transmission of fiscal policy shocks. As a results, our modelling approach allows for heterogeneous spillover impacts and asymmetric coordination effects. Because our interest is on long-run effects, we neglect business cycle fluctuations and focus on permanent changes or large shocks occurring at low frequency, such as policy reforms or crises. The first contribution of this study is thus a multi-country framework allowing quantitative assessments of long-run

[3]For examples see Jensen (1996), Beetsma and Bovenberg (1998), Beetsma et al. (2001), Beetsma and Bovenberg (2001) and Uhlig (2002).

[4]However the costs of the shock are important in this context. The costs are lower in the area-wide scenario as the respective country bears only a fraction of the total costs of the shock. Hence if the shock is same in size, then naturally the coordinated scenario is advantageous.

[5]QUEST II (European Commission), Marmotte (CEPII), NiGEM (National Institute of Economic and Social Research) and MULTIMOD Mark III (IMF). We limit the discussion to the results from QUEST II and Marmotte as we focus here on GE-models.

[6]See for instance Griliches (1969) or Duffy et al. (2004).

cross-country spillover effects which are enabled by the integration of capital markets in Europe.
The second contribution is an exploration of long-run spillover effects and coordination of fiscal policy across countries in Europe. More specifically, we perform simulations on a representative set of fourteen EU countries to quantify spillovers from labor tax reforms, large one-time exogenous shocks typical of crises, and combinations of both. Furthermore, we compare selected forms of fiscal policy coordination, with and without exogenous shocks, without considering all possible forms of coordination.
In the policy reform and exogenous shock cases that we consider, we find that spillovers emerging from fiscal policy actions in a single country are negligibly small. In scenarios where economies are not hit by a large shock, simultaneous implementation of a labor income tax cut, one example of coordination, does not provide any economic advantage. In case of large exogenous shocks, spillovers are moderate in size and larger than spillovers from sole policy reforms. Area-wide shocks generate larger effects for the respective country than shocks to the country alone. The form of fiscal policy response to a shock matters. An appropriate policy response can improve domestic economic circumstances and reduce negative spillovers to other countries. The gains are larger in case of an area-wide shock, but only to a small extent. Furthermore, we show that a temporary violation of public debt rules can be beneficial for all countries.
The remainder of this chapter is organized as follows: Section 1.2 outlines the specifics of our modelling approach while section 1.3 describes the model in detail. Section 1.4 explains the calibration approach. Section 1.5 presents the results of our quantitative explorations and section 1.6 concludes.

1.2 Approach Specifics

In comparison with existing quantitative general equilibrium analyses of fiscal spillovers and fiscal policy coordination our modelling approach differs along several dimensions.[7] One key difference with some, but not all, existing analyses is that we calibrate the model at European country levels, rather than taking Europe as a region, which is necessary for investigating cross-country spillovers within the European Union. In the following we highlight the main differences in our approach with all existing analyses: skill differences and capital-skill complementarity, which allow for heterogeneous spillover effects and heterogeneous coordination impacts across countries.[8]
Our model distinguishes households into three different skill classes, reflecting different levels of education. Across the EU there are large differences in the percentage of people having reached higher education levels (e.g. in Great Britain 31% of adults completed tertiary education while in Austria 13% of adults did). Higher levels of education are, among others, associated with higher relative earnings. The EU countries often rely on a progressive income tax system. Thus there are large differences in the structure of tax revenue. It is therefore likely that different countries in the EU react differently when applying the same tax reform. This leads to the conjecture that different spillovers could arise from this distinct behaviour.
Productivity differs by skill classes. The representative firm produces a single composite good using capital and three different types of labor which correspond to the three skill classes. We assume imperfect substitution between the various types of labor. High-skilled labor is assumed to be more complementary to capital than middle-skilled labor, itself more complementary to capital than low-skilled labor. This feature is consistent with empirical evidence and generates endogenous wage differentials between the skill classes. This is an important feature of our model as the channel for spillover effects is the integrated capital market. The same capital stock variation, due to a shock in another country, will lead to larger GDP variations in countries with a large proportion of highly skilled workers than countries with a small

[7]Models QUEST II and Marmotte in Gros and Hobza (2001), and Benes et al. (2013), Boersch-Supan et al. (2006), Corsetti et al. (2010), and Cwik and Wieland (2011).
[8]Other specifics of our modelling approach are presented in Appendix A.1.

proportion, because of capital-skill complementarity. For instance, a shock on the capital stock of a country where the agricultural sector is predominant generates different effects than a shock to a country where the service sector is predominant. Existing general equilibrium models of fiscal spillovers are lacking this feature.

1.3 Model

To quantify long-run cross-country spillover effects and potential gains from fiscal policy coordination, we develop a multi-country computable general equilibrium model with an integrated capital market. We assume that only capital is freely mobile, while labor is immobile.[9]

Spillover effects may be due to policy reforms, demographic changes or large one-time economic shocks which take place in times of crisis, such as the 2007 subprime crisis or the 2010 European sovereign debt crisis. Short-run spillover effects due to business cycle fluctuations are not considered.

Concretely, we start from an existing single-country overlapping-generations model routinely used for policy evaluation and extend it to a multi-country model following Buiter (1981).[10][11] The single-country model, of the Auerbach and Kotlikoff (1987) tradition, builds on Jaag, Keuschnigg, and Keuschnigg (2010), which features endogenous labor supply decisions along intensive and extensive margins as well as imperfect labor markets, and adds a separation in three skill levels following Jaag (2009). Because business cycle fluctuations are out of the scope of the analysis and we assume a single composite good, the model does not have money, price rigidities or any of the typical features of Real Business Cycle models.

We present details of the multi-country extension and the main features of the single-country model.[12]

1.3.1 Single-Country Setting

Demographics: Households go through several stages $a \in \{1, \ldots, 8\}$ in their life. A stage a lasts several time periods. After birth, households educate, then enter the labor market and retire. Several stages a cover labor market activity, reflecting different productivity levels (typically hump-shaped). Households face a constant, age-dependent probability of dying $1 - \gamma^a$. They differ in skills, birth date and death date.[13] After they are born, they are randomly assigned one of three skill levels, low, medium or high, $i \in \{l, m, h\}$. Medium and high skills are acquired through further education, which has no cost but delays access to the labor market. Education for medium skills takes place in stage $a = 1$, for high skills in stages $a \in \{1, 2\}$. Retirement is defined exogenously and happens some time during stage $a^R = 5$. Stages $a \in \{6, 7, 8\}$ are full retirement stages but with different probabilities of dying $1 - \gamma^a$, to better replicate the empirical age structure of the population. As in Blanchard (1985), a reverse life insurance allocates assets at death.[14]

[9] Clemens (2011) wonders why migration flows are so small, given the large welfare gains that model simulations exhibit.

[10] For studies using the single-country OLG-model see for instance Berger et al. (2009) or CPB et al. (2013).

[11] The extension proposed by Buiter (1981) has been used in a number of studies, including Frenkel and Razin (1986) and Boersch-Supan et al. (2006).

[12] The model is described in detail in the technical appendix Davoine and Molnar (2017), which is available upon request.

[13] In the implementation, households also differ in the the speed at which they go through the stages of the life cycle, which reflects differences in appetite for effort, luck or other unobserved attributes, a generalization of Gertler (1999) used in Jaag, Keuschnigg, and Keuschnigg (2010). For ease of presentation, we ignore this model feature. The complexity arises in numerical simulations. Aggregation results, presented in the on-line appendix of Berger et al. (2016), help to deal with it.

[14] We use an implementation where the average durations of stay in each life-cycle stage correspond to ages 15-19, 20-24, 25-39, 40-54, 55-69, 70-79, 80-84 and 85+. We later use the words "*life-cycle stage*" and "*age group*" interchangeably.

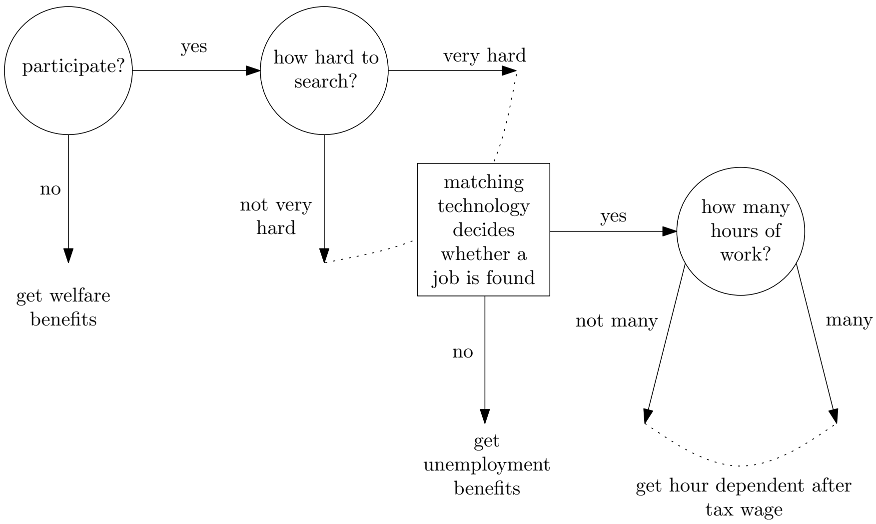


Figure 1.1: Sequence of Households Decisions Related to the Labor Market

Labor market: After education, households can enter the labor market. They choose whether to participate or not (at a rate $\delta^{a,i} \in [0,1]$, which represents the number of time periods of the life-cycle stage with participation).[15] The labor market is imperfect, leading to unemployment. Households who join the labor market start unemployed. Further, households who have a job may be hit by idiosyncratic unemployment shocks with probability $1 - \varepsilon^{a,i}$ in each time period. Depending on search efforts, a job may or may not be found. If unemployed, households choose job search efforts ($s^{a,i} \geq 0$). If they have a job, they decide how many hours to work ($l^{a,i} \geq 0$). Being spared the unemployment shock leads to rents, which are bargained with firms to define the wage, building on the static search and matching setting of Boone and Bovenberg (2002). As in Jaag, Keuschnigg, and Keuschnigg (2010), non-participation in life-cycle a^R is interpreted as retirement. The sequence of households decisions is summarized in Figure 1.1. Conditional on labor market participation and employment, gross labor income equals

$$y_{lab}^{a,i} = l^{a,i} \cdot \theta^{a,i} \cdot w^i,$$

where $\theta^{a,i}$ is an exogenous age-productivity profile calibrated with micro-data and w^i is the bargained wage per efficiency unit, assuming separate labor markets for each skill class.

Household maximization: Households make labor decisions ($\delta^{a,i}, s^{a,i}, l^{a,i}$) and consumption decisions $C^{a,i}$ to maximize their expected life-time utility $V_t^{0,i}$, where $V_t^{a,i}$ is the expected remaining life-time utility of a household in life-cycle stage a with skill level i at time t. Preferences are expressed in recursive fashion and restrict households to being risk neutral with respect to variations in income but allow for an arbitrary intertemporal elasticity of substitution:

$$V_t^{a,i} = \max \left[\left(Q_t^{a,i}\right)^\rho + \gamma^a \beta \left(GV_{t+1}^{a,i}\right)^\rho \right]^{1/\rho},$$

where ρ defines the elasticity of intertemporal substitution $1/(1-\rho)$, β is a time discounting factor, $Q_t^{a,i}$ is effort-adjusted consumption, $G = 1 + g$ is the gross factor of growth by which the model is detrended.

[15] To be more specific, the decision also depends on the time period t and the life history α of the household, which includes the birth date. One should thus write $\delta_{\alpha,t}^{a,i} \in [0,1]$. For ease of notation, we do not write indices α, t when there is no risk of confusion.

Labor market activity generates disutility. Effort-adjusted consumption $Q^{a,i}$ captures the utility cost of labor market activity expressed in goods equivalent terms, with

$$Q^{a,i} = C^{a,i} - \bar{\varphi}^{a,i}\left(\delta^{a,i}, s^{a,i}, l^{a,i}\right),$$

and $\bar{\varphi}^{a,i}$ a convex increasing function in all its arguments. Specifically,

$$\begin{aligned}\bar{\varphi}^{a,i} &= \delta^{a,i}\left[\left(1-u^{a,i}\right)\varphi^{L,i}\left(l^{a,i}\right)+\left(1-\varepsilon^{a,i}\right)\varphi^{S,i}\left(s^{a,i}\right)\right] + \\ &\quad \varphi^{P,i}\left(\delta^{a,i}\right) - \left(1-\delta^{a,i}+\delta^{a,i}u^{a,i}\right)h^{a,i},\end{aligned}$$

where $u^{a,i} \in [0,1]$ represents the fraction of time in unemployment, $h^{a,i}$ is the value of home production if the household is not working, $\varphi^{L,i}$ captures the disutility of working, $\varphi^{P,i}$ the disutility of participation and $\varphi^{S,i}$ the disutility of job search efforts.

Given the Blanchard (1985) insurance, the budget constraint of households is:

$$G\gamma^{a,i}A^{a,i}_{t+1} = R_{t+1}\left(A^{a,i}_t + y^{a,i}_t - C^{a,i}_t\right),$$

where $A^{a,i}$ represent assets, $y^{a,i}$ net income flows and $R = 1 + r$ the gross interest rate.

Social security: Before retirement, non-participants receive (net) welfare benefits y^a_{nonpar} while unemployed workers receive (gross) unemployment benefits $b^{a,i} = b^i \cdot y^{a,i}_{lab}$, where b^i is the skill-dependent replacement rate. After retirement, households receive (net) pension benefits $y^{a,i}_{pens} = \nu^a P^{a,i} + P^a_0$, where P^a_0 is a flat part, $P^{a,i}$ represents acquired pension rights and ν^a is a conversion factor between pension rights and pension payments. Pension rights accumulate with labor earnings, following $P^{a,i}_{t+1} = \delta^{a,i}_t\left(1-u^{a,i}_t\right)y^{a,i}_{lab,t} + P^{a,i}_t$. Taking labor income taxes and social security contributions $\tau^{a,i}_t$ into account and assuming that each labor market state (i.e. non-participation, unemployment and employment) is visited in each time period, net household income amounts to:[16]

$$y^{a,i} = \begin{cases}\left(1-\tau^{a,i}\right)\delta^{a,i}\left[\left(1-u^{a,i}\right)y^{a,i}_{lab} + u^{a,i}b^{a,i}\right] + \left(1-\delta^{a,i}\right)y^a_{nonpar} & \text{if } a < a^R,\\ \left(1-\tau^{a,i}\right)\delta^{a,i}\left[\left(1-u^{a,i}\right)y^{a,i}_{lab} + u^{a,i}b^{a,i}\right] + \left(1-\delta^{a,i}\right)y^{a,i}_{pens} & \text{if } a = a^R,\\ y^{a,i}_{pens} & \text{if } a > a^R.\end{cases}$$

Production: Production is made by a competitive representative firm taking input prices as given; namely wage rates, the interest rate, and the price of the output good, which serves as numeraire. Changes in the production process are costly variations in the capital stock, and are subject to convex capital adjustment costs, following Hayashi (1982).

The production function is linear homogenous:

$$Y_t = F^Y\left(K_t, L^{D,i=1}_t, L^{D,i=2}_t, L^{D,i=3}_t\right).$$

The labor inputs $L^{D,i}_t$ from different skill classes are not perfect substitutes. Consistent with empirical evidence (Griliches, 1969, Duffy et al., 2004), we assume that high skilled labor and capital are more complementary than low skilled labor and capital and use a nested CES-specification F^Y from Jaag (2009).

[16] The assumption follows Jaag, Keuschnigg, and Keuschnigg (2010).

Firms make investment I_t and hiring decisions to maximize the flow of dividends they can generate. Formally, the firm maximizes its end of period value W, which equals the stream of discounted dividend payments χ:

$$\begin{aligned} W_t = W(K_t) &= \max_{I_t, L_t^{D,i}} \left[\chi_t + \frac{GV(K_{t+1})}{R_{t+1}} \right], \\ s.t. \quad & \chi_t = Y_t - I_t - J(I_t, K_t) - \sum_i (1+\tau^{F,a}) w_t^i L_t^{D,i}, \\ & GK_{t+1} = \left(1-\delta^K\right) K_t + I_t, \end{aligned}$$

where $J(\cdot)$ denotes the adjustment costs and $\tau^{F,a}$ the firms social security contribution rate. Labor demands are pinned down by the marginal products and the labor costs, which consist of wage and contribution rates, i.e. $Y_{L^{D,i}} = (1+\tau^{F,a})w^i$. Given an interest rate, investment is defined so that the return on financial investments (the interest rate) equals the marginal cost of investment (Tobin's q), which depends on the marginal product of capital, net of capital adjustment costs and depreciation.[17]

Government: Government provides welfare benefits, unemployment insurance, pay-as-you-go pensions and investment subsidies. State expenditures also include public consumption, long-term care and health expenditures, all defined exogenously in per capita terms and generating no utility.

To finance expenditures, the government collects consumption taxes, labor and capital income taxes, profit taxes, and firm and worker social security contributions. The government can borrow on the capital market (with or without premium on the interest rate) to finance public debt, to meet some exogenously defined target (in simulations, most of the time we assume that debt must be kept constant).

Single-country equilibrium: In a single-country setting, we assume that the gross interest rate $R_{t+1} = 1 + r_{t+1}$ is exogenously defined, as for small open economies. Savings can be invested in firms, government debt and foreign assets. Assuming no arbitrage, the net returns on these three types of assets are the same and equal to the interest rate r_{t+1}. The goods market then clears because of trade with the rest of the world:

$$Y_t = C_t + I_t + G_t + TB_t,$$

where C_t is the aggregate private consumption, G_t is government expenditure and TB_t is the trade balance.[18] Holding of foreign assets by domestic households evolves with changes in the trade balance:

$$D_{t+1}^F = R_{t+1}\left(D_t^F + TB_t\right).$$

Private household assets A_t are invested in the domestic representative firm W_t, government debt D_t^G and foreign assets D_t^F, so that the asset market clearing condition is satisfied:

$$A_t = W_t + D_t^G + D_t^F.$$

[17] In steady-state, the capital stock is stable so that there are no capital adjustment costs. In this case, investment satisfies the standard condition where the interest rate equals the marginal product of capital net of depreciation, $r = F_K^Y - \delta^K$.

[18] So, $C_t = \sum_i \sum_a N_t^{a,i} C_t^{a,i}$ where $N_t^{a,i}$ is the number of households alive at time t, member of age group a and skill group i. Other households-related aggregate variables are defined in a similar fashion, including aggregate financial assets A_t.

1.3.2 Extension to a Multi-Country Setting

We follow Boersch-Supan et al. (2006), an extension of the two-country Buiter (1981) procedure to any number of countries and capital adjustment costs. We assume that labor is immobile, that capital is perfectly mobile and that all countries produce the same composite good. The interest rate is no longer exogenous, but endogenous.

Equilibrium: Under these assumptions, the equilibrium interest rate must be the same in all countries. The intuition is as follows. Assume there is an arbitrage opportunity. Investors in the low interest rate country start to invest in the high interest rate country. The capital stock in the first country declines, increasing the marginal product of capital and thus the interest rate in that country. The opposite happens in the second country. This continues until an equilibrium is reached where the two interest rates are identical.
As a whole, the set of countries is a closed economy, where the interest rate adjusts so that the goods market clear. The resulting equilibrium interest rate is thus the unique value such that the goods market clear over all countries. Formally, consider M countries indexed by $j \in \{1, ..., M\}$. Assume that terms of change are fixed and that each variables are normalized so that the numeraire value, after currency-exchange corrections, is the same in all countries. The interest rate is then the unique value such that

$$\sum_{j \in \{1,...,M\}} TB_{j,t} = 0.$$

Rest of the world: We do not consider all countries in the world but restrict policy analysis to a smaller subset, too small to be isolated from the world capital markets.[19] Consistent with empirical evidence, the goods market, as a whole, will not clear over this subset. We thus consider a large synthetic *Rest-of-the-world* country (or a small group of Rest-of-the-world countries), which will account for trade with the rest of the world. The goods market will clear over all countries which are either part of the subset, or one of the Rest-of-the-world countries. Compared to a case without a Rest-of-the-world country, the adjustment of the equilibrium interest rate is dampened. This reflects access of all countries in the subset to the world capital market.

1.4 Calibration

We use a calibration approach which is standard in the literature. Compared to other overlapping generations models, labor market and institutions are modeled in detail. The model incorporates extensive and intensive labor supply margins, different taxes, social security contributions and a pay-as-you-go pension system. Where available, we take consensual empirical estimates from the literature. Production function specifications are adopted from Jaag (2009). Labor market parameters are derived from Immervoll et al. (2007) and Mincer wage regressions on EU-SILC microdata. Microlevel calibration targets, such as participation rate, working hours or social security benefits are estimated using LFS and EU-SILC datasets. Parameters for institutions are derived using the MISSOC database (European Commission, 2009) and OECD's Tax-Benefit model (from OECD 2007, 2008). Intervivo transfer parameters are calculated to generate life-cycle consumption profiles in line with empirical evidence.
The multi-country setup requires the inclusion and subsequent calibration of a stylized rest of the world.

[19] In the implementation, the subset contains 14 member countries of the European Union: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Italy, The Netherlands, Poland, Slovakia, Spain, Sweden, and the UK.

To be able to reflect large economic differences between countries at least to some extent, we model and calibrate a "North Rest of the World" country (NROW) and a "South Rest of the World" country (SROW). The aim is to capture a sufficient part of the real rest of the world economy while not including many single countries in our stylized rest of the world countries. The scope of this chapter is indeed not to model impacts outside the EU but to capture the impact of forces coming from outside of the EU. Hence our stylized NROW consists of Canada, Japan and USA and SROW consists of Brazil, China and India.[20]
For calibration we need both macrolevel and microlevel data. Macrolevel data is available for the selected countries. We use the online available databases from: World Bank, OECD, WIOD Socio Economic Accounts, UNESCO, Penn World Table, UNO, ILO and IMF.
Most of the microlevel data is not available for the selected countries. Thus, we develop an approach which we label "twin country approach" in order to generate the missing microlevel data inputs for our model. The idea of "twinning" is the following: we create a table of various important economic and demographic indicators for each country. Then we look for a country in the scope (one of the 14 countries for which the model is already calibrated) which is the closest to the NROW (respectively SROW) region. We then take the calibrated value from the closest (twin) country to the NROW (respectively SROW) country. This approximation was typically necessary for data stemming from microlevel datasets, such as income and labor market data which allows to calibrate average tax rates for each age and skill class. One exception is applied: we use stylized approximation when there is a documented difference between the ROW countries and the designated twin country. For instance, if there is a documented lack of pensions, we manually adjust the respective parameter for the ROW country such that the difference is matched. Our approach results in approximating missing inputs for NROW by inputs from the already calibrated UK and missing inputs for SROW by a combination of inputs for the Czech Republic, the Slovak Republic and Poland and correct for documented differences concerning the social security systems. Appendix A.2 contains details on calibration of the Rest-of-the-world countries.

1.5 Results

In this section we provide the quantitative and qualitative results of our experiments. We perform simulations to quantify spillovers from labor tax reforms, large one-time exogenous shocks typical of crises, and combinations of both. Furthermore, we compare selected forms of fiscal policy coordination, with and without exogenous shocks, without considering all possible forms of coordination. We confine ourselves to presenting the most important results.
Table 1.1 provides an overview of the simulations we report. Details of the simulations will be provided when each result is discussed.

[20] With this approach we are capturing 58.5% of actual real world GDP and five of the eleven most important trade partners of the EU reflecting 41.5% of total trade of the EU (in terms of trade in million EURO).

Description	Magnitude	Financing	Country	Subsection
Simple policy reforms				
Single country labor tax cut	-20%	LS Tax	GER	1.5.1
Simultaneous labor tax cuts	-20%	LS Tax	All	1.5.2
Exogenous shocks				
Shock to the capital stock	-20%	LS Tax	GER	1.5.3
Shocks to the capital stock	-20%	LS Tax	All	1.5.4
Shocks and policy responses				
Spending shock with response	+25%	Lab Tax	GER	1.5.5
Spending shocks with response	+25%	Lab Tax	All	1.5.6

Notes. LS Tax = Lump-sum tax; *Lab Tax* = Labor income taxes.

Table 1.1: Simulation Overview

Throughout the analysis, we take gross domestic product as the main indicator of economic activity and focus our discussion of spillovers on this indicator. In the discussion we use the terms *goods market* and *capital market* interchangeably. We also characterize cross-country spillovers either in terms of variations in the trade balance or variations in the integrated capital market. These equivalences hold because the model features only a composite good which, after being produced, can either be consumed or invested without any further transformation.

1.5.1 Labor Tax Cut in a Single Country Financed by Lump-Sum Taxes

We calculate the spillovers on 13 other European countries when one country implements a 20% labor tax cut. The country which implements the reform finances the tax reduction by raising lump-sum taxes (equivalently, reducing unconditional subsidies to households).[21] We discuss the results for Germany, where the largest spillovers take place.

We find overall spillovers from a tax reform to be negative and quantitatively small. Table 1.2 displays the domestic impacts of the labor tax cut for Germany and the spillovers to Spain. We present the results for Spain because the spillovers are quantitatively the largest. For Germany the reform generates a long-term 0.93% improvement of GDP. The long-term spillovers on Spain's GDP are negative and about 1.7% of the effect for Germany: GDP decreases 0.016% in Spain.

First, we explain why a tax reform in Germany has negative spillovers on other countries. Then we continue to explain why spillovers are small.

In Germany labor taxes are lowered. This immediately creates incentives on the labor market. Thus effective employment increases. This has a positive effect on GDP, investment, consumption and the capital stock. An increase in GDP and consumption triggers a decrease in the trade balance over the short run. The reason why consumption grows more than GDP in the short run, which decreases the trade balance, is the following: the capital stock does not increase as fast as labor supply because of capital adjustment costs. Households are forward looking and anticipate future higher output. Consumption increases more immediately because households smooth consumption intertemporally. Germany imports

[21] In our simulations, we also considered changes in other taxes as closing instrument for policy reforms. The results are quantitatively similar and do not alter our conclusions. For the sake of space, we chose to confine ourselves presenting only the case of changes in lump-sum taxes as financing instrument.

more to cover the increased demand over the short run.
This has the following effect on other countries. First, their trade balance increases. Other countries export more to Germany, where demand is increased. Hence consumption and investment will decrease.[22] This leads to a decrease in the capital stock and GDP. As capital declines, the marginal product of labor declines. Hence wages are declining. This leads to reduced labor supply, contributing to the decline in GDP.
We now explain why spillovers are small. The only channel through which spillovers are transmitted is the trade channel. A reform in one country triggers a change in trade, leading to more exports or imports of goods and services. Goods and services are relatively mobile, but the net trade volumes remain small. For instance, the current account position of Germany, one of the largest in Europe, stands at about 7% of GDP. Hence changes in the trade balance, which affect other countries, are small compared to the changes in the entire economic activity of Germany. Moreover the total effects transmitted are distributed across all trade partners. Migration within the European Union would lead to bigger spillovers (see e.g. Clemens, 2011) but comes with societal challenges (see e.g. Borjas, 2015), and is not considered in this project.

[22] Another consistent angle is the following: as labor supply increases faster than the capital stock in Germany (due to capital adjustment costs), the increase in marginal product of capital in Germany increases returns for foreign investors, who shift some of their investments from their country to Germany.

	GER		ESP		Spillover %	
	1	FSS	1	FSS	1	FSS
Macroeconomics						
GDP (%)	0.612	0.934	-0.006	-0.016	0.980	1.713
Investment (%)	1.924	0.978	-0.077	-0.032	4.002	3.272
Capital Stock (%)	-0.001	0.978	-0.001	-0.032	100.000	3.272
Consumption (%)	1.170	0.991	-0.046	0.027	3.932	2.725
Assets (%)	1.998	0.821	-0.063	0.039	3.153	4.750
Trade Balance (%)	-0.429	0.168	0.040	-0.021	9.324	12.500
Interest Rate (%)	0.002	0.066	0.002	0.066	-	-
Public Finance						
Tax Ratio (pp)	-0.014	-0.015	0.000	0.000	0.000	0.000
Transfers to HH (pp)	-1.135	-1.118	-0.005	0.003	0.441	0.268
Labor Market						
Participation (pp)	0.173	0.204	-0.001	-0.003	0.578	1.471
Hours Worked (%)	0.196	0.233	-0.001	-0.002	0.510	0.858
Unemployment (pp)	-0.302	-0.357	0.001	0.004	0.331	1.120
Gross Wage Rate (%)	-0.848	-0.398	0.003	-0.020	0.354	5.025
Net Wage Rate (%)	2.839	3.298	0.003	-0.019	0.106	0.576
Taxes						
Consumption Tax (pp)	-	-	-	-	-	-
Worker Income Tax (pp)	-0.024	-0.024	-	-	-	-

Notes. 1 = year of impact, *FSS* = Final Steady State, (%) = changes in percentage from initial steady state, (pp) = changes in percentage points from initial steady state, *Tax Ratio* = government revenue over GDP, *Taxes* are average taxes over all age groups, *Spillover %*= percentage change in GDP (%) in ESP compared to change in GDP (%) in GER. This table shows the domestic effects and strongest spillover effects (in this case for Spain) for the case that Germany conducts a 20% labor tax cut, financed by lump-sum taxes.

Table 1.2: Spillovers From a Labor Tax Cut in Germany Financed by Lump-Sum Taxes

1.5.2 Simultaneous Labor Tax Cut

In this scenario we study the effects when all countries in our scope implement simultaneously a 20% labor tax cut which is financed by lump-sum taxes, one possible form of policy coordination. Taking spillovers into account, we want to compare outcomes with the single country scenario. The results indicate that simultaneous labor tax cuts are not beneficial: the increase in GDP is lower for Germany if the labor tax cut is performed in all countries than if only Germany implements the tax cut, as in section 1.5.1. This effect is slightly stronger over the short run. Table 1.3 displays the effects on GDP for Germany. In case of an area-wide simultaneous labor tax cut, German GDP is increasing 3.66% less in the short run and 3.03% less in the long run.

The main driver is the integrated capital market. The tax cut is an incentive to provide more labor, in both cases, which increases household income and consumption. When only one country performs a tax cut, the increase in consumption is supported by an increase in imports (see 1.5.1), which all other countries can cover with an increase in exports. When all countries perform the tax cut, they all would like to increase

imports. Only the rest of the world is in position to supply additional goods. On the goods market, there is thus a higher pressure when all countries perform the tax cut. Firms want to increase the capital stock in both cases, to keep a good capital-labor ratio, as labor supply increases. When all countries perform the tax cut, the pressure on the goods market is higher, so it is more expensive to increase the capital stock (which can be seen by a more than 4 times larger increase of the interest rate). As capital stock, a production factor, increases less with coordinated tax cuts, GDP increases less with coordinated tax cuts. In absolute terms, the difference between the single country case and the coordinated case is small (in the single country case Germany has a 0.934% increase in GDP, in the coordinated case a 0.907% increase). The fact that this form of coordination has quantitatively a small impact follows from the fact that spillover effects (without coordination) are small: if a reform in one country has small impact on other countries, then it does not really matter if other countries also do the same reform, quantitatively.
Hence we conclude that simultaneous implementation of a simple fiscal policy reform, namely a labor tax cut, is not beneficial. Nevertheless, a simultaneous implementation, where every participating country implements the policy reform at the same time, is not the only possible form of coordination. Precisely because of the quantitatively small spillover effects, other forms of fiscal policy coordination can be beneficial.

	GER tax reform		EU tax reform		Difference in %	
	1	FSS	1	FSS	1	FSS
GDP (%)	0.612	0.934	0.591	0.907	3.66	3.03
Interest Rate (%)	0.002	0.066	0.009	0.299		

Notes. 1 = year of impact, *FSS* = Final Steady State, (%) = changes in percentage from initial steady state. This table shows the effects on GDP for Germany if only Germany implements a tax cut (GER tax reform) and if all countries implement simultaneously the same tax cut (EU tax reform).

Table 1.3: Area-Wide Simultaneous Labor Tax Cut, Selected Outcomes for Germany

1.5.3 Asymmetric Shock to the Capital Stock

The scenarios discussed above have in common that the reforms are implemented in economically stable times. We now discuss scenarios where one or more economies are hit by a shock and such economically unstable times (crises) may require policy responses.
Let us consider the case where Germany is hit by an exogenous shock which destroys 20% of the capital stock, for instance an earthquake. Germany does not respond (yet) to the shock, as we want to investigate the spillover effects stemming from the shock alone. The government budget in Germany is balanced by lump-sum taxes, which are non distortive. Again, we take Germany as our benchmark scenario, as the spillovers are quantitatively the largest.
We find that spillovers from shocks are quantitatively larger than from simple policy reforms. As example, we provide details for the spillovers on Spain, where spillovers are quantitatively the largest. Table 1.4 summarizes our findings. After 10 periods, there is a 0.35% decrease in GDP for Spain. In Germany GDP decreases by 3.38% after 10 periods. Hence the spillovers in Spain amount to 10.3% of the effect in Germany. To compare: in the case of the labor tax reform in Germany spillovers in Spain amount to 2.1%. Hence the decrease in GDP is nearly 5 times stronger in case of a shock in Germany compared to a simple tax policy reform after 10 periods.
We first explain why there are spillovers. As a consequence of the negative shock the capital-labor ratio

decreases in Germany, which reduces wages. This creates negative incentives on the labor market and effective employment drops. Because both production factors (capital and labor) drop, GDP also drops. The drop in capital-labor ratio also increases the marginal product of capital (and ultimately the interest rate), so investment increases. As production is reduced and investment is increased, there is an increase in imports (for consumption and investment) and a simultaneous decrease in exports. Hence trade balance is decreasing.

The trade balance increases for other countries as there are more exports. Domestic consumption and investment decrease in turn, while investments increase in Germany. The marginal product of capital in Germany is indeed much higher, so foreign investors prefer to invest in Germany and not domestically. The capital stock thus also decreases in other countries. As the capital stock decreases, the marginal product of labor decreases and wages decrease as well. This has a negative effect on the labor supply and effective employment. As labor supply and capital decrease, GDP is likewise decreasing.

We next explain why spillovers are larger. The shock on the capital stock induces a strong reaction on the labor market (compared to the simple tax reform in section 1.5.1). Net wages decrease as adjustment to the change in marginal factor products, following the capital-labor ratio decrease. Then labor supply is reduced, as wages decrease. In case of a capital shock gross wages and hence net wages decrease by 0.37% after 10 periods, compared to a decrease by 0.016% after 10 periods in case 1.5.1. Effective employment decreases by 0.17% after 10 periods in case of a shock and by 0.009% in case 1.5.1. So labor market effects are significantly larger than in case of a policy reform. Furthermore the increase in the interest rate (2.3% compared to 0.1% in 1.5.1) reduces incentives for firms to invest in Spain. Part of the investment is crowded out in Spain and shifted to Germany (trade balance improves nearly 3 times more compared to 1.5.1). In combination, these effects induce a stronger decrease in the capital stock in Spain (0.58% compared to 0.026% in 1.5.1). Thus economic aggregates are more affected (e.g. GDP decreases by 0.35% after 10 periods compared to 0.018% in 1.5.1).

	K-shock to GER				Tax Cut in GER	
	GER		ESP		ESP	
	1	10	1	10	1	10
GDP (%)	-9.152	-3.384	-0.075	-0.350	-0.006	-0.018
Capital Stock (%)	-19.996	-7.540	0.006	-0.578	-0.001	-0.026
Eff. Employment (%)	-3.291	-1.124	-0.075	-0.174	-0.004	-0.009
Gross Wage (%)	-10.065	-3.587	0.084	-0.372	0.003	-0.016
Net Wage (%)	-9.843	-3.505	0.080	-0.350	0.003	-0.015
Trade Balance (%)	-7.008	-0.642	0.723	0.028	0.040	0.011
Interest Rate (%)	-0.013	2.305	-0.013	2.305	0.002	0.096

GDP Spillover %			
K-Shock to GER		Tax Cut in GER	
%ESP/GER		%ESP/GER	
1	10	1	10
0.8	10.3	0.9	2.1

Notes. 1 = year of impact, *10* = 10 years after impact, (%) = changes in percentage from initial steady state. *GDP Spillover %* = change of GDP in Spain over change of GDP in Germany. This table shows the domestic effects of a shock to the capital stock in Germany (K-shock to GER, GER), spillover effects to Spain (K-shock to GER, ESP) and spillover effects to Spain from a tax cut in Germany (Tax Cut in GER, ESP)

Table 1.4: Spillover Effects From a Shock on the German Capital Stock

1.5.4 Symmetric Shock to the Capital Stock

Next, we consider the case of a symmetric shock to all countries in our scope, which destroys 20% of the capital stock in each country. Budgets are again balanced by lump-sum taxes. We compare outcomes of this symmetric shock with the asymmetric shock in section 1.5.3.
For the respective countries, the negative effects of a symmetric shock are stronger than the effects of an asymmetric shock to one country. Table 1.5 shows that for Germany the negative impact on GDP is 22.6% larger in case of a symmetric shock to all countries after 10 periods.
In the asymmetric case all countries which are not hit by a shock can cover the increased demand for imports in Germany with more exports. This is does not hold for the symmetric case. Only the rest of the world is in position to increase exports. As the capital stock declines more in the symmetric case, the marginal product of labor declines more in this case. Hence wages are declining and labor supply is reduced more in the symmetric case. The decrease in GDP is larger in case of a symmetric shock, as both labor supply and capital are lower.

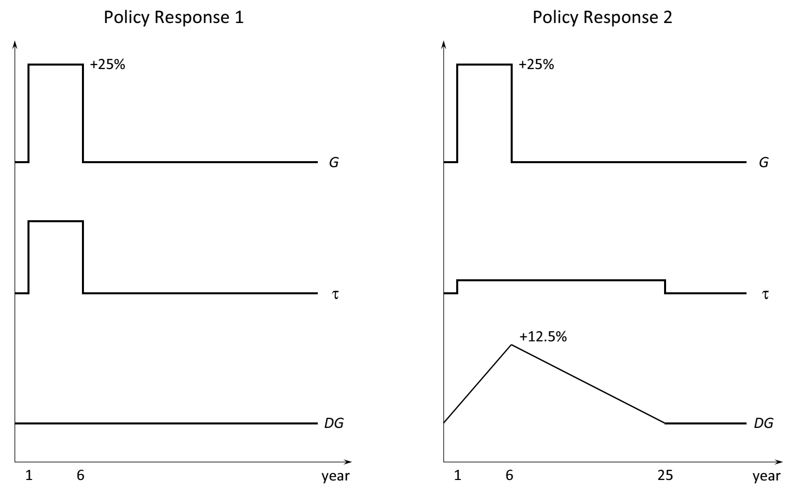
1.5.5 Asymmetric Shock to a Single Country with Policy Response

We continue our analysis with the simulation of large one-time exogenous shocks and consider different policy responses to the shock. We assume that Germany is hit by an exogenous shock which requires

	GER K-shock		EU K-shock		Difference in %	
	1	10	1	10	1	10
GDP (%)	-9.15	-3.38	-9.25	-4.15	1.12	22.63

Notes. 1 = year of impact, 10 = ten years after impact, (%) = changes in percentage from initial steady state. This table shows the effects on GDP for Germany if only Germany is hit by a shock to capital stock (GER K-shock) and if all countries are hit by the same shock to the capital stock (EU K-shock).

Table 1.5: Effects of an Area-Wide Shock to the Capital Stock on German GDP



Legend: G = public spending, τ = labor income tax, DG = public debt

Figure 1.2: Policy Responses R1 and R2

an increase in public spending (by 25%) to provide relief to households and firms.[23] We implement two different policies as reaction to the shock. The first policy option, which we label response 1, consists of an increase in public consumption over five years financed by an increase in labor income taxes to keep public debt constant. The second option, which we label response 2, consists of an increase in public consumption over 5 years, but the government is allowed to increase public debt over 6 years by 12.5%. Public debt then has to return to its initial level after 25 years. Budget balance in this case is achieved by a moderate increase in labor income taxes. Figure 1.5.5 provides a stylized representation of the two responses, displaying variations in government consumption, average labor income taxes and public debt. Coordination rules may prescribe implementation of response 1, of response 2 or leave the country hit by the shock free to choose.

We quantify spillovers from the interaction of the shock and the policy response and compare the outcomes of the two different policy responses.

Table 1.6 summarizes the results. We report the results for Germany (hit by a shock), for Spain (were spillovers are largest) and Poland (where spillovers are smallest). We find that the total loss in GDP due to the shock is smaller with response 2 for Germany. Average yearly GDP loss (over 25 years) is 0.54% with

[23] This measure is comparable to the support the German government provided its financial sector in the aftermath of the financial crisis. Up to 2012, the International Monetary Fund (2013) estimates the support to be 10.8% of GDP.

response 2 and 0.59% with response 1. Spillover effects on GDP can be large, certainly larger than from a simple fiscal policy reform. The negative effects on Spain amount to 24.4% of the effects in Germany. However the size of the spillovers differ by country (24.4% for Spain, 10.0% for Poland). Furthermore negative spillovers on GDP of other countries is smaller with response 2. The average yearly GDP loss for Spain is 0.14% with response 1 and 0.12% with response 2.

First we explain why response 2 dominates response 1 and why the spillover effects are larger with response 1 than with response 2. With response 1 labor taxes are increasing. Consequently effective employment is decreasing in Germany. Since labor supply declines and firms keep their capital-labor ratio optimal, they reduce their capital stock (with reduced investment). This leads to a decrease in the capital stock and GDP. With lower production inputs (capital and labor), GDP declines. This simultaneous increase in public consumption and decrease in GDP induces Germany to increase imports. Thus the trade balance is decreasing.

The trade balance increases for other countries. More exports lead to a decrease in consumption and investment. This has a negative effect on the capital stock. As capital declines, the marginal product of labor declines. Hence wages are declining. This negatively affects labor supply, which together with the drop in capital affects GDP.

With response 2, the government can increase public debt. There is no need to raise labor income taxes as much as in response 1. Because disutility of labor increases in a convex fashion, tax increases generate over-proportional reactions in the labor market, so the decrease in labor supply is weaker with response 2. The decrease in GDP is smaller with response 2.

Next we explain why spillovers are larger than in the case of a simple policy reform (as in section 1.5.1). The largest impact is for Spain (average yearly GDP loss of 0.14% when Germany is hit by a shock and uses response 1). As the German government increases public consumption to counterbalance the exogenous shock, the demand on the capital market is increased (crowding out of capital markets). The increase in demand is immediate and strong, following the shock in government consumption (2.8%-points of GDP). The strong initial drop in the trade balance of Germany illustrates this (-2%-points of GDP). By contrast, the increase in demand in the capital market in case of a fiscal reform is gradual, even if it is of the same magnitude (the capital stock increases close to 3.5%-points of GDP over the long run, but only 1%-point of GDP after the first 5 years). The increase in savings from German households is almost sufficient to respond to the increase in capital demand. The assistance of foreign investors is barely needed, as can bee seen with the small variation in trade balance in Germany (never more than -0.3%-points of GDP). In case of a shock, the increase in demand on the capital market has a stronger effect on the interest rate (e.g. +0.4% after 7 periods in case of a shock with response 1, compared to +0.1% in case 1.5.1). This reduces incentives for firms to invest in Spain. Also, the crowding out effect means that part of the production from Spain is exported Germany, which further reduces capital stock replacement. The capital stock in Spain declines (10 times larger decrease after 7 periods in this case, compared to case 1.5.1). As the interest rate increases and the capital stock declines, the marginal product of labor decreases (gross wage rate maximum decline of 0.16% in Spain in this case compared to 0.02% in case 1.5.1). This puts pressure on the wage. To maintain finances, the Spanish government increases labor taxes, hence net wages are decreasing (stronger than in case of a policy reform: 0.4% in this case instead of 0.015% in case 1.5.1). As a result labor supply drops (effective employment as much as 0.15% in this case compared to almost nothing in case of 1.5.1). Thus GDP is more affected than in case of a simple tax reform (maximum loss of 0.2% in this case for Spain, given labor supply decline of 0.15% and capital stock drop).

	GER		ESP		PL	
	R1	R2	R1	R2	R1	R2
	Period 7		Period 7		Period 7	
Macroeconomics						
GDP (%)	-0.447	-0.579	-0.198	-0.161	-0.090	-0.074
Capital Stock (%)	-0.523	-0.461	-0.315	-0.247	-0.195	-0.155
Trade Balance (%)	0.667	0.412	-0.106	-0.067	-0.058	-0.038
Interest Rate (%)	0.426	0.301	0.426	0.301	0.426	0.301
Labor Market						
Gross Wage Rate (%)	-0.071	0.245	-0.159	-0.118	-0.101	-0.079
Net Wage Rate (%)	-0.859	-1.892	-0.338	-0.278	-0.156	-0.127
Eff. Employment (%)	-0.247	-0.527	-0.123	-0.101	-0.055	-0.045
Yearly AVG Change						
GDP (%)	-0.591	-0.543	-0.144	-0.120	-0.059	-0.050

GDP Spillover %			
%ESP/GER		%PL/GER	
R1	R2	R1	R2
24.4	22.1	10.0	9.2

Notes. (%) = changes in percentage from initial steady state, *Yearly AVG Change* = yearly average changes over the medium run (25 years after impact), *GDP Spillover %* = yearly average change of GDP in Spain (resp. Poland) over yearly average change of GDP in Germany . This table shows effects of a shock to Germany where Germany reacts by increasing public spending, as well as spillovers to Spain and Poland.

Table 1.6: Effects of a Spending Shock to Germany and Spillovers to Other Countries

1.5.6 Symmetric Shock to All Countries with Policy Response

This scenario is very similar to the case presented in 1.5.5, except that all countries are hit by the same exogenous shock and all provide relief to households and firms, increasing public spending by 25%. We investigate the difference when all countries implement response 1 and when they implement response 2. We find that response 2 is better than response 1 for all countries in our scope. Coordination rules may impose response 1 or response 2 to all countries. Our simulations show that rules which prevent response 2 would be detrimental. As example we report results for Germany in Table 1.7. The average loss in GDP amounts to 0.85% with response 2 and to 0.94% with response 1 over the medium run (25 years). A symmetric shock generates larger negative effects for the respective country than a shock to the country alone. For Germany the average loss in GDP in case of a symmetric shock and response 2 is 0.85% and 0.54% in case of an asymmetric shock to Germany.

First we explain why the symmetric shock is worse than a shock to the country alone. The main driver is the capital market. The reason capital drops more with a symmetric shock is a stronger crowding out effect in the capital (goods) market. The crowding out effect happens in all cases: as government increases its investment (consumption), it draws more from the goods market, making it harder for firms to draw from this market. Firms therefore reduce investment. When the shock only happens in one country, the pressure on the integrated capital market is lower, so the reduction in firm investment (and hence capital stock) is smaller. In this case, there is only one country which increases government investment and puts pressure on the capital market. As the capital stock is decreasing more in case of a symmetric shock, the optimal capital labor ratio and the marginal product of labor are more affected. Furthermore labor income taxes increase less in case of an asymmetric shock to Germany, because production, and thus the wage basis, are dropping less. So in that case, the negative incentives on the labor market are weaker. This amplifies the described effect.

Next we explain why a simultaneous response of all countries using response 2 is economically superior to a simultaneous response of all countries using response 1. The mechanism is the same as in section 1.5.5. Keeping constant public debt as target and simultaneously increasing public consumption to counterbalance a shock lead to a strong increases in labor income taxes. Hence the negative reaction on the labor market is stronger. This has a stronger effect on macroeconomic aggregates such as GDP and capital stock. In case the governments increase public debt, the effects are similar but as labor income taxes are not increased dramatically, the reactions are smaller.

We also note that the gains from implementing response 2 are larger if all countries are hit by a shock, than if only one country is hit by a shock, to a limited extent. There is a 10.7% gain in case of a symmetric shock compared to a 8.8% gain in case of an asymmetric shock (see Table 1.7).

The explanation is the following: With a symmetric shock, the crowding out effect is larger, because all countries are hit and little help from foreign investors takes place. When public debt cannot (temporarily) increase, labor income taxes need to be increased more, which reduces labor supply incentives. This increases the capital-labor ratio, decreases the marginal product of capital and thus exacerbates the crowding out effect (investment in firms becomes even less interesting). The symmetric shock with response 1 combines both negative effects: little help from foreign investors (because in the symmetric case, all countries are hit) and no help from intertemporal smoothing (because public debt is not allowed to increase). While response 2 is more advantageous with an asymmetric shock compared to response 1 (see section 1.5.5), it becomes even more advantageous with a symmetric shock.

	Shock to GER			Shock to EU		
	R1	R2	%	R1	R2	%
GDP (%)	-0.591	-0.543	8.84	-0.935	-0.845	10.65

Notes. R1 = response 1, R2 = response 2, % = Gain from response 2 in percentage, (%) = changes in percentage from initial steady state, *GDP* = average yearly change in GDP over the medium run (25 years). This table shows the yearly average loss in GDP for Germany for two cases: *Shock to GER* = Germany is hit by shock and increases public spending (see 1.5.5). *Shock to EU* = all countries are hit by a shock and increase public spending (see 1.5.6).

Table 1.7: Effects of Different Spending Shocks on the GDP of Germany

1.6 Conclusions

We develop a rich OLG-model which is calibrated for a representative sample of the EU28 countries and two stylized Rest-of-the-World countries in a multi-country setting. We use the model to quantify spillovers within the EU stemming from standard tax policy reforms, exogenous shocks and combinations of shocks and policy reforms. Specifically, we consider labor tax reforms and large one-time shocks to the capital stock or to government spending, typical for times of economic distress. We also compare some examples of fiscal policy coordination, without considering all possible forms of coordination.

We find that spillovers are small in case of standard labor tax policy reforms, when no exogenous shocks take place, and that a simultaneous area-wide implementation of such fiscal policy reforms is not beneficial. However spillovers are bigger in case of large, one-time unexpected shocks, as GDP losses in shock-free countries can amount to 24% of the losses in countries hit by a shock. Such sizable spillovers provide a rationale for policy coordination. When these shocks take place, negative economic consequences can be reduced if public debt is allowed to increase temporarily and come back to its initial level at a later point. The benefits from this policy option are larger when more than one countries are hit by a shock. Under the conservative assumption on interest spread and labor elasticities that we consider gains are however limited: the GDP losses being reduced by 10% or less when public debt is allowed a temporary increase. For many countries of the European Union, however, such temporary increases in public debt would not be compatible with the current coordination rules, which impose an upper limit on fiscal deficits and public debts. Countries which have not been able to respect these rules in the past are usually in a weaker economic position, and less likely to have the room for a temporary increase in public debt if they are hit again by an adverse shock. Over time, countries with bad luck or unsound fiscal public finance management or both may find themselves in growingly weaker economic position because of coordination rules, rather than their own economic policy (vicious circle). The European Union fiscal rules may thus benefit from an adjustment, seeking to differentiate cases of unsound public finance management from other cases.

The study provides a modelling framework and uses it to explore spillovers and different forms of policy coordination. Altogether, for the cases that we consider, our exploration exhibited visible spillovers but only small gains of coordination. Future research can further make use of the framework to investigate other spillover sources and alternative forms of policy coordination. In particular, policy coordination gains may be larger with more sophisticated coordination rules.

Chapter 2

Asymmetric Habits in Asset Pricing

2.1 Introduction

Consumption-based asset pricing models are standard in finance for determining asset prices and returns.[1] This model-class features a sound theoretical foundation, but also shortcomings in empirical validation. Mehra and Prescott (1985) calibrate a consumption-based asset pricing model in the style of Lucas (1978) to U.S. data from 1889-1978 and show that the model is not able to rationalize asset return statistics for any reasonable parameter combination.[2] This finding is known as "*the equity premium puzzle.*" Since then, a vast literature emerged over the decades in response to the equity premium puzzle. Still, this chapter of research is not concluded yet. Mehra and Prescott (2003) and Mehra (2012) argue that a completely satisfactory resolution is lacking, although a variety of different approaches and explanations exist. Nevertheless, a particular strand of research has achieved remarkable success. Integrating habit formation into the preference structure of consumption-based asset pricing models proves to enhance results significantly in comparison to standard time-separable preferences. Seminal contributions in this respect are those of Abel (1990), Constantinides (1990), and Campbell and Cochrane (1999). For all their prominence, these habit formation models are not fully successful in explaining the equity premium puzzle. Abel (1990) nests two different habit specifications into his model: internal and external habit formation.[3] Applying external habits, the model generates a larger interest rate spread than the standard model; but the riskless interest rate is too high compared to the data. Under internal habit formation, the model produces a higher interest rate spread, but both interest rates do not match their empirical counterparts. Constantinides (1990) introduces internal habits in a neoclassical growth model. The consumption growth process which solves for equilibrium is consistent with the data and the required risk aversion parameter can be considered as plausible.[4] However, in this specific formulation consumption may not drop below the

[1]Early contributions developing the class of consumption-based assset pricing models include Rubinstein (1976), Breeden and Litzenberger (1978), Breeden (1979), and Lucas (1978). They build on previous work of Sharpe (1964), Lintner (1965), and Merton (1973). For a more detailed and recent survey see Breeden et al. (2015).

[2]While in the data, the return premium on equity is approximately 6pp, the standard model produces a maximum premium of about 0.35pp for risk aversion $\alpha \in (0, 10)$ and subjective time discount $\beta \in (0, 1)$ (see also footnote 4). Moreover, the return on the riskless asset is considerably higher than in the data. Weil (1989) discusses this additional phenomenon in detail.

[3]With internal habits, the household derives utility from consumption relative to its own past consumption; with external habits, the household derives utility from consumption relative to aggregate (or average) consumption in the economy. This difference is important, as only internal habits enter into the optimization problem of the household. See Campbell (2000) for a more detailed discussion on differences in habit formation specifications.

[4]It is very hard, if not impossible, to state an unambiguous interval for reasonable values of risk aversion. Mehra and Prescott (1985) review the literature on this topic and propose an interval ranging from 1 to 10. This proposal has been

subsistence level of consumption; and the equilibrium subsistence level of about 80% of past consumption is unrealistically high.[5] Moreover, Chapman (2002) shows that the results are not robust: if the Constantinides (1990) model is calibrated to more recent data, it fails to match data statistics with a reasonable risk aversion parameter.

Campbell and Cochrane (1999) consider a representative agent endowment economy with external habit formation. Risk aversion is time varying and related to the surplus consumption ratio.[6] As the surplus consumption ratio approaches the habit level, risk aversion increases. The model is able to solve for the cyclicality of asset return, but as Campbell (2000) points out, the Campbell and Cochrane (1999) model does not sucessfully solve the equity premium puzzle, because on average, risk aversion is too high. Furthermore Ljungqvist and Uhlig (2007) show that welfare gains are possible, if the agent destroys part of its endowment.

The intuition for the approach we develop in this chapter, is derived from the empirical work of Shea (1995a,b) and Garcia et al. (1997). They find empirical evidence for asymmetric excess sensitivity in consumption; in both macro and micro level data. Asymmetric excess sensitivity means that consumption is more sensitive to predictable income declines than to predictable income increases. Summarized, their findings suggest a rejection of the life-cycle/permanent income hypothesis, inconsistency with myopic or liquidity constrained behavior; but a general consistency with the concept of loss aversion, and a role for time non-separable preferences.

Building intuition from these empirical findings, we develop a habit preference structure and apply it to a standard consumption-based asset pricing model economy - similar to Mehra and Prescott (1985) - to take a step forward on the equity premium puzzle. In particular we consider the idea of an asymmetric utility function, stemming from the concept of loss aversion, and combine it with the idea of time non-separable preferences - habit formation - to explicitly model asymmetric habit formation.[7] The appeal of our approach is its simplicity: we advance a standard consumption-based asset pricing model with simple, intuitively comprehensible preferences.

We test asymmetric habit preferences in ratio and in difference formulation to ensure comparability with Abel (1990) and, at least to some extent, with Constantinides (1990). Using asymmetric habit formation, we are able to match historically observed interest rates with reasonable risk aversion in both formulations. These results indicate that asymmetric habits can improve on both studies. In comparison to Abel (1990) we match interest rates with the data using low risk aversion. In comparison with Constantinides (1990), our model allows for a more comprehensive domain of utility and we match interest rates with the data using low risk aversion; even if we calibrate the model to more recent data as used by Chapman (2002).

The remainer of this chapter is organized in the following way: section 2.2 presents the model, section 2.3 the solution method. In section 2.4 we present the data and calibration strategy. Results are presented in section 2.5 and discussed in section 2.6. Section 2.7 concludes.

implicitly accepted, since all studies concerned with the equity premium puzzle try to solve for the interest rate spread with a risk aversion parameter within this interval. See for example the discussion in Mehra (2012).

[5]Kocherlakota (1996), for instance, agrees with this argument.

[6]The surplus consumption ratio is the part of consumption above the habit level. Utility is not defined for consumption below habit level.

[7]The idea of loss aversion originates in the seminal work of Kahneman and Tversky (1979); subsequent contributions in the asset pricing literature utilize the concept of prospect theory; see for example Benartzi and Thaler (1995), Barberis et al. (2001). Although these models feature similar ideas, a distinguishing feature of our approach is that we do not consider a notion of wealth as the agents reference point, but rather derive a reference point from habit formation. Barberis (2013) elaborates on the difficulties in defining a reference point in relation to wealth.

2.2 Model

Consider a consumption-based asset pricing model in the style of Lucas (1978) or Mehra and Prescott (1985). Assume an infinitly lived representative agent stands in for a large number of households. This agent has time-non separable preferences over consumption and wishes to maximize discounted expected utility

$$\mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t u\left(c_t,\, c_{t-1}\right)\right] \tag{2.1}$$

where c_t is period consumption, β is the subjective discount factor, and $\mathbb{E}_0\left[\,\right]$ denotes the expectation operator conditional on information available at time 0. Habits are formed internally. That means the representative agent cares about consumption relative to its own past consumption. Thus the agent derives utility from changes in consumption. Additionally assume that habits are asymmetric. Technically, that means negative marginal utility of a loss is larger than positive marginal utility of an equally sized gain; intuitively, the agent dislikes a loss in consumption more, than it values a gain of equal size. Let $x_t = \frac{c_t}{c_{t-1}}$ be the gross growth rate of consumption and $g:\,\mathbb{R}_+\to\mathbb{R}$ of the form

$$g\left(x_t\right) = \left[1+\mathbb{I}_{(x_t<1)}\lambda\right]\frac{x_t^{1-\sigma}-1}{1-\sigma} \tag{2.2}$$

where σ measures risk aversion, $\lambda > 0$ the strength of habit asymmetry, and $\mathbb{I}$ is an indicator function

$$\mathbb{I}_{(x_t<1)} = \begin{cases} 0 & \text{if}\, x_t \geq 1 \\ \\ 1 & \text{if}\, x_t < 1 \end{cases}$$

Define $u\left(c_t,\, c_{t-1}\right) = g\left(x_t\right)$. The only source of income is exogenous, stochastic, and assumed to follow an ergodic Markov process. Market clearing in equilibrium requires consumption to equal income. Hence the assumptions made on income also apply to consumption - respectively its growth rate. Let the growth rate of consumption x_t follow an erdogic Markov process, concretely an AR (1) process of the form

$$\ln x_{t+1} \;=\; \alpha + \rho \ln x_t + \varepsilon_t \qquad \varepsilon_t \sim \mathcal{N}\left(0,\, \sigma_\varepsilon^2\right) \tag{2.3}$$

The agent maximizes 2.1 subject to a budget constraint

$$c_t + p_t s_{t+1} \;\leq\; \Pi_t s_t \tag{2.4}$$

where p_t is the price, s_t the shareholding of the available asset, and Π_t the payoff of the available asset. Consumption is assumed to be the numéraire good. Solving the optimization problem and combining the first order conditions we derive the Euler equation

$$\left\{g'\left(x_t\right)\frac{1}{c_{t-1}} - \beta\mathbb{E}_t\left[g'\left(x_{t+1}\right)\frac{c_{t+1}}{c_t^2}\right]\right\}p_t \;=\; \beta\mathbb{E}_t\left\{\left(g'\left(x_{t+1}\right)\frac{1}{c_t} - \beta\mathbb{E}_{t+1}\left[g'\left(x_{t+2}\right)\frac{c_{t+2}}{c_{t+1}^2}\right]\right)\Pi_{t+1}\right\} \tag{2.5}$$

which implies that in equilibrium the marginal cost of buying an additional asset is offset by the expected marginal payoff of that asset. Rearranging the Euler equation yields the fundamental pricing equation, familiar in consumption-based asset pricing

	price	payoff Π_{t+1}	gross return R_{t+1}
stock	p_t	$p_{t+1}+d_{t+1}$	$\frac{p_{t+1}+d_{t+1}}{p_t}$
bond	p_t^f	1	$\frac{1}{p_t^f}$

Table 2.1: Asset Prices, Payoffs, and Returns

$$p_t = \beta \mathbb{E}_t \left\{ \frac{g'\left(x_{t+1}\right)\frac{1}{c_t} - \beta \mathbb{E}_{t+1}\left[g'\left(x_{t+2}\right)\frac{c_{t+2}}{c_{t+1}^2}\right]}{g'\left(x_t\right)\frac{1}{c_{t-1}} - \beta \mathbb{E}_t\left[g'\left(x_{t+1}\right)\frac{c_{t+1}}{c_t^2}\right]} \Pi_{t+1} \right\} \tag{2.6}$$

which states that the equilibrium price of an asset equals its expected discounted payoff. Let us consider two different types of assets separately: a risky asset, comparable to a stock, and a relatively safe asset, comparable to a one-period riskless bond.
If the representative agent buys a stock today, its next-period payoff equals its price p_{t+1} plus a dividend d_{t+1}. In contrast, the safe asset "guarantees" a next-period payoff of 1 (unit of consumption). We can write the next-period gross return R_{t+1} on any asset as the payoff-price ratio $\frac{\Pi_{t+1}}{p_t}$. Table 2.1 summarizes prices, payoffs, and returns for the two different assets taken into consideration.

2.3 Solution Procedure

We rely on standard techniques in dynamic macroeconomics to solve our model in two steps.[8] First, we rewrite the asset price equations in recursive fashion to express asset prices as functions of the state x. Second, we use finite-state discrete Markov chain approximation as in Mehra and Prescott (1985), but we calculate a richer transition matrix - following Tauchen (1986) - and solve for unconditional expected returns of the two different assets.

2.3.1 Recursive Formulation

2.3.1.1 Risky Asset

Recall the fundamental price equation 2.6, insert the payoff of the risky asset from table 2.1, and use the functional form of $g(x)$ from 2.2. Then equation 2.6 reads

$$p_t = \beta \mathbb{E}_t \left\{ \frac{\frac{1}{c_{t+1}}\left[\left(1+\mathbb{I}_{(x_{t+1}<1)}\lambda\right)x_{t+1}^{1-\sigma} - \beta \mathbb{E}_{t+1}\left(\left(1+\mathbb{I}_{(x_{t+2}<1)}\lambda\right)x_{t+2}^{1-\sigma}\right)\right]}{\frac{1}{c_t}\left[\left(1+\mathbb{I}_{(x_t<1)}\lambda\right)x_t^{1-\sigma} - \beta \mathbb{E}_t\left(\left(1+\mathbb{I}_{(x_{t+1}<1)}\lambda\right)x_{t+1}^{1-\sigma}\right)\right]} \left(p_{t+1}+d_{t+1}\right) \right\}$$

We want to derive the price-dividend ratio of the risky asset, hence divide by d_t

$$\frac{p_t}{d_t} = \beta \mathbb{E}_t \left\{ x_{t+1}^{-1} \frac{\left[\left(1+\mathbb{I}_{(x_{t+1}<1)}\lambda\right)x_{t+1}^{1-\sigma} - \beta \mathbb{E}_{t+1}\left(\left(1+\mathbb{I}_{(x_{t+2}<1)}\lambda\right)x_{t+2}^{1-\sigma}\right)\right]}{\left[\left(1+\mathbb{I}_{(x_t<1)}\lambda\right)x_t^{1-\sigma} - \beta \mathbb{E}_t\left(\left(1+\mathbb{I}_{(x_{t+1}<1)}\lambda\right)x_{t+1}^{1-\sigma}\right)\right]} \left(\frac{p_{t+1}}{d_t} + \frac{d_{t+1}}{d_t}\right) \right\}$$

[8] Standard textbooks include for instance Ljungqvist and Sargent (2004).

By definition $c_{t+1} = x_{t+1}c_t$; and since in equilibrium it must hold that $c_t = d_t$, we can substitute for d_t on the RHS

$$\frac{p_t}{d_t} = \beta\mathbb{E}_t\left\{x_{t+1}^{-1}\frac{\left[\left(1+\mathbb{I}_{(x_{t+1}<1)}\lambda\right)x_{t+1}^{1-\sigma} - \beta\mathbb{E}_{t+1}\left(\left(1+\mathbb{I}_{(x_{t+2}<1)}\lambda\right)x_{t+2}^{1-\sigma}\right)\right]}{\left[\left(1+\mathbb{I}_{(x_t<1)}\lambda\right)x_t^{1-\sigma} - \beta\mathbb{E}_t\left(\left(1+\mathbb{I}_{(x_{t+1}<1)}\lambda\right)x_{t+1}^{1-\sigma}\right)\right]}x_{t+1}\left(\frac{p_{t+1}}{d_{t+1}}+1\right)\right\}$$

and simplify to

$$\frac{p_t}{d_t} = \beta\mathbb{E}_t\left\{\frac{\left[\left(1+\mathbb{I}_{(x_{t+1}<1)}\lambda\right)x_{t+1}^{1-\sigma} - \beta\mathbb{E}_{t+1}\left(\left(1+\mathbb{I}_{(x_{t+2}<1)}\lambda\right)x_{t+2}^{1-\sigma}\right)\right]}{\left[\left(1+\mathbb{I}_{(x_t<1)}\lambda\right)x_t^{1-\sigma} - \beta\mathbb{E}_t\left(\left(1+\mathbb{I}_{(x_{t+1}<1)}\lambda\right)x_{t+1}^{1-\sigma}\right)\right]}\left(\frac{p_{t+1}}{d_{t+1}}+1\right)\right\} \tag{2.7}$$

2.3.1.2 Riskless Asset

Recall the fundamental price equation 2.6, insert the payoff of the riskless asset from table 2.1, and use the functional form of $g(x)$ from 2.2. Then 2.6 reads

$$p_t^f = \beta\mathbb{E}_t\left\{x_{t+1}^{-1}\frac{\left[\left(1+\mathbb{I}_{(x_{t+1}<1)}\lambda\right)x_{t+1}^{1-\sigma} - \beta\mathbb{E}_{t+1}\left(\left(1+\mathbb{I}_{(x_{t+2}<1)}\lambda\right)x_{t+2}^{1-\sigma}\right)\right]}{\left[\left(1+\mathbb{I}_{(x_t<1)}\lambda\right)x_t^{1-\sigma} - \beta\mathbb{E}_t\left(\left(1+\mathbb{I}_{(x_{t+1}<1)}\lambda\right)x_{t+1}^{1-\sigma}\right)\right]}\right\} \tag{2.8}$$

2.3.2 Approximation

Since we are interested in equilibrium prices and returns, the time subscript can be dropped as equilibrium values are time invariant by definition. Let the state variable x take on values $x \in \{\xi_1, \dots, \xi_n\}$ and let $\mathbb{P}\left(x_{t+1} = \xi_j \,|\, x_t = \xi_i\right) = \phi_{ij}$ be the transition probability from state i to j.

2.3.2.1 Risky Asset

Given transition probabilities and discrete state space we can define the price-dividend ratio 2.7 in state i as $w_i \equiv \frac{p}{d}\left(\xi_i\right)$ such that

$$w_i = \beta\sum_j \phi_{ij}\left\{\frac{\left[1+\mathbb{I}_{(\xi_j<1)}\lambda\right]\xi_j^{1-\sigma} - \beta\sum_k \phi_{jk}\left[1+\mathbb{I}_{(\xi_k<1)}\lambda\right]\xi_k^{1-\sigma}}{\left[1+\mathbb{I}_{(\xi_i<1)}\lambda\right]\xi_i^{1-\sigma} - \beta\sum_l \phi_{il}\left[1+\mathbb{I}_{(\xi_l<1)}\lambda\right]\xi_l^{1-\sigma}}\left(w_j+1\right)\right\} \tag{2.9}$$

From 2.9 we see that the equation for the price-dividend ratio takes the form

$$w = Aw + b$$

where $A \in \mathbb{R}^{n\times n}$ and $b \in \mathbb{R}^{n\times 1}$, in particular

$$A_{ij} = \beta\frac{\phi_{ij}\left\{\left[1+\mathbb{I}_{(\xi_j<1)}\lambda\right]\xi_j^{1-\sigma} - \beta\sum_k \phi_{jk}\left[1+\mathbb{I}_{(\xi_k<1)}\lambda\right]\xi_k^{1-\sigma}\right\}}{\left[1+\mathbb{I}_{(\xi_i<1)}\lambda\right]\xi_i^{1-\sigma} - \beta\sum_l \phi_{il}\left[1+\mathbb{I}_{(\xi_l<1)}\lambda\right]\xi_l^{1-\sigma}} \tag{2.10}$$

$$b_i = \beta\sum_j \phi_{ij}\frac{\left\{\left[1+\mathbb{I}_{(\xi_j<1)}\lambda\right]\xi_j^{1-\sigma} - \beta\sum_k \phi_{jk}\left[1+\mathbb{I}_{(\xi_k<1)}\lambda\right]\xi_k^{1-\sigma}\right\}}{\left[1+\mathbb{I}_{(\xi_i<1)}\lambda\right]\xi_i^{1-\sigma} - \beta\sum_l \phi_{il}\left[1+\mathbb{I}_{(\xi_l<1)}\lambda\right]\xi_l^{1-\sigma}} = \sum_j A_{ij} \tag{2.11}$$

The solution to this problem is given by

$$w = (I - A)^{-1} b$$

where $w \in \mathbb{R}^{n \times 1}$ and $I \in \mathbb{R}^{n \times n}$ is the Identity matrix. The price-dividend ratio is now used to calculate returns. First, lets calculate the expected period return of the risky asset in state i, if next period is j. We can make use of the definition of the price-dividend ratio $w_t = \frac{p_t}{d_t}$ and the equilibrium condition $d_t = c_t$ to re-write the return on the risky asset from table 2.1 as

$$r_{ij}^e = \frac{(w_j + 1)}{w_i} \xi_j \qquad \forall i, j = 1, \ldots, n \tag{2.12}$$

which is the period return in state i, if the next period is j. Now we can sum over states j to determine the expected period return in state i

$$R_i^e = \sum_{j=1}^{n} \phi_{ij} r_{ij}^e \tag{2.13}$$

Finally, to determine the unconditional expected return on the risky asset we have to compute and apply stationary probabilities. Let $\pi \in \mathbb{R}^{n \times 1}$ be the vector of stationary transition probabilities.[9] Then

$$R^e = \sum_{i=1}^{n} \pi_i R_i^e \tag{2.14}$$

2.3.2.2 Riskless Asset

Analogously to the risky asset, we use transition probabilities and discrete state space to write the price of the riskless asset

$$p_i^f = \beta \sum_j \phi_{ij} \left\{ \xi_j^{-1} \frac{\left[1 + \mathbb{I}_{(\xi_j < 1)} \lambda\right] \xi_j^{1-\sigma} - \beta \sum_k \phi_{jk} \left[1 + \mathbb{I}_{(\xi_j < 1)} \lambda\right] \xi_k^{1-\sigma}}{\left[1 + \mathbb{I}_{(\xi_i < 1)} \lambda\right] \xi_i^{1-\sigma} - \beta \sum_j \phi_{il} \left[1 + \mathbb{I}_{(\xi_l < 1)} \lambda\right] \xi_l^{1-\sigma}} \right\} \tag{2.15}$$

and solve for the (certain) return on the riskless asset in state i

$$R_i^f = \frac{1}{p_i^f}$$

We then apply stationary transition probabilities $\pi \in \mathbb{R}^{n \times 1}$ to determine the unconditional expected return on the riskless asset

$$R^f = \sum_{i=1}^{n} \pi_i R_i^f$$

[9] The stationary transition probabilities $\pi \in \mathbb{R}^{n \times 1}$ (i.e. equilibrium transition probabilities) are derived from $\pi = \Phi^T \pi$ and satisfy $\sum_{i=1}^{n} \pi_i = 1$; Φ^T is the transpose of the transition probability matrix.

Time	% Consumption growth		% Return on riskless security		% Return on Stock		% Risk premium	
	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
1889-1978	1.83	3.57	0.80	5.67	6.98	16.54	6.18	16.67
1949-2000	2.07	1.23	1.74	1.73	10.46	17.37	8.73	17.41

Note. Source: Mehra and Prescott (1985) and Chapman (2002)

Table 2.2: Aggregate US-Statistics

Parameter	Interpretation	$\text{Value}_{1889-1978}$	$\text{Value}_{1949-2000}$
$\bar{x}$	Mean of consumption growth	1.018	1.023
x	Consumption growth grid	$[0.89, 1.14]$	$[0.98, 1.07]$
ρ	First-order serial correlation of consumption growth	$\{-0.14, 0\}$	0.32
σ_ε	Standard deviation of consumption growth	0.036	0.012
β	Subjective time discount factor	0.99	0.99
λ	Strength of asymmetry in habit formation	> 0	> 0

Table 2.3: Model Calibration

2.4 Data and Calibration

We use two different datasets to calibrate and test our model. The first dataset covers the time period from 1889-1978 and is used by Mehra and Prescott (1985). The second dataset covers the time period from 1949-2000 and is used by Chapman (2002). Table 2.2 reports summary statistics from the mentioned studies and displays the equity premium.

For the sake of accuracy, we did not rely on the reported summary statistics; instead we used the original datasets and performed our own calculations to derive the corresponding calibrations.[10] There are some differences between our own calculations and the provided statistics. In contrast to Mehra and Prescott (1985) we find that serial correlation is insignificant for that specific time period. In contrast to Chapman (2002) we find that average consumption growth is somewhat higher than reported.[11] Table 2.3 displays the two different calibrations we use in this chapter.

To model the discrete state space, we construct a 20-point grid of consumption growth around its mean, ranging from 3.5 standard deviations below to 3.5 standard deviations above the mean. The transition probabilities ϕ_{ij} and the corresponding transition matrix $\Phi \in \mathbb{R}^{20\times 20}$ are calculated following the procedure of Tauchen (1986).

2.5 Results

Using parameters from Table 2.3 we solve the model for a sequence of values of risk aversion σ and asymmetry strength λ. Moreover, we implement the idea of asymmetric habits in difference formulation, to be comparable to Constantinides (1990).[12] Table 2.4 shows the equilibrium returns on the riskless and risky asset for the different setups.[13]

With risk aversion $\sigma = 1.117$ and asymmetry strength $\lambda = 0.002$, the model closely resembles the historically observed interest rate spread and corresponding mean interest rates from 1889-1978. In comparison, Abel (1990) reports an equity premium of 7.37pp for a similar value of risk aversion, but both interest

[10]The original dataset from Mehra and Prescott (1985) is available online: http://www.academicwebpages.com/preview/mehra/re

σ	$\mathbb{E}[R^e]$	$\mathbb{E}[R^f]$	Risk Premium	λ	β
A. Calibration to data from 1889-1978, ratio formulation					
1.117	6.93	0.90	6.03	0.002	0.99
B. Calibration to data from 1949-2000, ratio formulation					
0.996	10.42	1.74	8.68	0.008	0.99
1.022	10.43	1.75	8.68	0.007	0.99
C.Calibration to data from 1889-1978, difference formulation					
1.14	7.01	0.81	6.2	0.002	0.992
D. Calibration to data from 1949-2000, difference formulation					
1.01	10.57	1.74	8.83	0.047	0.97

Notes. $\mathbb{E}[R^e]$= unconditional expected return on the risky asset in %, $\mathbb{E}[R^f]$= unconditional expected return on the riskless asset in %, Risk Premium = $\mathbb{E}[R^e] - \mathbb{E}[R^f]$, σ= risk aversion, β = subjective time discount factor, λ = asymmetry parameter

Table 2.4: Unconditional Expected Returns

rates do not match the data (the riskless rate being 1.93%). In addition, our specification is robust to the more recent dataset from 1949-2000 with $\sigma = 1.022$ and $\lambda = 0.007$. Furthermore, using asymmetric habits in difference formulation, our model replicates the interest rate spread and corresponding mean interest rates for the time period 1889-1978 with $\sigma = 1.14$, $\lambda = 0.002$, and for the time period 1949-2000 with $\sigma = 1.01$, $\lambda = 0.047$. In comparison, Constantinides (1990) solution requires risk aversion of 2.81 and Chapman (2002) reports risk aversion larger than 10 for the calibration to data from 1949-2000.
Similar to Abel (1990), we found our results to be sensitive with respect to several parameters. If we allow for negative serial correlation in the calibration to data from 1889-1978, the model is not able to solve for the mean interest rates consistent with data. Moreover, the interest rates are sensitive to the width of the consumption growth grid. Intuitively, a wider grid includes more adverse states of the world which creates more risk. This has an effect on expected marginal utility and hence on prices and returns. On the other hand, higher serial correlation in consumption growth improves predictability and reduces uncertainty.[14]

2.6 Discussion

The objective of the representative agent is to smooth consumption over time and different states of the world. Assets are an insurance against this consumption risk. The willingness to pay for an asset depends on the state of the world in which it will pay off. If consumption is low, marginal utility is high, and the willingness to pay for an asset in that state of the world is high. Higher demand leads to a higher price and a lower return; and vice versa. With habits, the agent dislikes consumption falling below the reference level - even small changes in the level of consumption can lead to relatively large changes in marginal

(last accessed: March 2018). The dataset from Chapman (2002) can be reconstructed using the instructions therein.

[11] Appendix B.2 presents details on data construction and estimation.

[12] See Appendix B.1 for technical derivation.

[13] Note that our model replicates the results of Abel (1990) and Constantinides (1990), if asymmetry $\lambda = 0$.

[14] Similarly, Otrok et al. (2002) note that reducing the persistence of consumption volatility leads to increases in the equity premium.

utility. The agent is willing to insure against being in this state of the world. This precautionary savings motive increases demand for the riskless asset. Its price rises while the return falls.[15] Simultaneously, the demand for the risky asset decreases, which decreases its price and increases return. Similarly, it could be argued that the agent requires a premium for holding the risky asset. This premium is increasing in risk and attitude to risk.

With asymmetric habits, the agent dislikes a decrease in consumption more than he values an equally sized increase in consumption. This asymmetry amplifies the divergence of the interest rates by driving down the riskless rate even more and raising the risky rate in turn. These mutually reinforcing effects allow us to rationalize the observed interest rate spread. We want to stress however, the major part of the observed interest rate spread can be explained by habit formation; which explains its prominence in the literature on the equity premium puzzle. The distinction between gains and losses adds an intuitively plausible element and closes the gap.

Since we base our intuition on empirical findings, we would like to to interpret the relevant coefficients in our model environment. To this end, let us restrict our focus on Shea (1995a), as the utilized data is at the macro level. Shea (1995a) finds consumption reacts approximately 4.89-times stronger to a predictable 1% income decline than to a predictable 1% income increase. This relationship between consumption and income, however, does not exist in a consumption-based asset pricing model.[16] So this value for asymmetry may give a point of reference, but a direct comparison or interpretation is not possible. We want to highlight however, that our solutions require very low values of asymmetry; these values are by more than an order of magnitude smaller than related literature suggests. [17]

2.7 Conclusions

Habit formation appears to be a conceptual breakthrough in the literature on the equity premium puzzle, but a definite resolution is still missing. Building intuition from empirical evidence, we extend a standard consumption-based asset pricing model by modeling asymmetric habits. We calibrate our model to data sets from two different time periods, to be more comprehensive in our analysis. With this approach we are able to match observed average interest rates and the corresponding interest rate spread for both calibrations. The major part of the observed interest rate spread can be explained by habit formation. By introducing an asymmetry in the valuation of gains and losses, it is possible to increase the divergence between the interest rates. The mutually reinforcing effects of habit formation and asymmetric valuation of gains and losses allow us to rationalize the observed interest rates simultaneously with a low riskless interest rate. Thus, our results indicate an improvement on the related literature: Abel (1990) reports large equity premium, but the interest rates are too high and do not match the data; we match observed average interest rates and the corresponding spread fairly precisely. In addition our results hold when we calibrate the model to more recent data. Constantinides (1990) solves for the equity premium, but the solution is not robust to more recent calibrations. In a comparable setup, we are able to match observed interest rates, even for a more recent calibration, with lower risk aversion. However, our model setup is sensitive to parameters and model assumptions. In particular, assumptions on the consumption growth process influence our results. Further research will investigate the properties and the potential of

[15] This argument provides an explanation why households save despite low riskless rates; an issue pointed out by Kocherlakota (1996).

[16] The only source of income is the exogenous dividend stream, which, in equilibrium, equals consumption.

[17] As already noted, Shea (1995a) estimates the order of magnitude of the asymmetry parameter to be 4.89; Tversky and Kahneman (1992) experimentally estimate an asymmetry parameter value of 2.25, and Yogo (2008) confirms this order of magnitude with an estimated asymmetry parameter of 3.06.

asymmetric habits in more detail.

Chapter 3

Asymmetric Habits, Asset Returns, and the Business Cycle

3.1 Introduction

The introduction of uncertainty in the neoclassical growth model initiated a research program which evolved to be now one of the cornerstones of contemporaneous macroeconomics: the real business cycle model is an essential building block in state-of-the-art dynamic stochastic general equilibrium (DSGE) analysis. This success is based on the model's ability to predict, quite accurately, second moments and correlations of macroeconomic aggregates utilizing a relatively simple modeling setup.[1]
However, the real business cycle model fails to simultaneously explain asset return characteristics - such as the risk premium on equity, the low risk-free rate and correct corresponding volatilities of returns - and maintain accurate predictions of cyclical components. This deficiency has proved to be a persistent challenge to the model.[2]
In the consumption-based asset pricing literature, the introduction of habit formation marks a breakthrough in explaining the equity premium.[3] It seems therefore like a next logical step to make use of habit formation to overcome the real business cycle model's weakness in explaining financial facts. Using conceptually closely related approaches, Jermann (1998) and Boldrin et al. (2001) try to eradicate this weakness. They incorporate habit formation and factor rigidities to substantially improve the models empirical fit with respect to asset returns.[4] The intuition is simple: habit formation increases the agents desire to smooth consumption over time which can be achieved through adaptations in capital supply, given capital supply is perfectly elastic. If the agent is restricted in capital supply, for example through capital adjustment costs or factor-market inflexibilities, consumption smoothing is impeded, which increases the volatility of the stochastic discount factor and hence affects asset prices.[5] Moreover, adjustment costs

[1]By introducting stochastic shocks into the neoclassical growth model, Brock and Mirman (1972) paved the way for Kydland and Prescott (1982), who were the first to test the empirical fit of a real business cycle model on U.S. data. Subsequent seminal papers contributing to the emergence of the real business cycle model include, among others, Long and Plosser (1983), Hansen (1985), Rogerson (1988), King et al. (1988a), and King et al. (1988b). For a more thorough survey of real business cycle theory see King and Rebelo (1999) or the classic textbook of Cooley (1995).

[2]See for instance Danthine et al. (1992), Rouwenhorst (1995), or Miao (2014).

[3]Seminal contributions in this respect are Abel (1990), Constantinides (1990), and Campbell and Cochrane (1999).

[4]In addition to habit formation, Jermann (1998) considers capital adjustment costs and Boldrin et al. (2001) a two sector production technology with impeded adjustment between sectors.

[5]Importantly, Lettau and Uhlig (2000) show that habit formation alone is not sufficient. Both is needed: a desire to smooth consumption and restricted possiblities to do so.

increase the volatility of capital gains, which affects the return on equity [see Jermann (1998) and Boldrin et al. (2001) for an extensive argumentation].
However, both models are not fully successful for several reasons. First, and most importantly, both models predict a counterfactually high volatility of the riskless rate - compared to the data, the volatility of the risk-less rate is by more than an order of magnitude higher. Second, both models have to draw on unsatisfactory parametrization. Jermann (1998) needs high risk aversion and Boldrin et al. (2001) very restrictive sector adjustment to achieve useful results. Additionally, both assume habits to be formed additively and report habit persistence to be higher than 70%, which we consider as implausibly high.[6] That means consumption may not drop below the habit level which is at least 70% of past consumption. Aside from plausibility, such a restriction also imposes technical difficulties.
In this chapter, we want to take a step forward. We apply the concept of asymmetric habit formation in a real business cycle model with the aim to improve on the studies of Jermann (1998) and Boldrin et al. (2001). Our approach is motivated by the recent findings of Molnar (2018). He shows that a consumption-based asset pricing model with asymmetric habits can explain the observed risk premium on equity and the low risk-free rate together with a low value of risk aversion. In this sense, the current study could also be understood as a subsequent investigation into the concept of asymmetric habit formation. The question is then: Can asymmetric habit formation explain financial facts in a general equilibrium model where consumption is endogenous?
Our results indeed imply an improvement on the studies of Jermann (1998) and Boldrin et al. (2001). The model is able to replicate the equity premium with a low risk-free rate, high volatility of equity, and low volatility of the risk-free rate together with a low value of risk aversion and moderate capital adjustment costs. Thus, we think that our approach may contribute to the discussion on the equity premium puzzle, as recently updated by Cochrane (2017).
The remainder of this chapter is organized in the following way: Section 3.2 presents the formal model, section 3.3 our solution and calibration procedure. In section 3.4 we present results and discuss them in section 3.5. Section 3.6 concludes.

3.2 Model

Consider a decentralized real business cycle model, building on Jermann (1998). We assume an infinitely lived representative agent stands in for a large number of households and an infinitely lived representative firm for a large number of firms. We start with the household problem.

3.2.1 Households

The representative household maximizes expected lifetime utility subject to its budget constraint

$$\max \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t u\left(c_t,\, c_{t-1}\right) \right]$$

$$\text{s.t. } s_t \Pi_t \geq c_t + s_{t+1} p_t \tag{3.1}$$

where $\mathbb{E}[]$ is the expectation operator and β is the subjective time preference. c_t denotes consumption, s_t the share of an asset held by the household, p_t the price, and Π_t the payoff of an asset; all at time t.

[6]Kocherlakota (1996) agrees with this argument.

Asset	**Price**	**Payoff** Π_{t+1}	**Return** R_{t+1}
equity	p_t	$p_{t+1} + d_{t+1}$	$(p_{t+1} + d_{t+1})/p_t$
risk-less	p_t^f	1	$1/p_t^f$

Table 3.1: Asset Prices, Payoffs, and Returns

In the following we will consider two different types of assets in our model. A risky asset like equity and a relatively safe asset like a bond. These assets have different prices and payoffs. If the household buys a share of equity today, it pays the price and a dividend in the next period. On the other hand, the risk-less asset guarantees a payoff of 1 unit of consumption in the next period. Even though this is standard in the literature, we summarize the two different assets in Table 3.1.
The distinguishing part of our model is the preference specification of the representative household. We assume that the preferences are given by the specification proposed by Molnar (2018). In particular, we assume that preferences over consumption are time non-separable, that means they feature habit formation. In additon we assume that habits are formed internally, multiplicatively, and asymmetrically. The household derives utility from changes in consumption and dislikes losses more than it values gains. Hence, the negative marginal utility of a loss in consumption is larger than the positive marginal utility of an equally sized gain. Formally, define a function $g : \mathbb{R}_+ \to \mathbb{R}$ such that

$$g\left(x_t\right) = \left[1 + \mathbb{I}_{(x_t<1)}\lambda\right] \frac{x_t^{1-\sigma} - 1}{1-\sigma}$$

and assume the representative agents derives utility according to

$$u(c_t) = g\left(x_t\right) \tag{3.2}$$

where $x_t = \frac{c_t}{c_{t-1}}$ is the gross growth rate of consumption, σ measures risk aversion, $\lambda > 0$ habit asymmetry, and $\mathbb{I}$ is an indicator function

$$\mathbb{I}_{(x_t<1)} = \begin{cases} 0 & \text{if } x_t \geq 1 \\ 1 & \text{if } x_t < 1 \end{cases}$$

3.2.2 Firms

The objective of the representative firm is to maximize the present discounted value of future dividends to its shareholders (the household), by choosing optimal investment, taking into account the law of motion of capital accumulation. Concretely

$$\max d_t = \sum_{i=0}^{\infty} \beta^i \frac{\eta_{t+i}}{\eta_t} \left[z_{t+i} K_{t+i}^{\alpha} - I_{t+i}\right]$$

$$\text{s.t. } K_{t+1} = (1-\delta) K_t + \phi\left(\frac{I_t}{K_t}\right) K_t \tag{3.3}$$

where $\beta^i \frac{\eta_{t+i}}{\eta_t}$ is the stochastic discount factor of the household (as it owns the firm), which captures time preference and the marginal rate of intertemporal substitution. K_t is the capital stock at time t, I_t are investments at time t, δ is the depreciation rate of capital and $\phi(.)$ is a positive, concave function related to capital adjustment costs.[7] In particular,

$$\phi\left(\frac{I_t}{K_t}\right) = \left[\frac{b}{1-a}\left(\frac{I_t}{K_t}\right)^{1-a} + \kappa\right] \tag{3.4}$$

with parameters a, b, and κ.[8] z_t is the exogenous, stochastic productivity level and we assume that the logarithm of technological progress follows

$$\ln z_t = \rho \ln z_{t-1} + \varepsilon_t \qquad \varepsilon_t \sim \mathcal{N}\left(0,\, \sigma_\varepsilon^2\right) \tag{3.5}$$

3.2.3 Equilibrium

In equilibrium markets are cleared. Thus, on the goods market, all goods produced are either consumed or invested and on the asset market investors hold all shares of the firm; other assets are in zero net supply. So

$$z_t K_t^\alpha = c_t + I_t \tag{3.6}$$

$$s_t = 1 \tag{3.7}$$

Moreover, prices and quantities satisfy first oder optimality conditions in equilibrium. From the household side we have the following FOC with respect to consumption and shareholding

$$\frac{\partial \mathcal{L}}{\partial c_t} : \eta_t = \frac{1}{c_t}\left[\left(1 + \mathbb{I}_{(x_t<1)}\lambda\right) x_t^{1-\sigma} - \beta \mathbb{E}_t\left\{\left(1 + \mathbb{I}_{(x_{t+1}<1)}\lambda\right) x_{t+1}^{1-\sigma}\right\}\right] \tag{3.8}$$

$$\frac{\partial \mathcal{L}}{\partial s_{t+1}} :\ \eta_t p_t = \beta \mathbb{E}_t\left\{\eta_{t+1}\Pi_{t+1}\right\} \tag{3.9}$$

where η_t is the Lagrange multiplier on consumption. The FOC from the firm side, with respect to investment and capital, are

$$\frac{\partial \mathcal{L}}{\partial I_t} : 1 = q_t b\left(\frac{I_t}{K_t}\right)^{-a} \tag{3.10}$$

$$\frac{\partial \mathcal{L}}{\partial K_{t+1}} : q_t\eta_t = \beta \mathbb{E}_t\left\{\eta_{t+1}\left[\alpha z_{t+1}K_{t+1}^{\alpha-1} + q_{t+1}\left((1-\delta) + \frac{ab}{1-a}\left(\frac{I_{t+1}}{K_{t+1}}\right)^{1-a} + \kappa\right)\right]\right\} \tag{3.11}$$

where q_t is the Lagrange multiplier on investment, known as Tobin's marginal q. Conditions (3.6) - (3.11), together with the exogenously given law of motion of technological progress (3.5), fully characterize the model and its dynamics.

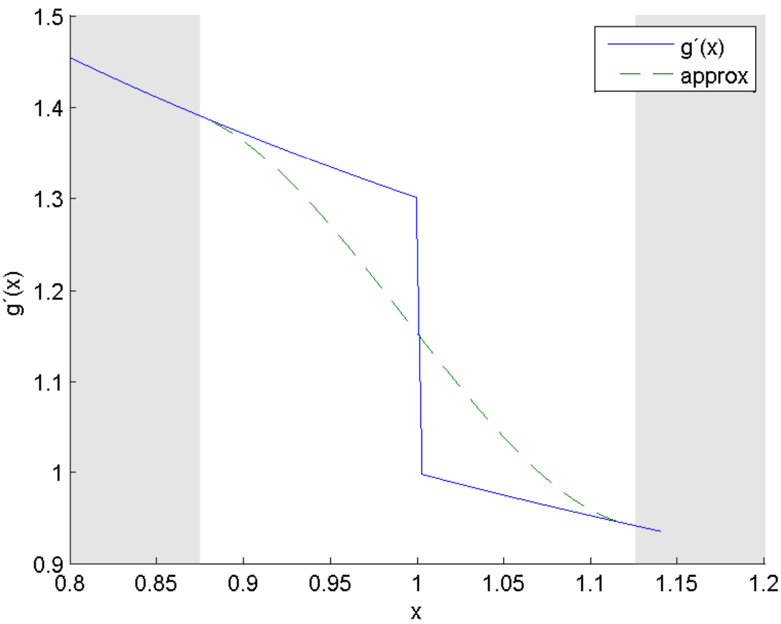
[7] We borrow the specification of the adjustment cost function from Jermann (1998).

[8] Parameter a can be related to the elasticity of the investment-capital ratio with respect to Tobin's q. Parameters b and κ can be derived from the model's steady state. In steady state, $K_{t+1} = K_t$ from which it follows that $\phi\left(\frac{I}{K}\right) = \delta$ and $\phi(.)$ satisfies $\phi'(.) > 0$, $\phi''(.) \leq 0$. Since adjustment costs are zero in in steady state, $\frac{I}{K} = \delta$. This can be used to calculate parameters b and κ.

3.3 Model Solution

3.3.1 Solution Method

We implement and solve the model in Dynare. Using perturbation methods, Dynare calculates the non-stochastic steady state and approximates policy and transition functions around the steady state under the assumption of rational expectations.[9] We require approximations to be at least of second order for two reasons: First, to derive reasonable asset pricing implications, we want to ensure that the riskiness of an asset enters the decision making of the household, which requires at least second order approximation. Second, our utility specification involves a strong non-linearity - and we believe that this captures crucial features of decison making. This feature cannot be captured with first order approximation. However, the asymmetry in the utility function imposes technical difficulties. Perturbation methods require functions to be globally smooth, which is not the case for our specification; the utility function has a kink at $x_t = 1$, which implies a jump in the derivative of the utility function. To circumvent this problem, we use polynomial approximation of the derivative of the utility function in our implementation. Figure 3.1 show the result of our approximation approach.



Notes. Polynomial approximation of order 3 of the derivative of the utility function. The non-shaded area indicates the relevant interval of consumption growth x in our simulations. Calibration: $[\sigma, \lambda] = [1.5, 0.3]$. See Table 3.2 for variable explanations.

Figure 3.1: Polynomial Approximation

Obviously, an approximation error remains - altough, numerically, differences are relatively small. Nevertheless, we think that the approximation captures the core of our idea: small variations in x around 1 lead to large variations in marginal utility - gains and losses are asymmetrically evaluated.

[9]See Adjemian et al. (2011) for more details on Dynare. All our simulations we carried out using Dynare Version 4.5.6.

3.3.2 Calibration and Data

We choose the model parameters specific to real business cycle models in line with the established literature.[10] For parameters specific to our approach we consider an interval of values to gain deeper insights into the working mechanisms of the model. In particular, we consider values for the elasticity of the investment capital ratio with respect to Tobin's q, ξ, in a similar range as Jermann (1998), who relies on the estimates of Abel (1980). Risk aversion, σ, is considered on the lower end of a reasonable interval.[11] Finally, but not least important, we define an interval for λ, which defines the strength of asymmetric valuation of gains and losses. As lower bound of the interval we take the highest estimates from Molnar (2018), which successfully solve for first moments of asset returns and the risk premium in a consumption-based asset pricing setup.[12] As upper bound of the interval we take experimental evidence from Tversky and Kahneman (1992), who estimate the factor of asymmetric valuation of gains and losses be to around 2.25.[13] Table (3.2) summarizes our parameter choice.

Parameter	Interpretation	Value
α	capital share of income	0.33
β	subjective time discount factor	0.99
δ	depreciation rate of capital	0.025
ρ	persistence of technology shock	0.99
σ_ε	standard deviation of technology shock	0.0089
ξ	elasticity of investment capital ratio	[0.1, 0.6]
σ	risk aversion	[1.01, 5]
λ	asymmetry strength	[0.01, 1.6]

Table 3.2: Calibration

To evaluate the empirical fit of our model, we adopt the statistics used by Boldrin et al. (2001). This is not just for convenience, but also reasonable: the statistical moments usually considered in real business cycle analysis proved to be rigid over time; quantitatively, there may be minor differences across studies, but the qualitative statements are the same.[14]

3.4 Results

We use the parameters from Table (3.2) and solve the model for different combinations of values of σ, λ, and ξ. Table (3.3) summarizes three of our most convincing simulation results.
Our model is able to explain simultaneously a large set of financial and business cycle facts. We match the mean of the riskless rate and the equity premium. Moreover, the volatility of the riskless rate is in line with

[10]Similar parameter values are used by Boldrin et al. (2001), Jermann (1998), or more recently by Miao (2014) and Gomme et al. (2017); among many others.

[11]For discussion on the reasonability of values of risk aversion see for instance Mehra (2012).

[12]The value of λ used by Molnar (2018) to solve correctly for unconditional means of asset returns and the equity premium is relatively low. This is due to the households inability to smooth consumption, since consumption is - by design - exogenously given in the consumption-based asset pricing model.

[13]Although the concept of utility of Tversky and Kahneman (1992) differs from ours, the basic idea of asysmmetric valuation of gains and losses is similar. By estimating similar values, Yogo (2008) provides additional evidence for the findings of Tversky and Kahneman (1992).

[14]See for instance Kydland and Prescott (1982), Cooley (1995), recently Miao (2014), which are all similar to Boldrin et al. (2001).

Statistic	**Data**	**Model**				
		$[\sigma, \lambda, \xi] =$ $[1.5, 0.22, 0.23]$	$[\sigma, \lambda, \xi] =$ $[1.05, 0.3, 0.23]$	$[\sigma, \lambda, \xi] =$ $[1.5, 1.6, 0.31]$	J(98)	B(01)
A. Financial Statistics						
$\mathbb{E}\left[R^f\right]$	1.19	1.05	1.10	1.36	0.82	1.20
$\mathbb{E}\left[R^e - R^f\right]$	6.63	6.22	6.14	5.08	6.18	6.63
σ_{R^f}	5.27	4.58	4.59	2.78	11.46	24.6
σ_{R^e}	19.40	12.92	12.85	11.11	19.86	18.4
$\mathbb{E}\left[R^e - R^f\right]/\sigma_{R^e}$	0.34	0.48	0.48	0.46	0.31	0.36
B. Business Cycle Statistics						
σ_Y	1.89	1.21	1.21	1.20	n/a	1.97
σ_C/σ_Y	0.40	0.74	0.75	0.48	0.49	0.69
σ_I/σ_Y	2.39	2.79	2.77	3.51	2.64	1.67
$\rho\left(Y, C\right)$	0.76	0.78	0.79	0.59	n/a	0.95
$\rho\left(Y, I\right)$	0.96	0.84	0.84	0.94	n/a	0.97

Notes. $\mathbb{E}\left[R^f\right]$ is the unconditional mean of the riskless asset, $\mathbb{E}\left[R^e - R^f\right]$ is the equity premium; both in percentage. σ_X denotes the standard deviation of variable x in percentage, $\mathbb{E}\left[R^e - R^f\right]/\sigma_{R^e}$ is the Sharpe ratio, and $\rho(x, y)$ denotes the correlation between variable x and y. The simulated model results are based on 100 replications of a simulation length of 100 time periods. Columns J(98) and B(01) report the corresponding model simulation results of Jermann (1998) and Boldrin et al. (2001), respectively. The financial data sample covers the time period from 1892-1987, the business cycle data sample covers 1964:1-1988:2. Both data statistics are taken from Boldrin et al. (2001); for more details see the corresponding references therein.

Table 3.3: Results

the data, while the volatility of equity is slightly underestimated, which results in a slightly overestimated Sharpe ratio. We want to highlight however, that the model generates a substantial difference in asset return volatilities: equity is multiply more volatile than the riskless asset. While the comovement of consumption and investment with output is close to the data, output volatility is somewhat underestimated. Furthermore, the volatility of consumption relative to output is overestimated, but the volatility of investment relative to output is quite close to the data. Compared to the standard real business cycle model, our model performance can be considered as at least as good with respect to business cycle statistics, but is superior with respect to financial statistics.

Given these results on financial variables, we think that our results even constitute an improvement on the closely related studies of Jermann (1998) and Boldrin et al. (2001). Both are able to match the mean of the riskless rate, the equity premium, and the volatility of equity, but the volatility of the riskless asset is significantly overestimated and of same order of magnitude than the volatility of equity. Moreover, both assume that habits are formed additively. The necessary level of habit persistence to achieve favorable solutions is implausibly high.[15] In addition, Jermann (1998) needs relatively high risk aversion, and the two-sector production specification of Boldrin et al. (2001) restricts the elasticity of the investment capital ratio with respect to price changes completely.

In contrast, our model not only matches first moments of asset returns, but also second moments of both assets. Additionally, we differ in terms of the parametrization of the model: we solve our model with lower risk aversion and are able to consider larger elasticities of the investment capital ratio with respect to Tobin's q while maintaining our results. Moreover, our specification does not require unfavorable assumptions about a high level of habit persistence and is not subject to the implications of additive habit formation; in our setting, consumption may fall below the habit level.

To summarize, we can improve model implications for the second moments of asset return without sacrificing accuracy in other dimensions, while using more plausible parameter values.

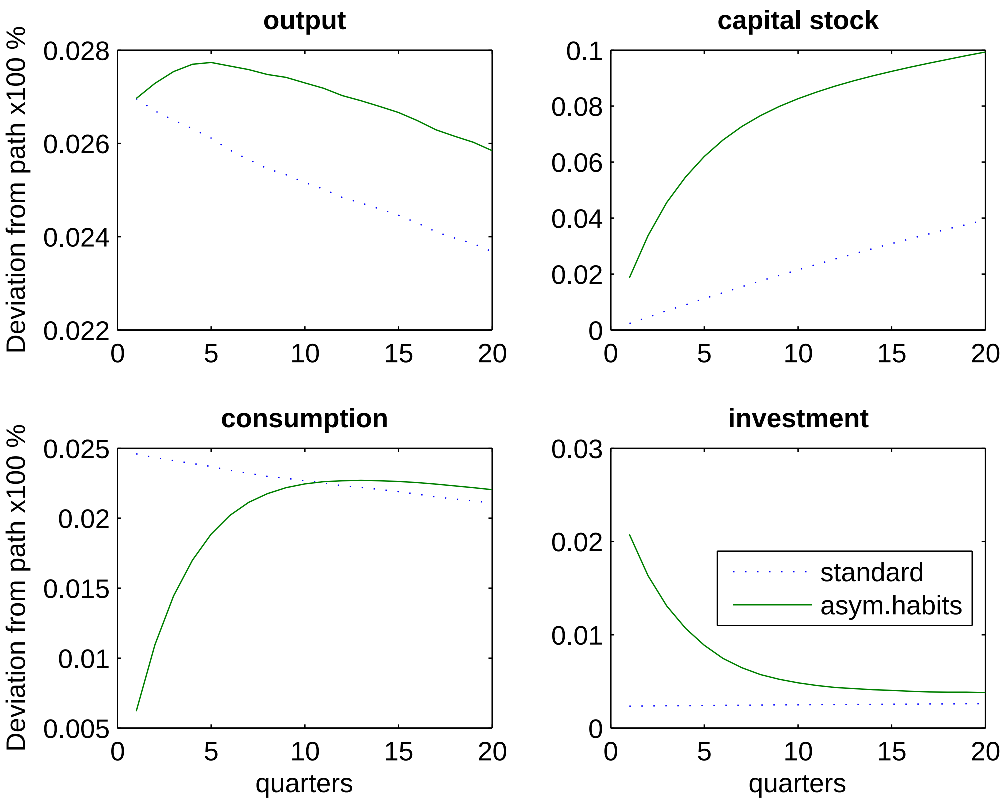
3.5 Discussion

With asymmetric habits, the household cares about its change in consumption and dislikes losses more than it values gains; so in that sense, the household is loss averse. Thus, the main objective of the household is to have a smooth consumption path over time and loss aversion intensifies this motive. The household is keen to avoid being in a state of the world where it has to reduce consumption by a large fraction, given its accustomed consumption level. Assets are an insurance against this risk. This precautionary savings motive makes the household anxious to invest in equity, since it takes the riskiness of an asset into account. This leads to an increased demand for the riskless asset, which decreases its return. At the same time, the household requires a large premium for holding a risky asset like equity, which increases the return on equity. Loss aversion amplifies this effect and drives an even larger wedge between asset returns. In addition, the larger the degree of loss aversion, the more stable the demand for the riskless asset will be, since risky equity becomes increasingly unappealing; this has a stabilizing effect on the volatility of the riskless asset. Note that this is only possible, if the household is impeded to perfectly smooth consumption. Without capital adjustment costs that achieve such a rigidity, the household would choose consumption to be perfectly smooth at no cost and there would be no variation on financial markets. [16]

Since our utility specification relies on habit formation, the useful property of propagation of shocks survives if we include loss aversion: output and consumption do not follow exactly the exogenous shock,

[15] Jermann (1998) reports habit persistence to be 82% and Boldrin et al. (2001) report 73%.

[16] Lettau and Uhlig (2000), Jermann (1998), and Boldrin et al. (2001) agree with this argument that is also discussed by Rebelo (2005), for instance.



Notes. Impulse responses of output, capital stock, consumption, and investment for a one standard deviation shock to technology. The deviation is measured as the difference to a path where technology is not shocked. Calibration: $[\sigma, \lambda, \xi] = [1.05, 0.3, 0.23]$. See Table 3.2 for variable explanations.

Figure 3.2: Impulse Response Functions

but are hump-shaped in response to a shock. The standard model lacks such a mechanism. Hence, our approach provides additional evidence that habit formation improves on the propagation mechanisms of the real business cycle model. Figure 3.2 shows the responses of output, capital stock, consumption, and investment in response to a one standard deviation shock to innovation.

We want to note however, that we consider a relatively large interval for λ. Unfortunately, the literature is relatively scarce on the quantification of the asymmetric valuation of gains and losses in stochastic general equilibrium settings. The idea for the approach we apply orginiates in the empirical work of Shea (1995a), who estimates for aggregate U.S. data that consumption is roughly 5-times more responsive to a predictable 1% income decline than to a predictable 1% income increase. However, this relationship cannot be translated straightforwardly into our setting. Molnar (2018) applies this idea in a consumption-based asset pricing model and shows that relatively small values of λ are sufficient for suitable results with respect to first moments of asset returns - though the consumption-based asset pricing model does not allow for consumption smoothing, which influences results in a general equilibrium setting like ours. Grüne and Semmler (2008) consider loss aversion in a production economy, using an even more generous interval for the strength of loss aversion. Their model differs from ours, as we do not apply prospect theory and assume a non-linear functional form of loss aversion. De Giorgi et al. (2007) estimate similar values to Tversky and Kahneman (1992) to be consistent with aggregate data U.S. data. This supports our assumptions on λ, but a direct adoption is questionable, given that their model is not general equilibrium and an application of prospect theory. We hence consider our proposed interval for λ to be based on justifiable assumptions, for the time being at least. More research would be needed to narrow down a reasonable interval for λ; which we could then use to reevaluate our results. We consider this as an area of future empirical research.

3.6 Conclusions

The standard real business cycle model is one of the cornerstones of contemporaneous macroeconomics. It is distinguished by its established ability to predict second moments and correlations of macroeconomic aggregates with high accuracy. However, a longstanding failure of the standard model is the simultaneous explanation of business cycle facts and financial facts like first and second moments of asset returns. Jermann (1998) and Boldrin et al. (2001) make substantial progress in this regard by including habit formation and factor rigidities. Still, there is room for improvement. In particular, both models overestimate the volatility of the riskless rate by more than an order of magnitude. Moreover, the parametric assumptions of both models are not fully satisfactory. Either high risk aversion is necessary, like in the model of Jermann (1998), or factor adjustment must be very restrictive, like in the model of Boldrin et al. (2001), to achieve useful results.

In this chapter, we want to take a step forward. Motivated by recent results, we apply the concept of asymmetric habits of Molnar (2018) to a real business cycle model with capital adjustment costs. Our model is able to closely match not only business cycle data, but also a large set of financial statistics including first and second moments of both equity and the riskless rate. Specifically, our model is able to replicate the equity premium with a low risk-free rate, high volatility of equity, and low volatility of the risk-free rate, which leads to a realistic Sharpe ratio. In addition, our solutions require low risk aversion (close to 1) and we can allow for similar or less restrictive capital adjustment compared to related literature. Thus, we believe that we have an argument to add to the discussion on the equity premium puzzle, as it is recently condensed by Cochrane (2017).

Further research will be devoted to refining our approach and establishing an empirically validated and theoretically sound concept of asymmetric habits.

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Appendix A

Chapter 1

A.1 Additional Model Specifics

This section summarizes additional specific features of the model, provides a rationale for their inclusion and compares our model with these features with existing general equilibrium analysis of fiscal spillovers and fiscal policy coordination[1].

Involuntary unemployment: Households can be hit by an exogenous unemployment shock and we include a matching process in the labor market. These two channels generate involuntary unemployment in our model. EU unemployment rates differ significantly across countries (e.g. Germany: 5,0% and France: 10,3%). Thus social security expenditures for unemployed people form different shares in the public spending structure of European countries (e.g. Great Britain: 0.4% of GDP and France: 1,6% of GDP). When hit by an exogenous shock or by applying a policy reform countries may therefore react differently. This may have an effect on the resulting spillovers. The studies of Benes et al. (2013), Boersch-Supan et al. (2006) and Corsetti et al. (2010) do not take unemployment into account. Only models QUEST II and Marmotte, presented in Gros and Hobza (2001), include unemployment.

Intensive and extensive margins: We model intensive and extensive margins on the household side of the labor market, considering in particular endogenous labor market participation and working hours decisions. Endogenous participation decisions delivers a more realistic welfare benefit cost model. For instance, higher unemployment benefits increase participation but not work hours. Berger et al. (2016) quantifies the bias generated with exogenous and constant participation in a population ageing context and argue that inflating intensive margin elasticities does not always help. There is no endogenous participation margin in the above mentioned studies.

Earnings-related pension system: The determination of life-time consumption decisions of ageing households is one of the main benefits using OLG models. Life-time income of the households therefore plays a key role in this decision. Considering only flat pension payments, independent of previous earnings, generates large income redistribution and affects household decisions. Without considering earning-related pension income this redistribution will be overestimated. Furthermore, for some countries the share of flat pension payments in total pension payments is significantly larger than for other countries (e.g. Beveridge

[1] QUEST II and Marmotte in Gros and Hobza (2001), Benes et al. (2013), Boersch-Supan et al. (2006), Corsetti et al. (2010) and Cwik and Wieland (2011).

system in Great Britain compared to Bismarck system in Continental Europe). Our model is able to capture this difference between countries. Spillover effects depend on household behaviour which depend on the balance between flat and earning-related part of the pension system in each country. Except for Boersch-Supan et al. (2006), existing general equilibrium models of fiscal spillovers do not take pensions into account.

Coverage of the European Union: Our model is explicitly calibrated for a representative sample of the EU28 countries. Hence we are able to measure spillovers within the European Union. Benes et al. (2013), Boersch-Supan et al. (2006) and Corsetti et al. (2010) include only aggregated regions in their models. Hence these approaches cannot quantify spillover effects within the EU.

A.2 Calibration Details

This section provides additional details on the calibration process for the two stylized Rest-of-the-world countries, NROW and SROW. First, we give an overview of different data inputs which are calculated based on available data. Next we provide a table of economic indicators which is used to determine the twin country for the stylized Rest-of-the-world countries, as described in section 1.4. Then we present the outcome of the calibration process and matching accuracy compared to actual data.

A.2.1 Data Inputs

We summarize the variables, corresponding indicators and databases and the calculation procedure. Recall that NROW is a composite of Canada, Japan and the USA, while SROW is a composite of Brazil, China and India.

Capital Stock

Database: World Input-Output Database
Indicator: VA (gross value added at current basic prices in million lcu), VA_P (price levels of gross value added, 1995=100), K_GFCF (real fixed capital stock, 1995 prices).
For each country we take VA/(VA_P/100) for value added in volumes and K_GFCF for capital stock in volumes. We calculate these values for the years 2005-2009 (latest available) and build the average. The country averages are summed up over each respective Rest-of-the-world region and the ratio gross value added in volumes over capital stock in volumes is built.

Depreciation Rate of Capital

Database: Penn World Table
Indicator: Average depreciation rate of the capital stock, delta
We use 2011 values as the latest available values. We calculate a weighted average for the respective countries. The weights are derived from GDP/Capita.

GDP

Database: Worldbank
Indicator: GDP at market prices (current USD), NY.GDP.MKTP.CD
We convert all currency values into EURO, the calibration currency.

Trade Balance

Database: Worldbank
Indicator: Current Account Balance (as % GDP), BN.CAB.XOKA.GD.ZS
We take the 2010-2014 average value of the current account balance and aggregate over each respective country. Then we compute the ratio GDP/GVA and correct the weighted average current account balance by this ratio. Gross value added is taken from the World Input-Output database and GDP from the Worldbank database.

Gross Government Debt

Database: OECD
Indicator: Gross General Government Debt as % of GDP
Government Debt is calculated using the Government Debt in % of GDP and GDP in current USD from the Worldbank database. The values of the respective countries are summed up and divided by total GDP for the respective Rest-of-the-world countries.

Public Health Expenditures

Databank: Worldbank
Indicator: Health Expenditures, Public (% of GDP), SH.XPD.PUBL.ZS
We use Worldbank data on public health expenditures in % GDP and Worldbank data on GDP and calculate the sum of total expenditures. Then we divide the sum by the aggregated GDP for the respective Rest-of-the-world countries.

Survival Probabilities

Database: UN Population Division (World Population Prospects: The 2015 Revision)
Indicators: total population, both sexes combined, by five-year age group (thousands), year 2013
We match the empirical age distribution, using age classes of 5 years from the data source, aggregating values over the three countries for each Rest-of-the-world region.

Skill Distribution

Database:OECD
Indicator: Highest adult education level attained. Categories: below upper secondary, upper secondary and tertiary
We calculate the number of people in the different skill group with the help of data on total population from OECD. Then we divide the number of people in a certain skill group by the total population for the respective countries.

Tax Shares

Database: OECD
Indicator: National Accounts / Annual National Accounts / Non-Financial Accounts by Sectors and National Accounts / Annual National Accounts / General Government Accounts / Taxes and Social Contribution Receipts and Government Expenditures by Function
We calculate the 2010-2014 average total government revenues for different tax categories and express the values as percentage of gross value added.

Public Pension Expenditures

Database: Worldbank
Indicator: Total Public Pension Spending
We use the indicator to calculate the total government spending and divide the sum by the aggregated GDP for the respective Rest-of-the-world country. We use the latest available values, 2009 respectively 2010 (except for China: 2006).

A.2.2 Economic Indicators for the "Twin Country Approach"

Tables A.1 and A.2 present the economic indicators which are used for determining the twin countries for each stylized Rest-of-the-world countries, as explained in section 1.4.
We eliminate the eastern European countries as potential twin country candidate for the North Rest-of-the-world (NROW) region as these countries have a lower economic development (GDP/Capita). Furthermore we eliminate Spain from the potential candidates because of large differences in unemployment rate. From the remaining countries the UK displays the closest values across all indicators. Hence Canada, Japan and the USA (forming the NROW) take UK as a twin country for calibration purposes.
The eastern European countries in our scope are the closest in terms of GDP/Capita, dependency ratio, share of people with tertiary education and overall indicators for the social security system. Thus the twin country for Brazil, China and India (forming the South Rest-of-the-world region, SROW) is an equally weighted combination of Czech Republic, Poland and Slovak Republic.

Indicator	AT	BE	CZ	DEN	FIN	FRA	GER	ITA	NL	PL
GDP	383	463	306	247	217	2484	3516	2126	783	888
GDP/C	45.4	41.9	29.1	44.2	40.1	37.9	43.7	35.2	46.8	23.1
Growth	1.2	1.2	0.9	0.5	0.5	1.0	2.1	-0.5	0.5	3.0
Consumption	54	52	49	48	54	56	55	61	45	61
Population	8.4	11.0	10.5	5.6	5.4	63.2	81.0	59.7	16.7	38.4
Labor Force	67.0	65.0	68.0	64.0	64.0	63.0	66.0	64.0	66.0	70.0
Old-Age Dep.	27.7	27.7	25.9	28.7	31.0	29.7	31.9	34.3	27.0	21.4
SG2	62.9	36.6	74.1	42.8	44.9	42.0	58.6	40.9	40.7	65.6
SG3	19.7	34.8	18.1	33.9	39.0	30.1	27.4	15.2	32.7	23.4
Participation	76.0	67.7	73.3	78.2	75.8	71.0	77.4	64.2	79.5	67.3
Unemployment	5.0	8.5	6.2	6.6	8.6	9.9	5.0	12.5	6.9	9.2
Work Hours	35.5	33.8	39.9	31.5	36.0	37.1	39.1	35.7	29.9	39.8
Ret. Age M	65	60	63	65	65	61	65	63	65	65
Ret. Age W	60	60	61	65	65	61	65	62	65	60
Gini on Income	30	29	26	28	28	32	32	34	29	34
Tax Ratio	48	49	39	55	53	50	44	46	46	39
Public Debt	86	106	41	40	63	96	72	133	67	51
Pension Exp.	11.8	9.8	9.2	5.8	9.1	13.3	10.6	14.9	5.0	11.9
Health Exp.	8.4	8.2	6.2	9.3	6.8	9.0	8.7	7.2	9.9	4.8
Education Exp.	5.5	6.3	4.0	8.2	6.4	5.6	4.7	4.3	5.4	5.0
UI Exp.	1.30	3.71	0.28	4.38	3.55	0.00	2.94	0.31	2.60	1.99
UI Rep. Rate	0.31	0.40	0.06	0.57	0.36	0.39	0.27	0.24	0.50	0.11

Notes. *GDP* = GDP in Billion USD, *GDP/C* = GDP per capita divided by 1.000, *Growth* = GDP growth in %, *Consumption* = Consumption in % GDP, *Population* = population in million persons, *Labor Force* = % of population aged 15-64, *Old-Age Dep* = Old-Age dependency ratio, *SG2* = % of labor force with upper secondary education, *SG3* = % of labor force with tertiary education, *Participation* = participation rate in % of labor force, *Unemployment* = unemployment rate in % of labor force, *Work Hours* = average weakly work hours, *Ret Age M (W)* = statutory retirement age for men (women), *Gini on Income* = Gini coefficient on labor income measuring wage inequality in %, *Tax Ratio* = tax and social security contribution revenues in % GDP, *Public Debt* = debt in % GDP, *Pension Exp* = expenditures in % GDP, *Health Exp.* = expenditures in % GDP, *Education Exp* = expenditures in % GDP, *UI Exp* = expenditures on unemployment insurance in % GDP, *UI Rep. Rate* = unemployment insurance replacement rate

Table A.1: Economic Indicators for the Twin Country Approach (start)

Indicator	SVK	ESP	SWE	UK	USA	CAN	JPN	CHN	BRA	IND
GDP	142	1526	420	2413	16130	1482	4517	15177	2661	4069
GDP/C	26.3	32.7	44.1	37.9	51.3	42.6	35.4	11.2	13.7	3.6
Growth	2.7	-0.8	2.4	2.0	2.1	2.5	1.5	8.6	3.2	7.2
Consumption	57	58	46	65	68	56	60	37	60	58
Population	5.4	46.6	9.5	62.4	319	35.5	127	1364	206	1295
Labor Force	71.0	67.0	63.0	65.0	67.0	68.0	61.0	74.0	69.0	65.0
Old-Age Dep.	18.8	27.7	31.0	27.0	21.6	23.0	41.9	12.5	11.0	8.4
SG2	73.2	22.1	52.0	37.1	46.7	37.2	54.2	18.7	31.5	38.9
SG3	18.1	31.8	35.0	39.5	42.5	51.4	45.8	3.6	12.3	12.6
Participation	70.2	74.4	81.3	76.4	71.8	78.2	75.1	77.6	75.0	56.5
Unemployment	13.3	24.7	8.0	6.3	6.2	6.9	3.7	4.7	6.8	3.6
Work Hours	34.7	35.1	36.3	39.5	33.8	30.9	42.4	46.5	41.8	47.0
Ret. Age M	62	65	65	65	66	65	65	60	55	58
Ret. Age W	62	65	65	63	66	65	65	60	55	58
Gini on Income	27	35	27	34	41	34	32	42	54	34
Tax Ratio	35	37	53	40	32	39	31	20	36	20
Public Debt	52	101	44	89	103	87	229	41	66	66
Pension Exp.	8.4	8.2	8.2	5.0	6.8	4.5	10.1	2.5	6.1	1.0
Health Exp.	5.7	6.8	7.8	7.7	8.1	7.7	8.3	2.9	4.4	1.2
Education Exp.	3.9	4.6	6.5	5.5	5.3	5.0	3.7	3.3	5.7	3.6
UI Exp.	1.02	3.64	2.91	0.28	0.42	2.23	0.41	0.02	2.03	0.01
UI Rep. Rate	0.11	0.35	0.32	0.17	0.13	0.16	0.12	0.02	*	0.06

Notes. For explanations see Table A.1.

Table A.2: Economic Indicators for the Twin Country Approach (end)

A.2.3 Calibration Outcomes

We present selected results of the calibration process for the stylized Rest-of-the-world countries. Table A.3 shows the outcome of the model calibration in comparison to real data.

	NROW		SROW	
	Calibration	Data	Calibration	Data
Macroeconomics				
Capital/Output	2.81	2.82	3.17	3.18
Consumption/Output	0.57	0.66	0.42	0.44
Investment/Output	0.24	0.21	0.42	0.39
Participation Rate	69.9	73.10	68.26	68.50
Unemployment Rate	5.65	5.64	4.39	4.39
Government				
Public Debt	117.64	127.64	43.23	48.82
Tax Ratio	30.91	32.38	21.25	22.23
Pension Expenditures	7.32	7.32	3.32	2.66
Health Expenditures	7.47	8.08	2.73	2.79
Unemployment Expenditures	0.50	0.54	0.02	0.03*
Demographics				
Dependency Ratio	27.2	26.71	12.34	10.65
Education				
Low-Skilled	7.96	8.02	63.17	62.95
Medium-Skilled	48.04	47.99	28.62	28.77
High-Skilled	44.00	43.99	8.21	8.28

Notes. Capital/Output = capital stock in % GDP, *Consumption/Output* = consumption share in % GDP, *Investment/Output* = investment ratio in % GDP, *Participation Rate* = participation in % of labor force, *Unemployment Rate* = unemployment in % of labor force, *Public Debt* = debt in % GDP, *Tax Ratio* = tax and social security contribution revenues in % GDP, *Pension Expenditures* = expenditures in % GDP, *Health Expenditures* = expenditures in % GDP, *Unemployment Expenditures* = expenditures in % GDP, for SROW Brazilian data is lacking, *Dependency Ratio* = old-age dependency ratio, *Low-Skilled* = % of population with education lower than upper secondary education, *Medium-Skilled* = % of population with upper secondary education, *High-Skilled* = % of population with tertiary education

Table A.3: Calibration Results for the Stylized ROW Countries

Appendix B

Chapter 2

B.1 Asymmetric Habits in Difference Formulation

As a second exercise, we want to test the idea of asymmetric habits in additive formulation. This allows for comparison with Constantinides (1990). If we keep the CES power utility function from section 2.2, several problems arise in the corresponding additive habit case. First, utility would not be defined for consumption below the reference level - a deficit common to Constantinides (1990) and Campbell and Cochrane (1999). This property could be interpreted as a form of implicit asymmetry, but as a result the agent would never evaluate outcomes on opposite sides of its reference level. Moreover, this feature also leads to difficulties in determining a meaningful reference level. Second, by introducing asymmetry, we would allow for possible discontinuity in the utility function. As a consequence first order conditions would be necessary but not sufficient for equilibrium. Hence, it would not be valid to evaluate first order conditions to determine asset returns, which is the case in consumption based asset pricing models. To circumvent these problems, we slightly modify the utility function, but maintain the idea of asymmetric additive habits and the ability to compare our results with Constantinides (1990).

B.1.1 Optimization Problem and Recursive Pricing Equations

Reconsider the optimization problem of the representative household in 2.1 and 2.4 from section 2.2, but assume

$$u\left(c_t,\, c_{t-1}\right) \;=\; -e^{-\sigma\left(1+\mathbb{I}_{\{(c_t-c_{t-1})<0\}}\lambda\right)(c_t-c_{t-1})}$$

where $\lambda > 0$ and $\mathbb{I}_{\{(c_t-c_{t-1})<0\}}$ denotes an indicator function of the form

$$\mathbb{I}_{\{(c_t-c_{t-1})<0\}} = \begin{cases} 1 & \text{if}\, c_t - c_{t-1} < 0 \\ \\ 0 & \text{if}\, c_t - c_{t-1} \geq 0 \end{cases}$$

To shorten notation, we will use $\mathbb{I}_{c_t}$ to denote $\mathbb{I}_{\{(c_t-c_{t-1})<0\}}$ in the following. Solve the optimization problem and combine first order conditions to derive the Euler equation

$$\left[\sigma\left(1+\mathbb{I}_{c_t}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_t}\lambda\right)(c_t-c_{t-1})}-\beta\sigma\mathbb{E}_t\left\{\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)(c_{t+1}-c_t)}\right\}\right]p_t$$
$$=$$
$$\beta\mathbb{E}_t\left\{\left[\sigma\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)(c_{t+1}-c_t)}-\beta\sigma\mathbb{E}_{t+1}\left\{\left(1+\mathbb{I}_{c_{t+2}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+2}}\right)(c_{t+2}-c_{t+1})}\right\}\right]\Pi_{t+1}\right\}$$

cancel σ and rearrange to obtain the pricing equation

$$p_t = \beta\mathbb{E}_t\left\{\frac{\left[\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)(c_{t+1}-c_t)}-\beta\mathbb{E}_{t+1}\left\{\left(1+\mathbb{I}_{c_{t+2}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+2}}\right)(c_{t+2}-c_{t+1})}\right\}\right]}{\left[\left(1+\mathbb{I}_{c_t}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_t}\lambda\right)(c_t-c_{t-1})}-\beta\mathbb{E}_t\left\{\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)(c_{t+1}-c_t)}\right\}\right]}\Pi_{t+1}\right\}$$

B.1.1.1 Price of the Risky Asset

Let us start with the price-dividend ratio of the risky asset. Insert the payoff from table 2.1

$$p_t = \beta\mathbb{E}_t\left\{\frac{\left[\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)(c_{t+1}-c_t)}-\beta\mathbb{E}_{t+1}\left\{\left(1+\mathbb{I}_{c_{t+2}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+2}}\right)(c_{t+2}-c_{t+1})}\right\}\right]}{\left[\left(1+\mathbb{I}_{c_t}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_t}\lambda\right)(c_t-c_{t-1})}-\beta\mathbb{E}_t\left\{\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)(c_{t+1}-c_t)}\right\}\right]}\left(p_{t+1}+d_{t+1}\right)\right\}$$

divide by d_t, and use $c_{t+1}=x_{t+1}c_t$ and the equilibrium condition $c_t=d_t$ then

$$\frac{p_t}{d_t} = \beta\mathbb{E}_t\left\{x_{t+1}\frac{\left[\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)(c_{t+1}-c_t)}-\beta\mathbb{E}_{t+1}\left\{\left(1+\mathbb{I}_{c_{t+2}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+2}}\right)(c_{t+2}-c_{t+1})}\right\}\right]}{\left[\left(1+\mathbb{I}_{c_t}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_t}\lambda\right)(c_t-c_{t-1})}-\beta\mathbb{E}_t\left\{\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)(c_{t+1}-c_t)}\right\}\right]}\left(\frac{p_{t+1}}{d_{t+1}}+1\right)\right\}$$

B.1.1.2 Price of the Riskless Asset

The price of the riskless asset follows directly by inserting its payoff from 2.1 into the pricing equation

$$p_t^f = \beta\mathbb{E}_t\left\{\frac{\left[\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)(c_{t+1}-c_t)}-\beta\mathbb{E}_{t+1}\left\{\left(1+\mathbb{I}_{c_{t+2}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+2}}\right)(c_{t+2}-c_{t+1})}\right\}\right]}{\left[\left(1+\mathbb{I}_{c_t}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_t}\lambda\right)(c_t-c_{t-1})}-\beta\mathbb{E}_t\left\{\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)e^{-\sigma\left(1+\mathbb{I}_{c_{t+1}}\lambda\right)(c_{t+1}-c_t)}\right\}\right]}\right\}$$

B.1.2 Approximation

We want to apply a similar approximation method as introduced in section 2.3. For this purpose we introduce a new state variable. Let $d_t = c_t - c_{t-1}$ be the difference in consumption in adjacent periods of time. Assume the law of motion of d is described by

$$d_t = (1-\rho)\,\bar{d} + \rho d_{t-1} + \varepsilon_t \qquad \varepsilon_t \sim \mathcal{N}\left(0,\,\sigma_\varepsilon^2\right)$$

where $\bar{d}$ denotes the average of d over time.[1] Let d take on values $d \in \{\delta_1, \ldots, \delta_n\}$ and let $\mathbb{P}\left(d_{t+1}=\delta_j \mid d_t=\delta_i\right) = \phi_{ij}$ be the transition probability from state i to j. Then we can define the price-dividend ratio in state i,

[1]Hung and Wang (2005) use a (in a sense) related utility function - as proposed by Kahneman and Tversky (1979) - to apply prospect theory to a consumption-based asset pricing model. However, their simulations are based on the assumption that consumption itself is a stationary process with constant mean and variance over time, which is evidently not the case. To circumvent this problem we introduce d as state variable and assume an associated stationary law of motion. Appendix B.2.2 provides empirical support for our assumption. We should note however, consumption can become negative with positive probability; a generic weakness of the additive habit model. Yet this possibility is of no consequence in both our calibrations. To confirm, we simulate d_t for 200 time periods, using parameters from table B.9 and starting values from the data, and calculate consumption. In 10.000 iterations no negative period consumption occured.

$w_i \equiv \frac{p}{d}(\delta_i, \xi_i)$, as

$$w_i = \beta \sum_j \phi_{ij} \left\{ \xi_j \frac{(1+\mathbb{I}_j\lambda)\, e^{-\sigma\delta_j(1+\mathbb{I}_j\lambda)} - \beta \sum_k \phi_{jk} (1+\mathbb{I}_k\lambda)\, e^{-\sigma\delta_k(1+\mathbb{I}_k\lambda)}}{(1+\mathbb{I}_i\lambda)\, e^{-\sigma\delta_i(1+\mathbb{I}_i\lambda)} - \beta \sum_l \phi_{il} (1+\mathbb{I}_l\lambda)\, e^{-\sigma\delta_l(1+\mathbb{I}_l\lambda)}} (w_j + 1) \right\}$$

and the price of the riskless asset as

$$p_i^f = \beta \sum_j \phi_{ij} \left\{ \frac{(1+\mathbb{I}_j\lambda)\, e^{-\sigma\delta_j(1+\mathbb{I}_j\lambda)} - \beta \sum_k \phi_{jk} (1+\mathbb{I}_k\lambda)\, e^{-\sigma\delta_k(1+\mathbb{I}_k\lambda)}}{(1+\mathbb{I}_i\lambda)\, e^{-\sigma\delta_i(1+\mathbb{I}_i\lambda)} - \beta \sum_l \phi_{il} (1+\mathbb{I}_l\lambda)\, e^{-\sigma\delta_l(1+\mathbb{I}_l\lambda)}} \right\}$$

From these expressions, asset returns can be calculated analogously to section 2.3.2.1 and 2.3.2.2.

B.2 Data and Statistics

We downloaded the data from the source stated in footnote 10 and calculated consumption growth following the instructions in Mehra and Prescott (1985). In particular, real per capita consumption is expressed by the Kuznets-Kendrick-USNIA measure on non-durables and services in thousands of 1972 US-Dollars from 1889-1978. Consumption growth in period t is then calculated as

$$\Delta c_t = \frac{c_t - c_{t-1}}{c_{t-1}}$$

Table B.1 provides summary statistics for consumption growth from 1889-1978.

Variable	Obs	Mean	Std.Dev.	Min	Max
$\Delta c_{1889-1978}$	90	.0182644	.0358676	-.090909	.111111

Table B.1: Summary Statistics: Consumption Growth 1889-1978

Next, we tested for serial correlation by regressing consumption growth on its first lag, that means an equation of the form

$$\Delta c_t = \alpha + \beta \Delta c_{t-1} + \varepsilon_t \qquad \varepsilon_t \sim N(0, \sigma_\varepsilon^2)$$

The regression results are displayed in table B.2.

Source	SS	df	MS
Model	.002526385	1	.002526385
Residual	.109862197	87	.001262784
Total	.112388583	88	.001277143

Number of Obs	89
F(1, 87)	2.00
Prob > F	0.1608
R-squared	0.0225
Adj R-squared	0.0112
Root MSE	.03554

$\Delta c_{1889-1978}$	Coeff.	Std.Err.	t	P > t	[95% Conf.	Interval]
β	-.1485459	.1050208	-1.41	0.161	-.3572861	.0601943
α	.0214871	.004226	5.08	0.000	.0130876	.0298867

Table B.2: Serial Correlation: Consumption Growth 1889-1978

Strikingly, the coefficient on the first lag is insignificant, which supports our assumption of no serial correlation in the calibration and is in contrast to Mehra and Prescott (1985). They use negative serial correlation of -0.14. Given our calculations, we conclude that our calibration presented in Table 2.3 fits the data from 1889-1978 reasonably well.

B.2.1 Data from 1949-2000

Since the exact data source stated in Chapman (2002) is not available anymore, we constructed consumption growth time series following the instructions of Chapman (2002), but using the economic database of the St.Louis Federal Reserve.[2] Real per capita consumption is constructed the following way: We take nominal personal consumption expenditures on nondurable goods (in billions of US-Dollars) and nominal personal consumption expenditures on services (in billions of US-Dollars) and deflate them using the implicit price deflator (deflated to 1992 US-Dollars).

$$\text{(real consumption nondurables)}_t = \frac{\text{(nominal consumption nondurables)}_t}{\text{(implicit price deflator)}_t/100}$$

$$\text{(real consumption services)}_t = \frac{\text{(nominal consumption services)}_t}{\text{(implicit price deflator)}_t/100}$$

Then we use the civilian noninstitutional population (in thousands of persons) to calculate real per capita consumption

$$\text{(real pc consumption)}_t = \frac{\text{(real consumption nondurables)}_t + \text{(real consumption services)}_t}{\text{(population)}_t/1000}$$

Again, consumption growth in period t is calculated as

$$\Delta c_t = \frac{c_t - c_{t-1}}{c_{t-1}}$$

Summary statistics for consumption growth from 1949-2000 are presented in Table B.3.

Variable	Obs	Mean	Std.Dev.	Min	Max
$\Delta c_{1949-2000}$	52	.0227221	.0122586	-.0125842	.0443392

Table B.3: Summary Statistics: Consumption Growth 1949-2000

Remarkably, mean consumption growth does not coincide with mean consumption growth reported by Chapman (2002). This may be due to a recent revision of the data, or to different data sources. We do not consider this difference as crucial, however. Next, we test for serial correlation in consumption growth by estimating an equation of the form

$$\Delta c_t = \alpha + \beta \Delta c_{t-1} + \varepsilon_t \qquad \varepsilon_t \sim N(0, \sigma_\varepsilon^2)$$

[2] https://fred.stlouisfed.org/

The regression results are presented in table B.4.

Source	SS	df	MS		
				Number of Obs	51
				F(1, 49)	5.95
Model	.00080365	1	.00080365	Prob > F	0.0184
Residual	.006618883	49	.000135079	R-squared	0.1083
Total	.007422533	50	.000148451	Adj R-squared	0.0901
				Root MSE	.01162

$\Delta c_{1949-2000}$	Coeff.	Std.Err.	t	P > t	[95% Conf.	Interval]
β	.3245275	.1330492	2.44	0.018	.0571552	.5918999
α	.0156863	.0034203	4.59	0.000	.0088130	.0225596

Table B.4: Serial Correlation: Consumption Growth 1949-2000

In contrast to the time period 1889-1978, serial correlation has increased for the time period 1949-2000 and changed sign. This finding is in line with Otrok et al. (2002), who report similar estimates, and Chapman (2002). We conclude that our calibration presented in Table 2.3 fits the data reasonably well.

B.2.2 Asymmetric Habits in Difference Formulation

Since we use a different state variable, $d_t = c_t - c_{t-1}$, for the additive habit case, we need additional information for calibration. This section presents necessary statistics to support our assumptions and calibration. In order to make an appropriate assumption on the distribution of the state variable and its error term, we need to ensure that the law of motion is a stationary process. Table B.5 shows the results of an augmented Dickey-Fuller unit root test.

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value	p-value
$c_{1890-1979}$	3.382	-3.525	-2.899	-2.584	1.0000
$d_{1890-1979}$	-8.112	-3.525	-2.899	-2.584	0.0000
$c_{1949-2000}$	4.326	-3.579	-2.929	-2.600	1.0000
$d_{1949-2000}$	-3.633	-3.579	-2.929	-2.600	0.0052

Table B.5: Augmented Dickey-Fuller Unit Root Tests

Obviously, consumption is insignificant at all relevant levels and time periods, but our state variable $d_t = c_t - c_{t-1}$ is significant at the 1%-level for both time periods. This finding supports our assumption that d follows a stationary process. As next test, we plotted the histogram of d for both time periods to derive information about its distribution. Figure B.1 shows the results. By visual inspection of figure B.1, we conclude that it is plausible to assume that d is normally distributed for both time periods. To complete the calibration we calculate summary statistics and test for serial correlation of d. Tables B.6, B.7, and B.8 present the corresponding results.

	Mean	Std.Dev.	Min	Max
$d_{1890-1979}$	.031	.0505931	-0.13	0.13
$d_{1949-2000}$	.0031471	.0020219	-.0017384	.0083346

Table B.6: Summary Statistics d

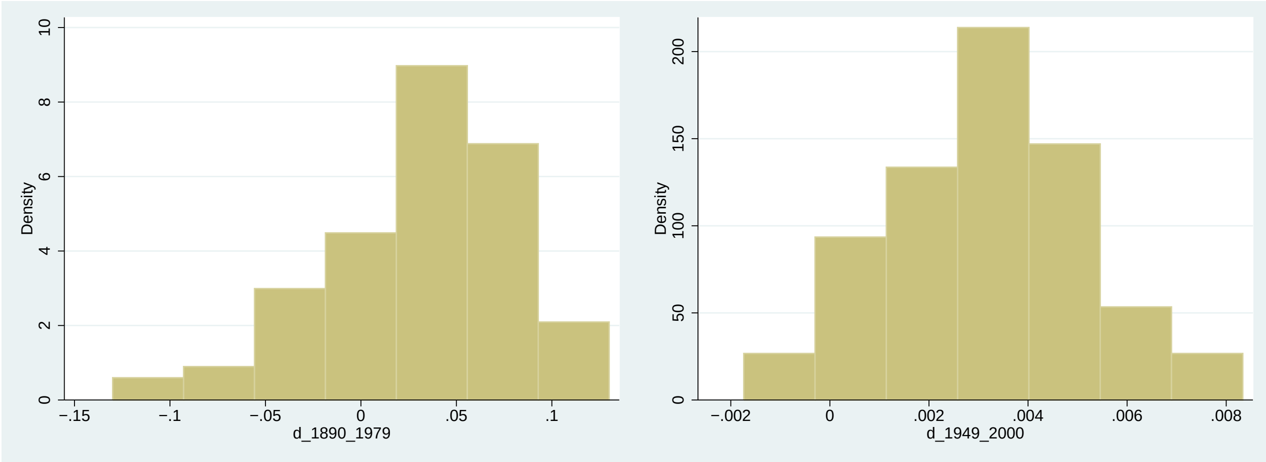

Figure B.1: Histogram of d

Source	SS	df	MS		
				Number of Obs	89
				F(1, 49)	1.78
Model	.004503309	1	.004503309	Prob > F	0.1862
Residual	.220676464	87	.002536511	R-squared	0.0200
Total	.225179773	88	.002558861	Adj R-squared	0.0087
				Root MSE	.05036

$d_{1890-1979}$	Coeff.	Std.Err.	t	P > t	[95% Conf.	Interval]
$L^1(d)$	.1410752	.1058773	1.33	0.186	-.0693675	.3515179
const	.0272615	.0062426	4.37	0.000	.0148536	.0396694

Table B.7: Serial Correlation: d 1890-1979

Source	SS	df	MS		
				Number of Obs	51
				F(1, 49)	21.91
Model	.000062281	1	.000062281	Prob > F	0.0000
Residual	.000139309	49	2.8430e-06	R-squared	0.3089
Total	.000201591	50	4.0318e-06	Adj R-squared	0.2948
				Root MSE	.00169

$d_{1949-2000}$	Coeff.	Std.Err.	t	P > t	[95% Conf.	Interval]
$L^1(d)$	.5629825	.1202839	4.68	0.000	.3212629	.8047021
const	.0014642	.0004393	3.33	0.002	.0005814	.002347

Table B.8: Serial Correlation: d 1949-2000

We conclude that state variable d follows a stationary process described by

$$d_t = (1-\rho)\,\bar{d} + \rho d_{t-1} + \varepsilon_t \qquad \mathcal{N} \sim (0, \sigma_\varepsilon)$$

where $\rho = 0$ for the time period 1890-1979. From the empirical evidence presented above, it follows the calibration of the model for the case of asymmetric additive habits in Table B.9.

Parameter	Interpretation	Value$_{1890-1979}$	Value$_{1949-2000}$
$\bar{d}$	Mean of consumption difference	0.0301	0.0031
d	consumption difference grid	$[-0.13, 0.13]$	$[-0.0017, 0.0083]$
ρ	First-order serial correlation	0	0.563
σ_ε	Standard deviation	0.0506	0.0020
β	Subjective time discount factor	[0.95, 0.99]	[0.95, 0.99]
λ	Strenght of asymmetry in habit formation	> 0	> 0

Table B.9: Calibration of the Additive Model

Appendix C

Copyright Declaration

Copyright Declaration

Hereby I declare that this dissertation and the accompanying computer code have been composed by myself, unless otherwise acknowledged in the text. All verbatim extracts have been distinguished by quotation marks, and all sources of information have been specifically acknowledged. None of the three chapters has been accepted as part of another degree.

Urheberrechtserklärung

Hiermit erkläre ich, dass diese Dissertation und der darin verwendete Computercode von mir verfasst wurden, insoweit nicht anderweitig im Text kenntlich gemacht. Alle wörtlichen Zitierungen wurden durch Anführungszeichen deutlich gemacht. Quellen, welche nicht wörtlich zitiert werden, sondern lediglich Ideen anderer Autoren widerspiegeln, wurden den in den Wirtschaftswissenschaften gängigen Zitierregeln gemäß gehandhabt. Die drei Kapitel wurden nicht im Zusammenhang mit dem Erwerb eines anderen akademischen Abschlusses verwendet.

Appendix D

Summary

D.1 English Abstract

This dissertation treats three questions related to the broad topic of the importance of financial markets in economics. In chapter 1 we quantify cross-country spillovers stemming from fiscal policy reforms or onetime, exogenous shocks. The financial market, or capital market, serves as transmission channel of cross-country spillovers and influences their magnitude. In chapter 2 we challenge modelling assumptions on investment behavior in a classical asset pricing model. We propose a new modification of preference structure, capturing a richer set of behavioral aspects, and apply it to a standard asset pricing model to rationalize historical asset returns on different types of assets. In chapter 3 we use the preference structure introduced in chapter 2 in the real business cycle modelling framework to improve on one of the model's salient weaknesses and increase its empirical accuracy with respect to first and second moments of financial data.

D.2 German Abstract

Der thematische Schwerpunkt dieser Dissertation liegt in der Wichtigkeit von Finanzmärkten in der heutigen Ökonomie und behandelt drei Fragestellungen zu diesem Thema. In Kapitel 1 werden länderübergreifende Übertragungseffekte von fiskalpolitischen Reformen und exogenen Schocks quantifiziert wobei der internationale Kapitalmarkt als Übertragungsmedium funktioniert. In Kapitel 2 wird mit Hilfe einer Erweiterung der Präferenzstruktur von Haushalten versucht das Equity Premium Puzzle zu erklären. Hierbei ist die Modellierung von asymmetrischen Gewohnheiten von zentraler Bedeutung. Dieses Konzept wird verwendet um empirische Finanzdaten zu replizieren. In Kapitel 3 wird das Konzept aus Kapitel 2 verwendet um eine empirische Schwachstelle des bekannten Konjunkturzyklusmodells zu überwinden. Mit Hilfe von asymmetrischen Gewohnheiten in der Präferenzstruktur von Haushalten wird versucht die empirische Genauigkeit des Modells vor allem in Bezug auf Erwartungswert und Varianz von risikolosen und riskanten Vermögenswerten zu verbessern.

Appendix E

Curriculum Vitae

Matthias Molnar

Curriculum Vitae

Education

2015–Present **PhD-Candidate in Economics**, *University of Vienna*.

2013–2014 **Magister der Wirtschafts- und Sozialwissenschaften (Mag.rer.soc.oec.)**, *University of Vienna*.
equivalent to Master of Science (MSc) in Economics

2009–2012 **Bachelor of Science (BSc) in Economics**, *University of Vienna*.

Academic Experience

Current Position

2015–Present **Junior Researcher**, *Institute for Advanced Studies (IHS)*, Vienna.

Research Interests

Macroeconomics, Finance, Asset Pricing, Behavioral Economics, Social Choice

Articles

Working Paper

2016 "*Cross-Country Long-Run Spillover Effects and Coordination of Fiscal Policy: A Quantitative Exploration for Europe*" (with Thomas Davoine and Michael Reiter)

2017 "*Cross-country Fiscal Policy Spillovers and Capital-Skill Complementarity in Currency Unions*", (with Thomas Davoine), submitted

2018 "*Asymmetric Habits in Asset Pricing*"

2018 "*Asymmetric Habits and the Business Cycle*"

Conferences

2017 *EcoMod 2017*, International Conference on Economic Modeling, University of Ljubljana, Slovenia

2017 *Arnoldshain Seminar XV*, The EU and Latin America Facing Globalization, Vienna University of Economics and Business, Austria

2018 *EcoMod 2018*, International Conference on Economic Modeling, Università Ca' Foscari Venezia, Italy

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