The Distributional Implications of Business Cycles and Fiscal Policy

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Introduction

Since the 1970's, macroeconomic theory has revolved around dynamic general equilibrium models, in which agents' decision-making is determined by the solution of constrained optimization problems under rational expectations. One common assumption within this framework is that all households have access to a complete set of state-contingent securities such that they are insured against any idiosyncratic component of risk. This conjecture of so-called complete markets implies that individual behavior and the distribution of endowments are irrelevant for the equilibrium behavior of aggregate variables. Therefore, the economy can be studied by only focusing on a single agent that is representative for a continuum of identical agents.

There are reasons why the assumption of complete markets, and consequently a representative household, was appealing to researchers in the early stages of modern macroeconomics. The lack of efficient numerical methods and the required computational power made the solution and analysis of models with heterogeneous agents and incomplete market economies infeasible. Moreover, representative agent economies have been successfully used to analyze business cycle fluctuations, monetary policy and long-run economic growth. The focus there was on explaining the behavior of aggregate quantities and prices, which does not obviously involve distributional concerns.

However, there are also convincing arguments to forgo the assumption of complete insurance markets. First, the set of insurance contracts that individuals can enter in reality is limited. Reasons for these limitations are the existence of private information and the related high costs of many contracts. Second, as e.g. Zeldes (1989) shows, there is a substantial amount of households facing borrowing constraints that severely limit their ability to insure away idiosyncratic risk. Motivated by these facts, the seminal papers by Huggett (1993), Aiyagari

(1994) and Krusell and Smith (1998) changed the landscape of macroeconomics in several dimensions. On the one hand, these papers provide a framework, in which household heterogeneity, initiated by idiosyncratic earnings risk, can be analyzed. Additionally, they show that heterogeneity affects both the level and the dynamics of aggregate equilibrium quantities. The reason is that market incompleteness in combination with occasionally binding borrowing constraints create a strong precautionary savings motive that is shown to be important for aggregate capital and business cycle fluctuations. Moreover, Heathcote (2005) points out that the Ricardian Equivalence theorem falls once incomplete markets are introduced in an otherwise standard real business cycle model, and shows that the positive effects of a tax cut are amplified by the heterogeneity of households. These results finally suggest that even when analyzing only the behavior of aggregate variables, heterogeneity is an important determinant that should not be left out.

This dissertation consists of three self-contained essays, in which household heterogeneity and the associated distributions of income and wealth play a crucial role. As such, it contributes to the macroeconomic literature by explicitly accounting for distributional consequences in the analysis of fiscal policy and business cycle dynamics. A detailed description of these essays and their contribution to the literature follows.

In Chapter 2, I investigate the relation between redistributive taxation and private insurance markets. When households face income risk and insurance markets are incomplete, there is a potential role for the government to intervene and provide additional insurance. The trade-off that the government faces here is that redistribution might also lead to negative effects on incentives to supply labor, to save or to repay a credit. These, in turn, can substantially impair individuals' access to credit markets and ultimately reduce risk sharing.

To address this issue, I construct an overlapping generations model, in which households are heterogeneous with respect to their skills and, additionally, subject to idiosyncratic productivity shocks. Households can smooth consumption by means of two instruments, a riskless asset and unsecured loans with the option to default. Following Chatterjee et al. (2007) and Livshits et al. (2007), the default option resembles bankruptcy filing under Chapter 7 of the U.S. Bankruptcy code, which implies the dischargement of debt and a temporary exclusion from credit markets. The price of a credit is a function of individual default risk. Hence, endogenous borrowing constraints arise in the form of effective borrowing limits. These imply that, at some debt level, even if the face value of a credit is increased, the actual amount received does not further increase.

Previous studies focused on stylized limited-commitment economies with otherwise complete markets (Broer, 2011; Krueger and Perri, 2011), which are known to generate counterfactual properties of the joint distribution of consumption and income (Broer, 2013). The contribution of this chapter is a quantitative analysis in a framework that is characterized by substantial household heterogeneity and distributions of wealth, income and consumption that are in line with their empirical counterparts.

I focus on stationary equilibria, in which the progressivity of the income tax code is varied, and find that more redistribution leads to tighter borrowing constraints. This is true for both high-skilled and low-skilled households although for different reasons. An increase in progressivity leads to a negative income shock for the high-skilled, and since the after-tax income itself is directly related to the credit price, this translates into more expensive credits and thus to a tightening of borrowing constraints. For the low-skilled, the increase in progressivity triggers negative incentive effects as they reduce labor supply and, additionally, raises the attractiveness of defaulting, resulting in a tightening of borrowing constraints as well. This tightening is particularly severe for young households, who rely on credit to smooth their lifetime consumption. Nonetheless, redistribution leads to a substantial reduction in after-tax income and consumption inequality so that consumption risk sharing improves. This, however, comes at the cost of crowding-out private insurance markets and thus ultimately questions the efficiency of redistributive taxation as a tool to smooth individual consumption fluctuations.

As in Chapter 2, Chapter 3 emphasizes the role of household heterogeneity for the transmission of fiscal policy as it studies the nature of countercyclical multipliers for government expenditure shocks. Recent empirical literature finds significantly higher multipliers when the economy is in a recession (Auerbach and Gorodnichenko, 2012, 2013; Linnemann and Winkler, 2016). In this chapter, I provide an intuitive mechanism that explains this finding. In particular, I propose a business cycle model that incorporates nominal rigidities and a monopolistically competitive firm sector into an incomplete markets model with aggregate uncertainty. Households are heterogeneous with respect to their access to capital markets, their patience and their exposure to idiosyncratic shocks. While a small group is wealthy enough to be perfectly insured, the majority of households is subject to idiosyncratic employment and productivity shocks, and faces occasionally binding borrowing constraints. This heterogeneous structure is important to generate wealth and income distributions that are consistent with empirical findings.

The two key components within this framework are the endogenous share of borrowing constrained households, which I find to be countercyclical, and the emerging non-trivial distribution of households' marginal propensity to consume (MPC). The transmission channel of fiscal policy shocks is then straightforward. Since borrowing constrained households have a higher MPC than unconstrained ones, the relatively high share during recessions of the former group amplifies the demand effect that is initiated by the respective fiscal shock and, therefore, different multipliers arise.

I investigate the effects of two deficit-financed government expenditure shocks, a government consumption shock and a fiscal transfer shock. To prevent an explosive government debt path, I explore two different sets of fiscal rules. In the benchmark setting, I let transfers adjust in the case of a government consumption shock and government consumption in the case of a fiscal transfer shock. Furthermore, I let the distortionary income tax rate adjust in both shock cases. The main results are the following. First, impact multipliers in recession scenarios are always larger than impact multipliers in expansion scenarios. Second, multipliers for government consumption shocks are always larger than multipliers for fiscal transfer shocks. And third, transfer and consumption multipliers are always lower when the income tax rate adjusts instead of the other instrument.

This chapter contributes to two different strands of literature. First, it contributes to the literature on state-dependent fiscal multipliers as it introduces a transmission channel that relies on substantial heterogeneity among households. Papers in this literature usually use a New Keynesian framework with a representative household or extend this setup by introducing a second type of households. Thus, distributions generally consist of two mass points while this chapter is the first that investigates this issue in a model that generates empirically plausible distributions.

In Chapter 4, which is joint work with Mathias Klein, we focus on the business cycle dynamics of consumer credit in the U.S. economy. Motivated by the procyclicality of consumer credit that is in contrast to basic consumer theory, we propose a business cycle model, in which credit is not only used for consumption smoothing but also to reduce consumption disparities between different income groups. The latter is supported by recent empirical studies, which show that interpersonal comparison is a significant determinant of individual consumption decisions (Bertrand and Morse, 2016; Carr and Jayadev, 2015; Drechsel-Grau and Schmid, 2014). We set up a simple model, in which households differ with respect to their source of income, and model the consumption externality as an additional argument in the utility function of income-poor households. This stylized framework is appealing as it is tractable enough to estimate a set of important parameters. We do so by a simulated method of moments (SMM) approach, which implies that parameter values are chosen such that the distance between a set of model-implied moments and their empirical counterparts from U.S. data is minimized. Two results emerge from this approach. First, the relative consumption motive, represented by one specific parameter in the model, is estimated to be positive and significantly different from zero. Second, given this positive parameter, the model is able to successfully replicate the procyclicality of consumer credit among a set of other business cycle moments. These findings imply that interpersonal comparison between different income groups is an important determinant of short-run credit movements. Complementary to recent literature that builds upon microeconometric approaches, we contribute to this literature by proposing a structural model that links consumption externalities with individual borrowing decisions.

Finally, Chapter 5 concludes.

Chapter 2

Borrowing constraints, equilibrium default, and progressive taxation

2.1 Introduction

This chapter studies the government's role in an environment where private insurance markets are incomplete. In particular, I explore the impact of progressive income taxes on borrowing constraints, inequality and risk sharing. As the main result, I find that redistributive taxes lead to an improvement in risk sharing but at the cost of crowding-out private insurance.

In much of economic theory, households face some kind of income fluctuations against which they would like to insure themselves. Since the absence of complete markets leads to imperfect risk sharing, the government could fill in and provide additional insurance to improve the allocation of risk. One specific tool that could achieve this is redistribution. However, the government faces a fundamental trade-off here. On the one hand, redistribution lowers the individual exposure to bad shocks and reduces fluctuations in consumption. At the same time, adverse effects on labor supply, savings or debt may arise as progressive income taxes distort the households' labor supply decision and disincentivize them to save or to pay back their debt. The consequences, in turn, could result in an actual worsening of consumption risk. The question is which of these opposing effects dominates. Or, put differently, is redistribution additional insurance or does it crowd-out private insurance markets such that risk sharing worsens?

To address this question, I focus on a framework in which households are subject to idiosyncratic, uninsurable productivity risk and can only smooth consumption by means of two instruments, a riskless asset and unsecured loans with the option to default. Following Chatterjee et al. (2007) and Livshits et al.

(2007), the default option resembles bankruptcy filing under Chapter 7 of the U.S. Bankruptcy Code, implying a temporary exclusion from credit markets and a complete discharge of outstanding debt. Credit markets are perfectly competitive and consist of risk neutral institutions which set interest rates on credit such that they reflect the individual default risk of the borrower. Hence, agents are endogenously borrowing constrained in the sense that, at some debt level, even if they increase the face value of their credit, the actual amount received does not increase further.

Otherwise, the modeling approach is close to Conesa et al. (2009) and Kindermann and Krueger (2014). There are overlapping generations (OLG) of households that are born either high-skilled or low-skilled and that are ex-post heterogeneous in consequence of idiosyncratic productivity shocks. The labor market is perfectly competitive and consists of a continuum of firms that use a constant returns to scale production technology. The fiscal authority has access to several instruments, including a nonlinear labor income tax function that is of particular importance in this study. The functional form for this tax is taken from Bénabou (2000, 2002). This specification allows the fiscal authority to implement a flexible tax code and Heathcote et al. (2017b) show that it closely approximates the current U.S. tax and transfer system. The model is calibrated such that it matches the private debt-to-GDP ratio, the number of indebted households and the number of bankruptcies per year, among others. The appealing property of this environment is that it gives rise to realistic cross-sectional earnings and wealth distributions that are inevitable when studying the risk sharing properties of progressive taxation.

I focus on comparing stationary equilibria, in which the progressivity of the income tax code is varying. The result is that borrowing limits are decreasing in the degree of tax progressivity, which is true for both high-skilled and low-skilled households. Moreover, the fraction of indebted households as well as the number of defaulting households falls with an increase in redistribution. The intuition is the following. For high-skilled households, higher tax progressivity is a negative income shock that leads to a decrease in labor supply. Since the after-tax income is an important determinant for the price of credit, the drop in income directly translates into lower borrowing limits. For the low-skilled, a rise in progressivity leads to a decrease in labor supply as well but also to an increase in the attractiveness of defaulting, which is taken into account by financial intermediaries, such that borrowing limits ultimately decrease. Lower borrowing limits, in turn, lead to less credit demand and subsequently to less defaulting households. So despite a decrease in default probabilities, which is supposed to have a positive effect on borrowing limits, the negative incentive effects are too large to compensate for this. These results have important consequences as especially young households typically rely on credit to smooth consumption over the lifecycle.

A second set of important results is concerned with inequality and risk sharing. I find that consumption and after-tax income inequality are clearly decreasing in tax progressivity. Pre-tax income inequality, however, is slightly increasing in redistribution, which is driven by a strong decrease in low-skilled labor supply. To evaluate the effects on risk sharing, I employ the measures of Krueger and Perri (2011). These are *total intermediation*, which is defined as the intermediation of risk achieved by both public and private channels, and *private intermediation*, which is the additional risk intermediation through private insurance contracts. I find that total intermediation is increasing in tax progressivity, while private intermediation is slightly decreasing. This result suggests that the improvement in risk sharing is more than one-to-one due to government intervention. To sum up, I show that redistribution in the form of progressive taxes can reduce individual fluctuations in consumption and therefore, provide substantial insurance in the presence of incomplete markets. However, negative incentive effects caused by redistribution counteract this improvement in risk allocation, leading to an aggrevated access to private credit markets. This eventually questions the efficiency of redistribution in dampening individual consumption fluctuations.

This chapter builds a bridge between two important strands of the macroeconomic literature. First, it contributes to the literature that analyzes how changes in tax policy affect private insurance and the cross-sectional distributions of income and consumption. Krueger and Perri (2011) build upon a stylized endowment economy, in which credit contracts can only be enforced by the threat of exclusion from private insurance markets. The endogenous borrowing limits are then set at the level such that households are indifferent between paying back their debt and defaulting. As the authors show, this lack of commitment leads to an equilibrium allocation that exhibits imperfect consumption risk sharing. In their quantitative analysis, the authors find that redistributive taxation generally leads to a crowding-out of private insurance and show that the magnitude of the reduction crucially depends on the level of private insurance. The reason is that, in most cases, an increase in redistribution raises the value of defaulting, which translates into a tightening of the borrowing constraint.

Broer (2011) extends this framework in two dimensions to study the conditions that can lead to a crowding-in of private insurance. First, by allowing for saving after default, and second, by considering a production economy with inelastic labor supply. Introducing saving after default, on the one hand, lowers the level of risk sharing in general, as it makes default more attractive and thus, tightens the borrowing constraint. On the other hand, allowing for saving after default can limit the adverse incentive effects of redistribution for income-rich households, which absorbs some of the reduction in private insurance but cannot prevent the crowding-out. However, Broer (2011) shows that redistribution in a production economy can generate a crowding-in of private insurance. This is because redistribution reduces the number of constrained income-poor households and therefore, limits the negative incentive effect for this group. Moreover, there are sufficiently high interest rates in this environment so that self-insurance becomes more effective, which reduces default-incentives. Overall, these two papers suggest that the question how redistribution affects private insurance markets depends on several model assumptions and behavioral responses of households.[1]

In another related paper, Ábrahám and Cárceles-Poveda (2010) use a production economy with incomplete markets and limited commitment to analyze the long-run implications of a revenue-neutral tax reform that eliminates the tax on capital earnings. In particular, the authors consider two experiments. First, increasing a linear labor income tax, and second, increasing the progressivity of labor income taxes. Both reforms lead to more capital accumulation which lowers the interest rate, and thus borrowing costs, making default less attractive and yielding higher borrowing limits. However, Ábrahám and Cárceles-Poveda (2010) assume that households inelastically supply labor so that higher tax rates or more progressive tax rates do not cause a negative incentive effect.

My contribution to this literature is a quantitative analysis on the impact of redistribution on private insurance markets in an empirically plausible life-cycle model with substantial heterogeneity among households. This implies distributions of wealth, earnings and consumption that are in line with their empirical counterparts. As Broer (2013) and Broer et al. (2017) document, limited-commitment economies such as those in Krueger and Perri (2011), are prone to exhibit log consumption distributions that are much more left-skewed than the respective log earnings distribution. This is clearly at odds with empirical findings and I show that my proposed model does not generate this counterfactual result.

Moreover, I acknowledge the (potentially) negative incentive effects of progressive taxes on labor supply and show that the labor supply elasticity is a crucial factor in determining the magnitude of crowding-out private insurance markets.

[1] A crowding-out of private insurance in slightly different settings is also found by Attanasio and Ríos-Rull (2000) and Golosov and Tsyvinski (2007).

Additionally, this chapter extends the existing literature by explicitly accounting for default as an equilibrium outcome and its consequences on private credit markets. This contingency is a crucial feature of unsecured credit markets and has a substantial impact on the determination of loan prices.

This chapter also contributes to the literature on the quantitative effects of private default. The seminal papers of Athreya (2002), Chatterjee et al. (2007) and Livshits et al. (2007) pre-eminently establish equlibrium conditions when households default on their outstanding debt. Furthermore, Athreya (2002) and Chatterjee et al. (2007) use their frameworks to investigate the welfare effects of means-testing that was introduced in a reform in 1998. While Athreya (2002) only finds modest welfare effects, Chatterjee et al. (2007) find that the policy change yielded large welfare gains. Livshits et al. (2007) investigate the differences of Chapter 7 bankruptcy (labeled as the "fresh start" system), where debt is completely discharged after the bankruptcy filing, and a Chapter 13 bankruptcy, where debt is rolled over after the filing. The authors find that the "fresh start" system generally leads to higher welfare. Livshits et al. (2010) use this framework to investigate the causes of the rise in consumer bankruptcies from 1970 to 2002 which they mainly ascribe to changes in the credit market. Athreya et al. (2012) study the role of informational frictions in explaining the strong increase in bankruptcy filings. Nakajima (2017) uses this framework to evaluate the bankruptcy reform of 2005. Nakajima and Ríos-Rull (2014) introduce this credit market setting into an incomplete markets framework with aggregate risk and explain the procyclicality of consumer credit and bankruptcy filings.

In a closely related paper to my work, Athreya et al. (2009) study the extent to which unsecured credit markets could mitigate the transition of increased income risk into consumption risk over the past decades. They find that credit markets are not very efficient at smoothing individual consumption fluctuations and conclude that, if there was an improvement in risk sharing over this period, it cannot be attributed to unsecured credit. My contribution to that strand of literature is that I investigate the impact of fiscal policy, and in particular redistribution, on unsecured credit markets with a specific focus on its effects on private risk sharing.

The chapter is organized as follows. Section 2.2 presents the model and Section 2.3 describes the parametrization. In Section 2.4, I present the properties of baseline model and the results of the computational experiment. In Section 2.5, I discuss the role of the labor supply elasticity and show that most of the results hold in the case of a considerably elasticity. Section 2.6 presents results of a similar experiment when the tax rate on interest earning is varied, and Section 2.7 concludes.

2.2 Model

I study an OLG economy with incomplete markets and heterogeneous agents as in Conesa et al. (2009) and Kindermann and Krueger (2014), augmented by equilibrium default on consumer credit as in Livshits et al. (2007) and Chatterjee et al. (2007).

2.2.1 Demographics

The economy is populated by J overlapping generations of finitely-lived agents. In each period, a new age cohort with mass one enters the economy, implying that there is no population growth. Agents face mortality risk in every period of their life, where ψ_j denotes the conditional survival probability from age j to age $j+1$. At age J, agents die with probability one, such that $\psi_J = 0$. Since it is not directly connected to the research question of this chapter, I refrain from modeling an explicit bequest motive. However, I assume that there are no annuity markets and consequently, deceased households leave accidental bequests. These bequests are collected and consumed by the government.[2] At age J_R, agents retire from the labor market and receive social security benefits, which are financed by a proportional payroll tax.

2.2.2 Preferences and Endowments

Agents are endowed with one unit of time, which they spend supplying labor or consuming leisure. They are born with zero assets. The labor productivity of an agent is determined by three factors. First, there is age-dependent productivity ε_j, which determines the average wage of an age-cohort. Retired agents are not productive and thus, $\varepsilon_j = 0$ for all $j \geq J_R$. Second, there are permanent productivity differences that are supposed to capture variations in education and innate ability. In particular, agents draw one of the m possible types $i \in \mathcal{I} \subseteq \mathbb{N}$ at the beginning of their life, which is fixed over their life cycle. Let p_i denote the probability of being born with ability type ν_i. Third, agents face idiosyncratic

[2] Alternatively, accidental bequests could be redistributed among households. Since the magnitude of bequests is quantitatively negligible, the results in this chapter would not affected by this assumption.

shocks to their labor productivity, $\eta \in \mathcal{E} \subseteq \mathbb{R}^+$. This shock is assumed to follow a first-order Markov process. More specifically, the process is given by

$$\log \eta_t = \rho_e \log \eta_{t-1} + \varepsilon_{e,t}, \tag{2.1}$$

where $\varepsilon_{e,t} \sim \mathcal{N}(0, \sigma_e^2)$ is the shock term of the process and $\rho_e \in [0,1)$ measures the persistence.

I assume that households are also subject to expenditure shocks $x \in \mathcal{X} \subseteq \mathbb{R}_0^+$. These shocks are supposed to capture unexpected medical expenses, divorces or unintended pregnancies, which are the most frequently mentioned causes to file for bankruptcy in the U.S., according to Livshits et al. (2007).

The preferences of an agent are given by the expected discounted sum of period utilities of the form

$$\mathbb{E}\left\{\sum_{j=1}^{J} \beta^{j-1} U(c_j, l_j)\right\}, \tag{2.2}$$

where $\mathbb{E}$ is an expectation operator with respect to mortality risk and the stochastic processes for idiosyncratic risk, β is the discount factor, c_j is consumption at age j and l_j is labor supply at age j. $U : \mathbb{R}^+ \times [0,1] \to \mathbb{R}$ is assumed to be bounded, strictly increasing in the first argument, strictly decreasing in the second argument, strictly concave and to satisfy the Inada conditions.

2.2.3 Bankruptcy

Households may file for bankruptcy on their outstanding debt. The default option is modeled as in Chatterjee et al. (2007) and Livshits et al. (2007), and captures the main features of the Chapter 7 Bankruptcy code, which is the predominant form of personal bankruptcy filing in the United States.[3]

If a household decides to file for bankruptcy, the outstanding debt or bills are discharged and there are no further obligations left that have to be paid back. The household is not allowed to save during this period. Moreover, a filing cost equal to a fraction $\xi \in [0,1)$ of the current after-tax labor income has to be paid to the creditor. The credit history of the defaulting agent turns bad, which results in an exclusion from the loans market for the next ten years.

In the model, I distinguish between two types of default. On the one hand, there is *voluntary* default, where households weigh the costs and benefits, and file for bankruptcy if it is optimal. The benefits are to get rid of the debt or bills, while

[3]During the years 1960-2017, around 75 percent of all private bankruptcy cases were filed under Chapter 7.

the costs are the filing costs, the one-year exclusion from the savings market and the exclusion from the loans market for an extended period of time. Thus, the costs of filing for bankruptcy are purely pecuniary.[4] On the other hand, Households *involuntarily* default if they simply do not have the funds to pay their bills or repay their debt, and would starve without the default option.

Chapter 7 bankruptcy prevents a second discharge of debt if there has been a filing in the last eight years. However, to avoid negative consumption, households with a bad credit record are allowed to involuntarily default in the model. To reduce computational costs, I follow Nakajima (2017) and use a stochastic determination of the credit status. More specifically, households with a bad credit history face a probability λ of getting a good credit status in the next period and probability $1 - \lambda$ of remaining with a bad record.

Following Livshits et al. (2007) and Nakajima (2017), retirees are completely excluded from the loans markets and do not have the possibility to file for bankruptcy.

2.2.4 Technology

Aggregate output Y_t is produced by competitive firms according to a production function given by

$$Y_t = F(K_t, L_t), \tag{2.3}$$

where K_t and L_t represent the aggregate capital stock and the aggregate labor input (in efficiency units) in period t, respectively. $F : \mathbb{R}^+ \times \mathbb{R}^+ \to \mathbb{R}^+$ is assumed to be strictly increasing and twice differentiable in both arguments, to exhibit constant returns to scale and diminishing marginal returns with respect to both factors, and to satisfy the Inada conditions. Each period, firms hire labor and rent capital to maximize their profits Π_t given by

$$\Pi_t = Y_t - w_t L_t - (r_t + \delta) K_t, \tag{2.4}$$

[4]Livshits et al. (2010) and Athreya et al. (2012), among others, introduce non-pecuniary costs in form of utility costs of filing for bankruptcy. Since this is not directly connected to the question in this chapter, I abstract from non-pecuniary costs.

where w_t is the aggregate wage per labor efficiency unit, r_t is the rental rate of capital and δ is the depreciation rate of capital. Optimal choices are then given by

$$w_t = \frac{\partial Y_t}{\partial L_t} = F_L(K_t, L_t), \tag{2.5}$$

$$r_t = \frac{\partial Y_t}{\partial K_t} = F_K(K_t, L_t) - \delta, \tag{2.6}$$

where $F_L(\cdot)$ and $F_K(\cdot)$ denote the partial derivatives of F with respect to labor and capital, respectively.

2.2.5 Government Policy

The government levies taxes on interest earnings, labor income and consumption expenditures to finance its obligations consisting of an exogenously given stream of government consumption G_t and interest payments on its debt B_t. The government budget constraint is given by

$$G_t + (1 + r_t)B_t = B_{t+1} + \tau_{k,t} r_t A_t^+ + \int \mathcal{T}(\widetilde{y}_t) d\Phi_t + \tau_{c,t} C_t, \tag{2.7}$$

where A_t^+ are aggregate positive asset holdings in period t, $\tau_{k,t}$ is the proportional tax rate on interest earnings, C_t is aggregate consumption, $\tau_{c,t}$ is the proportional tax rate on consumption, $\mathcal{T} : \mathbb{R}^+ \to \mathbb{R}$ is the (potentially non-linear) labor income tax schedule, $\widetilde{y}_t$ is the individual taxable labor income, and Φ_t is the cross-sectional distribution of households.[5]

Additionally, the government runs a pay-as-you-go social security system which is defined by benefits SS_t, received by each retiree independent of his earnings history. Social security taxes $\tau_{ss,t}$ are levied up to a maximum labor income threshold $\widehat{y}_t$ so that SS_t is set to balance the budget in each period. Hence, the social security budget is given by

$$SS_t \int \mathbb{1}_{j \geq j_R} d\Phi_t = \tau_{ss,t} \int \min\{y_t, \widehat{y}\} d\Phi_t, \tag{2.8}$$

where y_t is the individual pre-tax labor income.

[5] Note that the function $\mathcal{T}$ maps into the real numbers. This implies the possibility that households pay negative income taxes, which can be interpreted as fiscal transfers to the respective household.

2.2.6 Recursive formulation of the households' problem

The individual state space is characterized by the 6-tuple (j, a, i, η, x, h), where $j \in \mathcal{J} = \{1, \ldots, J\}$ is age, $a \in \mathcal{A} = \mathbb{R}$ is the current asset position, $i \in \mathcal{I} = \{1, \ldots, m\}$ refers to the household's innate ability, $\eta \in \mathcal{E} \subseteq \mathbb{R}^+$ is the idiosyncratic labor productivity state, $x \in \mathcal{X} \subseteq \mathbb{R}_0^+$ is the expenditure shock, and $h \in \mathcal{H} = \{0, 1\}$ is the credit status, where 0 refers to a good credit record and 1 to a bad one. In what follows, I state the households' problem in recursive notation, dropping time subscripts and using a prime to indicate the next period's value of the respective variable.

An agent with good credit history $(h = 0)$ chooses whether or not to default. Formally,

$$V(j, a, i, \eta, x, 0) = \max\{V_{non}(j, a, i, \eta, x, 0), V_{def}(j, a, i, \eta, x, 0)\}, \tag{2.9}$$

where $V_{non}(\cdot)$ and $V_{def}(\cdot)$ are lifetime values conditional on not defaulting and defaulting, respectively. The Bellman equation for an agent with a good credit status, conditional on not defaulting, is given by

$$V_{non}(j, a, i, \eta, x, 0) = \begin{cases} -\infty & \text{if } B_0(j, a, i, \eta, x, 0) = \emptyset, \\ \max\limits_{c,l,a'} \left\{U(c, l) + \beta \mathbb{E} V(j + 1, a', i, \eta', x', 0)\right\} & \text{if } B_0(j, a, i, \eta, x, 0) \neq \emptyset, \end{cases} \tag{2.10}$$

subject to

$$(1 + \tau_c)c + a'q(j, a', i, \eta, x, 0) + x = \begin{cases} w\varepsilon_j \nu_i \eta l + (1 + (1 - \tau_k)r\mathbb{1}_{a>0})a - \tau_{ss} \min\{w\varepsilon_j \nu_i \eta l, \hat{y}\} - \mathcal{T}(\tilde{y}), & \text{if } j < j_R, \\ SS + (1 + (1 - \tau_k)r)a, & \text{if } j \geq j_R, \end{cases} \tag{2.11}$$

where $q(\cdot)$ denotes the discount price of bonds, which depends on the characteristics of the household and the amount saved ($a' \geq 0$) or borrowed ($a' < 0$), see Section 2.2.7 for details on the pricing. $w\varepsilon_j \nu_i \eta l$ is the pre-tax labor income[6], and $\mathbb{1}$

[6] This is the explicit definition of y_t from Section 2.2.5.

is an indicator function that takes the value 1 if the condition attached is true and 0 otherwise. I follow Conesa et al. (2009) and define taxable labor income as

$$\widetilde{y} := w\varepsilon_j \nu_i \eta l - 0.5\tau_{ss} \min\{w\varepsilon_j \nu_i \eta l, \widehat{y}\}, \tag{2.12}$$

where the subtrahend accounts for the part of social security payments paid by the employer, which is not part of taxable income under U.S. tax law. B_0 is the budget set of an agent with a good credit history, defined as

$$B_0(j,a,i,\eta,x,0) := \big\{a' \in \mathbb{R}, c \in \mathbb{R}^+, l \in [0,1] \big| (1+\tau_c)c + a'q(j,a',i,\eta,x,0) + x = w\varepsilon_j\nu_i\eta l + (1+(1-\tau_k)r\mathbb{1}_{a>0})a - \tau_{ss}\min\{w\varepsilon_j\nu_i\eta l, \widehat{y}\} - \mathcal{T}(\widetilde{y})\big\}. \tag{2.13}$$

In the first case in (2.10), the budget set is empty, implying that there is no possibility to pay back the outstanding debt and/or pay the expenditure shock, and obtain a positive consumption level. The value function conditional on defaulting is assumed to be always finite, so that the household files for bankruptcy in this case. Since he basically has no other choice but to default, I refer to this case as an involuntary default.

The Bellman equation for an agent, conditional on defaulting, is defined as

$$V_{def}(j,a,i,\eta,x,h) = U(c,l) + \beta\mathbb{E}V(j+1,0,i,\eta',x',1), \tag{2.14}$$

subject to

$$(1+\tau_c)c = (1-\xi)\big[w\varepsilon_j\nu_i\eta l - \mathcal{T}(\widetilde{y}) - \tau_{ss}\min\{w\varepsilon_j\nu_i\eta l, \widehat{y}\}\big]. \tag{2.15}$$

In the case of default, the outstanding debt and the expenditure shock are discharged while a fraction of the after-tax labor income has to be paid to the creditor. Moreover, the agent is excluded from both the loans and the savings market ($a' = 0$) and his credit status in the next period is bad. Notice that this problem not only applies to households with a good credit record. To prevent households with a bad credit record from starving, they are also allowed to default on their negative expenditure shocks. The credit record then remains bad with certainty.

The problem of an agent with a bad credit history ($h = 1$) is defined as

$$V(j,a,i,\eta,x,1) = \begin{cases} V_{def}(j,a,i,\eta,x,1) & \text{if } B_1(j,a,i,\eta,x,1) = \emptyset, \\ \max\limits_{c,l,a'} \{U(c,l) + \beta[(1-\lambda)\mathbb{E}V(j+1,a',i,\eta',x',1) & \\ \qquad\qquad +\lambda\mathbb{E}V(j+1,a',i,\eta',x',0)]\} & \text{if } B_1(j,a,i,\eta,x,1) \neq \emptyset, \end{cases} \tag{2.16}$$

subject to

$$(1+\tau_c)c + a'q(j,a',i,\eta,x,1) + x = w\varepsilon_j \nu_i \eta l + (1+(1-\tau_k)r)a - \mathcal{T}(\widetilde{y}) - \tau_{ss}\min\{w\varepsilon_j\nu_i\eta l, \widehat{y}\}, \tag{2.17}$$

where λ denotes the probability to regain a good credit status. Since retirees are excluded from the loans market, this problem only applies to the working population. The budget set for agents with a bad credit status is given by

$$B_1(j,a,i,\eta,x,1) = \{a' \in \mathbb{R}_0^+, c \in \mathbb{R}^+, l \in [0,1] | (1+\tau_c)c + a'q(j,a',i,\eta,x,1) + x = w\varepsilon_j\nu_i\eta l + (1+(1-\tau_k)r)a - \mathcal{T}(\widetilde{y}) - \tau_{ss}\min\{w\varepsilon_j\nu_i\eta l, \widehat{y}\}\}, \tag{2.18}$$

where a' is now required to be non-negative because of the exclusion from the loans market.

The result of this dynamic programming problem is a value function V and policy functions c, l, a' and d as functions of the state (j,a,i,η,x,h) of a household, where $d(j,a,i,\eta,x,h) \in \{0,1\}$ is the policy function for defaulting.

2.2.7 Financial Intermediaries

Financial markets are perfectly competitive and consist of risk neutral savings institutions with unit measure and risk neutral lending institutions with unit measure. Savings institutions have access to a risk-free technology that yields r on deposits. Free entry is assumed so that the yield on savings offered to agents is equal to r. Lending institutions, on the other hand, offer one-period non-contingent bond contracts that include a transaction cost of making a loan and a risk premium conditional on the borrower's idiosyncratic default risk. These contracts are unsecured in the sense that borrowers are able to file for bankruptcy with their debts discharged afterwards. Since loans markets are competitive, lending institutions make zero expected profits. Moreover, I assume that the law of large numbers holds such that they can insure away idiosyncratic default risk and ex-post profits are zero.

The zero-profit condition for a loan of the amount a' to borrowers of type (j,i,η,x) is given by

$$(-a')q(j,a',i,\eta,x,0)(1+r+\iota) = (-a')\mathbb{E}\mathbb{1}_{d(j+1,a',i,\eta',x',0)=0}+ \\ (-a')\mathbb{E}\mathbb{1}_{d(j+1,a',i,\eta',x',0)=1}\frac{\xi\left(w\varepsilon_j\nu_i\eta l-\mathcal{T}(\widetilde{y})-\tau_{ss}\min\{w\varepsilon_j\nu_i\eta l,\widehat{y}\}\right)}{x'-a'}, \tag{2.19}$$

where $d(j+1,a',i,\eta',x',0)$ is the policy function of defaulting for a borrower of type (j,i,η,x) with a good credit record, and ι is a transaction cost of borrowing. The left-hand side of (2.19) represents the cost of lending to borrowers of type (j,i,η,x). The right-hand side gives the total income from lending. In particular, if a borrower repays his loan, i.e. $d(\cdot)=0$, the institution receives the face value of the loan $-a'$. If the borrower does not repay, i.e. $d(\cdot)=1$, he has to pay a cost that is proportional to his after-tax labor income. This cost is then divided by the issuer of the bill x' and the intermediary that lent the amount $-a'$. Solving equation (2.19) for loan price $q(\cdot)$ yields the following expression,

$$q(j,a',i,\eta,x,0) = \frac{\mathbb{E}\left\{\mathbb{1}_{d(j+1,a',i,\eta',x',0)=0}+\mathbb{1}_{d(j+1,a',i,\eta',x',0)=1}\frac{\xi(y-\mathcal{T}(\widetilde{y})-\tau_{ss}\min\{y,\widehat{y}\})}{x'-a'}\right\}}{1+r+\iota}, \tag{2.20}$$

for all $a'<0$, where I used $y=w\varepsilon_j\nu_i\eta l$. Moreover, $q(j,a',i,\eta,x,h)=1$ for all $a'\geq 0$, which applies to households with both a good credit record and a bad one.

Finally, since there does not exist a conventional borrowing constraint, I define the effective borrowing limit of a type (j,i,η,x) as follows,

$$\mathcal{B}(j,i,\eta,x) = \max_{a'} q(j,a',i,\eta,x,0)(-a'). \tag{2.21}$$

The effective borrowing limit is therefore defined as the amount of credit where an increase in the face value leads to a reduction of the actual amount received.

2.2.8 Equilibrium

Here, I define a stationary recursive competitive equilibrium in which the aggregate state of the economy is completely described by the joint probability measure Φ over individual states (j,a,i,η,x,h). Let $\mathcal{S}=\mathcal{J}\times\mathcal{A}\times\mathcal{I}\times\mathcal{E}\times\mathcal{X}\times\mathcal{H}$

be the state space of the individual state, let $\mathbb{B}(\mathcal{S})$ be the Borel σ-Algebra generated by $\mathcal{S}$, and let $\mathcal{M}$ be the set of all finite measures over the measurable space $(\mathcal{S}, \mathbb{B}(\mathcal{S}))$. A type distribution of agents is then represented by the probability space $(\mathcal{S}, \mathbb{B}(\mathcal{S}), \Phi)$ with $\Phi \in \mathcal{M}$.

Definition 1. *Given government expenditures G, government debt B, a tax system characterized by $(\tau_k, \mathcal{T})$, and a social security system characterized by $(\widehat{y}, \tau_{ss}, SS)$, a stationary recursive competitive equilibrium is a sequence of value and policy functions (V^*, c, n, a', d) for the households, optimal input choices (K, L) for the firms, prices (r, w, q), and the invariant probability measure Φ such that*

1. *given prices and government policies, V solves the households' problem, with c, n, a', and d as associated policy functions,*
2. *firms maximize profits such that factor prices are given by* (2.5) *and* (2.6)*,*
3. *financial intermediaries maximize profits such that $q(j, a', i, \eta, x, 0)$ satisfies the expected zero-profit conditions* (2.20) *for all types,*
4. *government policies satisfy the budget constraints* (2.7) *and* (2.8)*,*
5. *the labor market clears,*
$$L = \int \varepsilon_j \nu_i \eta l(j, a, i, \eta, x, h) d\Phi, \tag{2.22}$$
6. *the asset market clears,*
$$K + B = \int a'(j, a, i, \eta, x, h) d\Phi, \tag{2.23}$$
7. *each loan market clears and the expectations of financial intermediaries are consistent with the individual policy functions,*
8. *the goods market clears,*
$$C + \delta K + G + \int x \mathbb{1}_{d(j,a,i,\eta,x,h)=0} d\Phi = F(K, L) - \xi \int \mathbb{1}_{d(j,a,i,\eta,x,h)=1} \times \Big(y(j, a, i, \eta, x, h) - \mathcal{T}(\widetilde{y}(j, a, i, \eta, x, h)) - \tau_{ss} \min\{y(j, a, i, \eta, x, h), \widehat{y}\} \Big) d\Phi, \tag{2.24}$$

9. *aggregate consumption and aggregate positive asset holdings are given by*

$$C = \int c(j,a,i,\eta,x,h)d\Phi, \tag{2.25}$$

$$A^{+} = \int a'(j,a,i,\eta,x,h)\mathbb{1}_{a'>0}d\Phi, \tag{2.26}$$

10. *the invariant probability measure Φ is consistent with the population structure of the economy, with the exogenous processes and the households' policy functions.*

2.3 Parametrization

This section provides the necessary functional forms and parameter values to solve the model numerically.

2.3.1 Functional Forms

I assume that the period utility function of households is separable in consumption and labor,

$$U(c,l) := \frac{c^{1-\sigma}-1}{1-\sigma} - \chi\frac{l^{1+1/\gamma}}{1+1/\gamma}, \tag{2.27}$$

where σ is the coefficient of relative risk aversion, χ is a scaling parameter and γ is the Frisch elasticity of labor supply.

Aggregate output is assumed to be produced according to a Cobb-Douglas function,

$$F(K,L) := K^{\alpha}L^{1-\alpha}, \tag{2.28}$$

where $\alpha \in (0,1)$ determines the capital share of output.

For the labor income tax, I choose the functional form proposed by Bénabou (2000, 2002),

$$\mathcal{T}(y) := \bar{y}\left[\frac{y}{\bar{y}} - \vartheta\left(\frac{y}{\bar{y}}\right)^{1-\tau_l}\right], \tag{2.29}$$

where $\bar{y}$ is the average labor income, while ϑ and τ_l measure the level and the progressivity of the tax code. More specifically, the ratio of marginal to average tax rates is given by

$$\frac{1 - \mathcal{T}'(y)}{1 - \mathcal{T}(y)/y} = 1 - \tau_l, \tag{2.30}$$

so that $\tau_l > 0$ characterizes a progressive tax scheme and $\tau_l < 0$ a regressive system. For $\tau_l = 0$, (2.29) collapses to a proportional tax rate of $1 - \vartheta$. Heathcote et al. (2017b) estimate the parameters (ϑ, τ_l) for the United States and find that it fits the data remarkably well.

2.3.2 Calibration

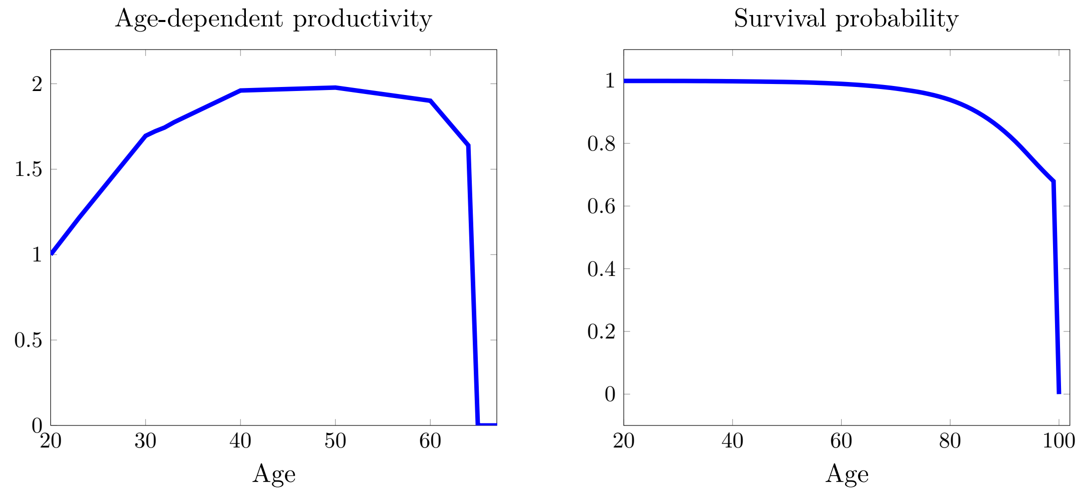
The baseline model is calibrated such that it is captures long-run characteristics of the U.S. economy. One model period is one year. Conceptually, I proceed as follows. First, I choose a subset of parameters based on model-exogenous information. In a second step, I determine the remaining parameters to match a set of aggregate and distributional parameters. Table 2.1 summarizes the exogenously chosen parameters, while the parameters that are calibrated within the model are reported in Table 2.2.

Exogenously determined parameters

In the model, households enter the economy at age 20, retire at age 65 and die with probability one at age 100. This corresponds to the model parameters $J_R = 46$ and $J = 81$. The conditional survival probabilities ψ_j for $j = 2, ..., J$ are calculated from the population numbers in Bell and Miller (2005). The age-dependent productivity profile ε_j for $j = 1, ..., 45$ is taken from Hansen (1993). Figure 2.1 displays both series. I set the coefficient of relative risk aversion σ to 2 as in Kindermann and Krueger (2014), and the Frisch elasticity of labor γ to 0.5, which is in line with the estimates in Chetty (2012).

There are three stochastic state variables in the model. First, the permanent ability state which is drawn at the beginning of each agent's life. I use $m = 2$ distinct states and refer to these as "low-skilled" and "high-skilled" agents. I follow Conesa et al. (2009) and assume that these two states have equal population mass $p_i = 0.5$ and fixed effect $\nu_{1,2}$ is set to $\{e^{-0.14}, e^{0.14}\}$. Second, I discretize the idiosyncratic labor productivity process into a five-state Markov chain by the

Figure 2.1: Exogenous life-cycle profiles



method of Rouwenhorst (1995).[7] Again, I follow Conesa et al. (2009) and set the persistence parameter ρ_e to 0.98 and the variance of the shock term to 0.029. Finally, I follow Livshits et al. (2007) and assume that the expenditure shock x can take on three values, which are independent and identically distributed. The corresponding shock values and probabilities are taken from Livshits et al. (2007) and annualized, since their calculations are for a three-year horizon. Following Gordon (2015), I assume that the annualized shocks are *i.i.d.* as well and that the shock values remain the same. The probabilities are then adjusted such that being hit by an expenditure shock within three years is the same as in Livshits et al. (2007). This yields a "small" expense shock x_1 of 0.762 with probability $\pi(x_1)$ of 2.42 percent and a "large" shock x_2 of 2.37 with probability $\pi(x_2)$ equal to 0.15 percent. The third state x_3 is a zero shock and has a probability $\pi(x_3)$ of 97.43 percent.

The share of capital α in total production is set to 0.36, as in Conesa et al. (2009), which implies a labor share of 64 percent. The average length of exclusion from the loans market λ is set to 0.1, implying that, on average, each agent who files for bankruptcy has to wait ten years to get a good credit status. This is in line with the Fair Credit Reporting Act, which mandates credit bureaus to keep negative information about borrowers for a ten-year period after bankruptcy and to remove it afterwards from the respective record.

The tax rate on interest earnings τ_k is equal to 0.283, following Kindermann and Krueger (2014). For the labor income tax progressivity, I use the estimate of

[7]This method is especially suited for stochastic processes with high persistence. See Kopecky and Suen (2010) for a detailed description and analysis of the method.

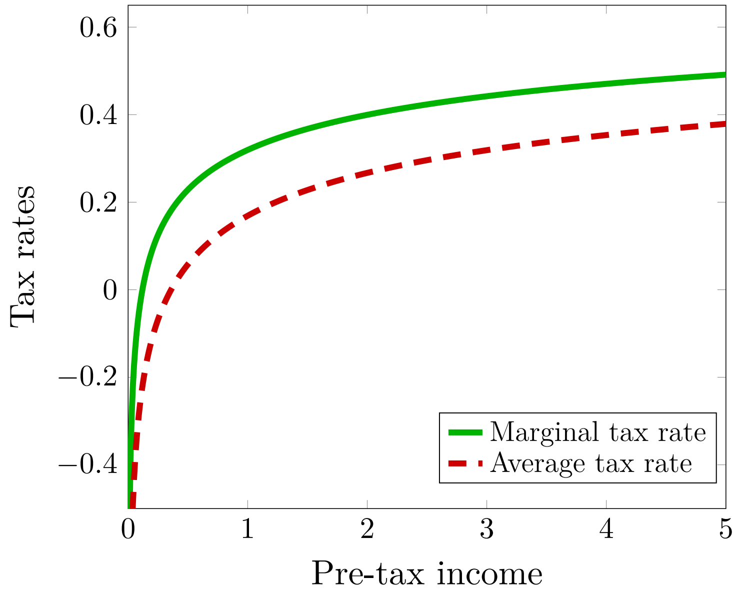
Table 2.1: Exogenously chosen parameters

Param	Explanation	Value	Target/Source
Demographics			
J	Maximum age	81	
J_R	Retirement age	46	
$\{\psi_j\}_{j=1}^{J}$	Survival probability	Fig. 2.1	Bell and Miller (2005), Table 6
$\{\varepsilon_j\}_{j=1}^{J_R-1}$	Age-dependent productivity	Fig. 2.1	Hansen (1993)
Preferences			
σ	Risk aversion	2	Kindermann and Krueger (2014)
γ	Frisch elasticity	0.5	Chetty (2012)
Government policy			
B/Y	Gov. debt-GDP-ratio	0.600	Data
G/Y	Gov. spending-GDP-ratio	0.160	Data
τ_k	Capital tax rate	0.283	Kindermann and Krueger (2014)
τ_c	Consumption tax rate	0.050	Kindermann and Krueger (2014)
τ_{ss}	Social security tax	0.124	Conesa et al. (2009)
τ_l	Income tax progressivity	0.181	Heathcote et al. (2017b)
ϑ	Income tax parameter	0.831	Budget balance
Technology			
α	Capital share	0.36	Long-run capital share in the U.S.
Credit			
λ	Prob. credit market access	0.1	Avg. exclusion duration 10 years
Shocks			
ρ	Persistence of idiosyncratic shock	0.980	Conesa et al. (2009)
σ_e^2	Variance of error term	0.029	Conesa et al. (2009)
x_1	Small expenditure shock	0.762	Livshits et al. (2007)
x_2	Large expenditure shock	2.370	Livshits et al. (2007)
$\pi(x_1)$	Prob. of small expenditure shock	0.0242	Livshits et al. (2007)
$\pi(x_2)$	Prob. of large expenditure shock	0.0015	Livshits et al. (2007)

Heathcote et al. (2017b) which is $\tau_l = 0.181$. This value is based on PSID data for the period 2000-2006 in combination with NBER's TAXSIM program. Government spending G is set to be 16 percent of output, while government debt B is set to 60 percent of output. Finally, I follow Kindermann and Krueger (2014) and set the consumption tax rate τ_c to 0.05. The second parameter in the income tax function ϑ is then determined by budget balance. Figure 2.2 plots marginal and average labor income tax rates given the choices for $\{\tau_l, \vartheta\}$ and an average pre-tax income of one.

Concerning the social security, I follow Conesa et al. (2009) by setting the payroll tax rate τ_{ss} to 0.124 and by setting the maximum labor income threshold to 2.5 times of the average income across households. The benefits SS are then determined by budget balance.

Figure 2.2: Implied average and marginal labor income tax rates



Endogenously calibrated parameters

The five remaining parameters $\{\beta, \chi, \delta, \xi, \iota\}$ are calibrated within the model to match five targets taken from U.S. data.[8] These are the aggregate debt-output ratio, the capital-output ratio, average labor supply, the percentage of indebted households, and the bankruptcy filing rate.

The choice for average labor supply is straightforward. The aggregate debt-output ratio is from Chatterjee et al. (2007) who use the 2001 Survey of Consumer Finance (SCF) to calculate this value. The measure for debt in this case is a household's negative net worth, which is equivalent to debt within a single-asset model as presented in the previous section. The aggregate capital-output ratio and the percentage of households filing for Chapter 7 bankruptcy are calculated for the period 1980-2012. For the percentage of households with negative net worth, I follow Athreya et al. (2012) and take the average of the estimates of 6.7 percent by Chatterjee et al. (2007) and 17.6 percent by Wolff (2006). The resulting parameters and the simulated model moments are listed in Table 2.2. As can be seen, the model does a good job at delivering the targeted values.

[8]See Appendix for a detailed data description.

Table 2.2: Endogenously calibrated parameters

Param	Explanation	Value	Target	Model
β	Discount factor	0.997	Debt-output ratio$\times$100 of 0.67	0.67
χ	Disutility of labor	85	Labor supply of 0.4	0.41
δ	Depreciation rate	0.120	Capital-output ratio of 2.54	2.49
ξ	Bankruptcy cost	0.365	Population filing (%) 0.64	0.71
ι	Transaction cost of loans	0.015	Population in debt (%) of 12.2	12.46

2.4 Results

In this section, I present the main results of the chapter. First, I show the characteristics of the baseline calibration. Then, I turn to the computational experiment, in which I vary the degree of progressivity in the income tax code and evaluate the effects on borrowing limits, inequality and risk sharing.

2.4.1 Characteristics of the baseline economy

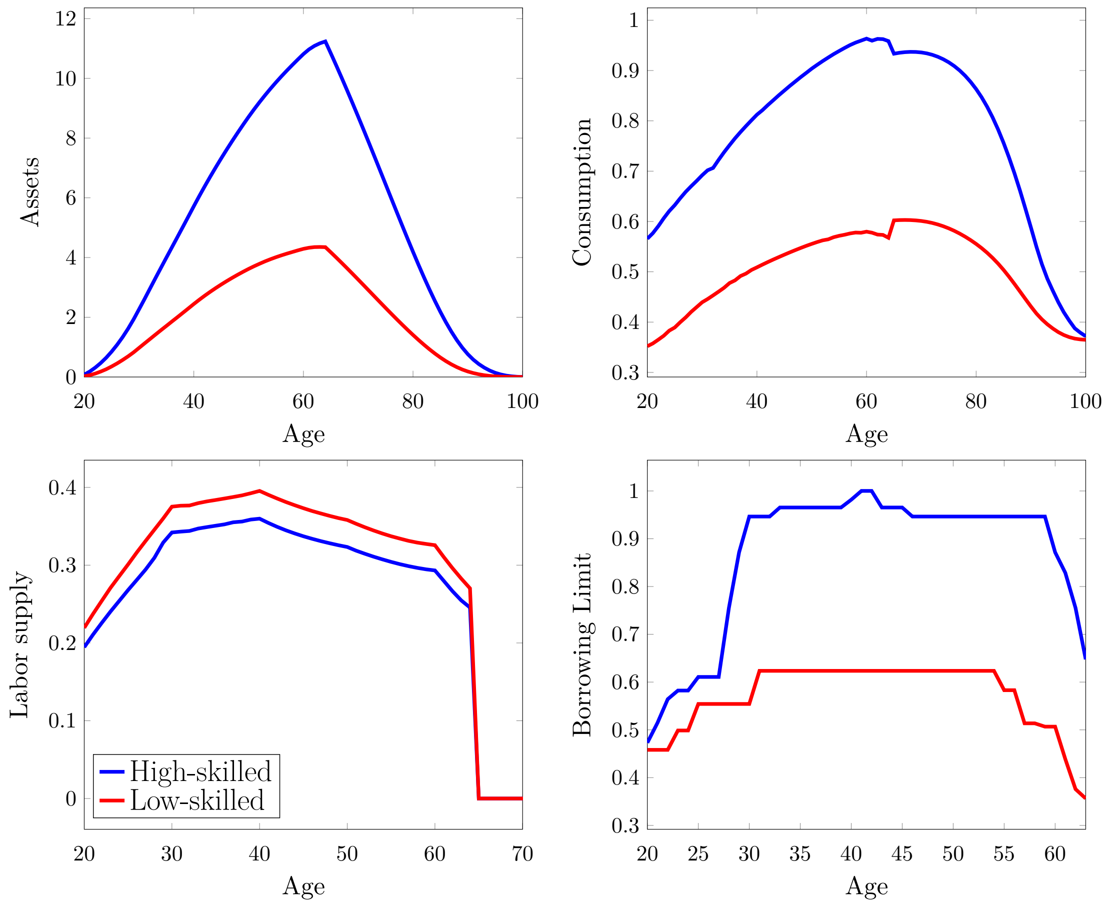
Life-cycle profiles. Figure 2.3 presents the first set of life-cycle profiles for both high-skilled and low-skilled agents. The upper left panel plots the respective asset choices which display a hump-shaped behavior as one would expect in life-cycle models. There are apparent differences in the magnitude of wealth accumulation between high-skilled and low-skilled agents. However, for both types of agents, the peak is in the last year before compulsory retirement and afterwards, both begin to dissave and ultimately converge within the last periods of their life.

The consumption profiles are displayed in the upper right panel of Figure 2.3. As for savings, there is a hump-shaped pattern but a considerably smoother one. Moreover, the differences in consumption levels are less pronounced, which is in line with the empirical fact that the wealth distribution is far more dispersed than the consumption distribution (see e.g. Heathcote et al., 2010).

The lower left panel shows the profile for labor supply. Both profiles display a hump-shaped pattern that strongly resembles the age-dependent productivity profile in Figure 2.1. However, there are significant differences in profiles as the low-skilled work more than the high-skilled. This is not surprising as they earn less because of lower productivity and, through the progressive income tax rate, their labor choice is less distorted. After working 45 years, both types go into compulsory retirement and labor supply goes to zero for the rest of their lives.

The lower right panel displays the average borrowing limit over the life cycle for the two types. Apparently, high-skilled agents face much lower loan costs than the low-skilled as indicated by the higher borrowing limits, which is to be

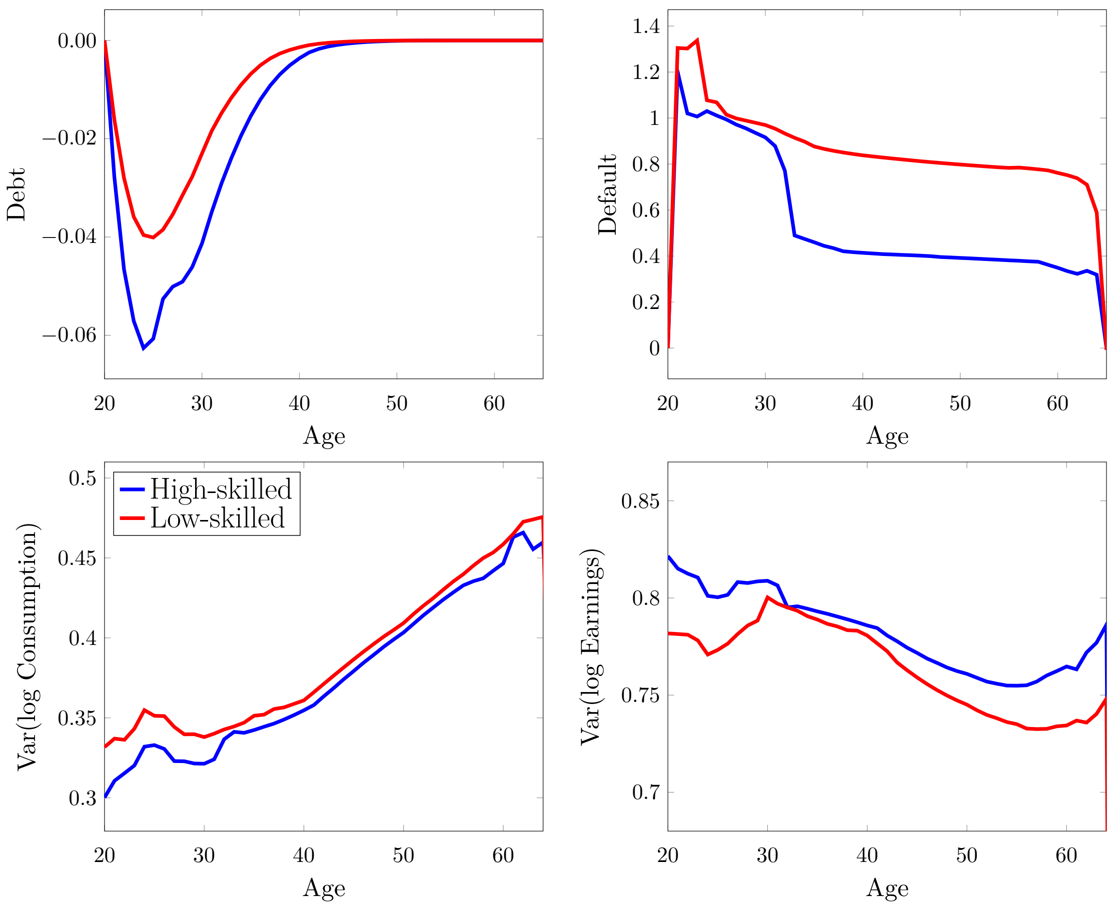
Figure 2.3: Average life-cycle profiles



expected. Both profiles display a hump-shaped pattern, which resembles the path of their income over the life cycle to some degree. The decrease of the low-skilled agents' borrowing limit starts already ten years before retirement while for the high-skilled, this process starts about five years later.

Figure 2.4 shows the second set of life cycle profiles. The upper left panel displays the average debt burden for the two types. High-skilled agents, when indebted, have higher debts than their low-skilled counterparts and keep them for a longer period of time. This is plausible as the high-skilled earn higher wages and are more probable to pay back their debt. Also, the penalty cost in case of default, which is proportional to the respective after-tax income, is higher, translating into a more favorable credit pricing. High-skilled agents who are in a low productivity state particularly rely on credit in their early stages of life. This is because they have the prospect to draw a better state at some point in time and use credit therefore to smooth consumption. In later periods of their working life, both high-skilled as well as low-skilled agents basically are not indebted anymore, or put differently, only very small fractions of both types are borrowers at this stage.

Figure 2.4: Average life-cycle profiles

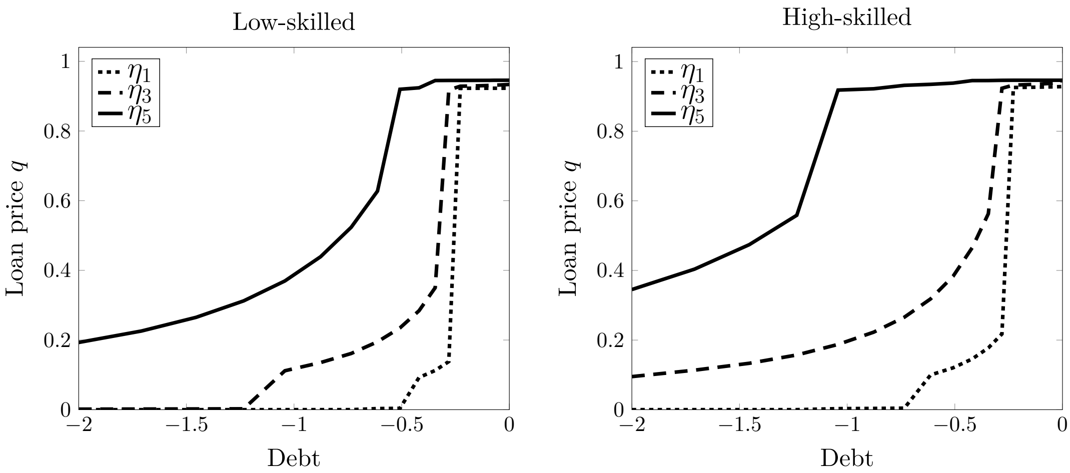


The upper right panel shows the defaulting behavior over the life cycle. For both types, the peak is very early in life and from age 35 on relatively constant. In general, low-skilled households file for bankruptcy more frequently which can be explained by their higher vulnerability to negative shocks. While most of the high-skilled build a strong buffer to absorb, for example, negative expenditure shocks, this is not the case for the low-skilled.

The lower two panels in Figure 2.4 show two inequality measures over the life cycle, the variance of log consumption and the variance of log earnings before taxes. Consumption inequality rises gradually over the working life for both types which is consistent with empirical findings (see e.g. Storesletten et al., 2004). When retiring, there is a sharp decrease of inequality which is because of the social security system that pays lump-sum benefits to each agent. Earnings inequality in the model is relatively constant within age groups, whereas inequality among the group of high-skilled is generally higher than within the group of low-skilled.[9]

[9]This result is somewhat counterfactual as Storesletten et al. (2004) show that earnings inequality rises throughout the working life. It results from the model because I assume that the productivity

Figure 2.5: Loan prices for both types



Credit markets. Figure 2.5 shows the loan price schedules conditional on the loan size for high-skilled (left panel) and low-skilled agents (right panel) at age 40. This choice is arbitrary but representative for basically every other age cohort that has access to the loans market. For small loan sizes around 0.25, the price schedule appears to be flat as all households are expected to pay back this amount. Except for the high productivity draws of both types, q decreases drastically afterwards, implying that the price strongly increases. Moreover, the default premium low-skilled agents have to pay is always higher than that of their high-skilled counterparts. This is not surprising as the high-skilled earn a higher income and are thus less likely to file for bankruptcy.

Distributional properties. The life-cycle profiles in Figure 2.3 suggest that the wealth distribution within the model economy is quite dispersed. To further analyze this and to evaluate the model's performance, the left half of Table 2.3 reports the model-implied wealth distribution together with its empirical counterparts from 1998 and 2007. Overall, the characteristics of the U.S. wealth distribution are well captured by the model. Only for the top quintile, or more specifically the top one percent, the model underestimates the respective wealth share. This is a common problem for incomplete market models that could be fixed by further assumptions. Kindermann and Krueger (2014) introduce two additional "super-productive" states that are not generated from the discretization of an AR(1) process. Instead, they calibrate the shock values and the transition probabilities to

of newborn households is distributed according to the invariant distribution of the Markov process. This assumption is necessary to generate sufficiently high earnings and wealth inequality in the cross-section.

Table 2.3: Wealth and income distributions

	Wealth			Earnings		
	Model	Data 1998	Data 2007	Model	Data 1998	Data 2007
Q1	−0.2	−0.3	−0.2	3.6	−0.2	−0.1
Q2	0.0	1.3	1.1	7.8	4.0	4.2
Q3	1.6	5.0	4.5	12.7	13.0	11.7
Q4	15.6	12.2	11.2	21.6	22.9	20.8
Q5	83.0	81.7	83.4	54.3	60.2	63.5
90-95	19.9	11.3	11.1	12.5	11.8	11.7
95-99	27.5	23.1	26.7	16.4	15.8	16.6
Top 1%	13.8	34.7	33.6	6.1	15.3	18.7
Gini	0.750	0.803	0.816	0.461	0.611	0.636

Notes: Data is taken from the Budría et al. (2002) and Diaz-Giménez et al. (2011).

match the characteristics at the top of the earnings and wealth distribution. Since this chapter rather focuses on the bottom of the wealth distribution, I forgo to explicitly model the top one percent, which would increase the computational costs by a significant amount.

The right half of Table 2.3 reports the model-implied labor earnings distribution together with its empirical counterparts from 1998 and 2007. Here, a similar picture becomes apparent. The model is able to generate a pronounced dispersion of the pre-tax earnings distribution. However, the earnings share of the bottom quintile is slightly overestimated, while the top share is underestimated. As for the wealth distribution, this is driven by the top one percent whose earnings share is much higher in the data. To account for these moments, further modeling assumptions would have to be implemented, which I forgo due to the computational costs.

As Broer (2013) and Broer et al. (2017) document, limited commitment economies as Krueger and Perri (2011) exhibit counterfactual properties of the earnings and consumption distributions. In particular, these models generate a distribution of log consumption that is much more left-skewed than the corresponding log earnings distribution. This is clearly at odds with empirical findings. Using U.S. data, Battistin et al. (2009) show that the skewness of log consumption is basically zero, implying that consumption is very well approximated by a log-normal distribution. Moreover, the authors find that the skewness of log earnings is slightly negative and therefore always smaller than the skewness of log consumption.

Table 2.4: Skewness of the log earnings and log consumption distribution

	Log consumption Skewness	Log earnings Skewness
Model	0.174	−0.053
Data	−0.106	−0.886

Notes: Data is taken from Heathcote et al. (2010). Earnings refer to after-tax labor earnings. See appendix for a detailed data description.

Table 2.4 reports the model-implied skewness of both distributions compared to the respective empirical moments from the Consumer Expenditure Survey (CEX) for the period 1980 to 2006. As can be seen, the skewness of log consumption is slightly positive while the skewness of log earnings is slightly negative. In this sense, the model accounts for the empirical fact that log consumption is more right-skewed than log earnings. The magnitude of consumption skewness is somewhat dependent on the exact definition for consumption expenditures and usually varies between –0.2 and 0.2. The qualitative property, namely the significant difference to the skewness of log earnings, preserves nonetheless.

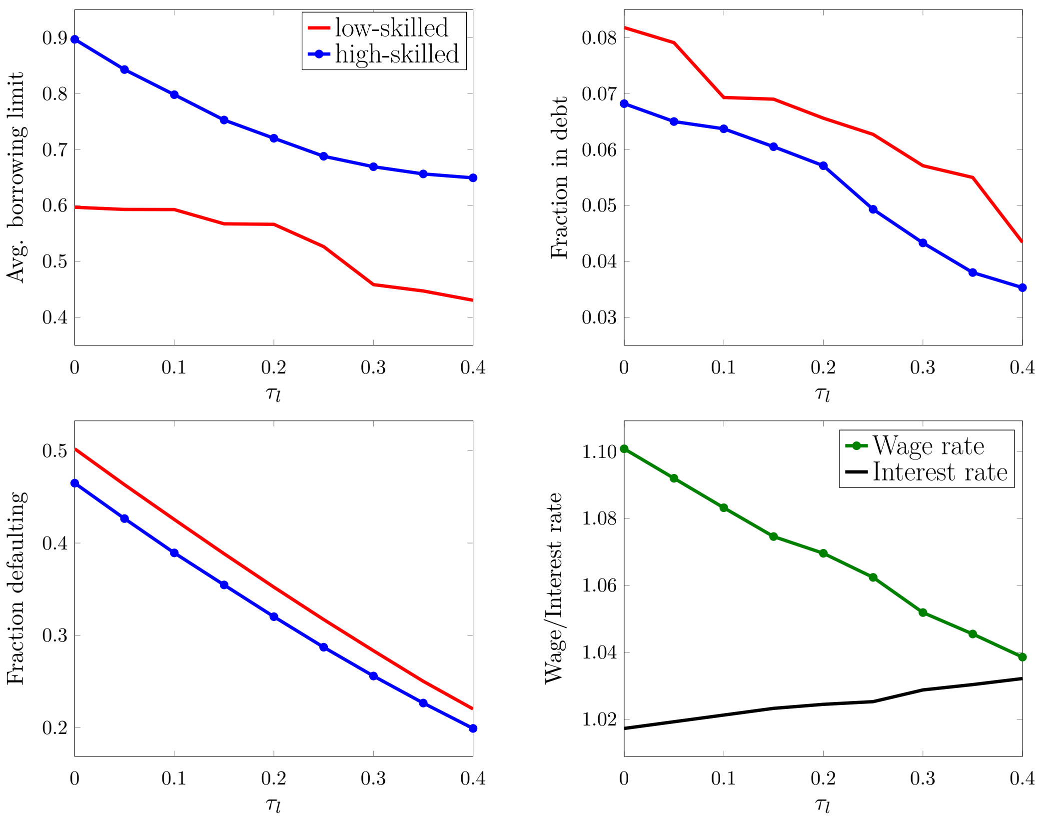
2.4.2 Computational Experiment

In this section, I use the proposed model to investigate the quantitative impact of changes in the progressivity of the income tax code on private borrowing limits, inequality and risk sharing. More specifically, I vary the degree of progressivity and analyze the impact within the interval $\tau_l \in [0, 0.4]$.[10] Note that I compare different stationary equilibria without taking the transition between them into account. When computing these stationary equlibria, the government consumption-to-output ratio and the public debt-to-output ratio as well as the consumption tax rate and the tax rate on interest earnings are held constant. To ensure that the government's budget is always balanced, the income tax parameter ϑ adjusts. As the main result, I find that redistribution leads to a decrease in (after-tax) income and consumption inequality but also to a significant crowding-out of private insurance.

Figure 2.6 displays the effects of different values of τ_l. The upper left panel presents one of the central plots of this analysis, namely the average borrow-

[10] As already stated, Heathcote et al. (2017b) estimate a τ_l of 0.181 for the United States. Kaas et al. (2018), on the other hand, find a range from 0.29 to 0.39 for Germany during the years 1995 to 2014. The upper bound, therefore, represents a realistic welfare state in the fashion of several European countries.

Figure 2.6: The effects of varying τ_l



ing limits.[11] Apparently, an increase in progressivity leads to tighter borrowing constraints for both types. There are, however, differences between the two. High-skilled households (blue line) face a steep decrease of borrowing limits in the area of low progressivity but only a mild decrease in the upper range. For low-skilled households (red line), it is rather the other way around. Their average borrowing limit is almost constant in the area of low progressivity, while they face a significant drop for larger values of τ_l.

The intuition behind these results is the following. For high-skilled households, a decrease in progressivity is a positive income shock, which, in combination with a dominating substitution effect (see Figure 2.9), leads to a strong increase in after-tax income. This increase improves their position on the credit market as the (proportional) bankruptcy cost rises, which directly translates into higher borrowing limits. A high degree of progressivity, on the other hand, increases the value of defaulting for low-income households. The significant drop in average borrowing limits of low-skilled households suggests that negative incentive effects dominate here. This general decrease in borrowing limits has important conse-

[11]This a weighted average of effective borrowing limits where each type of potential borrower is weighted by the respective probability mass in the distribution.

quences as especially young high-skilled households who drew a low idiosyncratic productivity state are less able to smooth consumption as they rely on credit in their early stage of life.

The upper right panel shows the fraction of agents that are indebted. This number is decreasing in τ_l which is to be expected. There are two reasons for this pattern. First, since credit conditions worsen, it becomes less attractive to rely on credit to smooth consumption. This especially applies to young high-skilled households. Second, since the increase in progressivity leads to an increase in after-tax income of low-income households, this group is less dependent on credit.

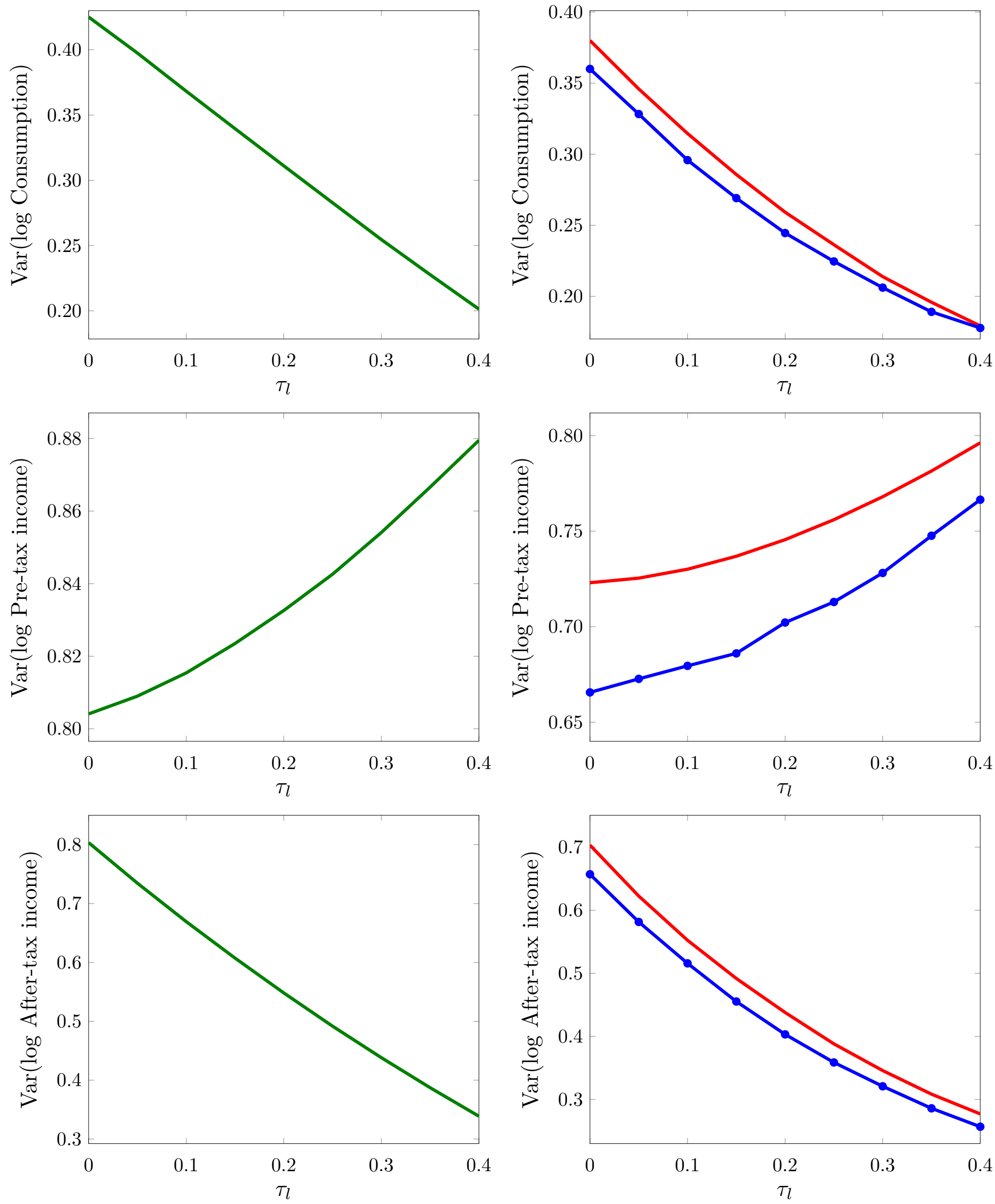
The lower left panel displays the fraction of defaulters among both groups. Apparently, both are strictly decreasing in the degree of redistribution, and therefore confirming the aforementioned results. Finally, the lower right panel shows the effects on the interest rate and the wage rate. While the interest rate is increasing in τ_l, the wage rate is decreasing. This implies that the crowding-out of capital is stronger than the crowding-out of labor.

Figure 2.7 shows the impact on consumption and earnings inequality, as measured by the variance of log consumption as well as the variance of log pre-tax and after-tax labor income. As expected, consumption inequality decreases sharply in tax progressivity. This results holds for both types, although the dispersion in the consumption distribution of the low-skilled is slightly higher for all τ_l. Pre-tax income inequality, on the other hand, is slightly increasing in progressivity. This is for three different reasons. First, the wage rate is falling and, as Figure 2.9 suggests, this drop is accompanied by a decrease in labor supply of all agents. Second, marginal tax rates are increasing in income, and third, a high degree of redistribution weakens the motive for precautionary savings. These three aspects account for the general drop in labor supply, while especially the latter account for the disproportionate decline of low-income households' labor supply. This, in turn, leads to an increase in pre-tax income inequality. The after-tax income inequality, however, is strongly decreasing in the degree of redistribution.

To determine the effect on risk sharing, I follow Krueger and Perri (2011) and define the following measures. Total intermediation (TI) of risk is the risk intermediation achieved by both public and private channels, and is given by one minus the ratio of the cross-sectional dispersion in consumption to the cross-sectional dispersion in pre-tax income,

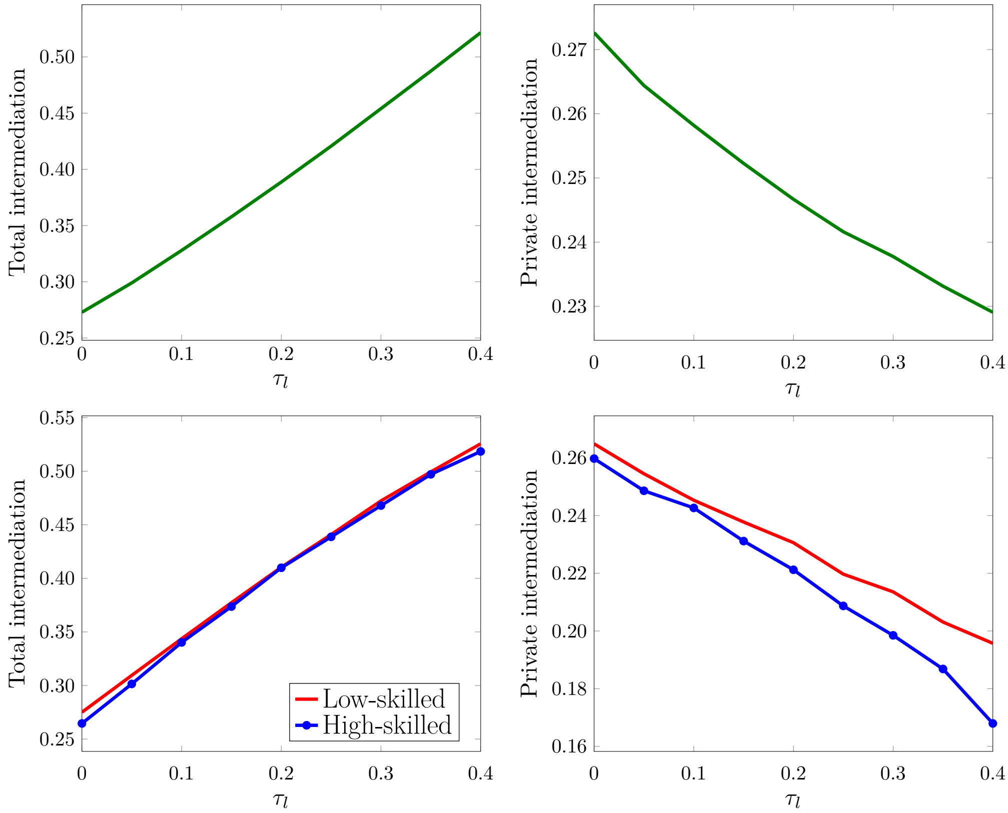
$$TI = 1 - \frac{\sigma_c}{\sigma_e}, \tag{2.31}$$

Figure 2.7: The effects of varying τ_l on inequality



where σ_c and σ_e are the standard deviations of the stationary distributions of consumption and pre-tax labor income, respectively. If $\sigma_c = 0$, there is no dispersion in the consumption distribution so that insurance is perfect and total intermediation is equal to one. If $\sigma_c = \sigma_e$, TI is equal to zero and consumption varies one for one with pre-tax income. For $TI \in (0, 1)$, there is only partial risk-sharing. Accordingly, Krueger and Perri (2011) define private intermediation (PI) of risk to

Figure 2.8: The effects of varying τ_l on risk-sharing



measure the reduction of consumption volatility beyond that provided by the tax system,

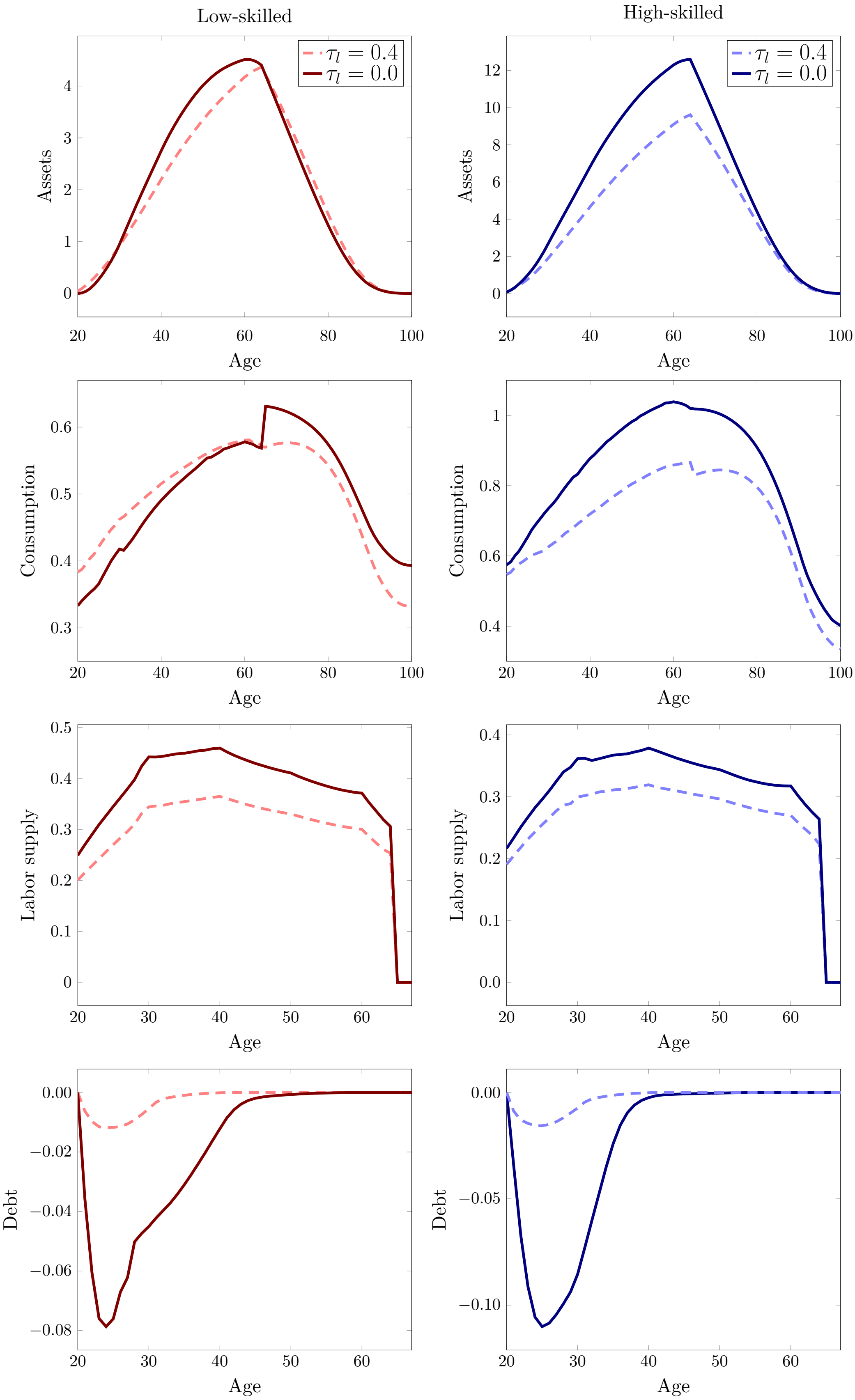
$$PI = 1 - \frac{\sigma_c}{\sigma_y}, \tag{2.32}$$

where σ_y denotes the standard deviation of the stationary distribution of after-tax income.

Crowding-out of private insurance is then a fall in PI in response to a rise in the tax progressivity, and vice versa for a crowding-in. A partial crowding-out is defined as a decrease in PI but an increase in TI while an excess crowding-out is characterized by a decrease in both, TI and PI.

Figure 2.8 shows the results for the risk sharing measures. There is a strong increase of total intermediation in tax progressivity which is also reflected in the decomposition of the two types. This result is not surprising as Figure 2.7 already shows that there is a strong decrease in consumption inequality and only a small increase in pre-tax income inequality. Aggregate private intermediation displays a slight decrease in τ_l as the reduction of consumption inequality is not as strong as the reduction in after-tax income inequality. The decrease in PI holds for both

Figure 2.9: Life-cycle profiles for different values of τ_l



groups, but is more pronounced for high-skilled households, especially in the area of high tax progressivity. To sum up, these results suggest that the decrease in consumption inequality can be entirely attributed to the increase in redistribution, while private insurance is crowded out.

Figure 2.9 presents the life-cycle profiles for the two extreme calibrations, $\tau_l \in \{0, 0.4\}$. In the upper row, the average savings choices are displayed for the low-skilled (left panel) and the high-skilled agents (right panel).

While savings change only slightly for the low-skilled, the crowding-out of capital becomes apparent in the right panel. High-skilled agents save significantly less when facing more progressive taxes. A similar picture evolves for the consumption profiles in the second row. Increasing the degree of redistribution translates into considerably lower consumption for the high-skilled. Low-skilled agents, in contrast, have a higher working time-consumption when redistribution is high but face a strong increase in retirement-consumption in the flat-tax case. This is because the income of all working agents is higher in this case and therefore social security benefits as well.

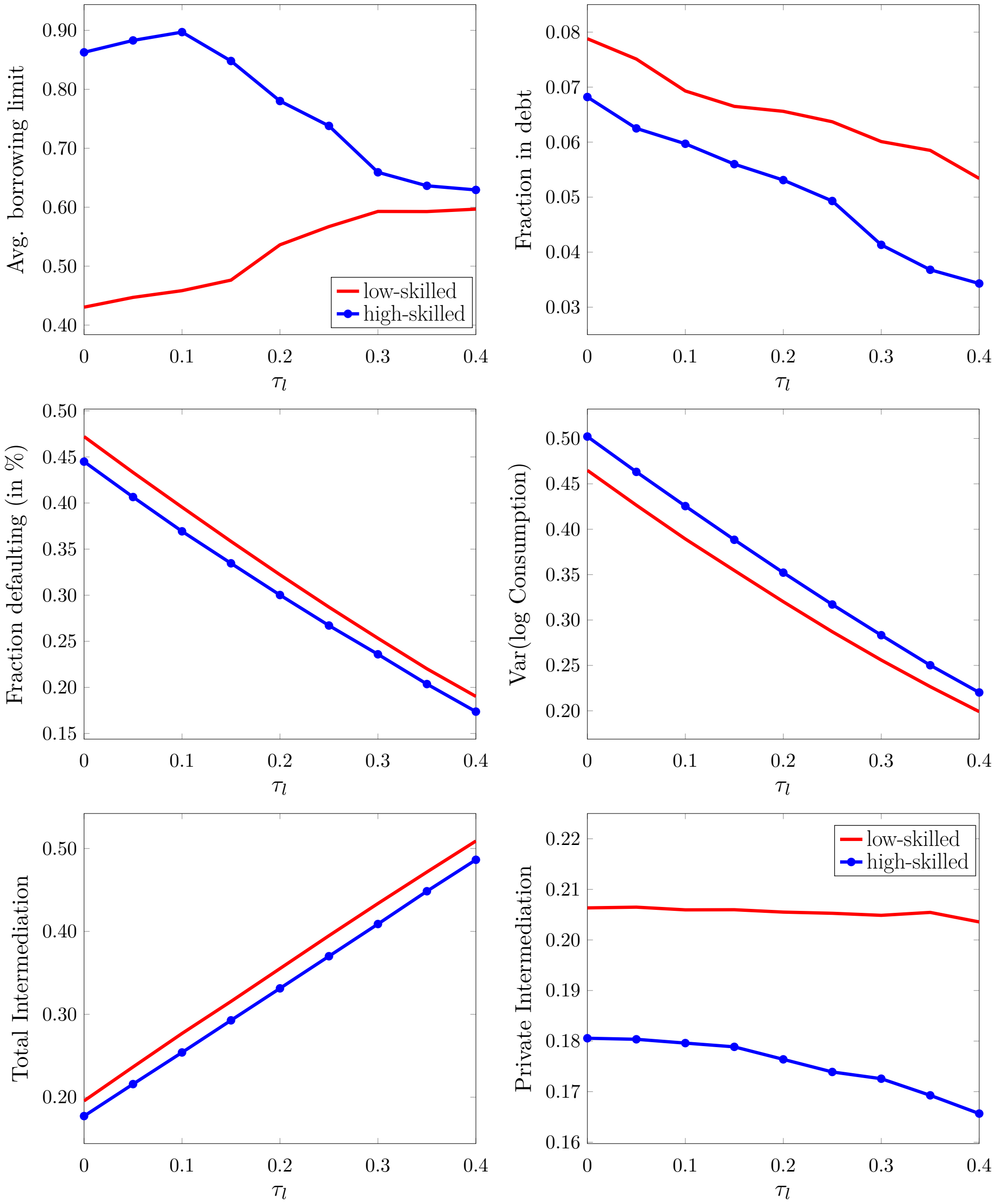
Average labor supply is shown in the third row of Figure 2.9. Both types decrease their labor supply when tax progressivity is high, although the reaction of the low-skilled is somewhat stronger for the reasons mentioned above. The last row displays the average indebtedness in the two scenarios and supports what can already be seen in Figure 2.6. Both types decrease their liabilities significantly when tax progressivity is high. The low-skilled, on the one hand, do not rely on credit as much when redistribution is high, while credit conditions become worse for the high-skilled.

2.5 The role of the labor supply elasticity

Negative incentive effects are a crucial driver of the baseline results. In this section, I explore the role of the labor supply elasticity and how it affects these results. Since the baseline elasticity is rather at the upper bound of empirical estimates (see e.g. Chetty, 2012), I consider a substantially lower elasticity of 0.3 and investigate to what extent incentive effects are mitigated. The computational experiment is exactly the same as in the previous section.

Figure 2.10 reports the effects of varying progressivity parameter τ_l on average borrowing limits, the fraction of indebted households, the fraction of defaulting households, the variance of log consumption as well as total and private intermediation for both types.

Figure 2.10: The effects of varying τ_l with $\gamma = 0.3$



In the upper left panel, it is apparent that average borrowing limits are affected quite differently. High-skilled households (blue line) face a strong decline of average borrowing limits, except for a minuscule increase in the area of very low to no progressivity at all. The low-skilled (red line), nevertheless, experience an increase of the average borrowing limit, which is in contrast to the baseline results. The intuition is the following. The lower labor supply elasticity prevents the strong decrease in labor supply, implying a weaker negative incentive effect. This and the fact that default rates are also decreasing in τ_l leads to considerably better conditions on credit markets for low-skilled households.

The fraction of indebted households as well as the fraction of defaulting households is decreasing in tax progressivity, which is in line with the results from the previous section. Only the fraction of indebted low-skilled households is decreasing at a slower rate and there is a general downward shift of defaulting households. The variance log consumption is decreasing in τ_l as expected. However, there are two differences to the baseline results. First, consumption inequality is significantly higher with a lower labor supply elasticity and second, the dispersion among the high-skilled is higher than among the low-skilled. This is because a lower labor supply elasticity compresses the labor supply distribution which translates into higher income inequality and consequently higher consumption inequality.

The effects on the risk sharing measures from Krueger and Perri (2011) are displayed in the lowest row. Total intermediation is again increasing in τ_l as the demand for insurance in this world is even higher than in the baseline. Private intermediation, on the other hand, shows a slightly different pattern. PI is relatively constant in the group of low-skilled households, implying that the dispersion of the consumption distribution is decreasing as fast as the dispersion in the after-tax income distribution. For the high-skilled, there is still a drop in PI, which is, however, less pronounced than in the baseline.

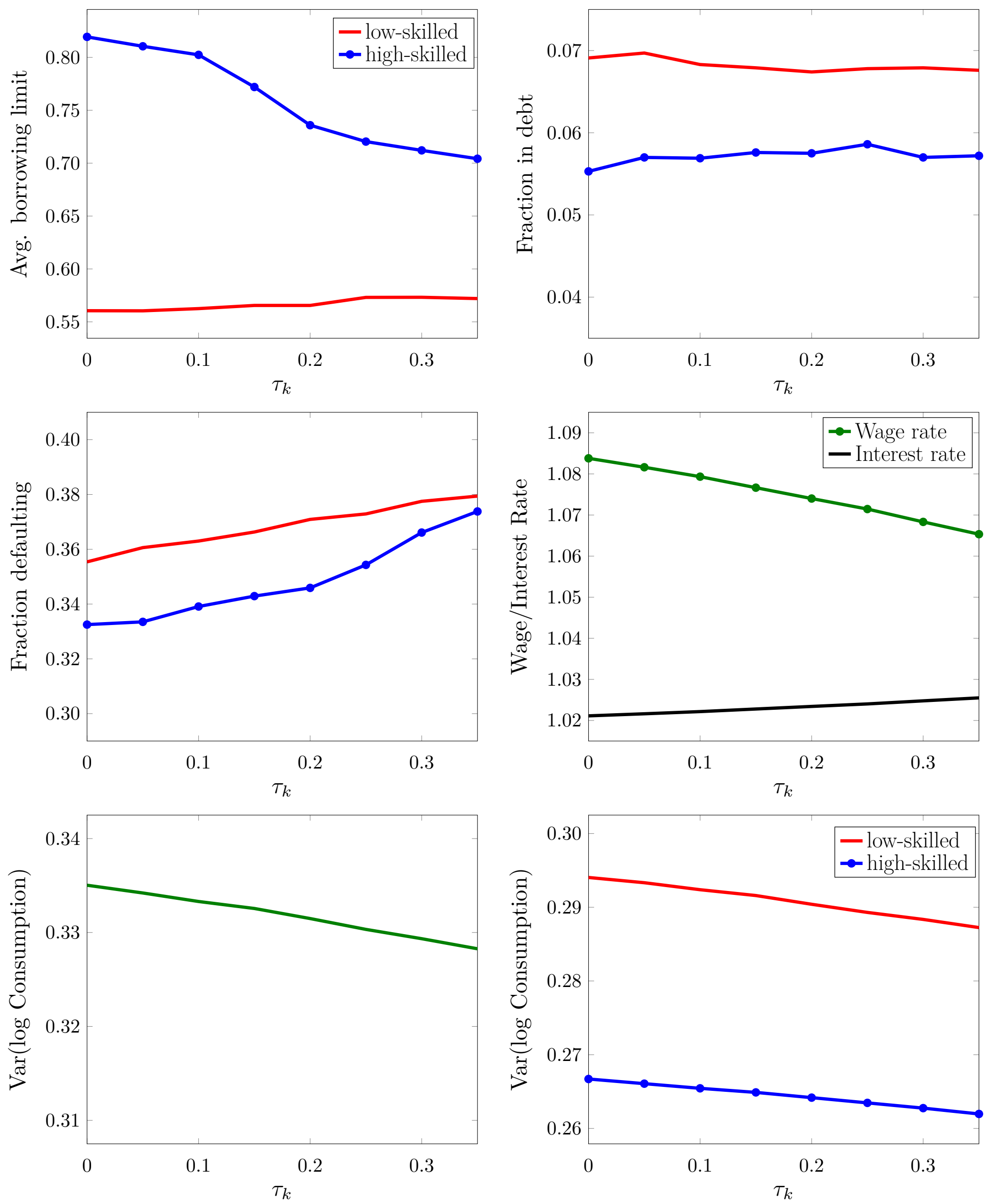
To sum up, the labor supply elasticity plays a crucial role in determining the effects of tax progressivity on private borrowing constraints and risk sharing. While several baseline results survive, the income distribution that emerges with a lower labor supply elasticity also causes some changes. Especially low-income households do not adjust their labor supply that strongly so that, on the one hand, pre-tax income inequality rises but also negative incentive effects are mitigated. This results in a more advantageous position on the credit market and therefore, a larger role of private insurance markets for consumption smoothing.

2.6 Varying the capital income tax

In this section, I vary the proportional tax rate on interest earnings τ_k in the interval $[0, 0.35]$ and investigate its influence on private borrowing limits and inequality. The progressivity of the labor income tax in this experiment is set to the baseline and ϑ adjusts to balance the fiscal budget.

Figure 2.11 reports the results. The average borrowing limit of high-skilled households (blue line) is decreasing in τ_k, especially in the area of high capital income taxes. For the low-skilled (red line), borrowing limits remain almost con-

Figure 2.11: The effects of varying τ_k



stant, but are slightly increasing when τ_k takes on higher values. The intuition is the following. As τ_k increases, the motive for precautionary savings is distorted, although not as much as through the progressive labor income tax. This is because the capital income tax does not have a redistributive role here and is (at least directly) irrelevant for a large part of low-income households. A lower precautionary savings motive, however, increases the exposure to bad shocks and therefore, raises the risk of defaulting.

The fraction of indebted households is almost constant for all τ_k, whereas the fraction of defaulting households is increasing. Especially high-skilled households file more often for bankruptcy, which is explained by the distorted precautionary savings motive and causes average borrowing limits to rise. As expected, capital is crowded-out by a higher capital income tax and therefore, the interest rate rises and the wage rate drops. The decline in the latter, however, is not as pronounced since the precautionary savings motive survives even with a relatively high tax rate on savings.

The effects on consumption inequality can be seen in the lowest row. The dispersion in the distribution of consumption is slightly decreasing in τ_k for both types. This is because the accumulation of savings is distorted, which compresses the wealth distribution and consequently, the consumption distribution. Because of this small effect on the consumption distribution, the effect on risk sharing is negligible.

To summarize, the tax rate on interest earnings only plays a minor role for borrowing constraints and risk sharing. While savings decisions of high-income households are definitely distorted, translating into a decline in borrowing limits, the relevance for low-income households with a relatively low number of assets is small.

2.7 Conclusion

This chapter investigates the link between redistributive taxation and private insurance markets. In particular, I explore to what extent the progressivity of the income tax code affects borrowing constraints and the cross-sectional distributions of earnings and consumption. For this reason, I construct an OLG model, in which credit constraints endogenously arise from individual default risk. The model exhibits substantial heterogeneity on the household side and is consistent with empirical observations in several dimensions, including wealth and income distributions. This framework provides a much better environment to analyze the impact of fiscal policy on private insurance markets compared to previous related literature.

As the main results, I find that higher progressivity leads to a fall in consumption inequality but also to a crowding-out of private insurance markets. This is reflected in a substantial tightening of private borrowing constraints, which is of particular importance for young high-skilled households who use credit to smooth consumption over their life-cycle. Takings this into account, one could question the efficiency of progressive taxation when it comes to dampening individual consumption fluctuations.

An interesting next step would be to investigate optimal tax progressivity or to set up a more general optimal taxation problem that takes endogenous credit constraints and individual default risk into account. One avenue for future research could be to explore optimal age-dependent tax progressivity that considers the potential crowding-out of private insurance markets and its effect on the younger generation in an economy. This could be done along the lines of Heathcote et al. (2017a), who build upon a Ramsey setting, or Weinzierl (2011), who uses a more general Mirrleesian framework. None of these papers, however, considers the influence of endogenous borrowing constraints on allocations and welfare.

Appendix

2.A Computational Appendix

Construction of asset grid

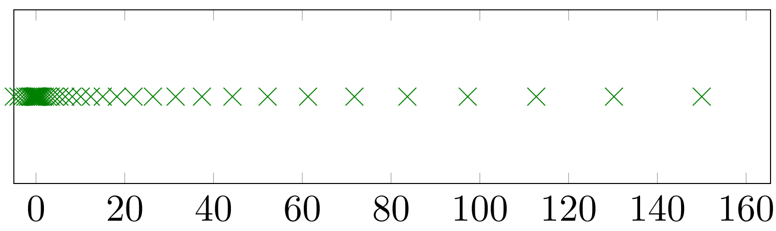
First I discretize the continuous asset dimension to make the problem computationally feasible. I choose a set of discrete points $\{a_1, \ldots, a_n\}$. In particular, I split this set into two subsets. One for negative assets or debt, $a^- := \{a_1, \ldots, a_{nm}\}$, and one for positive assets, $a^+ := \{a_{nm}, \ldots, a_n\}$, where $a_{nm} = 0$.

The respective subgrids are constructed via the formula

$$a_i = \left(\frac{i-1}{k-1}\right)^{\phi} \cdot (a_r - a_l) + a_l, \qquad \text{for } i = 2, \ldots, k-1, \tag{2.33}$$

on an interval $[a_l, a_r]$ with k grid points, where $a_1 = a_l$ and $a_k = a_r$. ϕ determines the degree of grid point concentration close to a_l. While $\phi = 1$ implies an equidistant grid, a high ϕ places a lot of points in the neighborhood of a_l. I choose $\phi = 7$ for both subgrids, since a large number of agents has asset holdings that are relatively close to zero. To make use of (2.33) for the debt subgrid, I choose the interval $[0, -a_1]$ and multiply the vector by (-1). I choose 31 grid points in the debt subgrid and 51 grid points in the positive asset subgrid. This amounts to 81 total grid points in the asset dimension since both subgrids contain $a = 0$ and the grids are spliced at this point. Lastly, I choose a_1 and a_n such that no probability mass is on these points in the construction of the wealth distribution. The resulting grid in the asset dimension is visualized in Figure 2.12.

Figure 2.12: Distribution of asset grid points



The resulting state space is now

$$\{1, \ldots, 81\} \times \{a_1, \ldots, a_n\} \times \{s_l, s_h\} \times \{\eta_1, \ldots, \eta_5\} \times \{x_1, x_2, x_3\} \times \{0, 1\},$$

where s_l and s_h indicate low-skilled and high-skilled households, respectively.

Solving the household problem

The household problem is solved by backward induction. Since the computations involve the discontinuous credit pricing function $q(\cdot)$, I cannot use algorithms that rely on Euler equations like the Endogenous Grid method or Time Iteration, but have to rely on derivative-free optimization methods. More specifically, I iterate on the following steps:

1. Compute household decisions at maximum age J for any (J, a, i, η, x, h).[12] Households at age J die for sure and do not work anymore, so that they consume all of their remaining resources and do not save. This gives the policy functions $a'(J, a, i, \eta, x, h) = 0$ and $c(J, a, i, \eta, x, h)$, so that the value function $V(J, a, i, \eta, x, h)$ is simply given by $u(c(J, a, i, \eta, x, h), 0)$.

2. Find the solution of the household optimization problem for all possible (j, a, i, η, x, h) recursively. I split this problem into two subproblems, one for retired households with age $j \in [J_R, J-1]$ and one for working households with age $j \in [1, J_R - 1]$.

   The subproblem of retired households consists of an optimization problem in one dimension, since they are only choosing the optimal amount of assets and consumption is then determined by the budget constraint. For this problem, I use a Golden Section Search algorithm (see Press et al., 1992, pp. 390-395). Since this involves evaluating next period's value function at points off-grid, I use linear interpolation.

   The subproblem of working households is more involved, since it requires optimization in two dimensions and the computation of two different value functions. For the value function conditional on not defaulting, I make use of Powell's line search method (see Press et al., 1992, pp. 406-413), which turned out to be more accurate and more efficient than the Nelder-Mead simplex method. For the value function conditional on defaulting, I again use the Golden Section Search, since $a'(j, a, i, \eta, x, h) = 0$ in this case.

[12]Since retired households are not allowed to be indebted and are not subject to idiosyncratic shocks, there is no need to compute the decisions on the whole state space. I omit theses simplifications for notational reasons, though.

Determining aggregate quantities and prices

To determine aggregate quantities and prices, I use the following algorithm. I start with initial guesses $\{K_0, L_0, \vartheta_0, SS_0, \bar{y}_0\}$. Then, I iterate over the following steps for $k \in \mathbb{N}_0$:

1. Use the (initial) guesses to compute factor prices r_k and w_k as well as the aggregate quantities Y_k, B_k, G_k.

2. Solve the household problem using the initial guesses and the corresponding factor prices and quantities.

3. Determine the type distribution of households using the policy functions that result from the previous step.

4. Using the type distribution, determine $K_{imp}, L_{imp}, SS_{imp}, \bar{y}_{imp}$ and calculate the budget balancing ϑ_{imp}.

5. Calculate the residual vector R,

$$\begin{aligned}
R_1 &= K_{imp} - K_k, \\
R_2 &= L_{imp} - L_k, \\
R_3 &= \vartheta_{imp} - \vartheta_k, \\
R_4 &= SS_{imp} - SS_k, \\
R_5 &= \bar{y}_{imp} - \bar{y}_k.
\end{aligned}$$

   If $||R||_\infty$ is smaller than some tolerance level, the algorithm converged and an equilibrium is found. If not, calculate the new guesses

$$\begin{aligned}
K_{k+1} &= (1-\omega)K_k + \omega K_{imp}, \\
L_{k+1} &= (1-\omega)L_k + \omega L_{imp}, \\
\vartheta_{k+1} &= (1-\omega)\vartheta_k + \omega \vartheta_{imp}, \\
SS_{k+1} &= (1-\omega)SS_k + \omega SS_{imp}, \\
\bar{y}_{k+1} &= (1-\omega)\bar{y}_k + \omega \bar{y}_{imp},
\end{aligned}$$

   where ω is a dampening parameter, and go back to step 1.

2.B Data Appendix

Table 2.5: Data sources

	Series title	Series ID	Source
(1)	Gross Domestic Product	GDP	BEA
(2)	Total Public Debt as Percent of Gross Domestic Product	GFDEGDQ188S	USDT
(3)	Government Consumption Expenditures and Gross Investment	GCE	BEA
(4)	Current-Cost Net Stock of Fixed Assets and Consumer Durable Goods	K1WTOTL1ES000	BEA
(5)	Non-Business filings, Chapter 7 of the Bankruptcy Code	-	USC
(6)	Total households	TTLHH	USCB
(7)	ND+ (Non-durable consumption expenditures)	NDPND2	CEX
(8)	Total income after taxes (real)	TIA	CEX

Notes: BEA: U.S. Bureau of Economic Analysis, CEX: Consumer Expenditure Survey, USC: U.S. Courts, USCB: U.S. Census Bureau, USDT: U.S. Department of the Treasury

Chapter 3

Fiscal policy over the business cycle

3.1 Introduction

The effectiveness of discretionary fiscal policy is an ongoing and controversial issue in economic research. The Great Recession and the large number of stimulus packages in its aftermath reinforced this debate, shifting the focus to the transmission channels of fiscal policy and how economic conditions affect these channels. The central question in this debate is whether multipliers are state-dependent, or, in a more general sense, whether countercyclical fiscal policy could be an effective tool to mitigate recessions.

Indeed, recent empirical studies (e.g. Auerbach and Gorodnichenko, 2012, 2013; Linnemann and Winkler, 2016) use a variety of different estimation techniques and find substantial nonlinear effects, indicating the existence of countercyclical fiscal multipliers.[1] Theoretical channels that rationalize these findings are rather scarce. In this chapter, I address this issue within a quantitative model and propose a mechanism in which incomplete insurance markets and occasionally binding borrowing constraints generate state-dependent responses to fiscal policy shocks. Key driver of this result is the substantial heterogeneity in the marginal propensity to consume (MPC) across households generated by the aforementioned model components. The general framework is based on McKay and Reis (2016) and incorporates nominal rigidities into an incomplete markets model with aggregate uncertainty. Households are heterogeneous with respect to their access to capital markets, their patience, and in their exposure to idiosyncratic shocks. This rich heterogeneity is important to generate realistic wealth and income distributions as well as a non-trivial distribution of households' MPC.

[1] These findings are, however, not uncontroversial. Ramey and Zubairy (2018) use U.S. historical data and find no significant differences in multipliers across the business cycle.

Differences in MPC across households are supported by empirical evidence. Jappelli and Pistaferri (2014) use survey questions to determine how much of an unexpected positive income shock would be spent on consumption and document significant differences across income groups. In particular, they find a strong negative correlation between the MPC and disposable income. Concerning the relationship between MPC heterogeneity and fiscal policy, Parker et al. (2013) use data from the Consumer Expenditure Survey (CEX) to determine consumption responses of households to the tax rebates that were implemented in the Economic Stimulus Act in February 2008. They find huge discrepancies in the consumption responses across households after the stimulus payments, ranging from 50 to 90 percent of the payments in the quarter of the receipt, where the largest response is found for low-income households. Similar results are found by Johnson et al. (2006) for the 2001 federal income tax rebates and by Misra and Surico (2014) who use the CEX to investigate both the tax rebates from 2001 and 2008. Therefore, I conclude that differences in MPC play a major role when trying to understand the transmission of fiscal policy.

The remainder of the model consists of a firm sector, a fiscal authority and a central bank. The firm sector has the typical New Keynesian structure characterized by a competitive final goods sector but monopolistic competition in the intermediate goods sector. These firms face nominal rigidities in the form of quadratic price adjustment costs and real rigidities in the form of convex capital adjustment costs. This ensures that a meaningful demand channel is operating and the effects of government expenditure shocks are reasonably close to empirical estimates. Aggregate uncertainty takes the form of neutral technology shocks that regularly hit the economy and create cyclical movements that are in line with their empirical counterparts. The fiscal authority collects distortionary income and consumption taxes, and trades nominal bonds with the household sector to finance its own consumption expenditures, fiscal transfers that are paid in a lump-sum fashion, unemployment benefits and their outstanding liabilities. Monetary policy is conducted via a Taylor rule.

I investigate the effects of two different government expenditure shocks, a government consumption shock and a fiscal transfer shock. In the benchmark model, these shocks are deficit-financed with either fiscal transfers or government consumption adjusting to prevent an explosive government debt path. In a later section, I also consider deficit-financed shocks with the distortionary income tax rate adjusting according to the level of government debt. The policy experiment is to simulate changes in government consumption or fiscal transfers at different points in the state space to investigate the different effects for discretionary fiscal policy shocks during recessions and expansions.

My findings indicate that household heterogeneity and in particular the non-trivial MPC distribution generate significant differences in fiscal multipliers and impulse responses of aggregate variables. For government consumption, I find impact multipliers between 0.8 and 0.69 when the shock hits in a recession, while the impact multipliers are between 0.5 and 0.36 when the shock hits during an expansion. In general, lower multipliers correspond to financing the increase in government debt by adjusting the income tax rate. Long-run multipliers range from 0.23 to −0.03 during recessions compared to a range from 0.13 to −0.1 during booms, implying that the tax rule scenario always leads to negative output multipliers after a few years. For fiscal transfer shocks, I find that the signs of impact multipliers differ conditional on the financing scenario. While there is a small positive increase of output when government consumption adjusts to public debt, it is generally negative when the income tax adjusts. In both cases, recession multipliers are larger on impact but decline faster over time than expansion multipliers. So in the long run, the effect of a fiscal transfer shock is more detrimental when the rise occurs in a recession.

The intuition of these results is as follows. In each simulated period of the model's stochastic steady state, a number of households is borrowing constrained and these households become virtually hand-to-mouth consumers. However, the share of these households is not fixed and varies considerably over the business cycle. In particular, I find that this share is countercyclical such that during recessions more households are borrowing constrained than during expansions. This implies that MPCs in the lower quintiles of the wealth distribution are considerably higher during recessions which has an immediate impact on aggregate demand. This demand effect caused by fiscal stimulus is therefore significantly stronger when induced during a recession.

The logic behind these differences in multipliers across different financing schemes is straightforward. Consider the government consumption shock. Although downward-adjusting fiscal transfers are a negative income shock for parts of the population, the increase in the real wage through the demand effect can make up for that loss, at least in the short term. If the income tax rate adjusts, the labor supply of the whole work force is further distorted and leads to a considerably smaller demand effect. In this sense, the benchmark financing scheme only hurts the bottom of the income distribution, while the tax-adjusting scheme hurts the whole population and especially the high-productive. Since the tax rate is only slowly adjusting to the level of public debt, the impact effect of an government consumption shock in this case is not that much affected. After a few periods, however, the demand effect dies out and the economy in the tax-adjusting case is generally in a worse state than the one with the transfer-adjusting scheme.

The consumption response for the government consumption shock is slightly positive during recessions. A decomposition according to the wealth distribution reveals that this positive impact response is driven by the wealth-poorest in the economy. Since their MPC is much higher than the MPC of the wealth-rich, the additional income is spent to a large part on consumption. However, the impulse responses also reveal that the demand effect is so strong that even the wealth-poorest can afford to save a little bit of their additional income. The wealth-rich, instead, lower their consumption and spend their additional income on bonds.

As already stated, the theoretical literature on countercyclical fiscal multipliers is relatively scarce. Shen and Yang (2018) use a simple New Keynesian model with downward nominal wage rigidity to explain the state-dependence of government consumption multipliers. Downward nominal wage rigidity is modeled as an occasionally binding constraint that is only binding in sufficiently severe recessions. In these recessions, a government consumption shock reduces unemployment and prevents the real interest rate to increase as much as in normal times so that the usual crowding-out effect is smaller during recessions. This mechanism generates recession multipliers that are more than twice as large as expansion multipliers. Canzoneri et al. (2016) use a borrower-saver framework with an ad-hoc countercyclical bank intermediation cost that creates a financial accelerator, which is much stronger in recessions than in expansions. They find that multipliers in their recession scenario are about twice as large as in the expansion scenario.

Another paper that is also concerned with state-dependent fiscal multipliers is Sims and Wolff (2018). In this paper, the authors study output and welfare multipliers over the business cycle in an estimated New Keynesian DSGE model. However, for a government consumption shock, they actually find slightly procyclical multipliers. The key difference to the aforementioned papers is the implementation of deep habits and "useful" government consumption, which are both usually employed to get a positive consumption response.[2] The usefulness of government consumption is modeled as an additional term in the households' utility function that is complementary to private consumption. While Sims and Wolff (2018) do not highlight a particular transmission channel that drives their results, they

[2]See Ravn et al. (2012) for deep habits and Linnemann and Schabert (2004) for useful government consumption.

point out that this complementarity might be responsible for the procyclicality of government consumption shocks.

Although these papers incorporate several additional components into New Keynesian DSGE models, all of them rely on the assumption of a representative households or on a distribution of households with only two mass points. Thus, this chapter is the first to investigate the issue of state-dependent fiscal multipliers in a model that takes distributional aspects of policy changes serious. Therefore, it also contributes to a growing literature that combines incomplete-markets models with nominal rigidities to simultaneously assess aggregate and distributional consequences of policy shocks.[3]

Several studies have assessed the transmission of fiscal policy within heterogeneous agent models. As in this chapter, Hagedorn et al. (2017) use a model with incomplete markets and nominal rigidities to determine multipliers for government consumption and fiscal transfer shocks. However, their approach differs from mine as they only consider "MIT shocks" and abstract from aggregate uncertainty and potential state-dependent effects.[4] Brinca et al. (2016) use an overlapping-generations model with incomplete markets but flexible prices and find that multipliers depend on wealth inequality and the share of credit-constrained households. In this sense, their mechanism is closely related to mine. However, they abstract from the cyclical component and aggregate risk in general. McKay and Reis (2016) use a model that is particularly close to the one presented in the next section and investigate the effect of automatic stabilizers over the business cycle but do not consider fiscal multipliers.

The remainder of the chapter is organized as follows. Section 3.2 presents the model, while Section 3.3 discusses the calibration and the numerical implementation of the model. In Section 3.4, I first provide the cyclical and distributional properties of the model and afterwards study the effects of government consumption and fiscal transfer shocks at different points in the state space. Section 3.5 presents the results for the same two shocks with an alternative financing scheme and Section 3.6 concludes.

[3]See Bayer et al. (2015), Gornemann et al. (2016), Guerrieri and Lorenzoni (2017), Kaplan et al. (2018), and Ravn and Sterk (2016), among others.

[4]MIT shocks are unexpected shocks that are assumed to only hit once and never again. The shock is conducted at the steady state and leads to a transition path either back to the old steady state or to a new one in a finite number of periods.

3.2 Model

The structure of the model is to a large part identical to McKay and Reis (2016). There are two types of households that differ along several dimensions, most importantly in their exposure to idiosyncratic risk. The firm sector is characterized by a representative final goods firm and monopolistically competitive intermediate goods producers, who face nominal rigidities in the form of quadratic price adjustment costs. As is done in much of the recent New Keynesian literature, I consider a cashless-limit economy as in Woodford (1998). Monetary policy is characterized by a Taylor rule that governs the nominal interest rate. The fiscal authority has access to several instruments and finances its expenditures by collecting taxes and issuing bonds.

3.2.1 State space

Let X be the vector of aggregate state variables, where $X_t := (K_t, B_t, R_{t-1}, \zeta_t, \Phi_t)$. K_t is the aggregate capital stock, B_t is government debt, R_{t-1} is the lagged nominal interest rate, ζ_t is the vector of exogenous aggregate shocks, and Φ_t is the type distribution of households.

In the model simulations below, there are always two aggregate shocks so that ζ consists of two elements. When investigating the effects of a government consumption shock G_t, ζ is defined as $\zeta_t := (z_t, G_t)$, where z_t is an aggregate productivity shock. When investigating the consequences of a fiscal transfers shock Tr_t, it is defined as $\zeta_t := (z_t, Tr_t)$.

Households are characterized by four idiosyncratic states. Let $H_t \in \{p, i\}$ denote the specific type of a particular household, where p characterizes the household as patient and i as impatient. This property is constant over time such that both the share of (im)patient households is always the same as well as the specific type of a particular household will not change. Furthermore, let $E_t := (s_t, \eta_t, a_t)$ denote the three potentially time-varying idiosyncratic states. $s_t \in \{e, u\}$ is the employment status, where e means that a household is currently employed, while u indicates unemployment. $\eta_t \in \mathcal{E} \subseteq \mathbb{R}^+$ is the idiosyncratic productivity level and $a_t \in \mathcal{A} = [0, \infty)$ is the amount of asset holdings.

One important difference between patient and impatient households is that patient households have access to a complete set of insurance contracts which implies that they are not exposed to idiosyncratic risk.[5] Therefore, they are always

[5]Patient households trade Arrow-Debreu securities among each other to pool idiosyncratic risk. To conserve on notation, I omit the details of these securities from the model description.

assumed to be employed, their productivity level is fixed and all impatient households hold the same amount of assets. This is not true for impatient households whose employment status as well as their idiosyncratic productivity are determined by stochastic processes. The type distribution of households is thus given by $\Phi_t := \Phi(H_t, E_t)$.

3.2.2 Patient households

This group of households with mass $1 - \nu$ (and subscript p) is assumed to be relatively more patient and, as already mentioned, does not face idiosyncratic shocks. Their preferences over consumption $c_{p,t}$ and hours worked $l_{p,t}$ are given by the following infinite sum of discounted period utilities,

$$U_p = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_p^t \left(\frac{(c_{p,t} - h(l_{p,t}))^{1-\sigma} - 1}{1-\sigma} \right), \tag{3.1}$$

where $\beta_p \in (0, 1)$ is the specific discount factor, σ is the coefficient of relative risk aversion, $h : \mathbb{R}^+ \to \mathbb{R}^+$ is assumed to be strictly increasing in both arguments and twice continuously differentiable, and $\mathbb{E}_0$ is the expectations operator conditional on the time-0 information set.

Patient households receive income from four different sources. Since they are the sole owner of the firms in this economy, they get dividends $d_{p,t}$, they receive returns on bonds at the gross nominal rate R_{t-1}, and they earn labor income at the real wage rate w_t. Moreover, they also obtain lump-sum transfer payments Tr_t from the government. The labor productivity of patient households is fixed at $\bar{\eta}$. This can be seen as a within-group average, since idiosyncratic shocks are perfectly insured. Thus, patient households face the following budget constraint at period t,

$$(1 + \tau_c)c_{p,t} + a_{p,t+1} = \frac{R_{t-1}}{\pi_t} a_{p,t} + (1 - \tau_t)(w_t \bar{\eta} l_{p,t} + d_{p,t}) + Tr_t, \tag{3.2}$$

where τ_c is the consumption tax rate, $a_{p,t}$ is the real value of their nominal bond holdings, $\pi_t := P_t / P_{t-1}$ is the inflation rate, and τ_t is the proportional (potentially time-varying) income tax rate.

3.2.3 Impatient households

The group of impatient households (with subscript i) has mass ν and the same type of preferences as patient households,

$$U_i = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_i^t \left(\frac{(c_{i,t} - h(l_{i,t}))^{1-\sigma} - 1}{1-\sigma} \right), \tag{3.3}$$

where $\beta_i \in (0, 1)$ is the specific discount factor. To generate a realistic degree of skewness in the wealth distribution, I follow McKay and Reis (2016) and assume that $\beta_i \leq \beta_p$.[6] In contrast to patient households, impatient households face two types of uninsurable idiosyncratic risk. On the one hand, impatient households are subject to unemployment risk. The employment status s_t follows a first-order Markov chain with transitions $\pi(s_{t+1}|s_t, z_{t+1}, z_t)$ that depend on the aggregate technology level. Therefore, unemployment risk as well as the number of unemployed households varies over the business cycle. On the other hand, impatient households face labor productivity risk that also follows a first-order Markov process which is assumed to be acyclical. Let $\eta_{i,t}$ denote the stochastic time-varying labor productivity of an impatient household, which evolves according to an autoregressive process,

$$\log \eta_{i,t} = \rho_e \log \eta_{i,t-1} + \varepsilon_{e,t}, \tag{3.4}$$

where $\varepsilon_{e,t} \sim \mathcal{N}(0, \sigma_e)$ is the shock term and $\rho_e \in [0, 1)$ measures the persistence of the process.

Conditional on being employed, an impatient household can choose the number of hours to work $l_{i,t}$ so that individual labor income is given by $w_t \eta_{i,t} l_{i,t}$. In case of being unemployed, labor income is zero but the household receives unemployment benefits $b_{i,t}^u$. I assume that these benefits depend on the current productivity state of the respective household to capture the link between unemployment benefits and previous earnings, which is a reasonable approximation given a sufficiently high persistence of the individual labor productivity.[7]

Impatient households are assumed to not own shares in firms which is in line with the fact that the majority of U.S. households does not directly own any equity (see e.g. Mankiw and Zeldes, 1991). However, impatient households can

[6] Krusell and Smith (1998) demonstrate that including heterogeneous discount factors significantly helps to match the key features of the U.S. wealth distribution.

[7] Furthermore, I assume that households do not internalize the dependence of unemployment benefits on potential/previous earnings.

use risk-free bonds to save. Altogether, this group receives income from three different sources. They get lump-sum transfers Tr_t from the government, they receive returns on bonds at the gross nominal rate R_{t-1}, and they obtain labor income at real wage rate w_t if they are employed or unemployment benefits $b^u_{i,t}$. This yields the following period-t budget constraint,

$$(1+\tau_c)c_{i,t} + a_{i,t+1} = \begin{cases} \dfrac{R_{t-1}}{\pi_t}a_{i,t} + (1-\tau_t)w_t\eta_{i,t}l_{i,t} + Tr_t & \text{if employed,} \\ \dfrac{R_{t-1}}{\pi_t}a_{i,t} + (1-\tau_t)b^u_{i,t}(\eta_{i,t}) + Tr_t & \text{if unemployed.} \end{cases} \tag{3.5}$$

Moreover, impatient household face the borrowing constraint

$$a_{i,t+1} \geq 0. \tag{3.6}$$

3.2.4 Final goods producers

The final consumption good Y_t is produced by a competitive representative firm that combines a continuum of intermediate goods $Y_t(j)$, indexed by $j \in [0,1]$, taking the input prices $p_t(j)_{j\in[0,1]}$ as given and using the constant returns to scale technology

$$Y_t = \left(\int_0^1 y_t(j)^{(\theta-1)/\theta}dj\right)^{\theta/(\theta-1)}, \tag{3.7}$$

where $\theta > 1$ is the elasticity of substitution between intermediate goods. The maximization problem is then given by

$$\max_{Y_t, y_t(j)} \Pi^F_t = P_tY_t - \int_0^1 p_t(j)y_t(j)dj \quad \text{s.t. (3.7)}, \tag{3.8}$$

which yields the demand function for intermediate good j,

$$y_t(j) = \left(\frac{p_t(j)}{P_t}\right)^{-\theta} Y_t, \tag{3.9}$$

and subsequently the price index for the final good

$$P_t = \left(\int_0^1 p_t(j)^{1-\theta}\right)^{1/(1-\theta)}. \tag{3.10}$$

3.2.5 Intermediate goods producers

Each intermediate good j is produced by a monopolistically competitive firm according to a production function given by

$$y_t(j) = z_t \mathcal{F}(k_t(j), n_t(j)), \tag{3.11}$$

where z_t is aggregate productivity in period t, and $k_t(j)$ and $n_t(j)$ are the effective capital and effective labor inputs of firm j. I assume that $\mathcal{F} : \mathbb{R}^+ \times \mathbb{R}^+ \to \mathbb{R}^+$ is strictly increasing, twice differentiable in both arguments, exhibits constant returns to scale, and satisfies the Inada conditions. Aggregate productivity follows an AR(1) process, given by

$$z_t = \bar{z} \left(\frac{z_{t-1}}{\bar{z}} \right)^{\rho_z} \exp(\varepsilon_{z,t}), \tag{3.12}$$

where $\varepsilon_{z,t} \sim \mathcal{N}(0, \sigma_z^2)$ is an exogenous shock term and $\rho_z \in [0, 1)$ measures the persistence of the shock.

Intermediate producers rent capital and hire labor services in competitive markets at rates r_t^K and w_t, respectively. Since intermediate goods are imperfect substitutes, each intermediate producer sells its output in a monopolistically competitive market and sets price $p_t(j)$ for its output. The maximization problem of intermediate goods firms, therefore, consists of choosing price level $p_t(j)$, and production inputs $k_t(j)$ and $n_t(j)$ to maximize profits $\Pi_{I,t}(j)$ subject to price adjustment costs and the given demand for the respective intermediate output. Formally, the producer of intermediate good j solves the following problem

$$\max_{p_t(j), k_t(j), n_t(j)} \Pi_{I,t}(j) = D_{I,t}(j) + \mathbb{E}_t \sum_{s=1}^{\infty} \phi_{t,t+s} D_{I,t+s}(j), \tag{3.13}$$

subject to (3.9) and (3.11), where $\phi_{t,t+1}$ is the stochastic discount factor. Since patient households are the sole owner of all firms, the stochastic discount factor is defined as

$$\phi_{t,t+1} = \beta \frac{\partial U_p / \partial c_{p,t+1}}{\partial U_p / \partial c_{p,t}} = \beta \left(\frac{c_{p,t+1} - h(l_{p,t+1})}{c_{p,t} - h(l_{p,t})} \right)^{-\sigma}. \tag{3.14}$$

Dividends of intermediate goods producers are defined as

$$D_{I,t}(j) := \frac{p_t(j)}{P_t} y_t(j) - w_t n_t(j) - r_t^K k_t(j) - \frac{\varphi_p}{2} \left(\frac{p_t(j)}{\bar{\pi} p_{t-1}(j)} - 1 \right)^2 y_t(j) - \kappa, \tag{3.15}$$

where $\varphi_p \geq 0$ determines the magnitude of price adjustment costs, $\bar{\pi}$ is the steady state inflation rate and $\kappa \geq 0$ are fixed costs of production. This form of quadratic price adjustment cost is based on the idea of Rotemberg (1982), while the specific functional form stems from Ireland (1997).

I assume symmetry among firms such that all firms charge the same prices and choose the same amounts of capital and labor services. This yields the following static first-order conditions for the factor prices

$$r_t^K = z_t \Psi_t \mathcal{F}_k(k_t, n_t), \tag{3.16}$$

$$w_t = z_t \Psi_t \mathcal{F}_n(k_t, n_t), \tag{3.17}$$

where $\mathcal{F}_x$ is the first derivative of the production function with respect to the input factor in the subscript and Ψ_t are real marginal costs. The first-order condition for the price level gives the following dynamic equation,

$$\varphi_p \left(\frac{\pi_t}{\bar{\pi}} - 1 \right) \frac{\pi_t}{\bar{\pi}} = 1 - \theta + \theta \Psi_t + \varphi_p \mathbb{E}_t \left\{ \phi_{t,t+1} \left(\frac{\pi_{t+1}}{\bar{\pi}} - 1 \right) \frac{\pi_{t+1}}{\bar{\pi}} \frac{Y_{t+1}}{Y_t} \right\}, \tag{3.18}$$

which is also known as the New Keynesian Phillips Curve.

3.2.6 Capital good producers

There is a representative firm that owns the capital stock and rents it to intermediate goods firms at the competitive price r_t^K. It maximizes profits by investing in new capital subject to quadratic adjustment costs. Formally, its maximization problem is given by

$$\max_{K_{t+1}, I_t} \Pi_{C,t} = D_{C,t} + \mathbb{E}_t \sum_{s=1}^{\infty} \phi_{t,t+s} D_{C,t+s} \tag{3.19}$$

$$\text{s.t. } K_{t+1} = (1 - \delta) K_t + I_t, \tag{3.20}$$

where I_t denotes investment and δ is the depreciation rate of capital. Dividends are given by

$$D_{C,t} := r_t^K K_t - I_t - \frac{\varphi_c}{2} \left(\frac{I_t}{K_t} - \delta \right)^2 K_t, \tag{3.21}$$

where $\varphi_c \geq 0$ determines the magnitude of capital adjustment costs. The first order conditions are given by

$$q_t = 1 + \varphi_c \left(\frac{I_t}{K_t} - \delta \right), \tag{3.22}$$

$$q_t = \mathbb{E}\phi_{t,t+1} \left[r^K_{t+1} - \frac{\varphi_c}{2} \left(\frac{I_{t+1}}{K_{t+1}} - \delta \right)^2 + \varphi_c \left(\frac{I_{t+1}}{K_{t+1}} - \delta \right) \frac{I_{t+1}}{K_{t+1}} + q_{t+1}(1-\delta) \right], \tag{3.23}$$

where q_t is the Lagrange multiplier for the law of motion of capital.

3.2.7 Government and central bank

The fiscal authority collects revenues from income and consumption taxes, and issues bonds B_{t+1}, to finance its interest payments, government consumption G_t, unemployment benefits Tr^u_t and lump-sum fiscal transfers Tr_t. The government budget constraint is therefore given by

$$\frac{R_{t-1}}{\pi_t} B_t + G_t + Tr^u_t + Tr_t = B_{t+1} + \tau_t(w_t n_t + D_t) + \tau_c C_t, \tag{3.24}$$

where $w_t n_t$ is aggregate labor income and D_t are aggregate dividends.

In the sections below, I analyze the effects of two aggregate fiscal shocks, a government consumption shock and a fiscal transfer shock. In general, I assume that both shocks are deficit-financed. To ensure that government debt remains non-explosive, at least one additional fiscal instrument has to adjust. In the benchmark scenario, I assume that lump-sum transfers respond to government debt when the economy is hit by a government consumption shock, and that government consumption adjusts when the economy is hit by a fiscal transfer shock. The set of equations for the government consumption shock is given by

$$G_t = \bar{G} \left(\frac{G_{t-1}}{\bar{G}} \right)^{\rho_T} \exp(\varepsilon_{T,t}), \tag{3.25}$$

$$Tr_t = \bar{Tr} \left(\frac{B_t}{\bar{B}} \right)^{\gamma_T}, \tag{3.26}$$

while for the fiscal transfer shock the set of equations is given by

$$Tr_t = \bar{Tr}\left(\frac{Tr_{t-1}}{\bar{Tr}}\right)^{\rho_T} \exp(\varepsilon_{T,t}), \tag{3.27}$$

$$G_t = \bar{G}\left(\frac{B_t}{\bar{B}}\right)^{\gamma_T}, \tag{3.28}$$

where $\varepsilon_{T,t} \sim \mathcal{N}(0, \sigma_T^2)$ is the shock term in each scenario, and $\rho_T \in [0,1)$ measures the persistence of the respective shock. The parameter γ_T determines the adjustment of the respective variable to government debt deviations from its steady state.[8]

Unemployment benefits $b^u_{i,t}(\eta_{i,t})$ are given by the replacement rate $\xi \in [0,1)$ times potential labor income,

$$b^u_{i,t}(\eta_{i,t}) = \xi w_t \eta_{i,t} l_{i,t}, \tag{3.29}$$

where potential labor income is defined as the labor income of an employed agent with the same idiosyncratic productivity state. Then, total benefits paid to unemployed households amount to

$$Tr^u_t = \xi w_t \int \eta_t l_t d\Phi(i, (u, \eta_t, a_t)). \tag{3.30}$$

The central bank follows a Taylor rule, in which the nominal interest rate R_t responds to the deviation of current inflation from its steady state and the deviation of the lagged nominal interest rate from its steady state. Formally, the rule is given by

$$R_t = \bar{R}\left(\frac{\pi_t}{\bar{\pi}}\right)^{\phi_\pi}\left(\frac{R_{t-1}}{\bar{R}}\right)^{\phi_R}, \tag{3.31}$$

where $\phi_\pi > 1$ captures the central bank's reaction to inflation deviations and $\phi_R > 0$ measures the degree of policy inertia.

3.2.8 Market clearing and aggregation

The labor market clears when

$$n_t = \int \eta_t l_t d\Phi(i, (e, \eta_t, a_t)) + (1-\nu)\bar{\eta} l_{p,t}, \tag{3.32}$$

[8]For a better comparison, I assume that the shock persistence, the shock variance and the adjustment speed in the fiscal rule are the same across experiments.

at the wage rate given in (3.17). The market for capital services clears when

$$K_t = k_t, \tag{3.33}$$

at the rental rate given in (3.16). The bonds market clears when

$$B_{t+1} = \int a_{t+1} d\Phi(i, (s_t, \eta_t, a_t)) + (1-\nu) a_{p,t+1}. \tag{3.34}$$

Finally, the goods market clears when

$$Y_t = C_t + I_t + G_t + \frac{\phi_p}{2}\left(\frac{\pi_t}{\bar{\pi}} - 1\right)^2 Y_t + \frac{\phi_c}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t + \kappa. \tag{3.35}$$

Aggregate consumption is defined as the weighted average of individual consumption,

$$C_t = \int c_t d\Phi(i, (s_t, \eta_t, a_t)) + (1-\nu) c_{p,t}. \tag{3.36}$$

Total dividends are the sum of dividends from intermediate and capital goods producers,

$$D_t = D_{C,t} + D_{I,t}, \tag{3.37}$$

as well as the weighted average of individual dividends received,

$$D_t = (1-\nu) D_{p,t}, \tag{3.38}$$

taken into account that only patient households own firm shares.

3.2.9 Equilibrium

Definition 2. *An equilibrium in this economy is defined as a sequence of aggregate quantities* $\{Y_t, C_t, D_t, l_t, K_t, k_t, I_t, \Psi_t, D_{I,t}, D_{C,t}, d_{p,t}\}_{t\in\mathbb{N}}$*, prices* $\{\pi_t, w_t, r_t^K, q_t\}_{t\in\mathbb{N}}$*, distributions* $\Phi_t(H,E)_{t\in\mathbb{N}}$*, decision rules* $\{c_t(H,E), l_t(H,E), a_{t+1}(H,E)\}_{t\in\mathbb{N}}$ *and government choices* $\{R_t, \tau_t, Tr_t, Tr_t^u, B_{t+1}, G_t\}_{t\in\mathbb{N}}$ *such that*

1. *patient households maximize* (3.1) *subject to* (3.2)*,*
2. *impatient households maximize* (3.3) *subject to* (3.5) *and* (3.6)*,*
3. *final goods producers behave optimally according to* (3.9) *and* (3.10)*,*

4. *intermediate goods producers maximize* (3.13) *subject to* (3.9) *and* (3.11),

5. *capital good producers maximize* (3.19) *subject to* (3.20) *and* (3.21),

6. *fiscal policy respects* (3.24), (3.29), *and* (3.25) *and* (3.26), *or* (3.27) *and* (3.28), *respectively,*

7. *monetary policy follows* (3.31),

8. *markets clear according to* (3.32)-(3.35),

9. *aggregation identities* (3.36)-(3.38) *hold,*

10. *the aggregate law of motion is induced by the exogenous stochastic processes for idiosyncratic and aggregate risk as well as the households' decision rules.*

3.3 Calibration

In this section, I describe how I map the model economy to the data. Since I am particularly interested in the business cycle properties of fiscal policy, the model is calibrated to the U.S. economy over the time period 1970q1 to 2017q4. One model period is a quarter. Table 3.1 summarizes the parameter choices.

3.3.1 Households

The patient households' discount factor β_p is set to 0.9925, implying a steady state annual real interest rate of 3 percent. The discount factor of impatient households β_i is set to 0.9698 so that the bottom 20 percent in the wealth distribution have a total net worth of zero.

The functional form for the disutility of labor is given by

$$h(l) = \chi\eta \frac{l^{1+1/\gamma}}{1+1/\gamma}, \tag{3.39}$$

where γ is the Frisch elasticity of labor supply and χ is a scaling parameter. The inclusion of η implies that households only adjust their labor supply to changes in the wage rate per efficiency unit and not to changes in their idiosyncratic productivity.

I choose standard values from the literature. In particular, I set the risk aversion parameter in the utility function σ to 2 as, for example, in Kindermann and Krueger (2014). The Frisch elasticity of labor supply γ is equal to 0.5 as in Bayer et al. (2015).

The disutility of labor χ is set to 4.159 so that hours worked are 0.5 in steady state. Following McKay and Reis (2016), I choose ν to be 0.8, implying that patient households make up for 20 percent of the economy.

3.3.2 Firms

Intermediate goods firms are assumed to produce according to a Cobb-Douglas production function

$$\mathcal{F}(k_t, n_t) = k_t^{\alpha} n_t^{1-\alpha}, \tag{3.40}$$

where $\alpha \in [0, 1]$ measures the output elasticity of capital. α is then set to 0.33, implying a labor share of income of about 60 percent. The elasticity of substitution between intermediate goods θ is 11, such that the steady state markup over marginal costs is 10 percent. The depreciation rate δ is 0.025 to have an annual depreciation on capital equal to 10 percent. Steady state inflation rate $\bar{\pi}$ is set to 1.005 for an annual inflation rate of 2 percent. Fixed cost parameter κ is chosen to guarantee a steady state dividend-to-output ratio of 3.8 percent. The parameter that governs the magnitude of the price adjustment costs ϕ_p is set to 117. Given the steady state markup, this is equivalent to price changes once every four quarters in a linearized Calvo framework. Finally, the capital adjustment parameter ϕ_c is chose to be 15, which is well in the range of values typically used in the literature.

3.3.3 Government and central bank

The steady state values of three fiscal variables are calibrated based on averages over the sample period considered in this chapter.[9] In particular, the share of government consumption in aggregate output is set to 20 percent. The ratio of fiscal transfers (including unemployment benefits) to output is 11 percent, while the annualized government debt to output ratio is 40 percent. The consumption tax rate is set to 11.5 percent, following Altig et al. (2001) so that the steady state of the income tax rate is then set such that the government budget constraint is satisfied. The adjustment parameter in the fiscal rules γ_T is set to −0.4, which is in the interval of values that are estimated in the literature.[10] Following Blank and Card (1991), I set the replacement rate ξ to 10 percent.

[9]See the appendix for the respective data series.

[10]Leeper et al. (2010) find a value of −0.23 for government consumption and value of −0.5 for fiscal transfers. I eventually chose −0.4 because this value always ensured boundedness of government debt and convergence of my computations.

Table 3.1: Calibrated parameters

Param	Explanation	Value	Target/Source
Households			
β_p	Discount factor of patient HHs	0.9925	Annual real interest rate of 3%
β_i	Discount factor of impatient HHs	0.9698	Bottom 20% has zero net worth
σ	Risk aversion parameter	2.0	Kindermann and Krueger (2014)
γ	Frisch elasticity of labor supply	0.5	Bayer et al. (2015)
χ	Disutility of labor	4.159	Steady state labor supply of 0.5
ν	Share of impatient HHs	0.8	McKay and Reis (2016)
$\bar{\eta}$	Productivity of patient HHs	9.2230	62.9% of total earnings (SCF avg.)
Firms			
α	Capital share of income	0.33	60% labor share of income
δ	Depreciation rate of capital	0.025	Annual depreciation of 10%
θ	Price elasticity of demand	11.0	Steady state mark up of 10%
ϕ_p	Rotemberg adj. cost coefficient	117.0	approx. 75% of firms adjusting
ϕ_c	Capital adjustment costs	15.0	Literature
κ	Fixed production cost	0.2592	Steady state dividends of 2.5%
$\bar{\pi}$	SS inflation rate	1.005	Annual inflation rate of 2%
Government			
ϕ_π	Inflation coefficient in Taylor rule	1.5	Standard value
ϕ_R	Interest rate smoothing	0.81	Smets and Wouters (2007)
γ_T	Fiscal rule	-0.4	see Text
$\bar{B}/\bar{Y}$	SS gov. debt-GDP-ratio (annually)	0.40	Data
$\bar{G}/\bar{Y}$	SS gov. spending-GDP-ratio	0.20	Data
$\bar{Tr}/\bar{Y}$	SS transfer-GDP-ratio	0.11	Data
τ	Income tax rate	0.3532	Budget balance
τ_c	Consumption tax rate	0.115	Altig et al. (2001)
ξ	Replacement rate	0.10	Blank and Card (1991)
Shocks			
ρ_z	Persistence of TFP shock	0.7533	Fernald (2014)
σ_z	SD of TFP shock term	0.0090	Fernald (2014)
ρ_e	Persistence of labor prod. shock	0.9853	Heathcote et al. (2004)
σ_e	SD of labor prod. shock	0.1476	Heathcote et al. (2004)
ρ_T	Persistence of fiscal shock	0.8000	Fernández-Villaverde et al. (2015)
σ_T	SD of fiscal shock	0.0025	Fernández-Villaverde et al. (2015)

For the Taylor rule, I pick standard values from the literature. The reaction parameter for inflation deviations ϕ_π is equal to 1.5 and smoothing parameter ϕ_R is set to 0.81.

3.3.4 Aggregate shocks

I derive the properties of the aggregate technology shock from the utilization-adjusted TFP series from Fernald (2014). In particular, I construct an index from the calculated growth rates for the time period 1970Q1 to 2017Q4 and take the natural logarithm of this index. The series is then detrended by a one-sided HP filter, as suggested by Watson and Watson (1999), with a smoothing value of 1600. The estimated persistence coefficient ρ_z is equal to 0.7533 and the standard deviation of the shock term σ_z is equal to 0.009. Finally, I discretize the process by the Rouwenhorst method into a two-state Markov chain.[11] For the fiscal shocks, I follow Fernández-Villaverde et al. (2015) and set ρ_T to 0.8 and σ_T to 0.0025.

3.3.5 Idiosyncratic risk

Households face two types of idiosyncratic risk, countercyclical unemployment risk and, conditional on being employed, acyclical productivity risk.

Unemployment risk

For idiosyncratic unemployment risk, I follow the setup of Krusell and Smith (1998, 1999), where unemployment shocks and the aggregate technology shock are correlated. It is assumed that the idiosyncratic shocks each satisfy a law of large numbers so that individual risk averages out and aggregate shocks are the only source of aggregate uncertainty. This implies that the unemployment rate is only a function of the aggregate technology level. Let u_g denote the unemployment rate in the good technology state and u_b in the bad technology state.

Furthermore, let $\pi_{s,s'}^{z,z'} := \pi(s_{t+1}|s_t, z_{t+1}, z_t)$ denote the joint probability of transition from state (z, s) today to (z', s') tomorrow. These transition probabilities then have to satisfy the following two restrictions

$$\pi_{u,u}^{z,z'} + \pi_{u,e}^{z,z'} = \pi_{e,u}^{z,z'} + \pi_{e,e}^{z,z'} = \pi^{z,z'}, \tag{3.41}$$

$$u_z \frac{\pi_{u,u}^{z,z'}}{\pi^{z,z'}} + (1 - u_z) \frac{\pi_{e,u}^{z,z'}}{\pi^{z,z'}} = u_{z'}, \tag{3.42}$$

for all (z, z'), where $\pi^{z,z'}$ are the marginal probabilities of transition from z to z'. To uniquely pin down the four 2×2 joint transition matrices, I follow Krusell and Smith (1998, 1999) and impose the following assumptions:

(i) the average duration of an unemployment spell is 1.5 quarters in the good technology state and 2.5 quarters in the bad state,

(ii) the unemployment rate is 4 percent in the good technology state and 10 percent in the bad state,

(iii) $\dfrac{\pi_{u,u}^{g,b}}{\pi^{g,b}} = 1.25 \dfrac{\pi_{u,u}^{b,b}}{\pi^{b,b}}, \quad \dfrac{\pi_{u,u}^{b,g}}{\pi^{b,g}} = 0.75 \dfrac{\pi_{u,u}^{g,g}}{\pi^{g,g}}.$

[11] This method is particularly useful for persistent processes. More details on this method can be found in Kopecky and Suen (2010).

Using the fact that $\pi_{u,e}^{z,z'}/\pi^{z,z'} + \pi_{u,u}^{z,z'}/\pi^{z,z'} = 1$ for all (z,z'), one can use (i) to find $\pi_{u,u}^{g,g}/\pi^{g,g} = 1/3$ and $\pi_{u,u}^{b,b}/\pi^{b,b} = 3/5$. Consequently, (iii) implies that $\pi_{u,u}^{g,b}/\pi^{g,b} = 3/4$ and $\pi_{u,u}^{g,b}/\pi^{b,g} = 1/4$. Using (3.42) for the pairs (g,g) and (b,b), one further obtains $\pi_{e,u}^{g,g}/\pi^{g,g} = 1/36$ and $\pi_{e,u}^{b,b}/\pi^{b,b} = 2/45$. The assumption that the unemployment rate directly adjusts from u_g to u_b (u_b to u_g) whenever the technology state switches from good to bad (bad to good) and the respective opposing entry in the transition matrix deliver the parameters $\pi_{e,u}^{b,g}/\pi^{b,g} = 1/60$ and $\pi_{e,u}^{g,b}/\pi^{g,b} = 7/96$. The remaining parameters can be obtained with the property that all row probabilities in the transition matrices must add up to one.

Unemployment risk is therefore given by the following four 2×2 matrices,

$$\begin{pmatrix} 0.6000 & 0.4000 \\ 0.0445 & 0.9555 \end{pmatrix}, \tag{3.43}$$

for the transition $(z,z') = (z_b, z_b)$, where the first row is the individual state of unemployment and the second row is the state of employment,

$$\begin{pmatrix} 0.3333 & 0.6667 \\ 0.0278 & 0.9722 \end{pmatrix} \tag{3.44}$$

for the transition (z_g, z_g),

$$\begin{pmatrix} 0.7500 & 0.2500 \\ 0.0729 & 0.9271 \end{pmatrix} \tag{3.45}$$

for the transition (z_g, z_b),

$$\begin{pmatrix} 0.2500 & 0.7500 \\ 0.0167 & 0.9833 \end{pmatrix} \tag{3.46}$$

for the transition (z_b, z_g).[12]

Labor productivity risk

To determine the parameters of the idiosyncratic labor productivity shock (ρ_e, σ_e), I make use of the estimates of Heathcote et al. (2004), who use annual data from the Panel Study of Income Dynamics (PSID). For the period 1967 to 1996, their estimates are $\rho_e^a = 0.9426$ and $\sigma_e^a = 0.1476$, where the superscript indicates annual values.

[12] The numbers are rounded to four digits.

I follow Krueger et al. (2016) in their procedure to transform annual values into their quarterly counterparts. This implies that $\rho_e = (\rho_e^a)^{0.25} = 0.9853$ to ensure that the annual persistence of productivity risk does not change. Similarly, I impose that the quarterly variance of risk is the same as the annual variance, which is achieved by the following condition,

$$\frac{(\sigma_e^a)^2}{1-\rho_e^a} = \frac{\sigma_e^2}{1-\rho_e}, \tag{3.47}$$

yielding $\sigma_e = 0.1476$. The shock is then discretized into a four-state Markov chain by the Rouwenhorst method.

The production level of patient households, on the other hand, is fixed as this group is assumed to have access to insurance markets that prevent them from productivity risk. I set this value to 9.223 which then yields a steady state earnings share of 62.9 percent for the top quintile of the earnings distribution which is determined by taking the average of various waves of the Survey of Consumer Finance (SCF).

3.3.6 Numerical Implementation

The model is solved using a solution method that combines a Krusell and Smith (1998)-type algorithm with a time iteration procedure. See Appendix 3.B for more details.

3.4 Results

In this section, I present the results of the baseline model given the parametrization presented in the previous section. I start by showing the cyclical and distributional properties of the model and compare them to the corresponding moments retrieved from data. Afterwards, I analyze the effects of the two government expenditure shocks in different states of the business cycle. In particular, I present impulse response functions (IRF) of aggregate variables, calculate fiscal multipliers and show the distributional effects of these shocks.

3.4.1 Cyclical properties

Table 3.2 compares second moments generated by the model and the counterparts from U.S. data (based on HP-filtered series with smoothing parameter 1600) for

Table 3.2: Business cycle statistics

	Model			Data		
	Rel. std.	Corr.	AR(1)	Rel. std.	Corr.	AR(1)
Output	1.00	-	0.88	1.00	-	0.87
Consumption	0.68	0.98	0.88	0.80	0.90	0.87
Investment	2.81	0.95	0.85	4.60	0.91	0.86
Wage rate	0.77	0.99	0.89	0.71	0.17	0.69
Labor supply	0.23	0.99	0.89	1.28	0.87	0.93
Gov. debt	5.29	−0.34	0.99	2.71	0.02	0.90
Inflation	0.04	−0.31	0.13	0.19	0.17	0.50
Nom. interest rate	0.52	−0.25	0.86	1.08	0.41	0.83
# Constrained HHs	0.30	−0.36	0.98			

Notes: Model with TFP shocks only. For a more detailed data description, see Appendix.

the period 1970q1 to 2017q4. Column 2 to 4 report the model-generated moments (without fiscal shocks), namely the relative standard deviation with respect to output, the contemporaneous correlation with output and the first-order autocorrelation of eight aggregate variables. Columns 5 to 7 report the respective moments from the data. Note that none of these values is targeted in the calibration exercise. However, the model replicates the empirical moments quite well. It is consistent with the large variability of investment and public debt to output as well as the relatively lower volatility of consumption, the wage rate and inflation. Labor supply and the nominal interest rate are somewhat off as these variables are not volatile enough in the model.

The model also produces negative output correlations for government debt, inflation and the nominal interest rate although the data series either show acyclical behavior or a positive correlation with output. The model-produced autocorrelations are mostly in line with the data, so that I conclude that the model does a good job when it comes to producing reasonable cyclical variations. Of course, one could improve the fit even more by incorporating some of these moments into the calibration procedure. This, however, would come at the cost of significantly higher computational time.

Another variable of interest for the following analysis is the number of constrained households. To the best of my knowledge, there is no (quarterly) measure for this variable in the data so that I only report the model-generated moments. Most importantly, Table 3.2 shows a negative correlation between output and the share of borrowing constrained households, implying that this share is higher

Table 3.3: Income and wealth distributions: Data vs. model

	Earnings			Wealth		
	Model	Data 1992	Data 2007	Model	Data 1992	Data 2007
Q1	2.7	−0.4	−0.1	0.0	−0.4	−0.2
Q2	3.9	3.2	4.2	1.8	1.7	1.1
Q3	10.7	12.5	11.7	6.1	5.7	4.5
Q4	19.8	23.3	20.8	15.7	13.4	11.2
Q5	62.9	61.4	63.5	76.4	79.6	83.4
Gini	0.61	0.63	0.64	0.75	0.78	0.82

Notes: Data is taken from the Diaz-Giménez et al. (1997) and Diaz-Giménez et al. (2011). The model-generated moments refer to the steady state of the model.

when the economy is in a recession. The fact that households with a binding borrowing constraint have a higher MPC than households that hold positive wealth is one of the crucial results of this chapter as this is key mechanism that generates the state-dependent multipliers in this setting.

3.4.2 Distributional properties

The distributional properties of the model are summarized in Table 3.3. In particular, this table reports selected statistics for the earnings and wealth distribution of the United States, drawn from the SCF, and the respective model statistics. Since the model is calibrated for the period between 1970q1 to 2017q4, I include two waves of the SCF.

Two of these values were part of the calibration strategy, namely the earnings share of the top quintile and the wealth share of the bottom quintile. All other moments of the empirical cross-sectional earnings and wealth distributions were not targeted and emerge endogenously from the model.

In general, the model is able to match the empirical distributions considerably well. Since the model does not allow negative earnings or negative wealth, one would need further ingredients or further assumptions to exactly match the lowest quantiles of both distributions. However, since both model values are close to their empirical counterparts, I refrain from those.

Overall, the model is able to generate the skewed earnings and wealth distribution of the United States and therefore, depicts a realistic environment for the question at hand.

3.4.3 Computational experiment

After having provided that the model economy delivers a good description of both the cyclical and distributional properties of the United States data, I now proceed to implement the main analysis of the chapter. In this experiment, I simulate government consumption shocks as well as fiscal transfer shocks in different states of the business cycle.

The implementation is as follows. First, I simulate the model for 5600 periods without any fiscal shock so that the technology shock is the only source of aggregate uncertainty. The first 500 periods are the burn-in phase, which ensures that the stochastic steady state of the model is reached. The following 5100 periods are then used to determine an average expansion and an average recession. For that purpose, I use aggregate output as the determinant and construct an output distribution for the simulated economy. Then, I choose the midpoint of the 20th percentile for the average recession and the midpoint of the 80th percentile for the average expansion. Equipped with these points, I simulate the model again until I reach them and increase the respective variable by one percent.

The IRFs in the next sections are then relating the simulation with the respective shock to the counterfactual simulation, in which no fiscal shock occurred. Formally, the IRF for variable x_t is given by

$$IRF(x_t) = \frac{x_t}{x_t^*} - 1, \tag{3.48}$$

where the asterisk denotes the value for x_t in counterfactual simulation.

In the analysis below, the impact period of recession scenario is characterized by an aggregate output level that is 3.35 percent smaller than in the expansionary scenario. The capital stock is 1.91 percent smaller, while the wage rate is 2.59 percent lower. The share of households at the borrowing constraint is 35.6% when the shocks hit in a recession compared to 19.7% in the expansion. The technology state is in the high state in the expansionary scenario, whereas it is in the low state at the beginning of the recessionary scenario.

3.4.4 Impulse responses

Government consumption shock

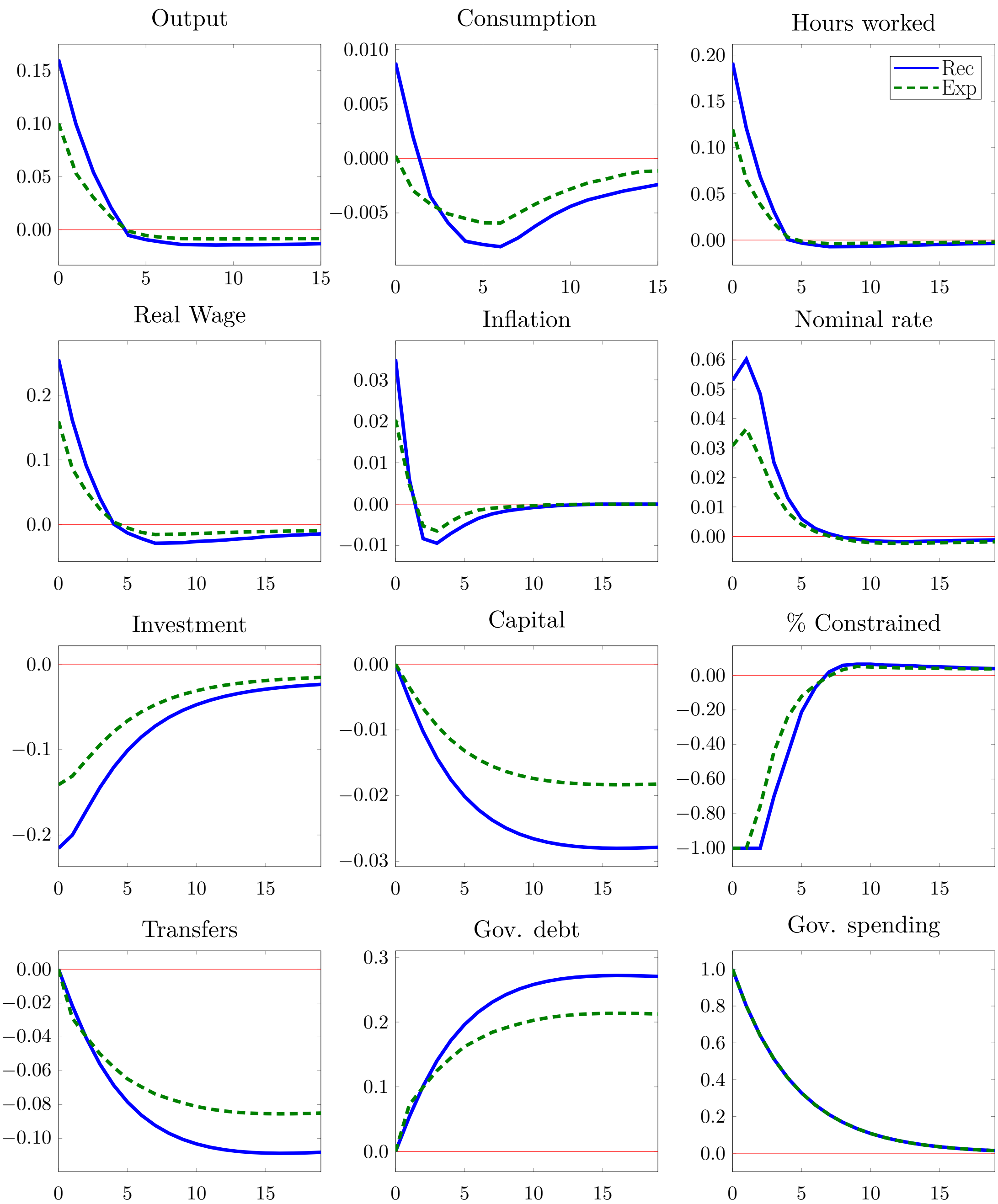
Figure 3.1 reports the IRFs to a one percent increase in government consumption. The solid line depicts the recession scenario, whereas the dashed line displays the expansion scenario. Starting with the recession scenario, the increase in government consumption induces a demand effect on impact that leads to rises in output, consumption, hours worked and the real wage. This demand effect is caused by price adjustment costs that create a wedge between the optimal price and the actual price that is set by intermediate firms so that there is a rightward shift in the labor demand curve. This then leads to an increase in production and subsequently to an increase in the real wage. The magnitude of this demand effect translates into a positive output response of about 0.15 percent.

Inflation rises by about 0.03 percent on impact which leads to a strong reaction of the nominal interest rate that follows a Taylor rule. The increase in the real interest rate then leads to a strong decline of investment and consequently in capital. Thus, the small crowding-in effect of consumption is contrasted with a strong crowding-out effect of investment. The number of constrained households drops to zero. This shows that the demand effect is especially important for the wealth-poorest households who can now afford to save at least some of their additional labor income.

The initial demand effect is rather short-lived and dies out after about one year. Afterwards output, consumption, hours worked and the real wage go below zero, implying that these variables are now lower than in the scenario without the shock occurring. This is basically because the strong crowding-out of investment causes the capital stock to decline significantly. The number of constrained households begins to increase, and this is because of two reasons. First, the real wage decreases quickly and therefore labor income. On the other hand, since the shock is deficit-financed with fiscal transfers adjusting downwards, low-income households eventually face a considerable negative income shock so that they start to dissave.

In the expansion scenario, an increase in public consumption also induces a demand effect on impact, although it is not as pronounced as in the recession. Here, output increases by about 0.10 percent while the consumption response is effectively zero. The increase in inflation is significantly smaller in this state so that both nominal and real interest rate do not respond as strongly as in the recessionary state. Thus, the crowding-out of investment is not as severe and the capital stock is reduced less markedly. The fraction of constrained households drops to zero as well but since the overall number of households during the expansion state is smaller than in the recessionary state, the effect on consumption turns out to be smaller as well.

Figure 3.1: IRFs to one percent increase in government consumption



Fiscal transfer shock

Figure 3.2 displays the IRFs to a one percent increase in fiscal transfers. In the recession scenario (blue solid lines), the increase in transfers induces a small demand effect, resulting in a 0.01 percent increase in output. While hours worked and the real wage rise in a similar magnitude, the response of private consumption of 0.08 percent is much more pronounced. This results is driven by the considerable amount of households at or close to the borrowing constraint, which have a particular high MPC and, therefore, spend a large part of their additional income on consumption. However, as can be seen in Figure 3.2, the number of constrained households goes to zero, which implies that the additional income induces the wealth-poor to save as well. Inflation and subsequently the nominal interest rate rise on impact, accompanied by a substantial crowding-out of investment.

After the very short-lived stimulation of the economy, output, hours worked and the real wage begin to decrease and fall below the level of the counterfactual. This drop is even more amplified by the gradual decrease of government consumption, which adjusts downwards to keep government debt on a non-explosive path. Aggregate consumption declines as well, albeit at a slower pace, and drops below zero after one year. The significant drop in investment leads to a strong reduction of the capital stock. After about two years, this downward trend is reversed and the net capital response approaches zero. The share of constrained households begins to rise after two quarters and finally exceeds the one of the counterfactual scenario.

In the expansion scenario, the demand effect on impact is substantially smaller with output rising by only 0.005 percent. The increase in private consumption is still relatively large in comparison to output but significantly smaller than in the recession scenario. However, also the crowding-out of investment is less pronounced, implying that the reduction in the capital stock is smaller. This in turn leads to slightly higher net responses of output, wages and labor supply after about five quarters. The share of borrowing constrained households does not go to zero on impact which can be explained by the considerably weaker demand effect so that for some households, the income shock through the transfer increase is not sufficient to afford assets.

To summarize, the transfer shock induces a small demand effect which is larger when the economy is in a recession. The differences are mainly driven by the different number of credit-constrained households, which amplifies the response of basically every aggregate variable. After the initial boost, the transfer shock

Figure 3.2: IRFs to one percent increase in fiscal transfers

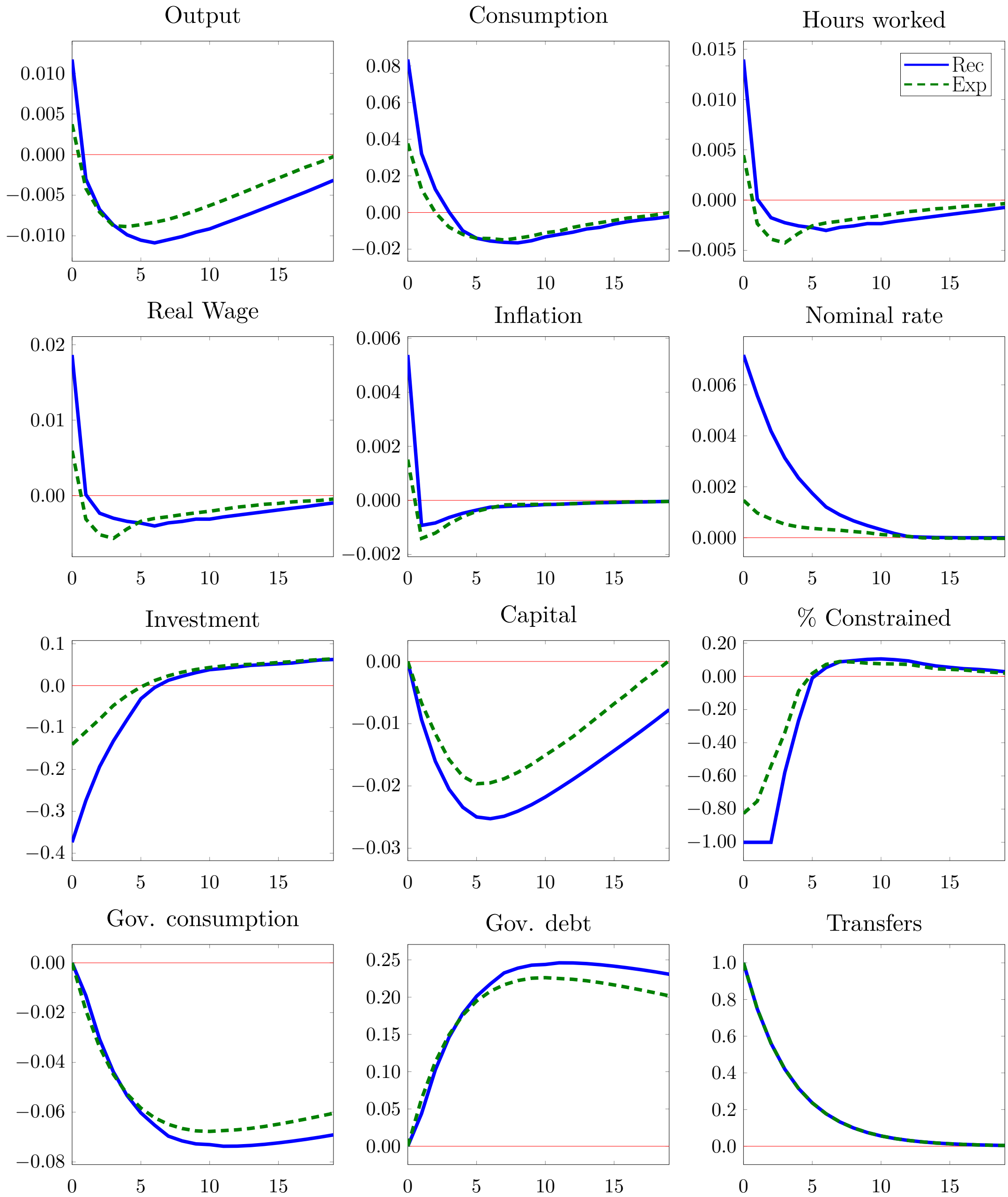


Table 3.4: Benchmark multipliers

	Gov. consumption		Fiscal Transfers	
	Recession	Expansion	Recession	Expansion
Impact Multiplier	0.80	0.50	0.11	0.03
Cumul. Multipliers				
4 quarters	0.50	0.30	−0.06	−0.06
8 quarters	0.35	0.20	−0.13	−0.11
12 quarters	0.27	0.16	−0.18	−0.15
16 quarters	0.23	0.13	−0.22	−0.16

leads in both scenarios to a contraction compared to the counterfactual, which ultimately questions the effectiveness of fiscal transfers to stimulate the economy.

3.4.5 Multipliers

The quantitative effects of fiscal shocks are generally evaluated in the form of multipliers. Following Mountford and Uhlig (2009), I report present-value multipliers which incoporate the entire path of responses and discount them properly.[13] The present-value of additional output over a k-horizon that is generated by a change in the present-value of the respective fiscal instrument FI is given by

$$m_t^k = \frac{\sum_{j=0}^{k} \widehat{\beta}^j \left(\frac{Y_j}{Y_j^*} - 1 \right)}{\sum_{j=0}^{k} \widehat{\beta}^j \left(\frac{FI_j}{FI_j^*} - 1 \right)} \frac{Y_j^*}{FI_j^*}, \qquad FI \in \{G, Tr\}, \tag{3.49}$$

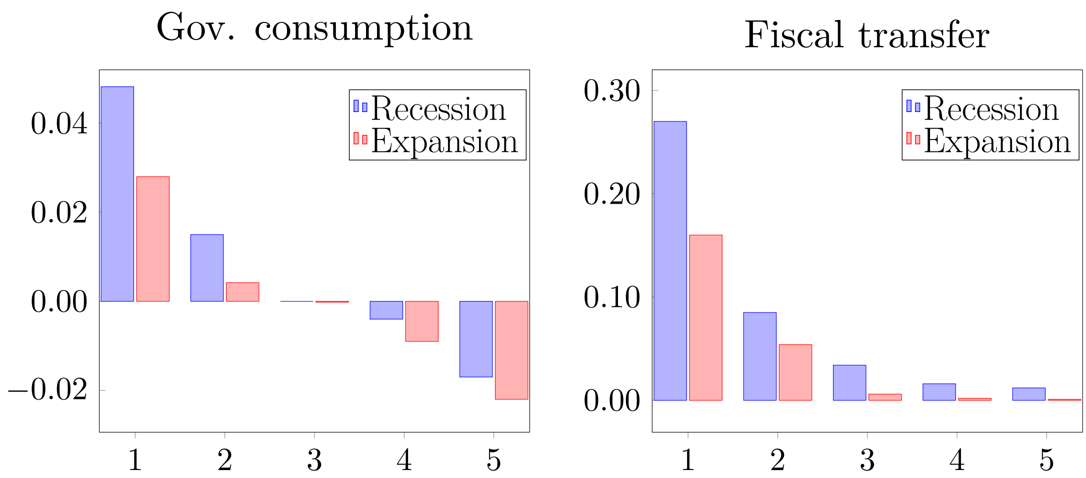
where the asterisk indicates the path of the respective variable in the counterfactual situation, in which no shock occurred. The impact multiplier is then the present-value multiplier with $k = 0$. Table 3.4 reports the results for the benchmark.

For government consumption, the impact multipliers for both scenarios are modest but clearly below one.[14] There are considerable differences in the magnitudes. While the recession multiplier amounts to 0.8, the multiplier of the expansion scenario is only 0.5. After one year, both multipliers almost halved and further decrease as time goes by. Four years after the impact, however, multipliers are still positive.

[13]Since households in the model economy have different discount factors, I take a weighted average, resulting in $\widehat{\beta} = 0.9743$.

[14]This is not a surprising result as the textbook New Keynesian model with a representative agent is also generally not able to generate multipliers above unity without further assumptions, see e.g. Galí, López-Salido, and Vallés (2007b).

Figure 3.3: Distributional effects



For fiscal transfers, the impact multipliers are much smaller as could already be seen in the IRFs. Both are slightly positive on impact but turn negative after four quarters. Moreover, the recession multipliers contract at a faster pace than the expansion multipliers.

To sum up, multipliers differ significantly across fiscal instruments and the state of the economy. While both instruments are more effective during recessions, multipliers always stay below unity. In terms of stimulating the economy, government consumption seems to be the better choice.

3.4.6 Distributional effects

Figure 3.3 shows the consumption response on impact to both fiscal shocks for each quintile of the wealth distribution. The blue bars represent the respective responses during a recession, the red bars stand for the responses during an expansion.

For both shocks, the amount of individual wealth has significant influence on the consumption response on impact. While wealth-poor households raise their level of consumption after a government consumption shock, it falls for the wealth-rich. This is because the bottom quintile solely consists of households at the borrowing constraint which are characterized by a high MPC out of additional income. Since the share of borrowing constrained households is countercyclical, the MPC of the bottom quintile is lower during expansions so that the impact response of consumption is lower in this scenario.

A similar pattern is displayed in the right panel of Figure 3.3. When facing a fiscal transfer shock, all households increase their consumption. The heterogeneity in the size of the increase is again attributed to the heterogeneity in the MPC. Moreover, since the transfer shock does not trigger a substantial demand effect, the relative increase in the income of the wealth-rich is basically zero. And given that their level of consumption is already relatively high, a substantial increase is simply not feasible.

3.5 Alternative fiscal rules

In the baseline model, the government consumption shock is deficit-financed with fiscal transfers adjusting to the level of government debt, whereas the fiscal transfer shock is deficit-financed with government consumption adjusting. In this section, I investigate the effects of these shocks and the differences to the baseline scenarios when the income tax rate adjusts to the fiscal deficit. In particular, the fiscal rule for both shocks is now

$$\tau_t = \bar{\tau} \left(\frac{B_{t-1}}{\bar{B}} \right)^{\gamma_T}, \tag{3.50}$$

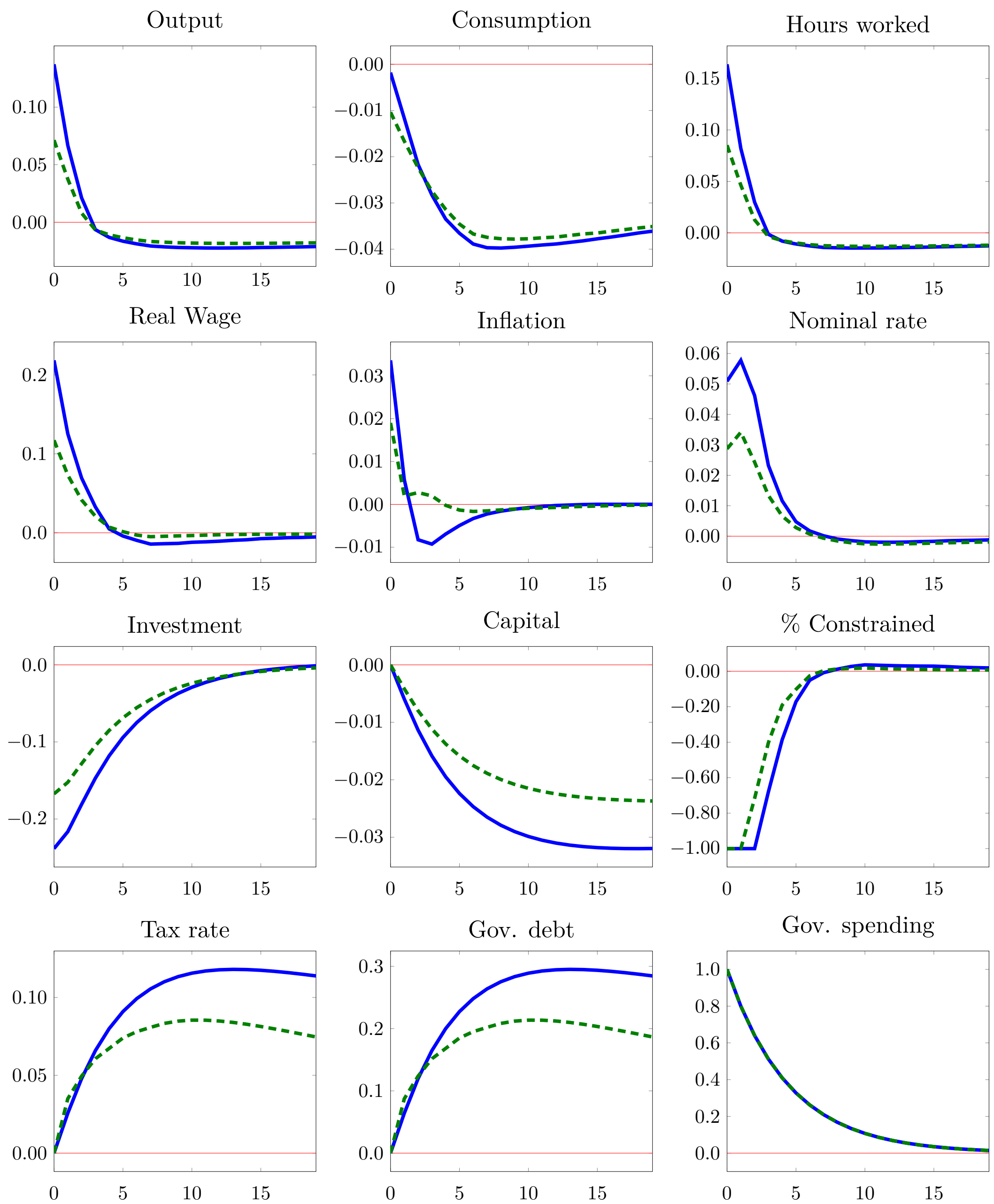
where the γ_T again determines the speed of adjustment. γ_T is set to 0.4, equivalent to the baseline case. I present IRFs to the two shocks, the respective multipliers and the distributional effects in the following.

3.5.1 Impulse responses

Gov. consumption shock

Figure 3.4 reports the IRFs to a government consumption shock, where the income tax rate instead of fiscal transfers adjusts to public debt. As in the baseline scenario, the increase in government consumption leads to an initial demand effect that raises output, hours worked and the real wage. When the shock hits in a recession, output rises by about 0.13 percent which is slightly below the initial response in the baseline. The same applies to hours worked and the wage rate. Following the fiscal shock, inflation rises by about 0.03 percent, leading to a strong response of the nominal interest rate. Consumption, however, does not increase on impact but slightly decreases, which is in contrast to the baseline scenario. The shock also leads to a crowding-out of investment, leading to a strong decline in the capital stock. The share of households at the borrowing constraints goes to zero as the

Figure 3.4: IRFs to one percent increase in government consumption (Tax rule)



initial demand effect generates a substantial increase in income that induces even the wealth-poor to save.

The demand effect vanishes as quickly as in the baseline but the more pronounced decline of capital leads to a more severe drop in output. This is because now the income tax rate rises as a reaction to the increase in the fiscal deficit, leading to a much stronger crowding-out of labor supply and private consumption.

When the shock hits during an expansion, a similar but somewhat weaker initial demand effect is generated. Output rises by about 0.06 percent, which is considerably lower than in the recession scenario, but also compared to the rise of about 0.1 percent in the baseline expansion. The same applies for the responses of consumption, hours worked and the real wage. Since the real interest rate does not increase as much as in the recessionary state, the crowding-out of investment is less severe, and thus, capital declines by a smaller amount. The number of borrowing constrained households falls to zero, indicating that the increase in income is sufficiently large so that even the wealth-poor begin to save.

As in the recession scenario, the demand effect dies out after four quarters caused by the substantial reduction of the capital stock. The responses of output, consumption, hours worked and the real wage are lower as in the counterfactual situation but sightly higher in comparison to the recession scenario. This is due to two factors. First, the less pronounced decline in capital, and second, since government debt does not increase as much, the income tax rate rises also by a smaller amount.

To sum up, the effects of the government spending shock with a different fiscal rule differ only quantitatively with respect to the benchmark rule. The initial demand effect is considerably larger when the shock hits during a recession but, on the other hand, smaller compared to the benchmark recession. The stronger crowding-out of capital in the recession scenario is further amplified by a rise in the income tax rate, exacerbating the drop of output once the demand effect is vanished.

Fiscal transfer shock

Figure 3.5 shows the IRFs to a one percent increase in fiscal transfers with the alternative fiscal rule. When the shock hits in a recession, the increase in transfers instantaneously translates into a reduction in demand as hours worked and output fall on impact. Consumption, however, increases by about 0.01%. The share of constrained households significantly declines, although not as much as in the baseline scenario. The fall in demand leads to a fall in prices, wages and the

Figure 3.5: IRFs to one percent increase in fiscal transfers (Tax rule)

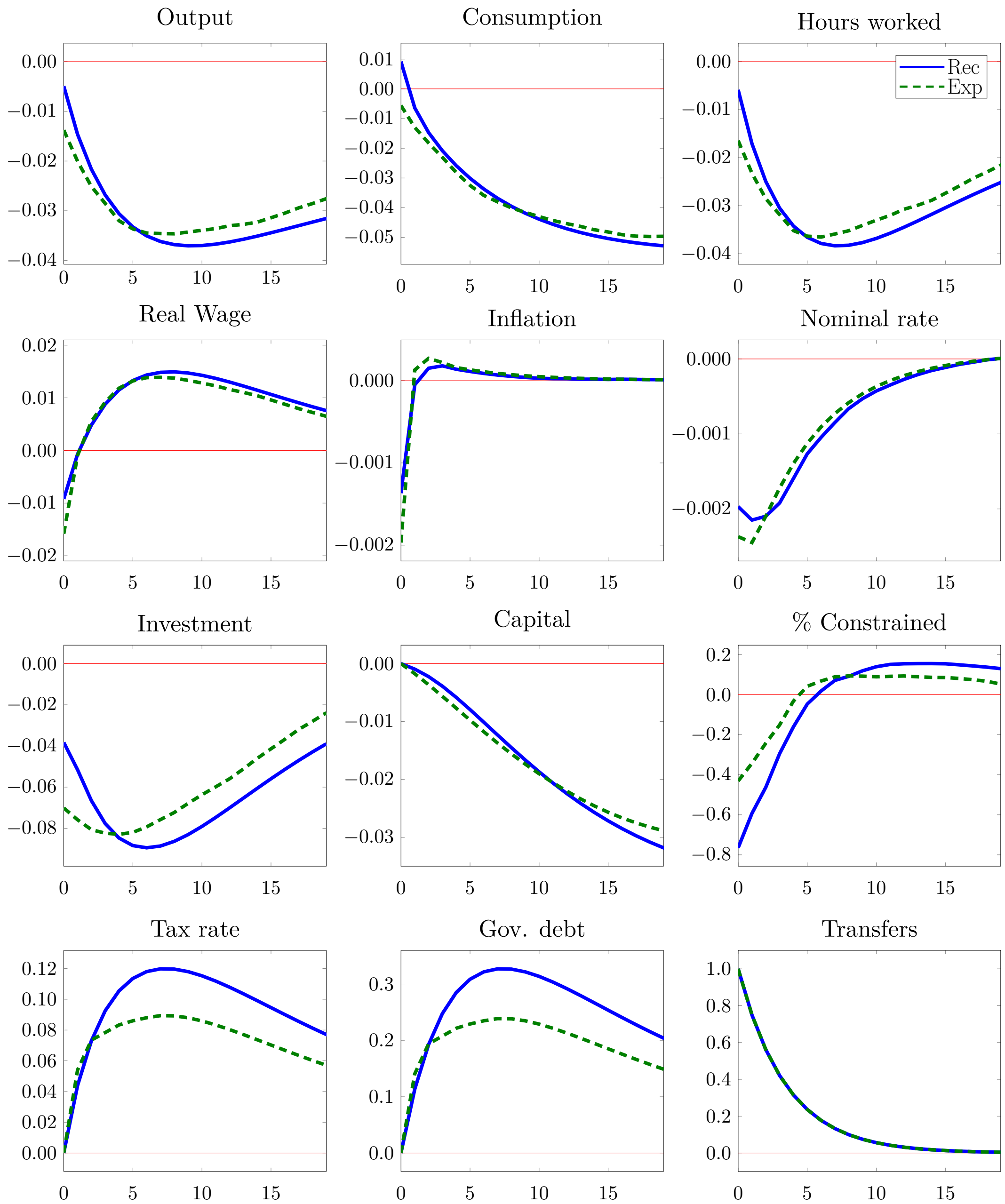


Table 3.5: Alternative multipliers

	Gov. consumption		Fiscal Transfers	
	Recession	Expansion	Recession	Expansion
Impact Multiplier	0.69	0.36	−0.04	−0.13
Cumul. Multipliers				
4 quarters	0.32	0.15	−0.23	−0.30
8 quarters	0.16	0.05	−0.60	−0.65
12 quarters	0.06	−0.03	−0.92	−0.93
16 quarters	−0.03	−0.10	−1.21	−1.19

nominal interest rate. The crowding-out of investment causes a steady decline of the capital stock, which in turn leads to a much more severe decrease in output compared to the baseline.

After the initial increase in consumption, there is also a steady decline as transfers are reduced. The number of constrained households then grows rapidly and exceeds the counterfactual by almost 20 percent.

When the shock hits in an expansion, the responses do not differ much. The initial drops in output, hours worked and the real wage are more pronounced while consumption also decreases on impact. This further decrease in demand can be explained by the smaller share of households at the borrowing constraint during expansions, implying smaller MPCs at the bottom of the wealth distribution. The reduction of this share is also considerably smaller in expansions.

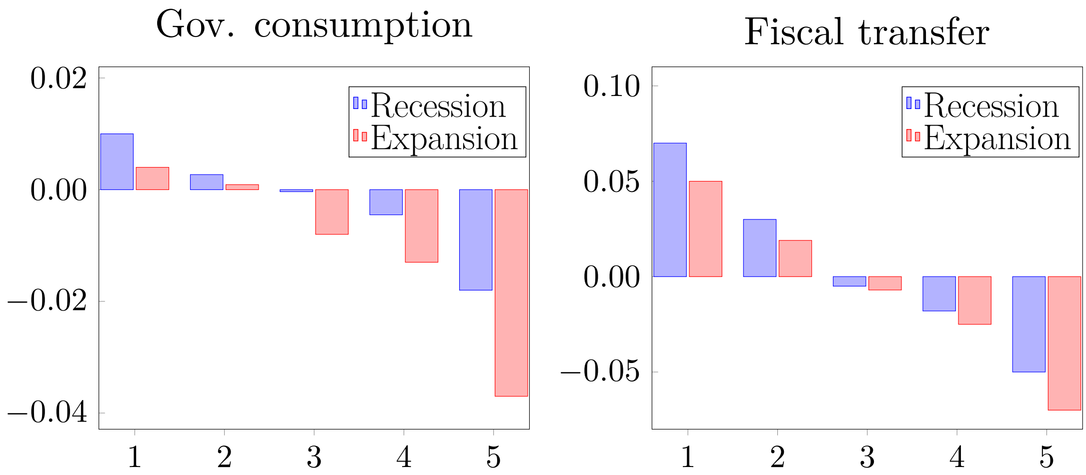
The crowding-out of investment on impact is stronger but approaches the counterfactual level faster after about one year. On the other hand, government debt increases less then during a recession. Thus, the income tax rate does not rise as much, and the negative effects on labor supply and output are not as strong so that the recovery to counterfactual levels is faster to some degree.

To sum up, the negative impact effects of output and hours worked are in stark contrast to the baseline scenario. There is no positive demand effect anymore because households anticipate that the tax rate will increase in the near future. Therefore, the negative effects after about one year are much more severe with this alternative fiscal rule.

3.5.2 Multipliers

Multipliers are calculated as in the baseline scenario and can be found in Table 3.5. For the government consumption shock, the impact multiplier in the recession is again considerably larger than in the expansion. On the other hand, both

Figure 3.6: Distributional effects



impact multipliers are somewhat smaller with this alternative fiscal rule. The cumulated multipliers decline relatively fast. It turns negative after three years in the expansion scenario and after four years when the shock hits in a recession.

In contrast to the baseline, the impact multipliers for the fiscal transfer shock are slightly negative. Although the multiplier for the recession scenario is somewhat larger than for the expansion, the speed of contraction is faster so that the cumulated multipliers after three years are almost equal.

To conclude, the multipliers that arise with the alternative fiscal rule are considerably smaller than in the baseline but still differ across the state of the economy.

3.5.3 Distributional effects

Figure 3.6 displays the consumption responses on impact for both shocks conditional on the quintile of the wealth distribution. For the government consumption shock, the responses are similar to the baseline. The wealth-poor increase their consumption level while the wealth-rich lower it. However, the magnitude of the wealth-poor's increase is considerably lower than in the baseline, while the reduction of the wealth-rich is larger. The reason is that households anticipate the future tax burden which has a negative effect across the distribution.

For the fiscal transfer shock, the impact responses differ quite substantially from the baseline, as it is no longer the case that all households raise their consumption. Instead, due to the contractionary nature of this shock, the wealth-rich respond by strongly decreasing their consumption. The high MPC of the wealth-poor, however, leads them to increase their consumption expenditures. This is also because the increase in fiscal transfers is much higher than the drop in their labor income.

3.6 Conclusion

Recent empirical studies indicate the presence of countercyclical fiscal multipliers. This chapter contributes to this literature by addressing this issue within a quantitative model and proposing a mechanism that naturally generates state-dependent responses to fiscal shocks. The main driver is a non-trivial MPC distribution that is induced by incomplete insurance markets and occasionally binding borrowing constraints. The share of constrained households in this framework is countercyclical, implying that the concentration at the bottom of the wealth distribution rises during recessions. These borrowing constrained households are characterized by a higher MPC than wealthier households so that a positive effect on their disposable income leads to a larger increase in personal consumption. Therefore, the higher share of constrained households during recessions serves as an amplification of the demand effect that is caused by fiscal shocks.

I investigate two types of government expenditure shocks, namely the traditional government consumption shock as well as a fiscal transfer shock, and control for different financing schemes. Although the size of fiscal multipliers across shocks and financing varies, the existence of countercyclical multipliers persists.

Appendix

3.A Data Appendix

Table 3.6: Data sources

	Series title	Series ID	Source
(1)	Gross Domestic Product	GDP	BEA
(2)	Personal Consumption Expenditures	PCEC	BEA
(3)	Gross Private Domestic Investment	GPDI	BEA
(4)	Nonfarm Business Sector: Real Compensation Per Hour	COMPRNFB	BLS
(5)	Nonfarm Business Sector: Hours of All Persons	HOANBS	BEA
(6)	Federal Debt Held by the Public	FYGFDPUN	USDT
(7)	Gross Domestic Product: Implicit Price Deflator	GDPDEF	BEA
(8)	Effective Federal Funds Rate	FEDFUNDS	BFED
(9)	Government Consumption Expenditures and Gross Investment	GCE	BEA
(10)	Government Current Transfer Payments	A084RC1Q027SBEA	BEA
(11)	Corporate Profits after tax with IVA and CCAdj: Net Dividends	DIVIDEND	BEA

Notes: BEA: U.S. Bureau of Economic Analysis, BFED: Board of Governors of the Federal Reserve System, BLS: U.S. Bureau of Labor Statistics, USDT: U.S. Department of the Treasury,

3.B Computational Appendix

Solution Method

The solution procedure can be divided into an inner and an outer problem. I start with the inner problem, which consists of the patient households' problem, the impatient households' problem and the simulation.

Patient Households' Problem.

The state space of this problem consists of six dimensions, current capital stock K_t, current government debt B_t, the lagged nominal interest rate R_{t-1}, government consumption G_t[15] aggregate technology z_t and an auxiliary state variable for lagged impatient households' consumption $c_{i,t-1}$. This can be summarized by the following vector of state variables,

$$\mathcal{S}_t = \{K_t, B_t, R_{t-1}, G_t, z_t, c_{i,t-1}\}. \tag{3.51}$$

I choose equidistant grids in the dimensions of all endogenous state variables.[16] The grids are chosen to be symmetric around the respective steady state (i.e. in the Aiyagari-version of the model) and the bounds are chosen such that the simulated values of each variable are always inside. The resulting space is the hypercube $\widehat{\mathcal{S}}_t$. I choose seven grid points in each endogenous dimension.

Given the state space, I solve the problem via a Time Iteration algorithm, which amounts to finding the equilibrium functions for K_{t+1}, π_t and w_t that are given by

$$\begin{aligned} K_{t+1} &= f_1(\mathcal{S}_t), \\ \pi_t &= f_2(\mathcal{S}_t), \\ w_t &= f_3(\mathcal{S}_t), \end{aligned}$$

where $f = (f_1, f_2, f_3)$ and $f_i : \mathbb{R}^5 \times [z_b, z_g] \to \mathbb{R}$ for $i \in \{1, 2, 3\}$.

To approximate f, I set initial function values on every grid point in the state space $\widehat{\mathcal{S}}$ and iterate on the set of dynamic first-order conditions that patient households are facing. In particular, I proceed as follows:

[15] This refers to the solution for the government consumption shock with transfers adjusting to public debt. Adjusting the problem for the fiscal transfer shock is straightforward.

[16] z_t is the only exogenous state variable here, since the process for TFP is discretized to a Markov chain.

1. Guess K_{t+1}, π_t, w_t on every point in $\widehat{\mathcal{S}}_t$, and guess a vector of coefficients $\alpha^0 = (\alpha_1(z_t), \ldots, \alpha_6(z_t))$.

2. Given states and guesses, it is straightforward to calculate the nominal interest rate from (3.31), investment from (3.20), fiscal transfers from (3.26), as well as the patient households' effective labor supply

$$l_{p,t} = \left(\frac{1-\tau_t}{\chi} w_t\right)^{\gamma},$$

impatient households' effective labor supply

$$n_{i,t} = (1-u_z)\left(\frac{1-\tau_t}{\chi} w_t\right)^{\gamma} \sum_j p_j^* \eta_j,$$

total effective labor supply

$$n_t = \nu n_{i,t} + (1-\nu)\bar{\eta}\left(\frac{1-\tau_t}{\chi} w_t\right)^{\gamma},$$

and unemployment benefits

$$Tr_t^u = u_z \xi w_t^{1-\gamma}\left(\frac{1-\tau_t}{\chi}\right)^{\gamma} \sum_j p_j^* \eta_j,$$

where u_z is the share of unemployed households and p^* is the invariant distribution of the idiosyncratic productivity shock.

3. Now, aggregate output can be calculated from (3.11), the shadow price of capital from (3.22), aggregate consumption from (4.35), next period's government debt from (3.24), as well as the rental rate of capital

$$r_t^K = \frac{w_t n_t}{K_t} \frac{\alpha}{1-\alpha},$$

dividends

$$D_t = z_t K_t^{\alpha} n_t^{1-\alpha} - w_t n_t - I_t - \frac{\phi_p}{2}\left(\frac{\pi_t}{\bar{\pi}} - 1\right)^2 y_t - \frac{\phi_c}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t - \kappa,$$

and finally real marginal costs

$$\Psi_t = \frac{w_t^{1-\alpha}(r_t^K)^{\alpha}}{z} \frac{1}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}}.$$

4. To determine the patient households' consumption, it is necessary to know impatient consumption. Since this depends on the wealth distribution of this group, I apply a Krusell and Smith (1998)-type approach and use a log-linear function that maps from state space $\mathcal{S}$ into the real numbers to forecast impatient consumption,

$$\begin{aligned} c_{i,t} = \exp(&\alpha_1(z_t) + \alpha_2(z_t)\log K_t + \alpha_3(z_t)\log B_t + \alpha_4(z_t)\log R_{t-1} + \\ &\alpha_5(z_t)\log G_t + \alpha_6(z_t)\log c_{i,t-1}), \end{aligned} \tag{3.52}$$

so that patient consumption is given by

$$c_{p,t} = \frac{C_t - c_{i,t}}{1-\nu}.$$

5. Given the next period values of the state variables, I use linear interpolation to get K_{t+2}, π_{t+1} and w_{t+1}, and use the respective equations one period ahead to obtain $c_{p,t+1}$, $l_{p,t+1}$, Y_{t+1}, r^K_{t+1}, I_{t+1} and q_{t+1}.

6. In the next step, I compute the expectation terms

$$\begin{aligned} &\mathbb{E}_t\left\{\phi_{t,t+1}\left(\frac{\pi_{t+1}}{\pi_t}-1\right)\frac{\pi_{t+1}}{\pi_t}\frac{Y_{t+1}}{Y_t}\right\}, \\ &\mathbb{E}_t\left\{\phi_{t,t+1}\left[r^K_{t+1} - \frac{\varphi_c}{2}\left(\frac{I_{t+1}}{K_{t+1}}-\delta\right)^2 + \varphi_c\left(\frac{I_{t+1}}{K_{t+1}}-\delta\right)\frac{I_{t+1}}{K_{t+1}} + q_{t+1}(1-\delta)\right]\right\}, \\ &\mathbb{E}_t\left\{\phi_{t,t+1}\frac{R_t}{\pi_{t+1}}\right\}. \end{aligned}$$

   Since some of the stochastic variables are discretized and some are continuous, I need to apply two different types of numerical integration here. For the continuous shocks, I use Gauss-Hermite quadrature (see Judd, 1998, for details), and for the discretized shocks, I use the corresponding transition matrix.

7. Given expectations, I use a multidimensional nonlinear equation solver to find the policy functions for K_{t+1}, π_t and w_t that solve this system of equations.[17]

8. If the difference between the guess and the obtained solution is sufficiently small, convergence is achieved. Otherwise, go back to step 2.

[17] I use Broyden's method (see Judd, 1998; Press et al., 1992, for details) to solve for the zeros.

Impatient Households' Problem

To solve the optimization problem of impatient households, the state space must be enlarged by three additional dimensions. More specifically, the adjusted state space is now $\mathcal{S} \times \mathcal{A} \times \mathcal{E} \times \{e, u\}$. Given this adjusted state space, I use the endogenous grid method (see Carroll, 2006) to find the policy functions $c_{i,t}$, $a_{i,t}$ and $l_{i,t}$.

Simulation

The simulation procedure works as follows:

1. Generate and fix a time series of length T for the aggregate shocks. Set an initial distribution of assets across N impatient households. For each agent, generate and fix time series of length T for the idiosyncratic shocks.

2. Use the policy functions obtained from the two optimization problems to simulate the economy T periods forward.

Outer Problem

The outer problem is then to run the regressions (3.52) with the time series obtained from the last simulation step. Use the set of estimated coefficients $\widehat{\alpha} = (\widehat{\alpha}_1(z_t), \ldots, \widehat{\alpha}_6(z_t))$ to compute a set of coefficients for the next iteration,

$$\alpha^{j+1} = b\alpha^j + (1 - b)\widehat{\alpha},$$

where $b \in [0, 1)$ is an updating parameter. If α^{j+1} and α^j are sufficiently close to each other, then the outer problem is solved and the model converged. If not, use α^{j+1} to solve the inner problem.

Equilibrium Forecasting Rules

Table 3.7: Laws of motion for impatient consumption

	Gov. consumption		Fiscal Transfers	
	z_b	z_g	z_b	z_g
α_1	−0.7198	−0.6343	−1.4245	−1.4680
α_2	0.2590	0.2015	0.2323	0.1842
α_3	−0.0364	−0.0458	−0.0172	−0.0255
α_4	−0.2458	0.2584	−0.3614	0.3967
α_5	0.0455	0.0030	0.1487	0.0588
α_6	0.8754	0.9223	0.8457	0.8691
R^2	0.9861	0.9735	0.9767	0.9853

Chapter 4

Income redistribution, consumer credit, and keeping up with the Riches

4.1 Introduction

This chapter[1] investigates the relevance of consumption externalities between different income groups for replicating consumer credit dynamics over the business cycle. For this purpose, we propose a dynamic stochastic general equilibrium (DSGE) model with upward looking consumption comparison that successfully reproduces credit movements during the Great Moderation. We estimate deep model parameters and thereby contribute to the literature as we show that consumption externalities are a significant determinant of short-run credit fluctuations.

Recent empirical studies show that consumption externalities significantly affect individuals' consumption decisions. Bertrand and Morse (2016) find empirical support for so-called "trickle-down-consumption", meaning that rising income and consumption at the top of the income distribution induces households in the lower parts of the distribution to consume a larger share of their income. Focusing on the period between the early 1980s and 2008, the authors present evidence for a negative relationship between income inequality and the savings rate of middle-income households. Carr and Jayadev (2015) show that rising indebtedness of US households is directly related to high levels of income inequality. The authors conclude that relative income concerns explain a significant part of the strong increase in household debt for the period 1999-2009. Using data from the German

[1]This chapter is a revised version of Klein and Krause (2014).

Socio-Economic Panel, Drechsel-Grau and Schmid (2014) demonstrate that upward looking comparison is a significant determinant of individuals' consumption decisions.

Regarding the interrelation between consumption externalities and private debt dynamics, there is yet no conclusive evidence. Bertrand and Morse (2016) provide indirect evidence that non-rich households rely on easier credit access to finance their desired keeping up with richer co-residents. Moreover, they find a positive relationship between the number of personal bankruptcy filings and top income levels. Georgarakos et al. (2014) show that a higher average income increases the tendency to borrow of households with incomes below average. Contrary, Coibion et al. (2014) find that low-income households in high-inequality regions accumulate less debt than similar households in low-inequality regions. However, their findings are mainly driven by mortgages, whereas for our variable of interest, consumer credit, the authors only find mixed results. Against this background, we investigate this relationship within a structural model and show that relative consumption concerns are an essential driver of aggregate credit dynamics.

Understanding how unsecured consumer credit fluctuates over the business cycle is of central importance because of several reasons. First, consumer credit is an important source of personal income. For our period of interest, the Great Moderation[2], credit averages 23% of aggregate personal consumption, indicating that more than one fifth of households' private expenditures were financed by relying on consumer credit. Second, short-run credit movements are characterized by a highly volatile behavior. As Table 4.1 reports, credit is more than twice (three times) as volatile as output (consumption). Third, and most importantly, business cycle correlations with other main aggregate variables contradict standard theory in which credit represents an instrument to smooth consumption in bad times. Table 4.1 shows positive co-movements between credit and output and consumption, respectively. In contrast to these empirical observations, one would expect countercyclical correlations when credit is primarily used to smooth consumption. The goal of this study is to show that a dynamic framework which allows for consumption externalities successfully replicates the credit statistics, and especially the procyclical correlations with output and consumption, reported

[2]Following Bertrand and Morse (2016) and Iacoviello and Pavan (2013), among others, we date the Great Moderation as the time span between the early 1980s (here 1982q1) and the outburst of the financial crisis (2008q2). We choose the Great Moderation as the underlying time span, because this period is characterized by a significant widening of income disparities and several innovations in financial markets which ultimately made credit access for individual households easier. Notably, all our qualitative findings are robust when extending the sample by the Great Recession.

Table 4.1: Credit-related moments (1982q1-2008q2)

	$\rho(x_t, D_t)$	σ_x/σ_D
Output	0.1523	0.4568
Consumption	0.1658	0.2783
Investment	0.0852	1.7524
Hours worked	0.3603	0.5080
Real wage	−0.3207	0.3994

Note: $\rho(x_t, D_t)$ is the cross-correlation of variable x with credit, σ_x/σ_D is the std. deviation of variable x relative to the std. deviation of credit. Consumer credit has been deflated using the price index of personal consumption expenditures. All variables are logged and HP-filtered (smoothing parameter of 1600) to obtain cyclical components. For data definitions and sources see Appendix.

in Table 4.1. We choose the Great Moderation as the underlying time span, because this period is characterized by a significant widening of income disparities and several innovations in financial markets which ultimately made credit access for households easier.[3]

Our proposed model economy is populated by two types of households. *Investors*, who hold the economy's entire capital stock, own firms and supply credit, and *workers*, who supply labor and demand credit to finance their desired level of consumption. Moreover, we include a mechanism through which workers value their own level of consumption relative to the investors' level of consumption. We refer to this mechanism as *keeping up with the Riches*.[4] This extension allows us to capture the "trickle-down-consumption" channel of Bertrand and Morse (2016), where the income-poor try to catch up with the income-rich. In the baseline model, fluctuations are driven by four stochastic innovations, namely a neutral technology, investment specific technology, price markup, and wage markup shock.

We estimate deep parameters of the four-shock model by a simulated methods of moments (SMM) approach. The parameter measuring the degree of workers' desire to keep up with their richer fellows is estimated to be positive and statistically significant. This leads to the conclusion that keeping up with the Riches is a central driver of credit dynamics over the business cycle. The models' implied credit moments successfully account for the (targeted) credit statistics as reported in Table 4.1. Notably, we also find that the estimated model replicates conventional

[3]Notably, all our qualitative findings are robust when extending the sample by the Great Recession.

[4]This term is inspired by the literature on *keeping up with the Joneses*. While studies which incorporate this mechanism model relative consumption concerns in relation to the average consumer (e.g. Galí, 1994), in our setup poorer households (workers) aim to keep up with richer ones (investors).

output-related statistics that are not targeted in the estimation. We interpret this result as a further justification of our proposed model.

We show that neither replacing the relative consumption motive by habit formation nor abstracting from consumption externalities at all helps to generate the targeted credit dynamics. In a robustness check, we consider stochastic default on loans but find that our baseline results are hardly affected.

When taking a closer look at the dynamics of the estimated model versions, we find that the price markup shock and the investment specific technology shock produce credit correlations which are qualitatively in line with the empirical ones as reported in Table 4.1. However, this is only true when we include the consumption externality in the workers' utility function. When we abstract from the relative consumption motive, we find that the model dynamics to both shocks no more correspond to the empirical counterparts. Notably, replicating the positive correlations between credit, output, and consumption does rely on the keeping up-mechanism. While recent literature finds that the price markup shock is of minor importance for output dynamics (Justiniano et al., 2010), our results indicate that innovations to the price markup, combined with consumption externalities, are essential in replicating short-run credit movements. Concerning the neutral technology shock and the wage markup shock, we find that the model responses do not replicate the empirical credit correlations but the inclusion of these two shocks helps to improve the quantitative performance of the model in terms of credit-related and output-related moments.

The rest of the chapter is organized as follows. Section 4.2 presents the baseline model. In Section 4.3, we introduce functional forms and show a set of theoretical results which connect the strength of the keeping up-mechanism to a set of deep model parameters. Section 4.4 describes the calibration and estimation strategy as well as our numerical results. In Section 4.5, we provide a detailed analysis of the implied model dynamics. In Sections 4.6 and 4.7, we show that our baseline results are not affected by allowing for habit formation and introducing stochastic default on loans. Finally, Section 4.8 concludes.

4.2 The model economy

In this section, we construct our baseline model that allows consumption externalities to influence the choices of households and that assesses its role within the business cycle. The economy is populated by a continuum of firms producing differentiated intermediate goods, a representative final good firm and a representative labor bundler. There are two types of households who are distinguished by their source of income as well as their access to capital and asset markets.

4.2.1 Final good firms

In this perfectly competitive sector, a representative firm produces final consumption good Y_t, combining a continuum of intermediate goods $Y_t(l), l \in [0,1]$, using the constant returns to scale technology

$$Y_t = \left[\int_0^1 Y_t(l)^{\frac{1}{\mu_t}} dl\right]^{\mu_t}, \tag{4.1}$$

with $\mu_t > 1$. The time-varying price markup μ_t is a function of the elasticity of substitution between intermediate goods and follows an exogenous stochastic process around its steady state value $\bar{\mu}$ given by

$$\log \mu_t = (1 - \rho_\mu) \log \bar{\mu} + \rho_\mu \log \mu_{t-1} + \varepsilon_{\mu,t}, \tag{4.2}$$

where $\varepsilon_{\mu,t} \overset{i.i.d.}{\sim} \mathcal{N}(0, \sigma_\mu^2)$, and $|\rho_\mu| < 1$. The firm chooses intermediate inputs to maximize profits subject to (4.1), which yields the demand function for intermediate good $Y_t(l)$,

$$Y_t(l) = Y_t \left(\frac{P_t(l)}{P_t}\right)^{\frac{\mu_t}{1-\mu_t}}, \tag{4.3}$$

and subsequently the price index of the final good,

$$P_t = \left[\int_0^1 P_t(l)^{\frac{1}{1-\mu_t}} dl\right]^{1-\mu_t}. \tag{4.4}$$

4.2.2 Intermediate goods firms

Each intermediate good is produced by a monopolistically competitive firm according to a production function given by

$$Y_t(l) = z_t F(K_{t-1}(l), N_t(l)), \tag{4.5}$$

where we assume that F is strictly increasing, twice differentiable in both arguments, exhibits constant returns to scale, and satisfies the Inada conditions. $K_{t-1}(l)$ and $N_t(l)$ denote the quantities of capital and labor services utilized to produce intermediate good $Y_t(l)$. z_t is the technology level common across all firms. We assume that z_t follows an exogenous stochastic process around its steady state value $\bar{z}$,

$$\log z_t = (1-\rho_z)\log \bar{z} + \rho_z \log z_{t-1} + \varepsilon_{z,t}, \tag{4.6}$$

where $\varepsilon_{z,t} \overset{i.i.d.}{\sim} \mathcal{N}(0, \sigma_z^2)$, and $|\rho_z| < 1$. Intermediate goods firms maximize profits, defined by

$$\Pi_t(l) = Y_t(l) - R_t K_{t-1}(l) - W_t N_t(l), \tag{4.7}$$

subject to the demand function (4.3) and to cost minimization, where R_t is the rental rate of physical capital and W_t is the aggregate wage rate. We assume symmetry such that firms charge the same prices and choose the same production inputs. Prices are perfectly flexible, which yields marginal costs that are equal to $1/\mu_t$. Thus, the aggregate wage rate can be expressed as a function of the marginal product of labor MPL_t and μ_t,

$$W_t = \frac{MPL_t}{\mu_t}. \tag{4.8}$$

The aggregate rental rate of physical capital equals

$$R_t = \frac{MPK_t}{\mu_t}, \tag{4.9}$$

where MPK_t is the marginal product of capital.

Following Chari et al. (2007), among others, μ_t can also be interpreted as the labor wedge on the firm side, as it drives a wedge between the wage rate and the marginal product of labor.

In the following sections, it will become apparent that the price markup shock shifts income from the poor to the rich households. Thus, we refer to (4.2) as a *redistribution shock*.[5]

4.2.3 Employment agency

As in Erceg et al. (2000), we assume that each working household j is a monopolistic supplier of a differentiated labor service $N_{w,t}(j)$. A representative labor

[5]Throughout the chapter, we use the two terms *redistribution shock* and *price markup shock* interchangeably.

bundler, termed as *employment agency*, combines the intermediate labor services into a homogeneous labor input $N_{w,t}$ using the constant returns to scale technology

$$N_{w,t} = \left[\int_0^1 N_{w,t}(j)^{\frac{1}{\nu_t}} dj \right]^{\nu_t}, \tag{4.10}$$

with $\nu_t > 1$. The time-varying wage markup ν_t is a function of the elasticity of substitution between labor types and follows an exogenous stochastic process around its steady state value $\bar{\nu}$,

$$\log \nu_t = (1 - \rho_\nu) \log \bar{\nu} + \rho_\nu \log \nu_{t-1} + \varepsilon_{\nu,t}, \tag{4.11}$$

where $\varepsilon_{\nu,t} \overset{i.i.d.}{\sim} \mathcal{N}(0, \sigma_\nu^2)$, and $|\rho_\nu| < 1$. The labor bundler operates in a perfectly competitive market and minimizes the cost of a given amount of aggregate labor $N_{w,t}$, taking each household's wage rate $W_t(j)$ as given, leading to the labor demand function

$$N_{w,t}(j) = N_{w,t} \left(\frac{W_t(j)}{W_t} \right)^{\frac{\nu_t}{1-\nu_t}}, \tag{4.12}$$

where W_t is the aggregate wage index. By substituting (4.12) into (4.10), we obtain the following expression for the latter,

$$W_t = \left[\int_0^1 W_t(j)^{\frac{1}{1-\nu_t}} dj \right]^{1-\nu_t}. \tag{4.13}$$

4.2.4 Households

Our model economy is populated by a continuum of infinitely lived households, indexed on the unit interval. A fraction χ of households, termed as *investors* (subscript i), holds the entire stock of physical capital and owns firms, while the remaining fraction $1 - \chi$, termed as *workers* (subscript w), makes up the entire labor force and does not have access to capital or asset markets. However, investors issue credit to workers. The respective shares of households are fixed.

In our baseline setting, we abstract from default on credit. In a later section, we show that introducing a stochastic default shock does not influence our main findings.

Investors

The preferences of investors are given by their expected lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta_i^t U_i(C_{i,t}), \tag{4.14}$$

where $\beta_i \in (0,1)$ is the specific discount factor of investors, $U_i(\cdot)$ is the period utility function, and E_0 is the expectations operator with respect to information in period 0. Since investors do not supply labor, we assume that the level of consumption is the only argument of the investors' utility function.

Definition 3 (Investors' utility function). *We impose the following assumptions on the investors' utility function U_i.*

(i) $\dfrac{\partial U_i}{\partial C_i} > 0$, $\dfrac{\partial^2 U_i}{(\partial C_i)^2} < 0$,

(ii) $\lim\limits_{C_i \to \infty} \dfrac{\partial U_i}{\partial C_i} = 0$, $\lim\limits_{C_i \searrow 0} \dfrac{\partial U_i}{\partial C_i} = \infty$.

Assumption (i) states that the utility function is strictly increasing, twice differentiable and strictly concave in the investors' level of consumption. Assumption (ii) ensures that the Inada conditions hold.

The investors' intertemporal budget constraint is given by

$$C_{i,t} + I_{i,t} + Q_t D_{i,t} \leq D_{i,t-1} + R_t K_{i,t-1} + \frac{\Pi_t}{\chi}, \tag{4.15}$$

where $I_{i,t}$ denotes investment, $Q_t \in (0,1)$ is the time t price of a credit that yields one unit of output in $t+1$, and Π_t/χ is the individual share of profits from ownership of firms. The law of motion for physical capital is

$$K_{i,t} = (1-\delta)K_{i,t-1} + \zeta_t I_{i,t}, \tag{4.16}$$

where δ is the depreciation rate. ζ_t denotes a shock to the relative price of investment in terms of the consumption good. We assume that the shock follows an AR(1)-process around its steady state value $\bar{\zeta}$,

$$\log \zeta_t = (1-\rho_\zeta) \log \bar{\zeta} + \rho_\zeta \log \zeta_{t-1} + \varepsilon_{\zeta,t}, \tag{4.17}$$

where $\varepsilon_{\zeta,t} \overset{i.i.d.}{\sim} \mathcal{N}(0, \sigma_\zeta^2)$, and $|\rho_\zeta| < 1$. The investors' optimization problem is then given by the objective function (4.14) which is maximized subject to (4.15) and (4.16) so that the first order conditions are given by

$$\Lambda_{i,t} = U_i'(C_{i,t}), \tag{4.18}$$

$$\Lambda_{i,t} = \beta_i E_t \zeta_t \Lambda_{i,t+1} \left(R_{t+1} + \frac{1-\delta}{\zeta_{t+1}} \right), \tag{4.19}$$

$$\Lambda_{i,t} Q_t = \beta_i E_t \Lambda_{i,t+1}, \tag{4.20}$$

where $U_i'(\cdot)$ denotes the first derivative of the utility function with respect to the argument in brackets, and $\Lambda_{i,t}$ denotes the Lagrange multiplier associated with (4.15). Finally, the transversality conditions that rule out infinite wealth accumulation, given by

$$\lim_{j\to\infty} E_t \beta^j \Lambda_{i,t+j} K_{i,t+j} = 0, \tag{4.21}$$

$$\lim_{j\to\infty} E_t \beta^j \Lambda_{i,t+j} Q_{t+j} D_{i,t+j} = 0, \tag{4.22}$$

are required to hold.

Workers

The preferences of worker j are given by his expected lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta_w^t U_w \left(C_{w,t}(j), X_t(j), N_{w,t}(j) \right), \tag{4.23}$$

where $\beta_w \in (0,1)$ is the specific discount factor of workers, $U_w(\cdot)$ is the period utility function, $C_{w,t}(j)$ is the workers' consumption level and $X_t(j)$ is a consumption externality that is strictly positive and that workers take as given. In each period, workers are endowed with one unit of time that is allocated between leisure $L_{w,t}(j)$ and individual labor services $N_{w,t}(j)$.

Definition 4 (Worker's utility function). *We impose the following assumptions on the workers' utility function U_w.*

(i) $\dfrac{\partial U_w}{\partial C_w} > 0, \dfrac{\partial^2 U_w}{(\partial C_w)^2} < 0, \dfrac{\partial U_w}{\partial N_w} < 0, \dfrac{\partial^2 U_w}{(\partial N_w)^2} < 0,$

(ii) $\dfrac{\partial^2 U_w}{(\partial C_w)^2} \dfrac{\partial^2 U_w}{(\partial N_w)^2} - \left(\dfrac{\partial^2 U_w}{\partial C_w \partial N_w} \right)^2 > 0,$

(iii) $\lim_{C_w \to \infty} \frac{\partial U_w}{\partial C_w} = 0, \lim_{C_w \searrow 0} \frac{\partial U_w}{\partial C_w} = \infty,$

(iv) $\frac{\partial U_w}{\partial X} < 0 \vee \frac{\partial U_w}{\partial X} > 0,$

(v) $\frac{\partial MRS_w}{\partial X} > 0 \vee \frac{\partial MRS_w}{\partial X} < 0,$ *where* $MRS_w := -\frac{\partial U_w / \partial L_w}{\partial U_w / \partial C_w}.$

Assumptions (i), (ii), and (iii) refer to the standard properties of utility functions, namely that they are twice differentiable, strictly increasing in consumption, strictly decreasing in labor, strictly concave in these two variables and that Inada conditions are satisfied. The key issue here is the role of the consumption externality in (iv) and (v). Following Dupor and Liu (2003), preferences exhibit *jealousy* if the worker derives disutility from an increase in the externality (first argument of (iv)), and *admiration* if the opposite is true (second argument of (iv)). Assumption (v) specifies the effect of X in terms of the marginal rate of substitution (MRS) between leisure and consumption. We say that preferences exhibit *keeping up with the Riches*, if the MRS is increasing in X (first argument of (v)). This implies that a rise in the consumption externality may raise the worker's marginal utility of consumption relative to leisure, leading the worker to work more hours if prices are fixed. Preferences that feature the opposite effect are termed *running away from the Riches* (second argument of (v)).[6] Note that assumption (iv) is necessary for (v) but not vice versa.

Including this consumption externality mechanism is motivated by recent microeconometric studies, which find that upward looking comparison significantly affect individuals consumption decisions (Bertrand and Morse, 2016; Carr and Jayadev, 2015; Drechsel-Grau and Schmid, 2014).

Workers face the following budget constraint,

$$C_{w,t}(j) + D_{w,t-1}(j) \leq W_t(j) N_{w,t}(j) + Q_t D_{w,t}(j) - \frac{\phi}{2}(D_{w,t}(j) - \bar{D}_w)^2, \quad (4.24)$$

where $D_{w,t}(j)$ denotes received credit at price Q_t, and $W_t(j)$ is the individual wage rate of household j. The last term of (4.24) represents a quadratic cost of choosing a quantity of credit different from the steady state value $\bar{D}_w$. This assumption can be thought of as a kind of transaction cost and is needed to rule out random walk

[6]For specific preferences that are additively separable in (C_w, X) and L_w, assumption (v) is equivalent to $[\partial^2 U_w / (\partial C_w \partial X)] / [\partial U_w / \partial C_w] \gtrless 0$, as used by Galí (1994), but in general this is not the case.

components in the equilibrium dynamics of credit.[7] To rule out Ponzi schemes, we impose

$$\lim_{j\to\infty} E_t \prod_{s=0}^{j} Q_{t+s} D_{w,t+j} \leq 0. \tag{4.25}$$

The optimization problem of working household j is then given by the objective function (4.23) subject to (4.24), (4.25) and the demand for the household's differentiated labor input (4.12). We assume symmetric working households such that all workers set the same wage, supply the same amount of labor, and choose the same amount of consumption and credit. As for the final good price, we assume that wages are perfectly flexible.

Letting $\Lambda_{w,t}$ be the workers' Lagrange multiplier on their budget constraint, the symmetric optimal choices for consumption, labor supply, and credit demand are then ultimately determined by

$$\Lambda_{w,t} = U_w'(C_{w,t}), \tag{4.26}$$

$$\Lambda_{w,t} W_t = -U_w'(N_{w,t})\nu_t, \tag{4.27}$$

$$\Lambda_{w,t}\left[Q_t - \phi\left(D_{w,t} - \bar{D}_w\right)\right] = \beta_w E_t \Lambda_{w,t+1}, \tag{4.28}$$

where $U_w'(\cdot)$ denotes the first derivative of the utility function with respect to the argument in brackets.

From (4.27), it is apparent that the wage rate is a function of the marginal rate of substitution between leisure and consumption, MRS_t, and the wage markup ν_t,

$$W_t = \nu_t MRS_t. \tag{4.29}$$

In close analogy to the price markup, ν_t can be interpreted as the labor wedge on the household side. In a perfectly competitive economy, μ_t and ν_t would be one such that wages equal the marginal product of labor on the one hand, and the marginal rate of substitution on the other.

[7] Similar to our problem, Schmitt-Grohé and Uribe (2003) compare different modeling strategies that induce stationarity within small open economy models.

4.2.5 Aggregation and market clearing

Aggregates are defined as the weighted average of the respective variables for each household type. Hence, we get

$$C_t = \chi C_{i,t} + (1-\chi) C_{w,t}, \tag{4.30}$$

$$I_t = \chi I_{i,t}. \tag{4.31}$$

The markets for capital and labor clear when

$$K_t = \chi K_{i,t}, \tag{4.32}$$

$$N_t = (1-\chi) N_{w,t}, \tag{4.33}$$

at their respective prices R_t and W_t, credit market clearing requires that

$$(1-\chi) D_{w,t} = \chi D_{i,t}, \tag{4.34}$$

while the aggregate resource constraint is given by

$$Y_t = C_t + I_t + (1-\chi)\frac{\phi}{2}(D_{w,t} - \bar{D}_w)^2. \tag{4.35}$$

4.2.6 Equilibrium

In this section, we define the equilibrium for the economy described above.

Definition 5 (Competitive equilibrium). *Given the exogenous realizations of* $\{\zeta_t, \mu_t, z_t, \nu_t\}_{t=0}^{\infty}$, *a competitive rational expectations equilibrium is a stochastic set of sequences*

$$\{C_t, C_{i,t}, C_{w,t}, D_{i,t}, D_{w,t}, I_t, I_{i,t}, K_t, K_{i,t}, \Lambda_{i,t}, \Lambda_{w,t}, N_t, N_{w,t}, \Pi_t, Q_t, R_t, W_t, Y_t\}_{t=0}^{\infty}$$

satisfying

1. *the investors' first order conditions* (4.18)-(4.20), *with binding budget constraint* (4.15) *and transversality conditions* (4.21) *and* (4.22),
2. *the workers' first order conditions* (4.26)-(4.28), *with binding budget constraint* (4.24) *and binding no-Ponzi condition* (4.25),
3. *factor prices* (4.8) *and* (4.9), *capital accumulation* (4.16), *profits definition* (4.7) *and production technology* (4.5),
4. *the aggregation identities* (4.30) *and* (4.31), *and*

5. *the market clearing condition for capital* (4.32), *labor* (4.33) *and credit* (4.34).

The model is solved by a log-linear approximation around its deterministic steady state.

4.3 Theoretical results

The next subsection presents our choice of functional forms for the production technology and the utility functions, as well as some qualitative results that connect the strength of the keeping up-mechanism with two model parameters.

4.3.1 Functional forms

The investors' period utility function is given by

$$U_i(C_i) = \log C_i, \tag{4.36}$$

while the workers' period utility function is assumed to be

$$U_w(C_w, X, N_w) = \frac{(C_w X^{-b})^{1-\sigma} - 1}{1-\sigma} - \frac{\gamma N_w^{1+\eta}}{1+\eta}, \tag{4.37}$$

where b indicates the strength of the consumption externality, σ is the Arrow-Pratt measure of relative risk aversion, γ is a scaling parameter, and η is the inverse Frisch elasticity of labor supply. This specification implies that $MRS_t = \gamma N_{w,t}^{\eta} / \Lambda_{w,t}$. We assume that X is defined as

$$X_t := \frac{C_{i,t}}{C_{w,t}}, \tag{4.38}$$

such that workers value the contemporaneous consumption level of investors relative to their own.[8] The sign of b then ultimately determines if preferences exhibit jealousy or admiration. If b is positive, U_w implies jealousy, while for negative values, the conditions for admiration are met.

In the following, we exclude the case of $\sigma = 1$. Assuming a logarithmic form for the first part of the workers' utility function would imply that the marginal rate of substitution between consumption and leisure is independent of the consumption

[8]Similar specifications of relative consumption motives are used by Airaudo and Bossi (2017) and Alvarez-Cuadrado and Japaridze (2017). They study how consumption externalities affect the impact of financial deregulation and monetary policy, respectively.

externality. This is a violation of condition (v) in definition 4 and therefore, we assume that $\sigma > 0$ and $\sigma \neq 1$.

The magnitude of σ and the sign of b are of crucial importance whether working households aim to keep up with the investors or if they are running away. In particular, there are the four different cases $\{b > 0, \sigma > 1\}$, $\{b < 0, \sigma \in (0,1)\}$, $\{b > 0, \sigma \in (0,1)\}$, and $\{b < 0, \sigma > 1\}$. While the first two cases imply that workers wish to keep up, the latter imply running away. As our estimations below indicate, only the first case is relevant.

Intermediate good firms produce according to the Cobb-Douglas production function

$$Y_t = z_t K_{t-1}^{\alpha} N_t^{1-\alpha}, \tag{4.39}$$

where $\alpha \in [0,1]$ measures the output elasticity of capital. This specification implies that $MPL_t = (1-\alpha)Y_t/N_t$ and $MPK_t = \alpha Y_t/K_{t-1}$.

4.3.2 A first set of results

The following two results clarify the role of b and σ on shaping the behavior of working households and consequently, their role for the cyclical properties of our economy. We first present the workers' specific consumption Euler equation which relates the consumption growth of investors and changes in the credit price to their own consumption growth. Afterwards, we analytically derive the response of the workers' consumption to a marginal increase in the investors' consumption level. The result is of particular importance to our quantitative analysis in the following, as we are then be able to compare our result to related empirical findings of Bertrand and Morse (2016).

Proposition 1. *Suppose that the consumption externality is given by* (4.38) *and abstracting from debt adjustment costs, the workers' log-linearized Euler equation is given by*

$$\widehat{C}_{w,t+1} - \widehat{C}_{w,t} = -\frac{1}{\sigma + b(\sigma-1)}\widehat{Q}_t + \frac{b(\sigma-1)}{\sigma + b(\sigma-1)}\left(\widehat{C}_{i,t+1} - \widehat{C}_{i,t}\right). \tag{4.40}$$

This proposition shows that the workers' intertemporal consumption choice is determined by two channels, consumption smoothing and the keeping up-motive. Since workers do not have access to capital markets, they are not able to transfer their income between periods so that the only option to smooth consumption is via credit. A high σ therefore implies that fluctuations in the price of credit have less influence on the consumption decision and the respective household prefers a smooth consumption profile. The strength of consumption smoothing in our setting is jointly determined by σ and b. In that sense, a positive b amplifies the consumption smoothing motive of workers, as long as $\sigma > 1$.

On the other hand, σ also affects the strength of the keeping up-motive, as can be seen in the second term on the right-hand side of (4.40). A positive b then implies that the keeping up-motive is increasing in σ. If b is equal to zero, the keeping up-channel is shut down and consumption smoothing is only determined by σ.

The following proposition characterizes the influence of b on the worker's consumption decision when there is an increase in the investor's consumption level.

Proposition 2. *Suppose that $\sigma > 1$. Given an exogenous one-time change in investor's consumption $d\widehat{C}_{i,t}$, the worker's consumption response is given by*

$$d\widehat{C}_{w,t} = \xi_0 d\widehat{C}_{i,t}, \tag{4.41}$$

where $\xi_0 := \dfrac{\frac{b(\sigma-1)}{\eta}\left(\bar{W}\bar{N}_w + \frac{\bar{Q}^2}{\phi}\right)}{\frac{(\sigma+b(\sigma-1))}{\eta}\left(\bar{W}\bar{N}_w + \frac{\bar{Q}^2}{\phi}\right) + \bar{C}_w}$, *and* $|\xi_0| \in [0, 1)$.

Proof. See Appendix. □

This proposition states that the (partial equilibrium) response of workers is determined by b and σ, besides a few positive steady state values and the labor supply elasticity. Unsurprisingly, the response is zero if b is equal to zero. This expression is of particular importance in our numerical analysis below, as we use it to compare this value to the values found in Bertrand and Morse (2016).

4.4 Parametrization

We use an SMM approach to estimate a subset of the structural parameters of the model. Of particular importance are the parameters that determine the impact of the relative consumption motive, namely b and σ. The characteristics of the neutral technology shock and the redistribution shock are estimated by ordinary least squares. The parameters that are not estimated are calibrated in a standard fashion.

Table 4.2: Model calibration

	Parameter	Value	Target
Preferences			
Discount factors	$\beta_i = \beta_w$	0.995	Real interest rate of 3%
Inverse Frisch elasticity	η	1	Hall (2009)
Disutility of labor	γ	8.305	SS labor supply of 0.33
Fraction of investors	χ	0.20	Bertrand and Morse (2016)
Technology			
Capital share	α	0.33	Capital share of income of 26%
Depreciation rate	δ	0.025	Annual depreciation of 10%
Steady state			
Price markup	$\bar{v}$	1.25	48% income share of investors
Wage markup	$\bar{\mu}$	1.10	Schmitt-Grohé and Uribe (2011)
Labor	$\bar{N}$	0.33	Normalization
Neutral technology	$\bar{z}$	1	Normalization
Inv. spec. Technology	$\bar{\zeta}$	1	Normalization
Credit-to-labor income	$\bar{D}_w/(\bar{W}\bar{N}_w)$	0.27	Data

4.4.1 Calibrated parameters

Table 4.2 reports the calibrated parameter values, where an upper bar denotes the steady state value of the respective variable. One model period corresponds to one quarter.

The discount factors of both agents are set to 0.995 to match an annual real interest rate of 3 percent. We choose an inverse Frisch elasticity η of 1, which is in the range of values suggested by Hall (2009). We normalize the steady state level of labor supply to 0.33 and set γ accordingly.

To ensure comparability to the empirical study of Bertrand and Morse (2016), the share of investors (rich households) in the overall population χ is set to 20 percent. α equals 0.33, implying a steady-state capital share of income of about 26 percent. The depreciation rate of capital δ equals 0.025, which corresponds to an annual depreciation rate on capital equal to 10 percent.

We assign a value of 1.25 to the steady state price markup to match an investors' income share of 48 percent.[9] For the steady state wage markup, we follow Schmitt-Grohé and Uribe (2011) and choose 1.1, which is in the interval of typically used values in the literature. The steady state levels $\bar{z}$ and $\bar{\zeta}$ are normalized to 1. The

[9]This value is taken from the Current Population Survey (CPS) for the years from 1982 to 2007.

steady state consumer credit-to-labor income ratio for workers, $\bar{D}_w/(\bar{W}\bar{N}_w)$, is calibrated to 27%, which is the empirical average for the Great Moderation.

4.4.2 OLS estimation

In line with the construction of the empirical moments reported in Table 4.1, the sample for the OLS estimation covers the period 1982q1 to 2008q2. With the exception of the TFP series, all data series mentioned in the following are obtained from the FRED database.[10]

TFP data are taken from Fernald (2014). This quarterly series on aggregate technology controls for aggregation effects, varying utilization of capital and labor, nonconstant returns, and imperfect competition. The variable is detrended before estimation by a one-sided HP-filter, as suggested by Watson and Watson (1999), with a smoothing value of 1600. The estimated AR-coefficient and standard deviation are 0.837 and 0.008 respectively. These estimates are similar to the findings of Bullard and Singh (2012) who use the standard (unadjusted) Solow residual to calculate the shock characteristics.

For constructing a time series of the price markup, we follow Galí, Gertler, and López-Salido (2007a) and use the following equation,

$$\mu_t = MPL_t - w_t, \tag{4.42}$$

where the marginal product of labor MPL_t equals $\log[(1-\alpha)y_t/n_t]$. y_t/n_t is measured as the real output per hour worked of all persons in the nonfarm business sector, and w_t is the log of real compensation per hour in this sector. Again, all series are detrended by the one-sided HP-filter. The estimates of the AR-coefficient and the standard deviation are 0.777 and 0.006 respectively, and thus, similar to those of Galí, Gertler, and López-Salido (2007a) and Karabarbounis (2014). The upper part of Table 4.3 summarizes the parameter values estimated by OLS.

[10]See Appendix 4.A for a detailed description of the data.

4.4.3 SMM estimation

According to (4.29), the wage markup ν_t is defined as the product of the real wage rate W_t and the marginal rate of substitution MRS_t. Given the specific utility function of working households,

$$MRS_t = \frac{\gamma N_{w,t}^{\eta}}{\Lambda_{w,t}}, \quad \text{where } \Lambda_{w,t} = C_{w,t}^{-\sigma} X_t^{b(\sigma-1)}. \tag{4.43}$$

Calculating a wage markup series would require data on C_i and C_w, and an appropriate value for b, the parameter measuring the strength of the relative consumption motive. However, since there is no such data available, to the best of our knowledge, and there is little guidance in the literature about values for b, we use the SMM estimator to overcome this data problem.[11] The objective of SMM is to find a parameter vector that minimizes the weighted distance between simulated model moments and their empirical counterparts.

Let $\widehat{\Omega}$ be a $k \times 1$ vector of empirical moments computed from the data and let $\Omega(\theta)$ be the $k \times 1$ vector of simulated moments computed from artificial data. The corresponding time series are generated from simulating the model given a draw of random shocks and the $p \times 1$ vector $\theta \in \Theta$, with $\Theta \subseteq \mathbb{R}^p$. The length of the simulated series is τT, where T is the number of observations in the real data set and $\tau \geq 1$ is an integer. Then, the SMM estimator is given by

$$\widetilde{\theta}_{SMM} = \underset{\theta \in \Theta}{\arg\min} \left[\widehat{\Omega} - \Omega(\theta)\right]' \Upsilon^{-1} \left[\widehat{\Omega} - \Omega(\theta)\right], \tag{4.44}$$

where Υ is a $k \times k$ positive-definite weighting matrix.

Specifically, $\widehat{\Omega}$ contains the consumer credit moments as shown in Table 4.1. $\widetilde{\theta}_{SMM}$ contains the estimates for b, σ, ϕ, ρ_ζ, σ_ζ, ρ_ν, and σ_ν. For the weighting matrix, we follow Ruge-Murcia (2013) and choose a matrix with diagonal elements equal to the optimal weighting matrix while all off-diagonal elements are equal to zero.[12] Hence, we only put weight on moments that are observed in the data and force the estimation to consider only economically meaningful moments (see Cochrane, 2005, chap. 11). Additionally, we follow Born and Pfeifer (2014) and incorporate

[11] The SMM approach was proposed by McFadden (1989) and extended by Lee and Ingram (1991), among others.

[12] Ruge-Murcia (2013) shows that this choice produces consistent parameter estimates, while standard errors are just slightly higher than those generated with the optimal weighting matrix. The optimal weighting matrix is given by the inverse of the variance-covariance matrix associated with the sample moments. We compute this matrix with the VARHAC-estimator with automatic lag selection by the Bayesian information criterion (see Den Haan and Levin, 1997).

prior information about the parameters to estimate. In particular, we choose prior means $\bar{\theta}$ for each parameter in θ and expand $[\widehat{\Omega} - \Omega(\theta)]$ by $(\widetilde{\theta}_{SMM} - \bar{\theta})$, the deviation of the estimated parameter from the respective prior mean. We expand Υ by attaching small penalty terms to the diagonal, which raise the objective function when deviating from the prior mean. The penalties are of negligible magnitude compared to the other elements in Υ but impose soft bounds on the parameters.[13] We choose this procedure to rule out local minima in implausible regions of the state space which is often the case when estimating DSGE models.[14] Since we want to be agnostic about the strength of the relative consumption motive b, we choose a prior mean of 0 so that deviations from zero are only tolerated if they imply significant improvements in the targeted moments.

To rule out dependence on one particular draw of shocks, we draw several sets of shocks and choose the parameter set that minimizes the mean of all objective functions. We use the following algorithm to estimate θ.

Algorithm 1 (Construction of objective function to be minimized). *We start with a guess for $\widetilde{\theta}_{SMM}$. Then:*

1. *Draw 50 sets of shocks, each consisting of $(\tau T + 1500) \times 4$ values.*

2. *For each set of shocks: solve the model, simulate time series, discard the first 1500 periods, compute moments, compute objective function.*

3. *Take the mean of all 50 objective function values and minimize this.*

We set τ to 10, implying that the artificial time series are ten times larger than the original sample size. Ruge-Murcia (2013) shows that this is a useful choice for handling the trade-off between accuracy and computational cost.

Following Ruge-Murcia (2013), we compute the standard errors of $\widetilde{\theta}_{SMM}$ from an estimate of its asymptotic covariance matrix as

$$(1 + 1/\tau)(J'\Upsilon J)^{-1} J'\Upsilon JSJ(J'\Upsilon J)^{-1}, \tag{4.45}$$

where J is the Jacobian matrix and S is the full variance-covariance matrix of the empirical moments.

The results of the SMM estimation are shown in the lower part of Table 4.3. For b, we obtain a value of 5.23 that is estimated to be significantly different from zero, indicating a strong presence of the relative consumption motive. For σ,

[13] Born and Pfeifer (2014) show that this procedure can be interpreted as using a truncated normal distribution.

[14] Also known as the "dilemma of absurd parameter estimates", see An and Schorfheide (2007).

Table 4.3: Estimated parameter values

	Parameter	Prior	Value	SD
OLS estimation				
AR(1)-coefficient technology shock	ρ_z		0.8368	(0.0554)
Standard deviation technology shock	σ_z		0.0084	(0.0031)
AR(1)-coefficient redistribution shock	ρ_μ		0.7769	(0.0629)
Standard deviation redistribution shock	σ_μ		0.0063	(0.0024)
	Parameter	Prior	Value	SD
SMM estimation				
Relative consumption motive	b	0.0000	5.2322	(0.4323)
Utility curvature	σ	2.0000	5.4771	(0.4002)
Debt adjustment cost parameter	ϕ	0.0000	1.1239	(0.0102)
AR-coefficient inv. spec. technology shock	ρ_ζ	0.5000	0.9209	(0.0019)
Standard deviation investment shock	σ_ζ	0.0050	0.0093	(0.0001)
AR-coefficient wage markup shock	ρ_ν	0.5000	0.5211	(0.0242)
Standard deviation wage markup shock	σ_ν	0.0050	0.0309	(0.0007)

we estimate a value of 5.48. To get a better interpretation of these values, we make use of Proposition 2, which quantifies the (partial equilibrium) reaction of workers' consumption to an increase in investors' consumption. Inserting the values of b and σ as well as the estimate of the debt adjustment cost parameter ϕ into ξ_0 gives a coefficient of 0.7988. This implies that a 1 percent increase in investors' consumption leads to an increase of about 0.8 percent in workers' consumption. This elasticity is in the upper range of estimates provided by Bertrand and Morse (2016), which implies that our estimated model is able to replicate microeconometric evidence on the strength of the keeping up-motive.

The investment specific technology shock is estimated to have a relatively high degree of persistence, whereas the wage markup shock displays a relatively low degree of persistence. Moreover, the standard deviations of both shocks, σ_ζ and σ_ν, are in line with values found by related studies. The estimated debt adjustment cost parameter, ϕ, takes a value take a value of 1.12.

Columns 2-5 of Table 4.4 report the credit moments obtained from the data and from the model simulation, respectively. All these model moments are close to the empirical ones with only minor discrepancies. In line with the empirical counterparts, the estimated model implies that output, consumption, hours worked, and the real wage are less volatile than consumer credit, whereas investment displays a higher relative volatility. As in the data, the model's dynamics imply positive correlations between credit and consumption, output and hours worked, respectively, whereas the real wage and consumer credit are negatively correlated.

Table 4.4: Data and simulated model moments

	$\rho(x_t, D_t)$		σ_x/σ_D		$\rho(x_t, Y_t)$		σ_x/σ_Y	
	Data	Model	Data	Model	Data	Model	Data	Model
Output	0.1523	0.1389	0.4568	0.3510	-	-	-	-
Consumption	0.1658	0.1793	0.2783	0.2961	0.8020	0.7835	0.6092	0.8439
Investment	0.0852	0.0334	1.7524	1.0116	0.9061	0.7637	3.8359	2.8839
Hours worked	0.3603	0.3386	0.5080	0.5963	0.8144	0.7652	1.1120	1.7000
Real wage	−0.3207	−0.4529	0.3994	0.4757	0.0023	−0.4157	0.8743	1.3571

Note: $\rho(x_t, D_t)$ is the cross-correlation of variable x with credit, σ_x/σ_D is the std. deviation of variable x relative to the std. deviation of credit, $\rho(x_t, Y_t)$ is the cross-correlation of variable x with output, σ_x/σ_Y is the std. deviation of variable x relative to the std. deviation of output.
Consumer credit has been deflated using the price index of personal consumption expenditures. All variables are logged and HP-filtered (smoothing parameter of 1600) to obtain cyclical components. For data definitions and sources see Appendix.

Investment does not show a contemporaneous correlation with credit. Importantly, the model implied correlations successfully replicate the empirical counterparts. Thus, the rather negligible differences suggest that our calibration/estimation exercise provides a set of reasonable parameter values and, furthermore, supports the inclusion of the *keeping up with the Riches* mechanism into the proposed theoretical setup.

Columns 6-9 of Table 4.4 show the correlations between output and the remaining four aggregate variables as well as the standard deviations of these aggregates relative to the standard deviation of output. Note that these statistics are not included in the moment-matching approach so that we can interpret these results as the model's ability to replicate important conventional business cycle relations.

Simulating the model leads to a strong procyclical behavior of investment and hours worked with correlation coefficients close to the empirical moments. Moreover, the model produces a strong positive co-movement between output and consumption as observed in the data. The implied relative standard deviations of these variables also show a similar magnitude as their empirical counterparts. The only two moments that are far off are those related to the wage rate. However, recent research has revealed significant changes in the co-movements of most labor market variables since the beginning of the Great Moderation (e.g. Andrés et al., 2013; Galí and Gambetti, 2009). Reproducing the acyclical behavior of real wages documented in Table 4.4 therefore poses a challenge for most macroeconomic models. Nevertheless, the differences between the two sets of moments are only small-sized so that we interpret the results of this quantitative exercise as a validation of our proposed model and the underlying calibration/estimation strategy.

Table 4.5: Estimated parameters values for both specifications

	Parameter	$b = \hat{b}$	$b = 0$
Relative consumption motive	b	5.2322	-
Utility curvature	σ	5.4771	8.2601
Debt adjustment cost parameter	ϕ	1.1239	1.0257
AR-coefficient investment specific technology shock	ρ_ζ	0.9209	0.8428
Standard deviation investment shock	σ_ζ	0.0093	0.0159
AR-coefficient wage markup shock	ρ_ν	0.5211	0.4347
Standard deviation wage markup shock	σ_ν	0.0309	0.0100

4.4.4 Estimation without b

In the following, we demonstrate that our proposed model that includes the relative consumption motive outperforms the model in which the relative consumption motive is excluded. In doing so, we repeat our model estimation but set $b = 0$ so that we abstract from any consumption externalities. Table 4.5 shows the estimated parameters of this exercise and compares them to our baseline estimation which includes the relative consumption motive. It turns out that some parameters for the model with $b = 0$ alter drastically compared to the baseline case. In particular, σ is estimated to be significantly larger than in our baseline case. This is not surprising as the baseline estimation suggests a strong consumption smoothing channel, as specified in Proposition 1. To achieve a similar strength of the channel in absence of b, σ has to be considerably higher than in the baseline.

The model in which $b = 0$ performs worse in replicating the credit moments compared to our proposed setup. As Table 4.6 shows, the model that excludes upward looking consumption comparison does neither reproduce the positive correlation between credit and output nor the positive correlation between investment and credit. Instead, both correlations are negative, although only slightly. Moreover, when $b = 0$, the positive correlation between consumption and credit is considerably smaller. Furthermore, both the positive correlation between credit and hours worked and the negative correlation between credit and the wage rate are considerably larger than in the data. In addition, the model that abstract from the consumption externality induces a negative correlation between output and consumption which stands in sharp contrast to the data. To conclude, we see the worse credit correlations implied by the model that does not include the relative consumption motive as a further justification of our proposed model mechanism. Including the keeping up-parameter significantly improves the model's ability to reproduce consumer credit moments.

Table 4.6: Data and simulated model moments for both specifications

	$\rho(x_t, D_t)$			σ_x/σ_D		
	Data	$b = \hat{b}$	$b = 0$	Data	$b = \hat{b}$	$b = 0$
Output	0.1523	0.1389	−0.0334	0.4568	0.3510	0.2621
Consumption	0.1658	0.1793	0.0836	0.2783	0.2961	0.2700
Investment	0.0852	0.0334	−0.0751	1.7524	1.0116	1.5940
Hours worked	0.3603	0.3386	0.5784	0.5080	0.5963	0.4797
Real wage	−0.3207	−0.4529	−0.6655	0.3994	0.4757	0.6476
	$\rho(x_t, Y_t)$			σ_x/σ_Y		
	Data	$b = \hat{b}$	$b = 0$	Data	$b = \hat{b}$	$b = 0$
Consumption	0.8020	0.7835	−0.0874	0.6092	0.8439	1.0316
Investment	0.9061	0.7637	0.8006	3.8359	2.8839	6.0850
Hours worked	0.8144	0.7652	0.0359	1.1120	1.7000	1.8343
Real wage	0.0023	−0.4157	0.1114	0.8743	1.3571	2.4771

Note: $\rho(x_t, D_t)$ is the cross-correlation of variable x with credit, σ_x/σ_D is the std. deviation of variable x relative to the std. deviation of credit.

4.4.5 Estimation without σ

When we exclude instead σ from the estimation procedure and set it to a more conventional value of 2, the results are quite similar to the baseline. Table 4.7 reports the corresponding parameter estimates and Table 4.8 the simulated model moments of this exercise. b is now estimated to be 8.58 as it has to compensate for the lower value of σ. However, this increase in b helps to generate the targeted model moments reasonably close to empirical ones. The same is true for the moments that were not targeted in the estimation procedure. If we exclude b from the estimation as well and set it to 0 instead, the model is not able to generate four of the five targeted correlations. In summary, while fixing σ prior to the estimation still leads to reasonably well model moments, this is not true when fixing b as well.

Table 4.7: Estimated parameters values for $\sigma = 2$

	Parameter	$b = \hat{b}$	$b = 0$
Relative consumption motive	b	8.5788	-
Debt adjustment cost parameter	ϕ	1.0625	0.1179
AR-coefficient investment specific technology shock	ρ_ζ	0.5156	0.9999*
Standard deviation investment shock	σ_ζ	0.0261	0.0976
AR-coefficient wage markup shock	ρ_ν	0.8882	0.8339
Standard deviation wage markup shock	σ_ν	0.0097	0.0179

* indicates that this parameter is at the upper bound.

Table 4.8: Data and simulated model moments for $\sigma = 2$

	$\rho(x_t, D_t)$			σ_x/σ_D		
	Data	$b = \hat{b}$	$b = 0$	Data	$b = \hat{b}$	$b = 0$
Output	0.1523	0.1227	−0.1669	0.4568	0.3384	0.3943
Consumption	0.1658	0.1743	−0.0364	0.2783	0.3073	0.3233
Investment	0.0852	−0.0008	−0.2710	1.7524	1.0341	0.9514
Hours worked	0.3603	0.3832	−0.0402	0.5080	0.5561	0.5626
Real wage	−0.3207	−0.4987	−0.2879	0.3994	0.4935	0.2420
	$\rho(x_t, Y_t)$			σ_x/σ_Y		
	Data	$b = \hat{b}$	$b = 0$	Data	$b = \hat{b}$	$b = 0$
Consumption	0.8020	0.7413	0.8811	0.6092	0.9084	0.8202
Investment	0.9061	0.7061	0.8215	3.8359	3.0574	2.4159
Hours worked	0.8144	0.6744	0.9483	1.1120	1.6448	1.4274
Real wage	0.0023	−0.2559	−0.5715	0.8743	1.4605	0.6153

Note: $\rho(x_t, D_t)$ is the cross-correlation of variable x with credit, σ_x/σ_D is the std. deviation of variable x relative to the std. deviation of credit.

Once again, these results highlight the importance of consumption externalities for understanding credit dynamics.

4.5 Model dynamics

In the previous section, we have shown that our proposed four-shock model successfully replicates the empirical credit moments. Now, we investigate the model dynamics induced by each of the four shocks separately. Table 4.9 presents the credit moments obtained from simulating our model where dynamics are driven by just one of the four shocks. Afterwards, we present impulse responses for the two different model estimations, the unrestricted baseline estimation and the restricted estimation with $b = 0$ from Section 4.4.4, to highlight the impact of the keeping up-mechanism.

4.5.1 Moment analysis

The upper part of Table 4.9 reports the correlations between credit and the respective macroeconomic aggregate for each shock separately. We find for the unrestricted model that the price markup and the investment specific technology shock lead to a positive co-movement between credit and output as well as between credit and consumption. The remaining two shocks produce negative

Table 4.9: Simulated model moments - shock analysis

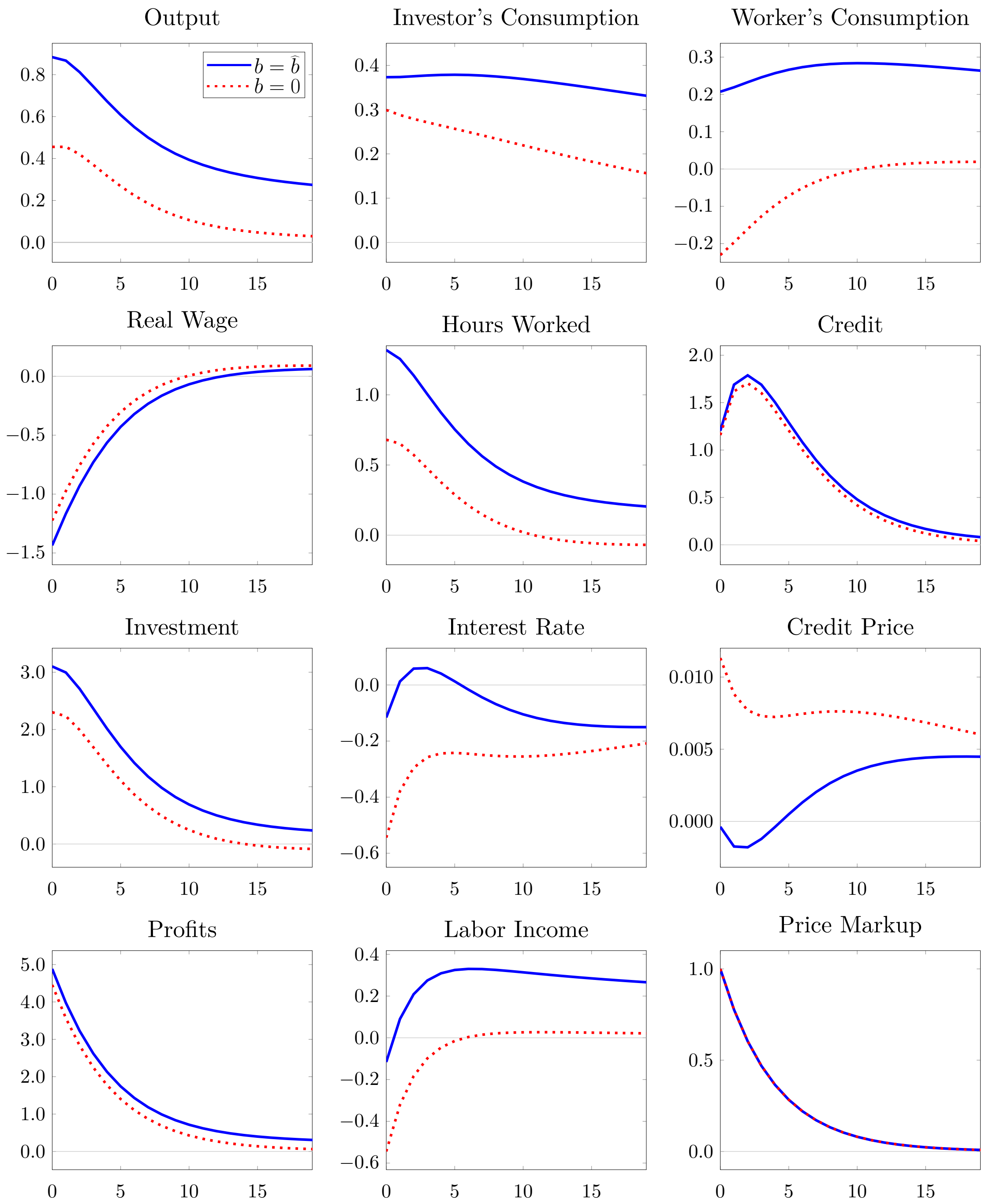
Variable	All Shocks		Price Markup		Investment Specific		Neutral Technology		Wage markup	
	$b=\hat{b}$	$b=0$	$b=\hat{b}$	$b=0$	$b=\hat{b}$	$b=0$	$b=\hat{b}$	$b=0$	$b=\hat{b}$	$b=0$
					Correlation with Credit					
Output	0.139	−0.033	0.956	0.962	0.893	−0.591	−0.531	−0.687	−0.449	−0.547
Cons.	0.179	0.084	0.862	−0.595	0.853	0.783	−0.936	−0.908	−0.975	−0.965
Inv.	0.033	−0.075	0.947	0.944	0.889	−0.741	−0.380	−0.525	−0.378	−0.448
Hours	0.339	0.578	0.945	0.932	0.891	−0.339	0.914	0.925	−0.403	−0.509
Wage	−0.453	−0.666	−0.854	−0.839	−0.888	−0.002	−0.864	−0.868	0.311	0.432
					Relative Standard Deviation w.r.t Credit					
Output	0.351	0.262	0.458	0.264	1.059	0.168	0.185	0.300	0.202	0.244
Cons.	0.296	0.270	0.137	0.048	1.285	0.655	0.055	0.141	0.025	0.048
Inv.	1.012	1.594	1.662	1.332	0.461	3.064	0.699	0.919	0.865	0.989
Hours	0.596	0.480	0.684	0.397	1.591	0.292	0.790	0.666	0.305	0.368
Wage	0.476	0.648	0.684	0.609	0.532	0.149	0.950	0.947	0.104	0.125

correlations between credit and output and credit and consumption irrespective of the inclusion of keeping up-behavior. In contrast to the unrestricted estimation, the price markup shock leads to a strong negative correlation between credit and consumption for the model that abstracts from consumption externalities. Moreover, the investment specific technology shock produces negative correlations between credit and output and credit and investment, while both correlations are positive when estimating b. In this case, the neutral technology, price markup, and investment specific technology shock also induce a positive correlation between credit and hours worked and a negative co-movement between credit and wages, perfectly in line with the data. Clear differences between the responses of both model estimations can be observed for the price markup and the investment specific shock. As we will explain in more detail in the next subsections, the wage markup and the investment specific technology shock are of major importance in reproducing procyclical credit dynamics.

Turning to the relative standard deviations as reported in the lower part of Table 4.9, we see for the unrestricted estimation that both markup shocks and the neutral technology shock lead to output, consumption and hours dynamics that are less volatile than the respective credit dynamics, while the investment specific technology shock produces exactly the opposite. In contrast, only the price markup shock induces investment responses that are more volatile than the credit ones. All four shocks produce wage series that are less volatile than the simulated credit series.

To get a better understanding for the respective responses, in the following, we will discuss in more detail impulse responses for each of the four shocks.

Figure 4.1: Impulse responses to price markup shock



Note: Responses are measured in percentage deviations from steady state. Horizontal axes measure time in quarters.

4.5.2 Price markup shock

Figure 4.1 presents the model responses to a price markup shock. The shock leads to a falling wage rate while not affecting the marginal product of labor. A similar effect can be observed for the rental rate of capital. Due to lower marginal cost, profits rise so that investors obtain a higher income, and increase their consumption level and investment. If the relative consumption motive is present (solid lines), working households respond by increasing their consumption level as well. They derive the additionally required income through two sources. First, workers raise their labor supply and second, they enhance their demand for credit so that the drop in labor income, defined as the product of the real wage and hours worked, is almost fully compensated. As investment and hours worked rise, aggregate output also goes up when the price markup shock hits the economy.

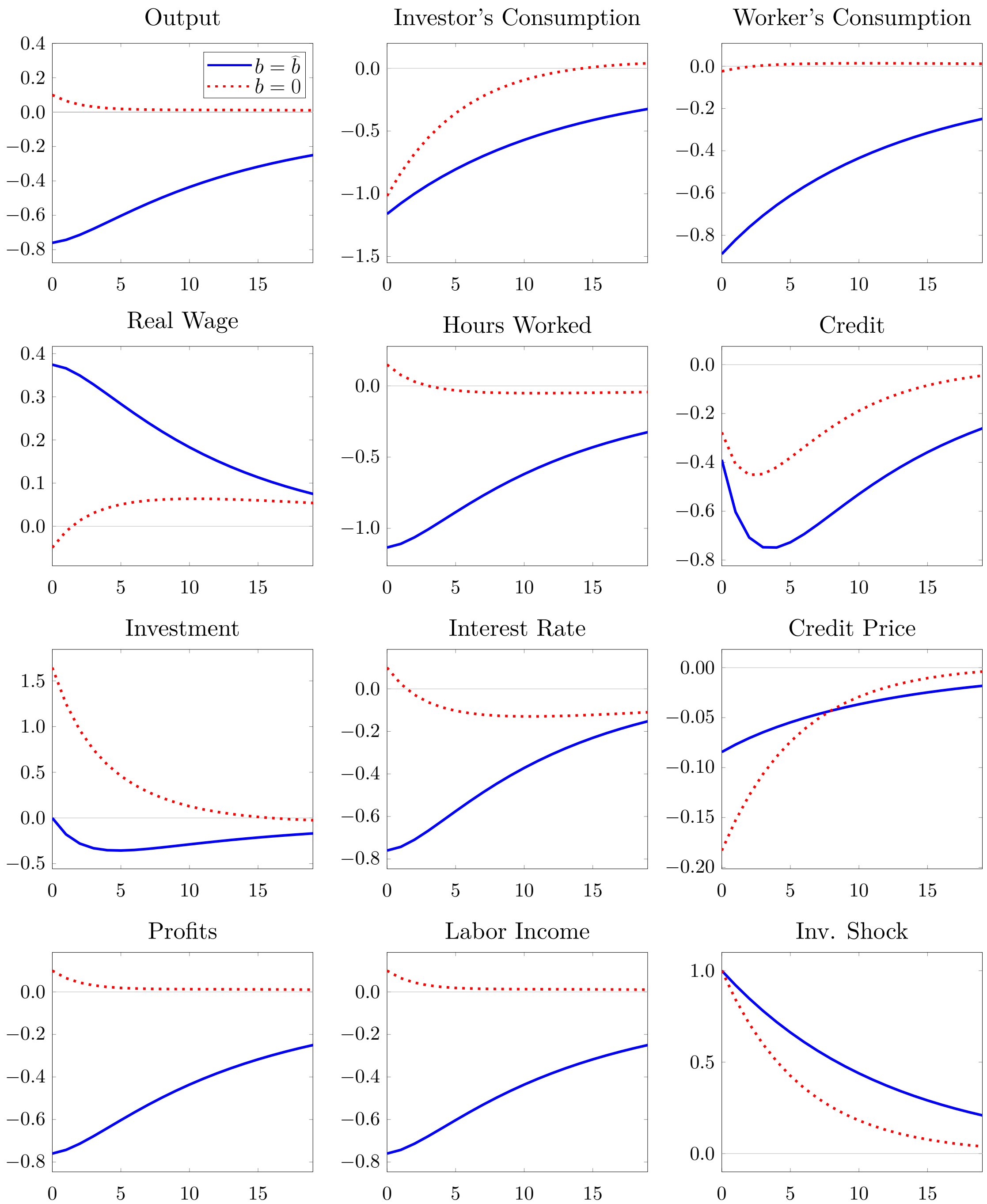
The outcome changes if we abstract from the relative consumption motive (dashed lines). Now, the workers' choice of consumption does not hinge on the investors anymore. In this case, workers increase their labor supply by a smaller amount and reduce their consumption expenditures. As a result, the drop in labor income is more pronounced and consequently, output also goes up to a lesser extent.

4.5.3 Investment specific technology shock

Figure 4.2 presents the model responses to an investment specific technology shock. In the unrestricted model (solid lines), investors shift their expenditures from consumption to investment on impact, as the shock makes saving in capital more profitable. Since workers imitate the consumption behavior of investors, they also decrease their consumption expenditures. This results in a reduced supply of hours worked and a falling demand for credit. The strong decrease in labor supply leads then to a fall in aggregate output and profits, resulting in a significant decrease of investors' income and their personal expenditures. Therefore, the net effect on investment is basically zero on impact. The negative demand effect is long-lasting so that even though investment is more productive, it falls below its steady state in the following periods. The negative responses of almost all aggregate variables is supported by empirical evidence showing that investment-specific technology shocks have contractionary effects (Basu et al., 2013).

The results change significantly when the consumption externality is switched off (dashed lines). Working households now increase their labor supply and reduce

Figure 4.2: Impulse responses to investment specific technology shock



Note: Responses are measured in percentage deviations from steady state. Horizontal axes measure time in quarters.

their credit demand by a smaller amount so that the reduction in consumption expenditures is only marginally. Similarly, the investors' consumption level drops less pronounced, also due to an increase in profits. Consequently, the rise in investment is more persistent and as both input factors increase also output goes up when the relative consumption motive is absent.

4.5.4 Neutral technology shock

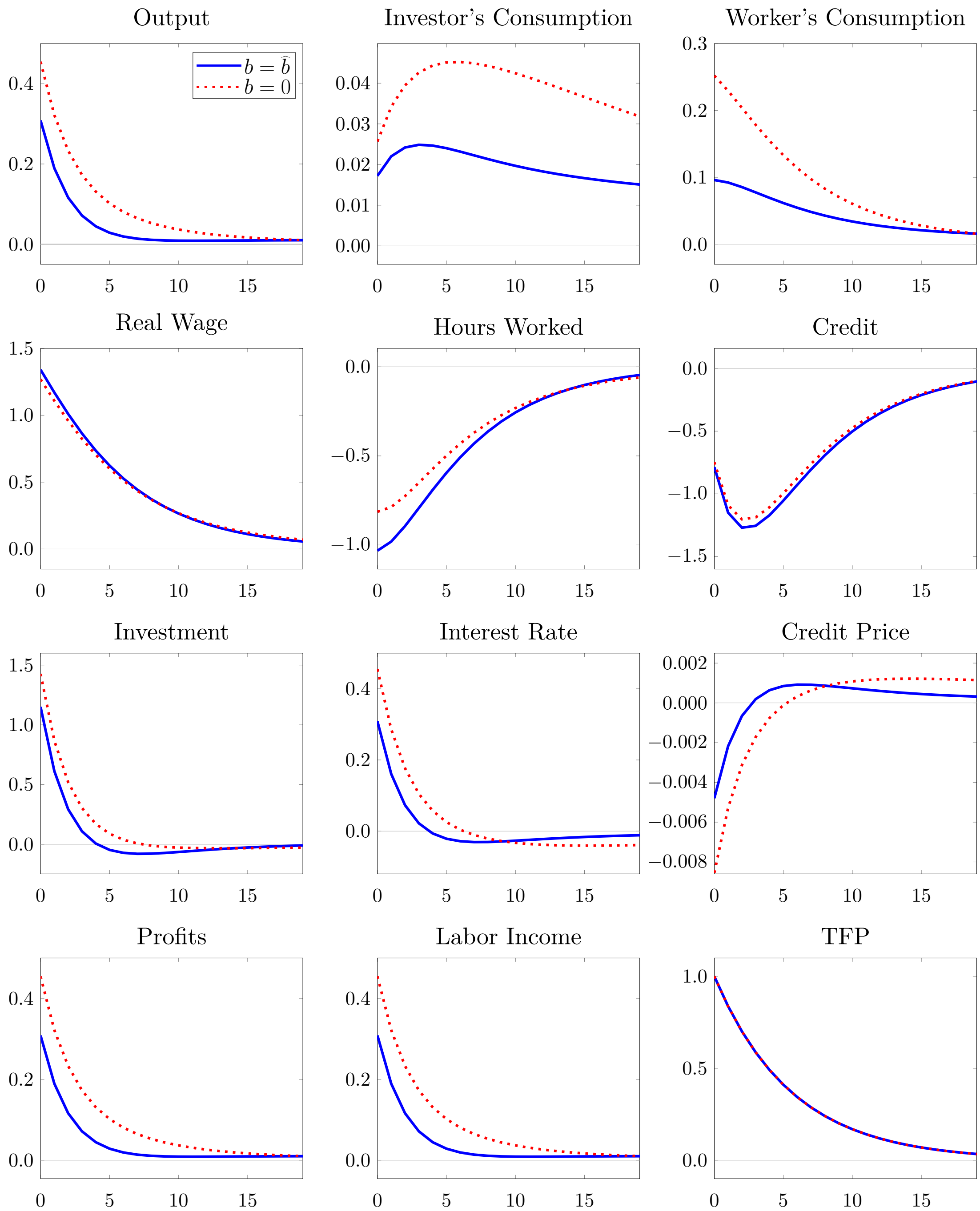
Figure 4.3 shows the effects of a positive neutral technology shock to the model economy. For $b = \hat{b}$, an increase in z_t causes output to go up immediately. As a result of the rise in productivity, the marginal products of labor and capital increase, leading to a higher wage rate and interest rate on capital. Both types of agents increase their respective consumption levels, although the rise is more pronounced for working households. As workers aim to keep up with investors, they reduce hours worked and credit demand substantially. However, workers' total labor income increases as the rise in the wage rate is more pronounced than the fall in hours worked. Real profits increase by a similar magnitude compared to output.

If we abstract from the relative consumption motive, the results are quantitatively different but do not change qualitatively. Profits and, therefore, investors' income and consumption increase by a larger amount compared to the case of $b = \hat{b}$. Since workers do not internalize the investors' consumption level, they also consume more compared to the unrestricted estimation. Consequently, workers reduce labor supply by a smaller amount. Workers' labor income increases stronger. Profits of investors as well as investment rise by a larger amount. To sum up, the introduction of the relative consumption motive dampens the expansionary effects of a neutral technology shock.

4.5.5 Wage markup shock

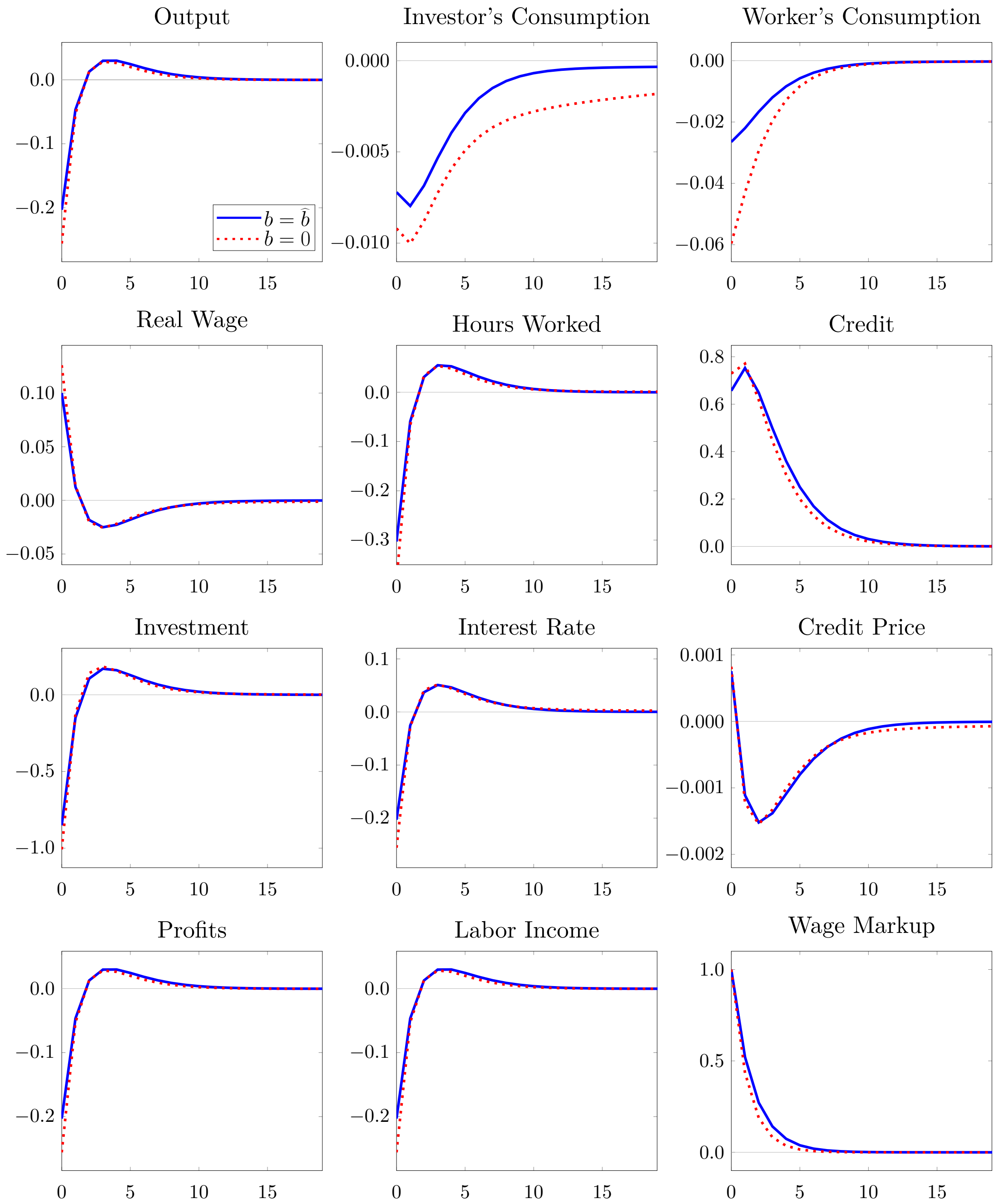
In Figure 4.4, the effects of a positive wage markup shock are presented. For $b = \hat{b}$, the shock leads to a boost in the wage rate, whereas the marginal product of labor remains unchanged. Due to cost minimization, the demand for labor falls and output decreases immediately. This leads to lower profits and investors reducing their consumption level slightly. On the workers side, the reduction in labor demand is so strong that, although wages rise, workers' labor income declines. The compensation of this income loss and their desire to keep up with

Figure 4.3: Impulse responses to neutral technology shock



Note: Responses are measured in percentage deviations from steady state. Horizontal axes measure time in quarters.

Figure 4.4: Impulse responses to wage markup shock



Note: Responses are measured in percentage deviations from steady state. Horizontal axes measure time in quarters.

the investors forces workers to demand a higher amount of credit to mitigate the drop in consumption.

When $b = 0$, the results show only quantitative differences. Both households reduce their consumption expenditures by a larger amount when we exclude the externality. The responses of the remaining variable display only marginal differences to the estimation with $b = \hat{b}$.

4.6 Habit formation

In this section, we replace the relative consumption motive by a related mechanism, namely habit formation, and examine its ability to reproduce the given credit moments. Habit formation has been shown to be a powerful tool for explaining the equity premium puzzle and the positive relationship between savings and growth[15], and is a natural competitor to our keeping up-preferences due to their technical similarity. In the following, we run the same experiment that we ran for our benchmark case with the same calibration and estimation procedure. We show that the habit formation economy fails to generate the positive relationship between credit and output, and that this specification is clearly outperformed by our benchmark economy.

The preferences of a worker are now given by

$$E_0 \sum_{t=0}^{\infty} \beta_w^t U_w^*(C_{w,t}, H_t, N_{w,t}), \tag{4.46}$$

where H_t is the stock of habits. The following definition states the assumptions we impose on $U_w^*(\cdot)$.

Definition 6 (Worker's utility function with habit formation). *We say that preferences exhibit habit formation if the adjusted workers' utility function U_w^* satisfies the following assumptions along with conditions (i)-(iii) of Definition 4.*

(i) $\dfrac{\partial U_w^*}{\partial H} \leq 0,$

(ii) $\dfrac{\partial^2 U_w^*}{\partial C_w \partial H} \geq 0.$

These two assumptions are common in the habit formation literature and imply that individual utility is weakly decreasing in the habit stock (condition (i)), and that the consumption and habits are complements (condition (ii)). The equalities in both cases refer to the boundary case where habits do not play a role at all.

[15]See e.g. Abel (1990), Carroll et al. (2000), and Constantinides (1990).

Table 4.10: Estimated parameter values with habit formation

	Parameter	Value	SD
Degree of habit formation	ω	0.0000	(0.0000)
Relative risk aversion	σ	8.2601	(0.1252)
Debt adjustment cost parameter	ϕ	1.0257	(0.0177)
AR-coefficient inv. specific technology shock	ρ_ζ	0.8428	(0.0087)
Standard deviation investment shock	σ_ζ	0.0159	(0.0001)
AR-coefficient wage markup shock	ρ_ν	0.4347	(0.1484)
Standard deviation wage markup shock	σ_ν	0.0100	(0.0007)

In the literature, habits have been incorporated mainly in two ways. On the one hand, there are additive habits where the habit stock determines a minimum level for today's consumption such that utility below this threshold is not defined. On the other hand, there are multiplicative habits that enter the utility function dividing today's consumption such that consumption relative to the habit stock matters for the respective household.

Since our baseline specification is close to the latter branch, we follow Abel (1990) and the subsequent literature, and use the following functional form,

$$U_w^*(C_w, H, N_w) = \frac{(C_w H^{-\omega})^{1-\sigma} - 1}{1-\sigma} - \frac{\gamma N_w^{1+\eta}}{1+\eta}, \tag{4.47}$$

where $\omega \in [0,1]$ determines the degree of habit formation. To ensure that condition (ii) is satisfied and that ω serves its purpose, we also have to restrict σ to be larger than unity. Moreover, we assume that habits are short-lived, that is $H_t := C_{w,t-1}$, and in close analogy to our baseline, that habits are not internalized by the respective households. The rest of our model economy remains unchanged.

We run the same procedure as with our baseline specification, namely estimate the vector of parameters $\theta^* = \{\omega, \sigma, \phi, \rho_\zeta, \sigma_\zeta, \rho_\nu, \sigma_\nu\}$ by SMM. Table 4.10 reports the results. The degree of habit formation is estimated to be zero implying that our selected data moments reject the presence of habit formation. As a consequence, the remaining parameters are the same as in our constrained baseline estimation with $b = 0$ (see Table 4.5) and the respective moments are given in Table 4.6. We conclude that allowing for the existence of habits does not help explaining the cyclical properties of consumer credit.[16]

[16]Note that, this finding does not imply that habit formation is not important for business cycle analysis in general. However, in contrast to most existing literature which shows that habit formation helps accounting for business cycle properties of real variables like output, consumption

4.7 Stochastic default

In our baseline setup, credit is a perfectly safe financial asset. In the following, we demonstrate that our main findings are not affected when allowing for stochastic default. We model default as a shock to the investors' income received from credit payments by working households.[17] The investors' intertemporal budget constraint is now given by

$$C_{i,t} + I_{i,t} + Q_t D_{i,t} = D_{i,t-1}(1-\psi_t) + R_t K_{i,t-1} + \frac{\Pi_t}{\chi}, \tag{4.48}$$

where ψ_t is the stochastic default shock. We assume that the shock follows an AR(1)-process around its steady state value $\overline{\psi}$,

$$\log \psi_t = (1-\rho_\psi)\log \overline{\psi} + \rho_\psi \log \psi_{t-1} + \varepsilon_{\psi,t}, \tag{4.49}$$

where $\varepsilon_{\psi,t} \overset{i.i.d.}{\sim} \mathcal{N}(0, \sigma_\psi^2)$, and $|\rho_\psi| < 1$. The investors' first-order condition for credit then takes the form

$$\Lambda_{i,t} Q_t = \beta_i E_t \Lambda_{i,t+1}(1-\psi_{t+1}). \tag{4.50}$$

Analogously, working households face the following budget constraint,

$$C_{w,t} + D_{w,t-1}(1-\psi_t) = W_t N_{w,t} + Q_t D_{w,t} - \frac{\phi}{2}(D_{w,t} - \bar{D}_w)^2, \tag{4.51}$$

and thus, their first-order condition for credit is given by

$$\Lambda_{w,t}\left[Q_t - \phi\left(D_{w,t} - \bar{D}_w\right)\right] = \beta_w E_t \Lambda_{w,t+1}(1-\psi_{t+1}). \tag{4.52}$$

The remaining structure is the same as in our baseline setup implying that the model is now driven by five stochastic shocks, the same four shocks of our main analysis and the stochastic default shock. The AR(1) coefficient and the standard deviation of the default shock are estimated by an OLS regression which uses data on delinquency rates as a proxy for default in the consumer credit market.[18]

or hours worked, our estimates suggest habit formation in consumption does not account for the empirical properties of consumer credit.

[17] We follow Cúrdia and Woodford (2010) and Iacoviello (2015) who model default in a similar way.

[18] The estimates of the AR(1) coefficient and the standard deviation are 0.963 and 0.001, respectively. This parametrization also rules out cases of "negative defaults", where the total amount of repaid credit exceeds unity.

Table 4.11: Estimated parameter values with additional default shock

	Parameter	Value	SD
Relative consumption motive	b	5.1200	(0.4510)
Utility curvature	σ	5.5099	(0.4060)
Debt adjustment cost parameter	ϕ	1.1356	(0.0103)
AR-coefficient inv. specific technology shock	ρ_ζ	0.9006	(0.0026)
Standard deviation investment shock	σ_ζ	0.0097	(0.0001)
AR-coefficient wage markup shock	ρ_ν	0.5195	(0.0236)
Standard deviation wage markup shock	σ_ν	0.0312	(0.0007)

Table 4.11 presents the estimated parameters when including stochastic default in our model. All estimates are similar to our baseline model which abstracts from any default on credit. Importantly, the estimated value of b is almost identical to our previous estimate shown in Table 4.5. The implied credit and output moments change just marginally when default is included, see Table 4.12. In sum, these findings suggest that allowing for stochastic default in the model does not overturn the result that consumption externalities are a key determinant of credit dynamics.

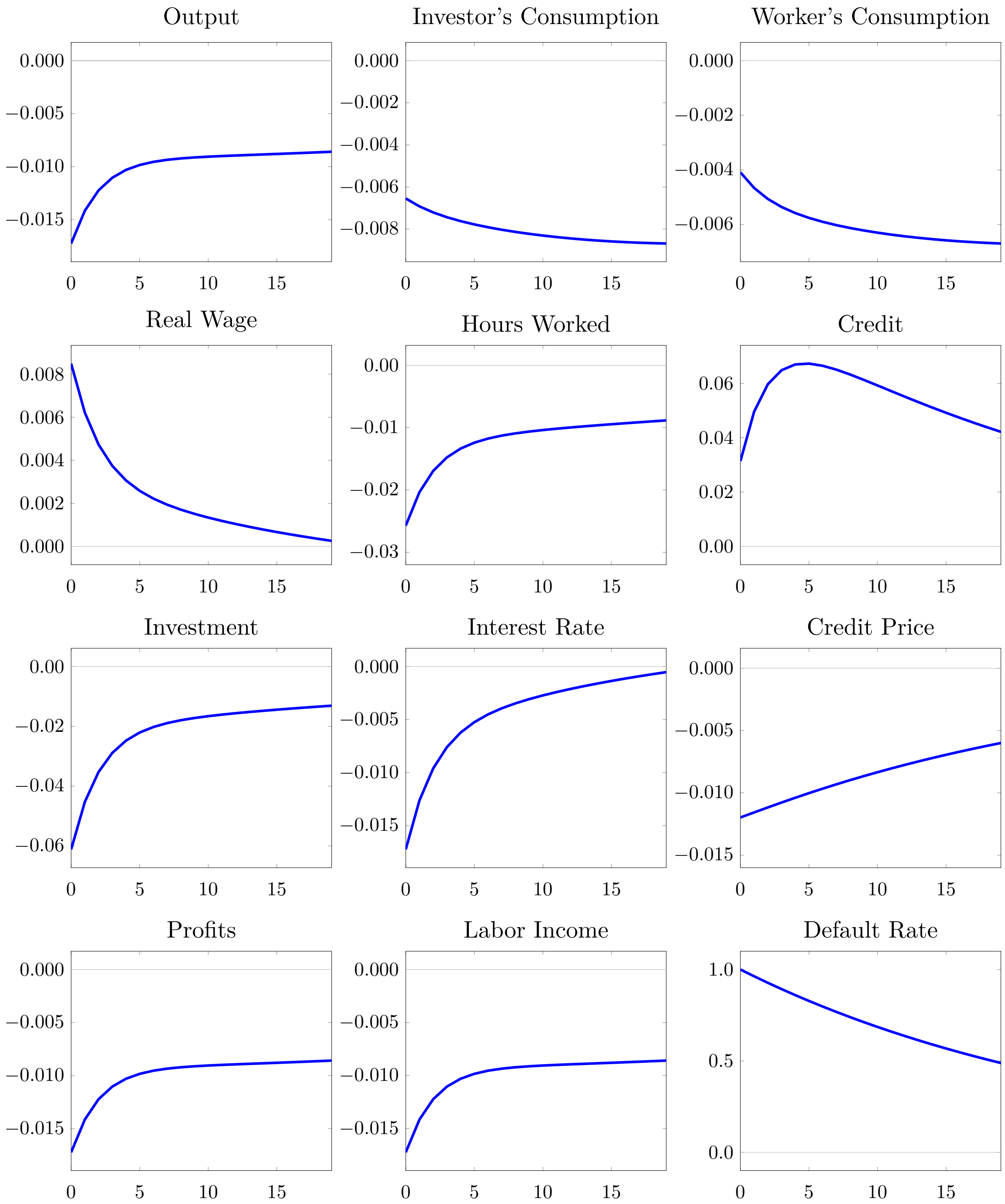
Finally, Figure 4.5 shows the impulse responses to a stochastic default shock. The reduced income from credit payments leads to lower consumption expenditures and investment of investors. The inclusion of the consumption externality induces working households also to cut back on their consumption expenditures implying a reduced amount of hours worked. As both input factors decline, the default shocks leads to a reduction in overall output.

Table 4.12: Data and simulated model moments with additional default shock

	$\rho(x_t, D_t)$		σ_x/σ_D		$\rho(x_t, Y_t)$		σ_x/σ_Y	
	Data	Model	Data	Model	Data	Model	Data	Model
Output	0.1523	0.1408	0.4568	0.3504	-	-	-	-
Consumption	0.1658	0.1809	0.2783	0.2959	0.8020	0.7871	0.6092	0.8450
Investment	0.0852	0.0347	1.7524	1.0035	0.9061	0.7636	3.8359	2.8658
Hours worked	0.3603	0.3353	0.5080	0.5973	0.8144	0.7658	1.1120	1.7056
Real wage	−0.3207	−0.4475	0.3994	0.4763	0.0023	−0.4196	0.8743	1.3610

Note: $\rho(x_t, D_t)$ is the cross-correlation of variable x with credit, σ_x/σ_D is the std. deviation of variable x relative to the std. deviation of credit, $\rho(x_t, Y_t)$ is the cross-correlation of variable x with output, σ_x/σ_Y is the std. deviation of variable x relative to the std. deviation of output.
Consumer credit has been deflated using the price index of personal consumption expenditures. All variables are logged and HP-filtered (smoothing parameter of 1600) to obtain cyclical components. For data definitions and sources see Appendix.

Figure 4.5: Impulse responses to default shock



Note: Responses are measured in percentage deviations from steady state. Horizontal axes measure time in quarters.

4.8 Conclusion

In this chapter, we set up a dynamic stochastic general equilibrium model that mimics the short-run dynamics of consumer credit for the period of the Great Moderation. The model consists of two different household types. Investors, who hold the economy's entire capital stock, own the firms and supply credit, and workers who make up the entire labor force and demand credit to finance their desired level of consumption. In addition, we incorporate a *keeping up with the Riches* mechanism so that workers aim to keep up with the investors' level of consumption.

When estimating deep model parameters, we find a positive significant value for the workers' keeping up-parameter. Qualitatively, an income redistribution from labor to capital and an investment specific technology shock lead to model dynamics that are perfectly in line with the empirical evidence. More precisely, both shocks generate positive correlations of consumer credit with output, consumption, and labor, while there is a negative co-movement between consumer credit and the real wage. In contrast, a technology shock and a wage markup shock are not able to generate the positive correlations between consumer credit, output, and consumption. In reproducing empirical credit moments, the proposed model significantly outperforms a model version in which consumption externalities are not included. Complementary to micro-evidence (Bertrand and Morse, 2016), we have provided macro-evidence on the link between income redistribution, consumption externalities, and credit dynamics.

Appendix

4.A Data Appendix

Data definitions and sources

Variable	Definition	Series ID	Source
Consumer credit	Level of consumer credit held by households and non-profit organizations	HCCSDODNS	BFED
Output	Real output in the nonfarm business sector	OUTNFB	BLS
Hours worked	Hours of all persons in the nonfarm business sector	HOANBS	BLS
Real wage	Real compensation per hour in the nonfarm business sector	COMPRNFB	BLS
Labor productivity	Real output per hour of all persons in the nonfarm business sector	OPHNFB	BLS
Consumption	Real personal consumption expenditures	PCECC96	BEA
Investment	Real gross private domestic investment	GPDIC96	BEA
Prices	Chain-type price index of personal consumption expenditures	PCECTPI	BEA
Total factor productivity	Utilization-adjusted total factor productivity		Fernald (2014)
Delinquency rate	Delinquency rate on consumer loans all commercial banks	DRCLACBS	BEA
Income share	Share of Aggregate Income Received by Each Fifth and Top 5 Percent of Households, All Races		CPS

Notes: BEA: U.S. Bureau of Economic Analysis, BFED: Board of Governors of the Federal Reserve System, BLS: U.S. Bureau of Labor Statistics, CPS: Current Population Survey

4.B Proof of Proposition 2

We make use of the workers' three first order conditions (4.26)-(4.28) as well as their budget constraint (4.24) in log-linearized form, given by

$$\widehat{\Lambda}_{w,t} - b(\sigma-1)\widehat{C}_{i,t} + (\sigma + b(\sigma-1))\widehat{C}_{w,t} = 0 \tag{4.53}$$

$$\widehat{W}_t - \eta\widehat{N}_{w,t} + \widehat{\Lambda}_{w,t} = 0 \tag{4.54}$$

$$\widehat{\Lambda}_{w,t+1} + \phi\frac{\bar{D}_w}{\bar{Q}}\widehat{D}_{w,t} - \widehat{Q}_t - \widehat{\Lambda}_{w,t} = 0, \tag{4.55}$$

$$\bar{W}\bar{N}_w(\widehat{W}_t + \widehat{N}_{w,t}) - \bar{C}_w\widehat{C}_{w,t} - \bar{D}_w\widehat{D}_{w,t-1} + \bar{Q}\bar{D}_w\widehat{Q}_t + \bar{Q}\bar{D}_w\widehat{D}_{w,t} = 0, \tag{4.56}$$

where a circumflex indicates log-deviations from the respective steady state, and a bar refers to the variable's steady state. We only consider a partial equilibrium effect here, so that changes in the wage rate and the price for credit do not occur. We use (4.53) to eliminate $\widehat{\Lambda}_w$ and (4.54) to eliminate $\widehat{N}_w$. Then, we combine (4.55) and (4.56) to get rid of $\widehat{D}_w$. The resulting equation is given by

$$\begin{aligned}&\left(\frac{b(\sigma-1)}{\eta}\left(\bar{W}\bar{N}_w + \frac{\bar{Q}^2}{\phi}\right)\right)\widehat{C}_{i,t} - \left(\frac{b(\sigma-1)}{\eta}\frac{\bar{Q}^2}{\phi}\right)\widehat{C}_{i,t+1}\\ &-\left(\frac{\sigma+b(\sigma-1)}{\eta}\left(\bar{W}\bar{N}_w + \frac{\bar{Q}^2}{\phi}\right) + \bar{C}_w\right)\widehat{C}_{w,t} + \left(\frac{\sigma+b(\sigma-1)}{\eta}\frac{\bar{Q}^2}{\phi}\right)\widehat{C}_{w,t+1} = 0.\end{aligned} \tag{4.57}$$

Rearranging gives

$$\widehat{C}_{w,t} = \xi_0\widehat{C}_{i,t} + \xi_1\widehat{C}_{i,t+1} + \xi_2\widehat{C}_{w,t+1}, \tag{4.58}$$

where

$$\begin{aligned}&\xi_0 := \frac{\frac{b(\sigma-1)}{\eta}\left(\bar{W}\bar{N}_w + \frac{\bar{Q}^2}{\phi}\right)}{\frac{\sigma+b(\sigma-1)}{\eta}\left(\bar{W}\bar{N}_w + \frac{\bar{Q}^2}{\phi}\right) + \bar{C}_w}, \quad \xi_1 := -\frac{\frac{b(\sigma-1)}{\eta}\frac{\bar{Q}^2}{\phi}}{\frac{\sigma+b(\sigma-1)}{\eta}\left(\bar{W}\bar{N}_w + \frac{\bar{Q}^2}{\phi}\right) + \bar{C}_w},\\ &\text{and } \xi_2 := \frac{\frac{\sigma+b(\sigma-1)}{\eta}\frac{\bar{Q}^2}{\phi}}{\frac{\sigma+b(\sigma-1)}{\eta}\left(\bar{W}\bar{N}_w + \frac{\bar{Q}^2}{\phi}\right) + \bar{C}_w}.\end{aligned} \tag{4.59}$$

Iterating equation (4.58) recursively forward, after $T-1$ times, we obtain the following expression

$$\widehat{C}_{w,t} = \xi_0 \widehat{C}_{i,t} + (\xi_1 + \xi_0 \xi_2)\widehat{C}_{i,t+1} + \cdots + \xi_2^{T-1}\widehat{C}_{i,t+T} + \xi_2^T \widehat{C}_{w,t+T}, \tag{4.60}$$

where T is a large number. With this equation at hand, we consider an exogenous on-time perturbation $d\widehat{C}_{i,0}$ of the investors' consumption level. This implies that it returns to its steady state in period 1 so that all $\widehat{C}_{i,t}$ are zero for $t > 0$. Given that $|\xi_2| < 1$ and letting $T \to \infty$, we obtain equation (4.41).

4.C Log-linearized equations

Investors:

$$\widehat{\Lambda}_{i,t} + \widehat{C}_{i,t} = 0 \quad (4.61)$$

$$\widehat{\Lambda}_{i,t+1} - \widehat{\Lambda}_{i,t} - \widehat{Q} = 0 \quad (4.62)$$

$$\widehat{\Lambda}_{i,t+1} - \widehat{\Lambda}_{i,t} + (1-\beta_i(1-\delta))\widehat{R}_{i,t+1} - \beta_i(1-\delta)\widehat{\zeta}_{i,t+1} + \widehat{\zeta}_{i,t} = 0 \quad (4.63)$$

$$\bar{R}\bar{K}_i(\widehat{R}_t + \widehat{K}_{i,t-1}) + \bar{D}_i\widehat{D}_{i,t-1} + \frac{\bar{\Pi}}{\chi}\widehat{\Pi}_t - \bar{C}_i\widehat{C}_{i,t} - \bar{I}_i\widehat{I}_{i,t} - \bar{Q}\bar{D}_i(\widehat{Q}_t + \widehat{D}_{i,t}) = 0 \quad (4.64)$$

Workers:

$$\widehat{\Lambda}_{w,t} + (\sigma + b(\sigma-1))\widehat{C}_{w,t} - (b(\sigma-1))\widehat{C}_{i,t} = 0 \quad (4.65)$$

$$\widehat{\Lambda}_{w,t} + \widehat{W}_t - \eta\widehat{N}_{w,t} - \widehat{\nu}_t = 0 \quad (4.66)$$

$$\widehat{\Lambda}_{w,t+1} - \widehat{\Lambda}_{w,t} + \frac{\phi\bar{D}_w}{\bar{Q}}\widehat{D}_{w,t} - \widehat{Q}_t = 0 \quad (4.67)$$

$$\bar{W}\bar{N}_w(\widehat{W}_t + \widehat{N}_{w,t}) + \bar{Q}\bar{D}_w(\widehat{Q}_t + \widehat{D}_{w,t}) - \bar{C}_w\widehat{C}_{w,t} - \bar{D}_w\widehat{D}_{w,t-1} = 0 \quad (4.68)$$

Production:

$$\widehat{Y}_t - \widehat{z}_t - (1-\alpha)\widehat{N}_t - \alpha\widehat{K}_{t-1} = 0 \quad (4.69)$$

$$\widehat{MC}_t + \widehat{\mu}_t = 0 \quad (4.70)$$

$$\widehat{MC}_t - (1-\alpha)\widehat{W}_t - \alpha\widehat{R}_t + \widehat{z}_t = 0 \quad (4.71)$$

$$\widehat{W}_t + \widehat{N}_t - \widehat{R}_t - \widehat{K}_{t-1} = 0 \quad (4.72)$$

$$\widehat{K}_t - \delta\widehat{I}_t - (1-\delta)\widehat{K}_{t-1} = 0 \quad (4.73)$$

$$\bar{\Pi}\widehat{\Pi}_t - \bar{Y}\widehat{Y}_t + \bar{R}\bar{K}(\widehat{R}_t + \widehat{K}_{t-1}) + \bar{W}\bar{N}(\widehat{W}_t + \widehat{N}_t) = 0 \quad (4.74)$$

Aggregation and market clearing:

$$\widehat{K}_t - \widehat{K}_{i,t} = 0 \quad (4.75)$$

$$\widehat{N}_t - \widehat{N}_{w,t} = 0 \quad (4.76)$$

$$\widehat{I}_t - \widehat{I}_{i,t} = 0 \quad (4.77)$$

$$\widehat{D}_{w,t} - \widehat{D}_{i,t} = 0 \quad (4.78)$$

$$\widehat{C}_t - \chi\bar{C}_i\widehat{C}_{i,t} - (1-\chi)\bar{C}_w\widehat{C}_{w,t} = 0 \quad (4.79)$$

Shocks:

$$\widehat{z}_t = \rho_z \widehat{z}_{t-1} + \varepsilon_{z,t} \tag{4.80}$$

$$\widehat{\mu}_t = \rho_\mu \widehat{\mu}_{t-1} + \varepsilon_{\mu,t} \tag{4.81}$$

$$\widehat{\nu}_t = \rho_\nu \widehat{\nu}_{t-1} + \varepsilon_{\nu,t} \tag{4.82}$$

$$\widehat{\zeta}_t = \rho_\zeta \widehat{\zeta}_{t-1} + \varepsilon_{\zeta,t} \tag{4.83}$$

4.D Weighting matrix

To compute the weighting matrix W, we make use of the procedure described in Den Haan and Levin (1997). This algorithm generates the optimal weighting matrix based on the VARHAC-estimator. As described in the main text, we only use the diagonal of the resulting matrix. Additionally, we want to incorporate prior knowledge about the parameters we estimate to avoid implausible values. In particular, we choose prior means for each parameter (see Table 4.3) so that deviations from these means increase the value of the objective function. We also expand W by attaching penalty terms to the diagonal. These penalties determine how much the deviation from a respective mean is punished.

In the case where we only use the diagonal of the optimal W, we observe that the minimization routine chooses σ and b to be extremely high without improving the targeted moments tangibly. We therefore implicitly impose that $\sigma \in (1, 10]$, which is a reasonably generous interval for this parameter.[19] We also impose that b should not be too high because microeconometric studies find a significant but moderate reference consumption behavior. Therefore, we relate the penalty terms corresponding to these two parameters to the highest on the diagonal of W, which is then the lowest on W^{-1}. We choose them to be a tenth of this entry because this ensures that our two assumptions hold and, on the other hand, that the penalties are still significantly smaller than all other entries in the adjusted W^{-1}. These "soft bounds" then imply that deviations from the chosen mean are only tolerated if they imply significant reductions in the objective function value. In the specific case of b, this implies that a positive (or similarly a negative) value is only chosen if this leads to significantly better moments. For the other parameters, we find that there is no need to use any penalty at all. Table 4.13 summarizes the entries on the diagonal of our W^{-1}.

[19] As already stated, we have to rule out the case of $\sigma = 1$ because of the specific functional form of the workers' utility function.

Table 4.13: Entries in the inverse weighting matrix

Moment/Parameter	Value
Corr(Output, Credit)	$1.6033e+08$
Corr(Consumption,Credit)	$3.5189e+08$
Corr(Investment, Credit)	$1.8559e+06$
Corr(Hours, Credit)	$5.0493e+07$
Corr(Wage, Credit)	$6.8707e+07$
Std(Output)/Std(Credit)	$1.6195e+08$
Std(Consumption)/Std(Credit)	$7.5977e+07$
Std(Investment)/Std(Credit)	$7.1863e+07$
Std(Hours)/Std(Credit)	$4.9029e+07$
Std(Wage)/Std(Credit)	$3.1813e+07$
Relative consumption motive b	$1.8559e+04$
Inverse substitution elasticity σ	$1.8559e+04$
Debt adjustment cost parameter ϕ	0.0
AR-coefficient inv. specific technology shock ρ_ζ	0.0
Standard deviation investment shock σ_ζ	0.0
AR-coefficient wage markup shock ρ_ν	0.0
Standard deviation wage markup shock σ_ν	0.0

Chapter 5

Concluding Remarks

This thesis presents three essays that emphasize the role of household heterogeneity in the analysis of fiscal policy and business cycle dynamics. Chapter 2 investigates the impact of redistributive taxation on private borrowing constraints and the cross-sectional distributions of consumption and income. It demonstrates that tax policy can have a substantial effect on households' access to private credit markets. Chapter 3 emphasizes the role of household heterogeneity in the transmission of government expenditure shocks and provides a mechanism that naturally generates state-dependent fiscal multipliers. Chapter 4 stresses the importance of upward-looking consumption comparison and shows that when accounting for this one can explain the procyclicality of consumer credit.

To summarize, this thesis provides insights into the influence of incomplete insurance markets and household heterogeneity on aggregate dynamics and individual decision-making. Each chapter contributes to the literature in this direction and lays the foundation for further analyses.

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