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The risk premium channel and long-term growth

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Abstract

We study a quantitative DSGE model linking a state of the art asset pricing framework à la Kung and Schmid (2015) with a constraint on leverage as in Gertler and Kiyotaki (2010). We show that a mere increase in the probability of firms being financially constrained leads to an increase in risk premia. Even for a small adverse shock to productivity a drop in asset valuation restrains firms from outside financing and by that induces a persistent low growth environment. In our framework a constraint on leverage induces countercyclical risk premia in equity markets even when it does not bind.

Keywords: risk premia, financial accelerator, asset pricing, endogenous growth

JEL: D53, G01, G12

Non-technical summary

The Financial Crisis of 2007-08 was characterised by a steep drop in consumption and output followed by protracted low real growth. At the same time global financial markets underwent a period of great uncertainty and volatility followed by excess returns in equities. In this paper we attempt to link these two phenomena and try to answer the question how excess leverage could increase risk premia and how to align the deleveraging of the firm with overall low growth rates in the aftermath of a joint downturn of the real economy and financial markets.

To this end, we then built a DSGE model that combines a state-of-the-art asset pricing framework with a standard financial accelerator mechanism and show that these, on the face of it, two distinct phenomenona can be explained jointly.

More specifically, in our framework output growth is endogenously generated by innovators, which are solely financed by equity and develop new products used in the production of final goods. The production sector is owned by a financial intermediary acquiring outside financing from households and features financial accelerator characteristics. The ability to acquire funds from households is limited as the household will only lend to viable (likely to pay back equity) intermediaries. The agents in our economy care about long-run fluctuations in consumption growth.

Our model is able to generate a low and stable risk free rate and a sizable and countercyclical equity risk premium. We explain in the paper how risk premia affect growth dynamics: an initial adverse productivity shock lowers interest rates as safe assets become scarce and investors are willing to accept lower rates on a riskless asset. As productivity is low balance sheets of firms contract and the value of staying in the business of financial intermediation drops. This, in turn, increases the probability of becoming financially constrained in a downturn and endogenously induces higher return volatility in equity markets. A higher probability of being financially constrained also increases equity premia, i.e. lowers prices of real assets, in subsequent period. As a result, intermediaries can no longer easily

rely on outside finance, while they require more equity capital to fund their projects. Higher expected premia attract more equity capital and thus help the firm do delever after the initial balance sheet contraction. This deleveraging restrains the firm from outside finance and at the same time depresses growth rates in subsequent periods.

We add to the literature by modelling the risk premium channel where the countercyclical equity risk premium is a reflection of equilibrium forces in the economy. We show that a constraint on leverage induces countercyclical risk premia in equity markets even when it does not bind. Unlike the majority of the literature, we allow for the participation constraint to only be occasionally binding. Due to persistent growth risks and agents that care about long-run fluctuation in consumption growth intermediaries hold less outside capital than they could to avoid becoming financially distressed in economic downturns. We show that the mere increase in the probability of financial distress leadsn risk premia to raise, which in turn creates incentives to deleverage.

Our model, i.e. a model with a financial friction in conjunction with a simple model of endogenous growth, induces higher persistence in consumption growth rates than a benchmark model waiving the financial friction. We attribute this to the long-run implications of the interplay of the financial friction and the innovation sector. The higher the probability of becoming financially constrained, the harder it is to acquire outside finance and risk premia rise. However, when risk premia are high the firm can deleverage, while the economy experiences a prolonged period of low growth rates due to a lack of financing of new innovations.

To allow for an occasionally binding constraint on firm leverage and to properly approximate asset pricing quantities we rely on global solution methods.

1 Introduction

The *Financial Crisis* of 2007-08 was characterised by a steep drop in output and consumption followed by protracted low real growth. At the same time financial markets exhibited an increase in volatility at the peak of the crisis followed by years of excess returns in equities. We argue that these two, on a face of it, distinct phenomena may be linked and could be explained jointly. This paper attempts to answer two questions: whether an increase in leverage could lead to an increase in risk premia and how to align the deleveraging of the firm with overall low growth rates in the aftermath of a joint downturn in the financial markets and in real economic activity.

To shed light on the research question at hand we combine a state of the art asset pricing framework with a standard stylized financial friction. Our quantitative DSGE framework features a production sector similar to Kung and Schmid (2015), in which productivity growth is generated endogenously by an innovation sector. Innovators, solely financed by household's equity, develop blueprints of new products which are used in final good production. A large variety of developed goods features positive spillovers on the further innovation of more advanced developed goods. An initial increase or decrease in research activity can thus imply long-lasting effects on productivity growth. We introduce an incompleteness to financial markets as proposed by Gertler and Karadi (2011). Along the lines of their model, households cannot invest in real assets directly, but need to do so through an intermediary. Intermediaries acquire outside financing from households and accumulate equity. They use their equity and outside finance to invest in the production sector, namely, final, and developed goods production. Their ability to acquire funds is limited as households will only lend money when intermediaries are likely to repay their debt. Once the value of continuing their business drops below a certain fraction of assets' value they will defy and discontinue operating. As in related models, households internalize this behaviour in their lending such that a default will never occur. While it is common to calibrate the financial friction on attaining outside finance such that the intermediary can be interpreted to be a bank, we interpret the intermediary as any firm that uses debt and equity to invest in real assets. We will however show that such an interpretation of the financial friction does not alter the results in our favour. Finally, agents in our economy have Epstein and Zin (1989)-preferences such that they care about long-run fluctuations in consumption growth.

Our model economy induces reasonable asset pricing implications. It generates a low and stable risk-free rate and a sizable and countercyclical equity risk premium. We explain in the paper how the risk premium interacts with real economic variables: after an initial adverse productivity shock balance sheets of firms contract and the value for an intermediary of staying in business diminishes. Due to the participation constraint of the household, a drop of intermediary value in turn increases the probability of becoming financially constrained in a downturn. As a result, intermediaries can no longer easily rely on outside finance, and require more equity capital to fund their investments in final and developed goods production. A higher expected risk premium in turn attracts more equity capital and thus helps the firm to delever after the initial balance sheet contraction. On the other hand, while firms delever they are restrained from outside finance. Therefore, the initial adverse shock depresses growth rates for subsequent periods.

We add to the literature by modelling the risk premium channel, where a constraint on leverage induces countercyclical risk premia in equity markets even when it does not bind. Unlike the majority of the literature, we allow for the participation constraint on lending to be only occasionally binding.[1] When uncertainty in the economy is sufficiently high, intermediaries hold less outside capital than they could in order to avoid becoming financially constrained in economic downturns. We show that a mere increase in the probability of being leverage constraint leads to a raise in the equity risk premium, which in turn allows the firm to deleverage. As the firm approaches the leverage constraint, return volatility increases, and, by implication, it endogenously increases the volatility in equity markets in economic downturns. We thus explain a countercyclical equity risk premium, financial volatility, and

[1] To allow for an occasionally binding constraint on firm leverage and to properly approximate asset pricing quantities we rely on global solution methods.

leverage in a joint framework with consumption growth. This allows us to identify how the deleveraging of firms slows consumption growth after a balance sheet contraction of firms. In our setup, a countercyclical equity risk premium and the low risk-free rate are a manifestations of the general equilibrium mechanism keeping the economy in balance and are a result from the long-run implications of the interplay of the financial friction and the innovation sector Consequently, the model is able to generate higher persistence in consumption growth rates than nested models waiving various channels are, i.e. models without the financial friction or without the endogenous growth mechanism.

To demonstrate this, we show that in an economy without a financial friction investment and research activity is less sensitive to productive shocks, while consumption growth is less persistent, as compared to our benchmark model. When initial research activity reacts more sensitive, do to the positive spillover effects, so will long-run productivity growth. As a result, in our setup, first, the mean risk-free rate is higher as households demand a higher rate than when lending is the only channel through which they can adjust consumption streams, and, secondly, the risk-free rate will react less pronounced. Consider, for example, an adverse temporary shock. In the economy with the financial friction a balance sheet contraction will make safe assets scarce and thus depress the return on this asset. On the other hand, in an economy without an endogenous growth mechanism, in a downturn households will be less affected by a temporary shock and hence will not desire to shift as much savings between periods and will not accept a risk-free return as low as in the model with a financial friction. Finally, we show that in a calibration with higher firm leverage agents choose a higher buffer above the leverage constraint to offset in this way negative effects of the friction.

We require a global solution to fully capture those risk considerations. Otherwise, a local (and linear) solution would not capture this dynamics and *ipso facto* infer a too extreme amplification of shocks.

The rest of this article is structured as follows. The remainder of this section gives a brief overview of the related literature. Section 2 introduces the model setup. Section 3 presents the calibrations and quantitative implications and Section 4 discusses the dynamic implications of the framework. Section 5 presents a thorough inspection of the channels driving our results. Section 6 concludes.

1.1 Literature Review

Pioneered by the seminal work of Bernanke and Gertler (1989), proposing a financial sector to a general equilibrium economy, gradual extension have been made to better understand the interplay of the financial sector and the production side of the economy. These models, as well as their successors, all have in common that a financial accelerator amplifies the impact of exogenous shocks to the economy. Amongst these early successor are for example Kiyotaki and Moore (1997) and Bernanke et al. (1999). Where the latter features one representative household and a risk neutral entrepreneur who borrows to invest in productive capital. Entrepreneurs are prone to default which in turn limits borrowing from the household.

Triggered by the global Financial Crisis of 2007, a new generation of literature proposing more sophisticated mechanisms to explain the interaction of the financial sector and the real side of the economy has emerged. Amongst these, for example, Jermann and Quadrini (2012) develop a model with debt and equity and find financial shocks to be a significant driver of real and financial variables and therefore identify the financial sector as a source of business cycle fluctuations. The economy relies on one representative risk averse household and one corporation that prefers debt over equity due to the *pecking order* theory. Gertler and Karadi (2011) propose an economy with workers and financial intermediaries. Even though the intermediary is part of a large family and thus inherits the households pricing kernel intermediaries invest suboptimally and induce a financial acceleration of exogenous shocks. Their model features financial and real shocks to analyse the impact of central bank intervention. Gertler and Kiyotaki (2010) combine this framework with liquidity risks as in Kiyotaki and Moore (1997), but remain in a purely real model to address the question of how credit market frictions affect real activity.[2] He and Krishnamurthy (2013) introduce financial intermediation to an asset pricing framework. Intermediaries in their model face an equity capital constraint and risk premia rise when the constraint binds. They explain risk premia during the global financial crisis in a partial equilibrium continuous time Lucas tree economy. Investors in their economy have CRRA preferences. Brunnermeier and Sannikov (2014) discuss a similar setup in a general equilibrium economy. However, agents in their economy are risk neutral. Risk premia arise fully endogenous as a result of the possibility of being financially constrained. In their economy experts manage assets. In case of financial distress the less proficient and unconstraint agent steps in. This causes state dependent return volatility and amplifies risk in distressed times even when exogenous risk is low.

Bansal and Yaron (2004) argue that a small but persistent component in consumption growth can explain several asset pricing puzzles, such as, for example, the equity premium puzzle and the low risk-free rate puzzle. Their agents are equipped with recursive preferences as in Epstein and Zin (1989) such that they strongly care about these long-run fluctuations in state variables. Croce (2014) introduces similar long-run risks to *productivity* growth and rationalizes several asset pricing puzzles in an economy with production and investment choice. Kaltenbrunner and Lochstoer (2010) argue that long-run risk in consumption growth can also arise in a reduced production economy as a result of consumption smoothing. They show that this increases the endogenous price of risk in the model economy. Kung and Schmid (2015) rationalize this predictable component in consumption growth in a general equilibrium framework facilitating endogenous growth through industrial innovation as proposed by Romer (1990).[3] This allows them to generate a sizable risk premium together with a low risk-free rate in an otherwise standard production economy with only real frictions. Anzoategui et al. (2016) relate the recent slowdown in productivity growth to the global Financial Crisis of 2007. They disentangle R&D expenditures from actual technology adoption and mainly attribute the slow down to a decrease in adoption rates. Comin et al. (2016)

[2] See also Gertler et al. (2012) for the analysis of fiscal policy in a similar setup.

[3] Comin and Gertler (2006) introduce this mechanism to a recursive equilibrium and suggest endogenous growth in productivity to be the source of medium term business cycles.

find general evidence for a connection of financial variables and growth slow downs. They both rely on exogenous fluctuations in (equity) risk premia in their frameworks.

Bocola (2016) uses a setup along the lines of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). He adds a crash state for sovereign bonds (default). His model is solved using a global solution algorithm and finds sopport for a precautionary savings motive of banks that offsets effects of credit market interventions.[4] A future sovereign default tightens the funding constraint and generates the precautionary motive to deleverage. An increase of the probability of a future default will: (i) make it more difficult to raise funds from the household, (ii) reduce willingness to intermediate firms assets. Uncertainty enters through exogenous fluctuations in productivity growth.[5] Compared to standard transitory shocks this adds more risk exogenously and by that an incentive to lend less than the participation constraint allows. Our framework only studies the endogenous amplification of productive shocks. Further, as they only allow for exogenous growth, they cannot study the growth implications of an increase in premia. Queraltó (2015) analyses the interplay of a financial accelerator and endogenous growth mechanism as in Bilbiie et al. (2012).[6][7] His framework is based on a small open economy with exogenous markups in lending and aims to explain slow recoveries after economic downturns, particularly for the case of South Korea. He suggests for future research to analyse this mechanism in the case of advanced economies. Ikeda and Kurozumi (2014) do this analysis in the framework of Jermann and Quadrini (2012) with a second order perturbed solution. Gomes et al. (2015) introduce a financial friction to an economy populated with agents of Epstein and Zin (1989)-type. Nezafat and Slavik (2015) study the asset pricing implications of financial shocks in a similar economy where investment opportunities are stochastic.

[4]It is standard in this type of literature to assume the participation constraint on lending to always be binding. As a result these models can be solved with linear and local (first order perturbation) methods.

[5]In his economy the actual growth rate of the economy fluctuates which is quite distinct from persistent long-run fluctuation as discussed above.

[6]They analyze endogenous producer entry over the business cycle.

[7]See Bilbiie et al. (2014) for an analysis with optimal financial policy of the government.

2 Model Setup

This Section introduces the main mechanism driving the results of our framework. We introduce a financial friction as in Gertler and Karadi (2011) into a state of the art asset pricing model with production and investment decisions as proposed by Kung and Schmid (2015). This allows us to analyze the interplay between a financial friction and long-run consumption dynamics.

The model economy consists of four different sectors. On the production side, a final good is manufactured with physical capital, labor, and developed goods. Developed goods are produced from blueprints in a monopolistically competitive sector. The innovation sector, producing blueprints for developed goods, is perfectly competitive with free entry.

The financial sector comprises of a *financial* intermediary, who uses loans from households and equity capital to invest into real assets in the final good sector and the sector for developed goods. On the other hand, innovators finance their research solely with households equity. Once their inventions have matured, blueprints are sold to the intermediary.

All enterprises in the economy are owned by different members of the household.

2.1 The Household

As in Gertler and Karadi (2011) the household consists of workers and entrepreneurs (in the intermediary sector). Each household, i.e. family, is populated by a continuum of agents that perfectly insure each other against consumption risks. Each period the constant probability to remain a worker is p^w and the probability to remain in the intermediary sector is p^b. The household derives utility from consuming a perishable good C_t. Individuals aggregate intertemporal (indirect) utility recursively in the fashion described in Epstein and Zin (1989). Intertemporal utility of the individual is thus given by

$$\mathcal{U}_{i,t} \quad = \left[\left(1-e^{-\delta}\right) C_{i,t}^{1-\frac{1}{\psi}} + \mathcal{R}_{i,t}^{1-\frac{1}{\psi}}\right]^{\left(1-\frac{1}{\psi}\right)^{-1}}, \qquad (1)$$

where δ is the subjective discount *rate* of the agents and ψ the elasticity of intertemporal substitution (EIS). $\mathcal{R}_t$ is the certainty equivalent of tomorrow's continuation utility ($\mathcal{U}_{i,t+1}$) defined as

$$\mathcal{R}_{i,t} \quad = E_t \left[\mathcal{U}_{i,t+1}^{1-\gamma}\right]^{(1-\gamma)^{-1}}, \tag{2}$$

with γ being the relative risk aversion parameter. Recursive preferences disentangle the agent's relative risk aversion from the elasticity of intertemporal substitution. When $\gamma = \frac{1}{\psi}$ the recursive aggregator collapses to the time-additive constant relative risk aversion case (CRRA), where the agents risk aversion is the inverse of the EIS. For $\gamma > \frac{1}{\psi}$ agents have a preference for early resolution of uncertainty, meaning that they dislike uncertainty about future consumption and cash flow streams. Generally speaking, agents with recursive preferences care about state variables influencing future growth dynamics in the economy.

Making use of the assumption of full risk sharing and since preferences are homothetic, we can aggregate over all household members. The household's dynamic budget constraint is given by

$$C_t + R_{t-1}^f B_t - B_{t+1} = \mathcal{D}_t + N_t W_t, \tag{3}$$

where $\mathcal{D}_t$ are the aggregate net proceeds from ownership of financial and non-financial firms. B_{t+1} is the amount of state incontingent claims held by the household (risk-free asset). B_{t+1} is lent from the households to a financial intermediary. $N_t W_t$ is labor income.

2.2 Financial Intermediaries

Households can only invest into real assets through a financial intermediary. While it is common to interpret those intermediaries as bankers, in the following we think of intermediaries as any firm that collects deposits and invests those deposits into real assets. We can thus generally refer to the individuals that populate the sector of intermediation as entrepreneurs.

Each entrepreneur owns and manages her own (financial) intermediary. Given the survival probability p^b, the average span of staying in the sector of financial intermediation is given by $1/(1-p^b)$. It collects deposits ($B_{j,t+1}$) from the household and invests into non-financial assets. Entrepreneurs accumulate their own wealth ($E_{t,j}$), which can be interpreted as the firm's equity. Each entrepreneur does not pay any dividend, but, when entrepreneurs become workers, take home the accumulated wealth. Thus, they seek to maximize the present value of their investment given by

$$\mathcal{J}_{j,t}^{FI} \qquad = \max E_t \sum_{i=0}^{\infty} \left[\left(p^b\right)^i \ \mathcal{M}_{t,t+1+i} \left(1-p^b\right) E_{j,t+1+i} \right], \tag{4}$$

where $\left(p^b\right)^i$ is the probability of remaining in business for i periods. This setup drives a wedge between the optimal decision of the household and the intermediaries' decision. For a zero survival probability this externality is partly shut off.

Intermediaries can buy shares ($S_{j,t}^k$) of non-financial corporations, either being in the sector of final goods ($k = F$), or the sector of developed (innovated) goods ($k = I$). Both sectors will be described in detail below in Section 2.3. Investments can either be financed by the entrepreneur's own wealth (equity) or the bonds issued to the household at the return of the risk-free rate. The balance sheet of assets and liabilities can thus be described by

$$P_{j,t}^F S_{j,t}^F + P_{j,t}^I S_{j,t}^I = E_{j,t} + B_{j,t+1}. \tag{5}$$

The prices of shares held by entrepreneur j are denoted by $P_{j,t}^F$ and $P_{j,t}^I$ for the final good sector and the sector for developed goods, respectively. The return on her portfolio or personal wealth is then given by the return on assets owned by the intermediary lessened by the interest paid on the intermediary's debt

$$\begin{aligned} E_{j,t+1} \qquad &= R_{t+1}^F P_{j,t}^F S_{j,t}^F + R_{t+1}^I P_{j,t}^I S_{j,t}^I - R_t^f B_{j,t+1} \\ &= \left(R_{j,t+1}^F - R_t^f\right) P_{j,t}^F S_{j,t}^F + \left(R_{t+1}^I - R_t^f\right) P_t^I S_{j,t}^I + R_t^f E_{j,t} \end{aligned} \tag{6}$$

The entrepreneur's net worth grows at the risk-free rate plus some risk premium $\left(R^k_{t+1} - R^f_t\right)$. Intuitively, entrepreneurs will only be willing to invest into the production sector if the expected (excess) payoff discounted with the economies pricing kernel ($\mathcal{M}$) over their lending rate is positive.

$$E_t\left[\mathcal{M}_{t,t+1+i}\left(R^k_{t+1+i} - R^f_{t+i}\right)\right] \geq 0 \qquad k \in \{F, I\} \tag{7}$$

For a positive discounted expected excess return the entrepreneur would indefinitely expand borrowing. This desire is only limited by the households' willingness to lend funds. The financial friction imposed in this framework assumes that the entrepreneur defies when the value of continuing her business drops below the value of the firms' assets and walks away with a fraction ω_d of the assets $P^F_{j,t}S^F_{j,t} + P^I_{j,t}S^I_{j,t}$. For the household to still lend to the intermediary the participation constraint must be satisfied:

$$\mathcal{J}^{FI}_{j,t} \geq \omega_d\left(P^F_{j,t}S^F_{j,t} + P^I_{j,t}S^I_{j,t}\right). \tag{8}$$

As soon as the value of continuing the business is lower than assets' value the intermediary will walk away. Finally, for later convenience we define the value of market capital held by the intermediary as

$$P^M_{j,t}S^M_{j,t} = \left(P^F_{j,t}S^F_{j,t} + P^I_{j,t}S^I_{j,t}\right). \tag{9}$$

Even though we could assume that the intermediary invests all collected deposits directly into real assets, we argue as if the intermediary buys shares of the non-financial firms and delegates investment decisions to a manager. Even though this does not alter the results of the model we find this to be a more straight-forward way to interpret the role of the intermediary. The two types of non-financial firms in the productive sector that the intermediary can invest into, are described in the following Section.

2.3 The Production Sector

The productive sector produces one final good which can be used for consumption and investment. The sector consists of a final good producer, production of intermediate (developed) goods, and an innovation sector in which blueprints are developed.

2.3.1 Final Good Production

For the production sector we resort to the simplest setup possible and only consider real prices with innovations to productivity as the only source of uncertainty in the economy. The final good producer uses a Cobb-Douglas (linear of degree one) production function to produce one final consumption good. The input factors are labor (N), physical capital (K), and a composite of developed goods (G).

$$Y_t = \left((A_t N_t)^{1-\alpha} K_t^{\alpha}\right)^{1-\omega_p} (G_t)^{\omega_p}, \tag{10}$$

with α being the share of capital and ω_p being the share of developed goods in production. The amount of labor supplied to the process of final good production will for simplicity be scaled and assumed to be constant over time. G_t is a constant elasticity of substitution aggregation over the variety of all developed goods in the economy given by

$$G_t = \left(\int_0^{K_t^p} \zeta_i^{\nu} di\right)^{1/\nu}, \tag{11}$$

with K^p being the measure of all available developed goods in the economy, and $\nu < 1$ being the inverse markup. The amount used of good i is denoted by ζ_i. Contingent on the realization of the state variables, particularly, the amount of physical capital she is provided with, the manager of the firm optimizes statically with respect to the amount of goods that are used of type i. The inverse demand schedule is then given by

$$P_{i,t}^{p} = \omega_p \left(A_t^{1-\alpha} K_t^{\alpha}\right)^{1-\omega_p} \left(\int_0^{K^p} \zeta_i^{\nu} di\right)^{(\omega_p-\nu)1/\nu} \zeta_i^{\nu-1}, \tag{12}$$

with ζ_i being the demand for a developed good of type i and $P_{i,t}^{p}$ the price the manager in the final good sector is willing to pay for a good of type i. Developed goods used in the final good's production are bought from the sector for developed goods which will be described in Section 2.3.2.

Uncertainty enters the economy only through variation in labor augmenting productivity which evolves as

$$a_t = \rho a_{t-1} + \sigma \varepsilon_t \qquad \varepsilon_t \overset{iid}{\sim} \mathcal{N}(0,1), \tag{13}$$

where a lower case letter denotes logs, ε_t is the innovation in period t, and σ the volatility of productivity. Capital accumulation follows a linear law of motion:

$$K_{t+1} = (1-p^k)K_t + \Phi(I_t/K_t)K_t, \tag{14}$$

with p^k being the rate of depreciation of physical capital and $\Phi(\cdot)$ the function determining adjustment cost.[8]

2.3.2 The Sector for Developed Goods

The sector for developed goods is monopolistically competitive as goods are not perfect substitutes. The owner of a blueprint can produce developed goods of type i. One developed good requires one consumption good to be produced. Developed good producers are aware of the demand schedule of the final good producers. Developed goods producers are completely financed by the intermediary and are credibly obliged to pay all proceeds back to the

[8] $\Phi(I_t/K_t) = a_0 + a_1/(1-1/\xi_k)(I_t/K_t)^{1-1/\xi_k}$ is concave in the investment ratio. We induce zero investment cost in deterministic steady state and set $\Phi(I_t/K_t) = I_t/K_t$ and $\Phi'(I_t/K_t) = 1$.

entrepreneur. Producers of developed goods use their market power to statically maximize their profits. The profit of holding a blueprint for good i is thus defined as

$$\Pi_{i,t} = \max_{P^p_{i,t}} \zeta_i \left(P^p_{i,t}\right) P^p_{i,t} - \zeta_i \left(P^p_{i,t}\right). \tag{15}$$

Agents entering the market can immediately produce and sell their product in the market. Consequently, the value of one blueprint is defined as today's profit plus the discounted expected value of one blueprint and is a result of the intermediaries optimality for investment in the sector for developed goods production. The producer buys the required blueprints from innovators at their recursively defined price $\mathcal{J}^p_t$.

2.3.3 The Innovation Sector

The innovation sector is operated by independent innovators which are fully financed by their family. The sector is perfectly competitive with free entry to the developed goods sector once a blueprint has been developed. The innovation sector introduces growth through the expansion of product variety as proposed by Romer (1990). The amount of blueprints is expanded by the development of new innovations and depleted by a constant fraction of goods becoming obsolete. The law of motion for blueprints (overall stock of blueprints) in the economy is given by

$$K^p_{t+1} = \chi_t I^p_t + K^p_{t+1}\left(1 - p^o\right), \tag{16}$$

where p^o is the probability of a developed good being replaced by a new one (becoming obsolete) and I^p_t being research expenditures. χ_t captures efficiency of R&D activity. Effectiveness of research activity is positively affected by the amount of blueprints already in place and is defined as

$$\chi_t = \frac{\bar{\chi} K^p_t}{\left(I^p_t\right)^{1-\eta}\left(K^p_t\right)^{\eta}}, \tag{17}$$

where $0 \geq \eta \geq 1$ is the parameter capturing the effect of positive spillovers of existing blueprints on the development of new technology. For $\eta = 1$ the amount of new blueprints in the economy solely depends on research expenditures. For $\eta = 0$ new blueprints put in place solely depend on the amount of blueprints already in place. The parameter $\bar{\chi}$ is simply used for scaling the average growth rate in the economy.

2.4 Equilibrium

This Section derives and summarizes all conditions defining the recursive equilibrium.[9] The household's optimality for consumption implies

$$E_t \left[\mathcal{M}_{t,t+1} R_t^f \right] = 1, \tag{18}$$

with $\mathcal{M}_{t,t+1}$ being the household's unique stochastic discount factor, defined as the marginal rate of substitution between today's and tomorrow's consumption. The stochastic discount factor of the representative agent is thus given by

$$\mathcal{M}_{t,t+1} = \frac{\mathcal{U}_{c_{t+1}}}{\mathcal{U}_{c_t}} = e^{-\delta} \left(\frac{C_{t+1}}{C_t} \right)^{-\frac{1}{\psi}} \left(\frac{\mathcal{U}_{t+1}}{\mathcal{R}_t} \right)^{\frac{1}{\psi} - \gamma} \tag{19}$$

All risk-free cash flows in the economy are discounted with this discount factor. The risk free rate R_t^f determines the demand of savings and by that the amount of funds supplied to the intermediation sector. As we will find out below do to constraint investment in assets equity, cash flows will be discounted by an *augmented* discount factor.

Entrepreneurs Rewriting the value of the financial intermediary recursively gives us

$$\mathcal{J}_{j,t}^{FI} = \max_{S_j^F, S_j^I} E_t \left[\mathcal{M}_{t,t+1} \left((1 - p^b) E_{j,t+1} + p^b \mathcal{J}_{j,t+1}^{FI} \right) \right]. \tag{20}$$

[9] See Appendix A for a detailed derivation of equilibrium conditions. The full set of equilibrium conditions is stated in Appendix B.

The intermediary solves this dynamic program such that it fulfills Equations (5), (6) and the inequality constraint given in Equation (8). As in Bocola (2016) we assert an affine form for the value function of the intermediary

$$\mathcal{J}^{FI}_{j,t} = \hat{\mathcal{J}}^{FI}_{j,t} E_{j,t}, \tag{21}$$

and by that derive first order conditions for investment in the final good sector and the sector for developed goods

$$\lambda_t \omega_d \quad = E_t \left[\tilde{\mathcal{M}}_{t,t+1} \left(R^F_{t,t+1} - R^f_t \right) \right] \tag{22}$$

$$\lambda_t \omega_d \quad = E_t \left[\tilde{\mathcal{M}}_{t,t+1} \left(R^I_{t,t+1} - R^f_{t,} \right) \right], \tag{23}$$

with λ_t being the Lagrange multiplier of the inequality constraint on Equation (8). The Lagrange multiplier can be interpreted as the marginal surplus of expanding investment. Consequentially, the wedge between the risk-adjusted expected excess return of investment over the risk-free rate is driven by the value of debt and the amount of assets that cannot be recovered in the case of bankruptcy. The pricing kernel of intermediary j is defined as

$$\tilde{\mathcal{M}}_{j,t,t+1} \quad = \mathcal{M}_{t,t+1} \left[(1 - p^b) + p^b \hat{\mathcal{J}}^{FI}_{j,t+1} \right]. \tag{24}$$

The second term accounts for the probability of dropping out of the sector of financial intermediation and the value of one unit of entrepreneurial equity ($\hat{\mathcal{J}}^{FI}_{j,t+1}$) varying over time. For perfect capital markets there would be no risk-adjusted excess return.

The Lagrange multiplier on the inequality constraint in Equation (8) takes the form

$$\lambda_{j,t} = \max \left\{ 1 - \frac{R^f_t}{\tilde{R}^f_{j,t}} \frac{E_{j,t}}{\left(P^M_{j,t+1} S^M_{j,t+1} \right)}, 0 \right\} < 1, \tag{25}$$

with $\tilde{R}^f_t$ being analogously defined to Equation (26):

$$E_t\left[\tilde{\mathcal{M}}_{j,t,t+1}\tilde{R}^f_{j,t}\right] = 1 \tag{26}$$

A simple mechanic of the shadow price of debt is that it is decreasing in the wealth of the intermediary ($E_{j,t}$), increasing in the amount of assets ($P^M_{j,t+1}S^M_{j,t+1}$), decreasing in the risk-free rate (R^f_t), and increasing in the intermediaries analog of the risk-free rate ($\tilde{R}^f_t$). In other words, a relative low amount of equity to the amount of assets in place and a low risk-free rate will drive up the demand for debt and, as a result, its shadow price. The value of one unit of entrepreneurial net worth is given by

$$\hat{\mathcal{J}}^{j,FI}_t \quad = \frac{R^f_t}{\tilde{R}^f_{j,t}}. \tag{27}$$

It is clear from this expression, that the value of one unit of equity depends on the ratio of the two discount rates, the one of the household and the one of the intermediary. The value of equity increases as it becomes more expensive to finance investments with debt issued by the household and the more the intermediary wants to postpone cash flows into the future, measured by the inverse of the risk-free rate analogue of the intermediary. Finally, to close the model with respect to the financial intermediary the law of motion for aggregate entrepreneurial wealth in the economy is derived as follows. Each period the fraction $1 - p^b$ drops out of the entrepreneurial sector and takes their funds out of the sector. Newcomers to the entrepreneurial sector are given a float to start their business proportional to all assets in place in the current period. As a result aggregate wealth of entrepreneurs is comprised of wealth accumulated from the previous period plus some transfer from the household

$$E_{t+1} = p^b\left[\left(R^F_{t+1} - R^f_t\right)P^F_{t+1}S^F_t + \left(R^I_{t+1} - R^f_t\right)P^I_{t+1}S^I_t + R^f_tE_t\right] + \omega_b\left(P^F_{t+1}S^F_t + P^I_{t+1}S^I_t\right). \tag{28}$$

Transfers from households are rather based on the value of current assets in place, than tomorrow's assets. This means that the asset expansion must be financed with debt. Otherwise, asset expansion would automatically bring along a higher supply of equity financing. Dropping index j indicates aggregate quantities. In particular, thanks to symmetry, we can also drop indices on the shadow price (λ_t), and the value of one unit of equity ($\hat{\mathcal{J}}_t^{FI}$), the entrepreneur's stochastic discount factor ($\tilde{\mathcal{M}}_{t,t+1}$), and the entrepreneur's risk-free rate ($\tilde{R}_t^f$).

Production For a linearly homogeneous production function and capital accumulation and price taking firms, the return on physical capital is as shown in Restoy and Rockinger (1994) equal to the return on investment, which is derived from first order optimality of the manager of the firm given by

$$R_{t,t+1}^F \quad = \Phi'\left(\frac{I_t}{K_t}\right)\left[\frac{\partial F_{t+1}}{\partial K_{t+1}} + \frac{\left(1-p^k\right)+\Phi\left(\frac{I_{t+1}}{K_{t+1}}\right)}{\Phi'\left(\frac{I_{t+1}}{K_{t+1}}\right)} - \frac{I_{t+1}}{K_{t+1}}\right] \tag{29}$$

Demand for developed good of type i is given by first order optimality of the final good producer:

$$\zeta_i = \left(P_i^p\right)^{\frac{1}{\nu-1}}\left(\omega_p\left((AN)^{1-\alpha}K^\alpha\right)^{1-\omega_p}\left(\bar{\zeta}\left(K^p\right)^\nu\right)^{\omega_p-\nu}\right)^{\frac{1}{\nu-1}}. \tag{30}$$

Optimality of price setting for Equation (15) and imposing symmetry amongst all developed goods yields a price for one developed good of

$$P_i^p = \frac{1}{\nu}. \tag{31}$$

Together with symmetry amongst developed good producers this results in the demand for any developed good given by

$$\bar{\zeta} = \left(\nu\omega_p\right)^{\frac{1}{1-\omega_p}} K^\alpha \left(NA\right)\left(K^p\right)^{\frac{\frac{\omega_p}{\nu}-1}{1-\omega_p}} \tag{32}$$

Further, the profit paid to the owner of the blueprint is simply the difference of the price and the price of the consumption good, which is defined as unity, times the amount of developed goods sold

$$\Pi_t^p = \frac{1}{\nu}\bar{\zeta}. \tag{33}$$

The cum-earnings return (in the innovation sector) for the intermediary can be written as

$$R_{t,t+1}^I = \frac{(1-p^o)\,\mathcal{J}_{t+1}^p}{\mathcal{J}_t^p - \Pi_t^p}. \tag{34}$$

Here $\mathcal{J}_{t+1}^p$ is the cum-earnings value of owning the blueprint for developed good i. Note that all indices can be dropped due to assumed symmetry.

Research expenditures of innovators are driven by the expected payoff from selling a developed goods to a producer. The break-even condition for investment is given by

$$\frac{1}{\chi_t} = E_t\left[\mathcal{M}_{t,t+1}\mathcal{J}_{t+1}^p\right]. \tag{35}$$

Note that the entrepreneur discounts with the discount factor of the household and not the one of the financial intermediary, as her investments are fully financed by equity by her family. Finally, substituting for G, the measure of blueprints, in the production function yields

$$Y_t \quad = (\nu\omega_p)^{\frac{\omega_p}{1-\omega_p}}(K_t)^\alpha (A_t)^{1-\alpha}(K_t^p)^{\frac{\frac{\omega_p}{\nu}-\omega_p}{1-\omega_p}} \tag{36}$$

We follow Kung and Schmid (2015) and impose a parameter restriction for stable growth $(\alpha + \frac{\frac{\omega_p}{\nu}-\omega_p}{1-\omega_p} = 1)$ and further simplify the production function to

$$Y_t \quad = (\nu\omega_p)^{\frac{\omega_p}{1-\omega_p}}(K_t)^\alpha (Z_t)^{1-\alpha} \tag{37}$$

$$Z_t \quad = A_t K_t^p \tag{38}$$

Z_t can be interpreted as measured total factor productivity and grows at the rate $\mu_t =$

$log\left(1 - p^o + \chi_t I_t^p / K_t^p\right)$, driven by research intensity.

State variable dynamics and budgets constraints Market prices of shares in capital are equal to the cost of replacing them such that[10]

$$Q_t^K = P_t^F = \frac{1}{\Phi_t} \tag{39}$$

$$Q_t^I = P_t^I = \frac{1}{\mathcal{J}_t^p - \Pi_t} \tag{40}$$

The overall budget constraint for the household is

$$C_t = Y_t - I_t - I_t^p - \bar{\zeta} K_t^p, \tag{41}$$

where $\bar{\zeta} K_t^p$ accounts for the cost of turning blueprints into devloped goods. As we detrend all variables with the stock of blueprints (K_t^p) the state of the economy can be fully characterized by the three variables *productivity* (A_t), *physical capital* (K_t), and *accumulated debt before transfers* (B_t^{ex}). We follow Bocola (2016) and define accumulated debt before transfers as the state variable that keeps track of wealth in the intermediary sector.

$$B_{t+1}^{ex} = \left[R_t^f \left(\left(\frac{1}{\mathcal{J}_t^p - \Pi_t} \hat{K}_{t+1}^p + \frac{1}{\Phi_t'} \hat{K}_{t+1} \right) - E_t \right) \right] \tag{42}$$

$$E_t = p^b \left(\left[\frac{\partial Y_t}{\partial \hat{K}_t^k} + \left(1 - p^k\right) \right] \hat{K}_t + \mathcal{J}_t^p \left(1 - p^k\right) - B_t^{ex} \right) \tag{43}$$

$$+\omega_b \left(\frac{1}{\mathcal{J}_t^p - \Pi_t} \hat{K}_t^p + \frac{1}{\Phi_t'} \hat{K}_t \right) \tag{44}$$

Risk premium and risk-free rate The risk-free rate is defined as the inverse of the expected pricing kernel:

$$\left(R_t^f\right)^{-1} = E_t \left[\mathcal{M}_{t,t+1}\right]. \tag{45}$$

[10] We define $S_t^i = K_{t+1}^i$. This essantially means that S_t^i denotes shares in the stock of capital in the subsequent period.

The return on assets is given by

$$R^{A}_{t+1} = \left(R^{F}_{t+1}\right) \frac{P^{F}_{t} S^{F}_{t}}{P^{F}_{t} S^{F}_{t} + P^{I}_{t} S^{I}_{t}} + \left(R^{I}_{t+1}\right) \frac{P^{I}_{t} S^{I}_{t}}{P^{K}_{t} S^{K}_{t} + P^{I}_{t} S^{I}_{t}}. \tag{46}$$

Further the levered market return is given by

$$R^{lev}_{t+1} = R^{A}_{t+1} + lev_t \left(R^{A}_{t+1} - R^{f}_{t}\right), \tag{47}$$

with lev_t being the leverage ratio (Debt-Equity) observed in the market which can be expressed as

$$lev_t = \frac{B_t}{E_t} = \frac{P^{F}_{t} S^{F}_{t} + P^{I}_{t} S^{I}_{t} - E_t}{E_t}. \tag{48}$$

And finally, the expected unlevered *risk* premium on investments in nonfinancial assets is given by

$$EP_t = E_t \left[R_{t+1} - R^{f}_{t}\right] = -R^{f}_{t} Cov_t \left(\mathcal{M}_{t,t+1} R_{t,t+1}\right) + \lambda_t \omega_d. \tag{49}$$

The first term in the Equation is the standard expression for the risk premium, which is mainly driven by the covariance of the assets return. The second term accounts for the cost of limited borrowing, that is when the intermediary is financially constrained the investment needs to pay a higher premium to attract more funds.

3 Quantitative Implications

To discipline our results and learn more about the implications of the model economy, this Section assesses model implied moments and quantitative implications of the model framework and different calibrations.

3.1 Calibration

Table I depicts all parameters characterizing the benchmark calibration (*Benchmark Model*) of our model economy. For most parameter values we remain fairly close to values adopted in the literature. As the growth mechanism is identical to the model of Kung and Schmid (2015) most parameters are very close to the calibration presented in their paper. Parameters characterizing the sector for financial intermediation are chosen very close to what can be found in the literature, but are calibrated to match certain financial moments. The parameter choice can differ for three reasons. First, when calibrating a model with an endogenous growth mechanism, the choice of parameters is considerably limited as every parameter essentially alters steady state growth in the economy. Second, a global solution method (and accounting for risk considerations) may infer different results than what can be obtained using a local and linear solution. As a result, parameter choices may be affected as well. Third, the model is stripped off from anything that is not needed to analyze our research question. All this may result in that the desired moments cannot be matched perfectly. However, the choice of parameters is such that we get as close as possible to the desired target values.

The survival rate in the intermediary sector (p^b) is set to 96% for one quarter, which is very close to the value suggested in Gertler and Karadi (2011). This implies an average time to remain in the intermediation sector of slightly above 6 years. We set the recovery rate for creditors at default to 52% and consequently the parameter ω_d to 48% in order to match the leverage-ratio of 53% for non-financial firms as we are in fact interested in implications for the whole economy.[11] The parameters determining the fraction of transfers from the household to the sector of intermediation (ω_b) is set to 0.25% per period and matches the probability of the leverage constraint being binding in 9% of all quarters. The

[11] When modelling the banking sector the literature usually resorts to a value for this parameter around 30%. If we interpret this as the inverse of the value at risk from the point of view of the creditor the parameter can be understood as follows. A bank needs to acquire a lot of outside finance relative to their own equity. As a result they need to be trustworthy or, put differently, be able to withhold less xof their own business from their creditors. This translates into a lower value of the parameter ω_d.

Variable	Description	Benchmark Model BM	Weak Accelerator WA	Strong Accelerator SA	Target
δ	Subjective discount rate	0.006	0.006	0.006	Risk-free rate
ψ	EIS	1.325	1.325	1.325	Vol. cons growth
γ	Risk aversion	10	10	10	Kung and Schmid (2015)
α	Capital share	0.35	0.35	0.35	Kung and Schmid (2015)
ξ^k	Adjustment cost for capital	1.5	1.5	1.5	Kung and Schmid (2015)
p^k	Depreciation rate of capital	8.00 %	8.00 %	8.00 %	Kung and Schmid (2015)
η	Elast. of new inventions wrt R&D	0.77	0.77	0.77	Autocor. cons. growth
ω_p	Developed good share	0.50	0.50	0.50	Kung and Schmid (2015)
ν	Inverse markup	0.61	0.61	0.61	Stable growth restriction
p^o	Blueprint obsolescence rate	15.00 %	15.00 %	15.00 %	Kung and Schmid (2015)
χ	Scale parameter	0.281	0.289	0.273	Average growth rate
p^b	Intermediaries survival probability	0.96	0.00	0.96	Levarage non-financials
ω_d	Recovery at default	0.52	0.48	0.41	Lifespan of banker
ω_b	Transfer from HH to intermediaries	0.250 %	48.000 %	0.050 %	Financial distress
$(\rho^l)^4$	Autocorrelation productivity	0.95	0.95	0.95	Kung and Schmid (2015)
σ^l	Volatility of productivity shock	3.00 %	1.60 %	3.00 %	Vol. output growth

Table I: Parameters

This table depicts all parameter values characterizing the three calibrations of the model economy: Benchmark Model (BM), Weak Accelerator (WA), and Strong Accelerator (SA). All parameters are stated on an annualized basis. The upper pannel describes the preferences of the household. The following panels describe in order parameters governing growth, the financial accelerator, and the stochastic process introducing uncertainty to the economy.

Bank of International Settlements (see Bank of Intenational Settlememts (2010)) estimates the unconditional probability of a financial crises to be slightly above 1% per quarter. We target a value slightly higher than this estimate as being leverage constrained negatively effects firms, but does not necessarily mean that the whole economy experiences a financial crisis. More concretely, the model of Gertler and Karadi (2011) does not allow for an explicit financial distress as agents will not enter any contract unless they will be repaid on their investment with certainty.[12]

Asset pricing moments are predominantly driven by parameters describing the household members. The annual subjective discount rate (δ) is set to 0.006. The low value is required to bring down the real risk-free rate. The value for the elasticity of intertemporal substitution (ψ, EIS) is at 1.325 even below the value of Bansal and Yaron (2004) (1.5), and by that very conservative. Newer estimates, as for example in Shaliastovich (2015), suggest even higher values above 2. The relative risk aversion parameter (γ, RRA) is set to 10, i.e. within the range of what is supported by Mehra and Prescott (1985).

For the developed good share in production (ω_p) we follow Comin and Gertler (2006) and set it equal to 0.5. According to estimates of the Bureau of Labor Statistics, we set the rate of depreciation for the stock of blueprints (obsolescence) in the economy (p^o) to 15% annually. The elasticity of new developed goods with respect to R&D (η) is set to 0.77 to maximize the autocorrelation of consumption growth. The scaling parameters for the development of new blueprints (χ) only serves the purpose of matching the mean growth rate of GDP in the economy. Finally, the inverse markup over the cost of production of developed goods is chosen endogenously to fulfil the parameter restriction for stable growth.

The choice of parameters for final good production is standard and follows Kung and Schmid (2015). The capital share (α) equals 0.35, the adjustment cost parameter (ξ^k) is 1.5, and the rate of depreciation (p^k) equals 8% annually.

Annual autocorrelation of the exogenous component of productivity (ρ^l) is 0.95 and the

[12] In the following sections we only discuss a riskless, state incontingent asset and risky shares of the firm. Due to this setup we will not be able discuss returns of a risky bond as we rule out a default.

annualized volatility (σ^l) is set to 3.5% to pin down the volatility of output growth.

To better understand the impact of the financial friction on top of our benchmark calibration we also include a calibration, *Weak Accelerator*, with a survival rate of entrepreneurs of 0% and a net transfer of 48% of assets in place. In a third calibration, *Strong Accelerator*, we induce higher leverage by lowering the parameter ω_d. Furthermore, this calibration also includes a lower ω_b to further restrain the entrepreneurial sector from acquiring more equity finance. This calibration essentially comes closer to the calibrations presented in papers focussing on the banking sector. In the following subsection, we will refer to the Benchmark Model as BM, the Weak Accelerator Model as WA, and the Strong Accelerator Model as SA. For the description of the data sample we use to discipline our model see Appendix C.1.

3.2 Macroeconomic Implications

To highlight the effect of the financial friction in an otherwise plain vanilla endogenous growth economy this section starts with discussing its quantitative macroeconomic implications. Table II displays key macroeconomic quantities for all three model calibrations. The annualized growth rate and volatility of output growth are about 1.9%. The ratio of consumption growth and output volatility in empirical data is about 50%, which can only be matched by the BM and SA calibrations. Overall, the SA calibration generates similar quantitative implications to our Benchmark Model, indicating that a more extreme calibration does not necessarily need to strengthen the effect of the financial friction. Without going into too much detail and anticipating further results this finding can be explained by one simple rationale. The financial friction makes investment more reactive to innovations in productivity and in this way it reduces the volatility of consumption, the residual of output and investment expenditures. As we want to keep the model calibrations comparable, we choose the exogenous productivity process such that we have similar volatilities in consumption growth. This allows us to compare asset pricing implications for a given volatility of consumption growth, and thus makes sure that differences in asset pricing quantities do

Variable	Description	Data	Benchmark Model BM	Weak Accelerator WA	Strong Accelerator SA
Panel A	Means				
$E[\Delta y]$	GDP	1.89%	1.86%	1.85%	1.85%
$SS[\Delta y]$	GDP	–	1.59%	1.74%	1.63%
Panel B	Standard Deviations				
$\sigma[\Delta c]/\sigma[\Delta y]$	Ratio volatilities	0.53	0.53	1.01	0.50
$\sigma[\Delta i]/\sigma[\Delta y]$	Ratio volatilities	2.69	1.34	1.23	1.36
$\sigma[\Delta i^p]/\sigma[\Delta y]$	Ratio volatilities	2.14	1.59	0.88	1.59
$\sigma[\Delta c]$	Consumption	1.01%	1.03%	1.04%	0.98%
$\sigma[\Delta y]$	Output	1.88%	1.95%	1.04%	1.94%
$\sigma[\Delta d]$	Dividends	10.36%	3.05%	–	3.40%
$\sigma[\Delta i]$	Investment	5.06%	2.61%	0.85%	2.64%
$\sigma[\Delta i^p]$	R&D Activity	4.03%	3.11%	1.18%	3.09%
Panel C	Autocorrelations				
$\rho[\Delta c]$	Consumption	0.31	0.20	0.01	0.20
$\rho[\Delta y]$	Output	0.37	0.03	0.01	0.03
$\rho[\Delta d]$	Dividends	-0.03	-0.05	–	-0.05
$\rho[\Delta i]$	Investment	0.52	-0.00	0.02	-0.00
$\rho[\Delta i^p]$	R&D Activity	0.66	-0.01	0.00	-0.01

Table II: Macroeconomic Moments

This table depicts moments for the most relevant macroeconomic quantities for the three calibrations of the model economy: Benchmark Model (BM), Weak Accelerator (WA), and Strong Accelerator (SA). Values are stated on an annualized basis. The upper panel (A) states the mean growth rate of output ($E\,[\Delta y]$) and its growth rate in deterministic steady state ($SS\,[\Delta y]$). The middle panel (B) reports volatilities for the growth rates of consumption (Δc), output(Δy), dividends (Δd), investment in capital (Δi), and investment in blueprints (Δi^p). The lower panel (C) reports autocorrelations for the same variables. Empirical moments are reported for quarterly post war U.S. data. Macroeconomic variables are obtained from the National Bureau of Economic Research. The data ranges from Q1 1947 to Q4 2016.

not stem from differences in consumption growth volatility, but can rather be linked to the impact of the financial friction. As a result, the output growth volatility is almost twice as low in the WA model. Finally, when looking at the autocorrelation of consumption growth, we see that the BM model exhibits a 10 times higher autocorrelation than the WA calibration. However, the benchmark calibration still does not fully reach the autocorrelation that is observed in empirical data. We are willing to accept this caveat for the sake of not introducing to much complexity in the model economy, which allows us to derive more clear-cut conclusions. This detriment could possibly be mitigated by including variable capital utilization, capital depreciation rates, or by introducing labour choice.[13] We conclude that adding the financial friction increases the volatility of investment and the autocorrelation of consumption growth, while at the same time it reduces the volatility of consumption growth.

In what follows we clarify the peculiarities of the different model calibrations. The WA calibration enables us to evaluate the impact of the tightening/loosening of the friction for a given level of leverage. To this end, consider Equations (4) and (28). The first equation drives a wedge between the decision horizon of the intermediary and the household. The latter equation limits equity transfers from the household to the entrepreneurs. The first equation can be interpreted as fixing the dividend to a constant fraction of the equity value, i.e. the value of the intermediary. This means that investing and divesting cannot be actively controlled via this channel. The higher the survival probability in the entrepreneurs' sector the less capital will be repatriated to the household. This, in turn, means less consumption today, more equity in the intermediary sector and in this way also more collateral to pledge when acquiring outside finance, and finally, caused by higher investment, a higher productivity growth. Equation (28) shows that not only the survival probability of entrepreneurs is involved in the evolution of capital in the intermediary sector. The second parameter governs the amount of transfers of households to the intermediary sector as a fraction of real assets in place. The lower the parameter, the lower the transfers. Again, when ω_b is high,

[13]The steady- state growth rate of output deviates in all three economies significantly when computing the deterministic and the stochastic steady state. This effect can be attributed to a precautionary savings motive and is most pronounced for the BM model.

households consume less, entrepreneurs can accumulate more capital, and the economy will grow faster. However, in an economic downturn, when equity capital in the intermediary sector is destroyed by an adverse shock a high transfer from the household will grant entrepreneurs new liquidity, which will be proportional to real assets in place. This means that a downturn will not have adverse implications for the intermediary sector, as the leverage constraint will never be of much importance. We thus refer to the calibration with a zero survival probability in the intermediary sector and a high transfer from households to the intermediary sector as the *Weak Accelerator* and the calibration, including a low ω_b and ω_d, as the *Strong Accelerator*. By that, we can analyze the effect of a more or less frictional intermediary sector compared to our benchmark calibration.

3.3 Financial Implications

Asset pricing implications for the model economy are displayed in Table III. The average return of a riskless bond in the BM calibration is at 1.35% lower than what is observed in the WA calibration. While it is a standard result that a constraint on finance lowers the return of a riskless asset we also observe a steeper drop from the deterministic economy to a risky economy in the case of the BM calibration. We rationalize this as follows. From the comparison of a deterministic economy and a risky economy, we infer that the rate earned by a riskless asset is lower when risk is introduced. In other words, the more risky the economy, the more households will pay for a risk-free asset. For the BM calibration this lowers the risk-free rate by about 40 basis points. As we discuss below in more detail, in the BM calibration the intermediary decides not to lever up as much as they can, but always hold a little less debt than possible. Put differently, intermediaries demand less outside capital in the stochastic steady state to reduce the probability of becoming financially constrained in economic downturns. This leads households to pay a higher price (lower rate) for the risk-free asset compared to what is observed in the WA economy - even in relative terms when compared to the deterministic steady state of the respective economy. In the WA

Variable	Description	Data	Benchmark Model BM	Weak Accelerator WA	Strong Accelerator SA
Panel A	Means				
$E[r^f]$	Risk-free rate	0.75%	1.35%	1.77%	1.36%
$E[r^A]$	Unlevered return	–	2.65%	2.78%	2.31%
$E[r^{lev}]$	Levered return	6.66%	3.99%	3.88%	3.60%
$E[r^{lev} - r^f]$	Levered ex. return	5.91%	2.64%	2.12%	2.24%
Panel B	Deterministic Steady States				
$SS[r^f]$	Risk-free rate	–	1.80%	1.91%	1.83%
$SS[r^A]$	Unlevered return	–	2.45%	2.74%	2.05%
$SS[r^{lev}]$	Levered return	–	3.16%	3.65%	2.39%
Panel C	Standard Deviations				
$\sigma[r^f]$	Risk-free rate	1.30%	0.26%	0.06%	0.24%
$\sigma[r^A]$	Unlevered return	–	1.79%	0.60%	1.81%
$\sigma[r^{lev}]$	Levered return	16.00%	3.67%	1.24%	4.35%

Table III: Asset Pricing

This table depicts the most relevant asset pricing quantities for the three calibrations of the model economy: Benchmark Model (BM), Weak Accelerator (WA), and Strong Accelerator (SA). All values are stated on an annualized basis. The upper panel (A) states stochastic means for the risk-free rate ($E[r^f]$), the unlevered return on assets ($E[r^A]$), and the levered market return ($E[r^{lev}]$). The middle panel (B) states values for a deterministic economy. The deterministic steady state value is indicated with SS. The lower panel (C) reports volatilities for the same variables. All empirical moments are computed for a data sample ranging from Q1.1947 until Q4.2016. The risk-free rate is the ex-ante yield on the 90 day treasury bill. Ex-ante yields are computed as described in Beeler and Campbell (2012). The return on the market is approximated with the return on the S&P 500 including distributions from the CRSP database (vwretd). All moments are computed from quarterly data.

economy, however, leverage in the stochastic steady state is only limited by the participation constraint. Intermediaries lever up until the household is not willing to lend out any more money due to their participation constraint. This in turn lowers the price of the riskless asset and increases the risk-free rate – the return on the riskless bond. This narrative also offers a reasonable rational for the higher volatility of the risk-free rate in the BM calibration. The higher the probability of reaching the participation constraint (leverage constraint), the more limited safe investment possibilities become. Due to the substitution effect households want to consume less and save more when the economy is contracting. As explained in Section 3.2 the households cannot actively adjust their equity investments, but solely rely on investment in the riskless bond to actively shift consumption streams between today and future periods. Contemporaneously, when the value of intermediaries' assets drops, they approach the leverage constraint. As a result, they want to reduce their short positions in the riskless bond. This reduces the demand for the riskless bond and lowers the risk-free rate more in economic downturns beyond what is observed for the WA calibration, yielding a higher volatility of the risk-free rate. Unfortunately, due to nonlinear dynamics and the lack of closed form expressions, these effects are not clearly distinguishable.

In the deterministic steady state the excess return of assets over the risk-free rate is only due to the desire of intermediaries to expand borrowing. As the participation constraint is almost never binding when uncertainty enters the economy, the excess return of assets over the risk-free rate is truly a risk premium. The levered equity return in the BM economy is about 4% annually and implies an equity risk premium of almost 3% for the market and a little more than 1% excess return on assets. Even though the benchmark economy generates a similar excess return on capital as the WA calibration, the levered return is higher due to a higher risk-free rate in the economy with the weak accelerator. The mean levered return for the SA economy is the lowest of the three calibrations. As we will find out below, the probability of being financially constrained, i.e the shadow price of the constraint being larger than 0, is much lower in the SA calibration, and as a result, equity is paid a lower premium.

To complete the above analysis, Table IV reports correlations of selected macroeconomic and financial variables. Correlations are in line with intuition. For the BM calibration the buffer for firm debt is positively correlated with consumption growth, while the leverage-ratio (B/E) is negatively correlated with consumption growth. The wealth-consumption ratio, a welfare measure for the economy, is low when the economy is in a bad state (low growth rates in the future) and should negatively predict excess returns (for all investments in assets as well as the levered market return), while correlations with realized returns are intuitively positive. This is both confirmed in the Table for the benchmark calibration. To the contrary, this is not true in the WA model. None of the mentioned key correlations is matched in this calibration. In addition, the WA calibration generates procyclical risk premia, i.e. expected excess returns of risky assets. This is true when using consumption growth as well as the wealth-consumption ratio as yardsticks of the state of the economy. While a high growth rate of consumption is more of a contemporaneous measure, the wealth-consumption ratio also incorporates future growth rates.[14]

In short, while empirical evidence conclusively suggests that risk premia are countercyclical, Table IV shows that only the BM and SA model can replicate this empirical stylized fact. We argue, and will further substantiate it in the following sections that even though the leverage constraint is almost never binding a mere increase in the probability of the constraint becoming active will induce a countercyclical risk premium. This is only the case when the financial friction is not *weak*, i.e. the economy is negatively affected by the leverage constraint in downturns. We further argue that this effect does not only go one way but also feeds back into the real economic variables. A lack of financing for investment projects will result in persistently low growth rates in the future even beyond a short-term effect. This is exactly the case when leverage of the firm increases inducing a higher probability of becoming financially constrained.[15]

[14]For a more detailed discussion of the predictability of returns when using the wealth-consumption ratio see for example Lustig et al. (2013) or Lettau and Ludvigson (2001).

[15]This links with the empirical results discussed in Appendix C.2. As indicated by the empirical analysis, an increase in firm leverage increases financial volatility and expected returns.

Variable	Description	Data	Benchmark Model BM	Weak Accelerator WA	Strong Accelerator SA
$\rho[\Delta c, \mathcal{J}^{FI}/P]$	–	–	0.64	-0.00	0.65
$\rho[\Delta c, B/E]$	–	–	-0.57	0.28	-0.61
$\rho[\Delta c, W/C]$	–	–	0.52	0.26	0.53
$\rho\left[\Delta c, E_t\left[r_{t+1}^{lev} - r_t^f\right]\right]$	–	–	-0.62	0.03	-0.17
$\rho\left[W/C_t, E_t\left[r_{t+1}^{lev} - r_t^f\right]\right]$	–	–	-0.47	0.99	-0.19
$\rho[W/C_t, \mu_t]$	–	–	1.00	1.00	1.00

Table IV: Correlations

This Table depicts correlations for most relevant macroeconomic, financial and asset pricing quantities for the three calibrations of the model economy: Benchmark Model (BM), Weak Accelerator (WA), and Strong Accelerator (SA). Values are computed with quaertlery observations.

Table V displays moments related to firms' leverage. For economies with an endogenous capital structure, firms will leverage as much as they can in the deterministic steady state, which means that Equation (8) is fulfilled with equality and

$$\mathcal{J}_{j,t}^{FI} = \omega_d \left(P_{j,t}^F S_{j,t}^F + P_{j,t}^I S_{j,t}^I\right). \tag{50}$$

This equation does not necessarily hold when uncertainty enters the economy. Only in the economy with the *Benchmark Model* and the *Stong Accelerator* calibration agents decide to hold less debt than they could acquire. They do so to avoid being financially constrained as this would limit their investment possibility in aggregate economic downturns. As described above, when transfers from the household to the intermediary sector are small, i.e. ω_b is low, an adverse shock to the economy will decimate entrepreneurs' equity, which will reduce real investment. In the benchmark calibration their buffer is on average a little lower than 1% of firm value. The inequality constraint on leverage is only active (binding) 10% of the time, meaning the representative firm is financially constrained. On the other hand, for the WA calibration entrepreneurs always choose full leverage. Even though the constraint is active in 100% of observation dates this does not imply financial distress as net wealth of entrepreneurs is fully renewed each period. The leverage (debt-to-asset ratio) of 52% is given by construction as equity is always 48% of all assets in place (the leverage constraint). The leverage is only reduced when investment in the (physical and developed) capital stock is cut. The buffer in the SA calibration is about 4 times higher than in the BM calibration and the probability of being financially constrained is so low that is not even worth noting. Apparently, due to the more severe financial friction, entrepreneurs will try to never let the ratio of entrepreneurial equity to debt to drop so much that it would cause him to be financially constrained. Due the low fraction of equity the intermediary sector is replenished with in each period it would take very long to deleverage and move away from the constraint. As a result, the negative effect of the strengthened financial accelerator can be partly offset by a *precautionary-savings*-like motive of the entrepreneur. As agents in a linearly-solved economy do not build up this buffer, since they do not include risk in their considerations, the effects of strengthening the financial accelerator will not be offset. Ceteris paribus, the effects of including the financial accelerator will thus be more pronounced in this case.

The volatility of the debt-to-equity ratio is more than one order of magnitude larger for the BM calibration than for the WA calibration. This can be rationalized by the same logic as above. When the debt level is chosen to be proportional to the value of overall assets, equity and debt will move in lockstep. As a result, the leverage ratio will be less volatile than in the case where equity is a stock that evolves over time, while debt is chosen each period to close the financing gap. Moreover, pure mechanics imply that a ratio of two variables will be more volatile, when these variables are negatively correlated. This points out the importance of a countercyclical equity risk premium, or in other words a negative correlation of the risk premium and the risk-free rate, as the driving force increasing the negative comovement of debt and equity. Finally, the average leverage-ratio of 51% in the BM calibration allows us to leverage returns in a reasonable way, which gives a more realistic assessment of the asset pricing implications than simply by applying a random amount of leverage to the equilibrium return on capital. The leverage ratio is slightly higher in the risky economy compared to the deterministic steady state.

Variable	Description	Data	Benchmark Model BM	Weak Accelerator WA	Strong Accelerator SA
Panel A	Means				
$E[\mathcal{J}^{FI}/\omega_d P^M S^M - 1]$	Excess firm value	–	0.89 %	0.00 %	3.77 %
$p[\mathcal{J}^{FI}/\omega_d P^M S^M = 1]$	Probability of const.	$> 1.00\%$	9.24 %	100.00 %	0.03 %
$E[B/E]$	Debt-equity ratio	1.16	1.06	1.09	1.41
$E[B/(E+B)]$	Debt-asset ratio	0.52	0.51	0.52	0.58
Panel B	Deterministic Steady States				
$SS[\mathcal{J}^{FI}/\omega_d P^M S^M]$	Excess firm value	–	1.00	1.00	1.00
$SS[B/E]$	Debt-to-equity ratio	–	1.10	1.09	1.53
$SS[B/(E+B)]$	Debt-to-asset ratio	–	0.52	0.52	0.60
Panel C	Standard Deviations				
$\sigma[B/E]$	Debt-to-equity ratio	32.63%	6.40%	0.12%	9.88%
$\sigma[B/(E+B)]$	Debt-to-asset ratio	20.91%	1.51%	0.03%	1.70%
Panel D	Autocorrelations				
$\rho[B/E]$	Debt-to-equity ratio	0.96	0.88	0.96	0.88
$\rho[B/(E+D)]$	Debt-to-asset ratio	0.96	0.88	0.96	0.88

Table V: Financial Moments

This table reports values for financial quantities for the three calibrations of the model economy: Benchmark Model (BM), Weak Accelerator (WA), and Strong Accelerator (SA). All values are stated on an annualized basis. Panel A of the table reports means for the excess firm value over the required fraction of overall assets ($E[\mathcal{J}^{FI}/\omega_d P^M S^M]$), the probability of a financial crisis/being financially constrained ($p[\mathcal{J}^{FI}/\omega_d P^M S^M = 1]$), the average debt-to-equity ($E[B/E]$) and debt-to-asset ($E[B/(E+B)]$) ratio. Panel B reports corresponding values or deterministic steady states. The deterministic steady state is indicated by SS. Panel C reports volailities for debt-to-equity and debt-to-asset ratios. Panel D reports autocorrelations for debt-to-equity and debt-to-asset ratios. We use the empirical probability of a financial crises reported in Bank of Intenational Settlememts (2010). They find an unconditional annual probability of a crisis of the order of 4 to 5 %. The empirical average debt-to-asset ratio of 0.52 is taken from Rauh and Sufi (2010) who do an extensive study on the capital structure based on a panel data set ranging from 1996 to 2006. Their whole data set includes overall 1,889 rated firms.

4 Risk Premia and Consumption Dynamics

The basic mechanism driving the result of the model is standard to dynamics induced by the financial accelerator. Households will only lend to the intermediary sector as long as the participation constraint in Equation (8) is not violated. When the economy is hit by an adverse shock, intermediaries will devalue and constrain lending activity. This mechanism reinforces downward movements and helps to replicate important asset price dynamics.

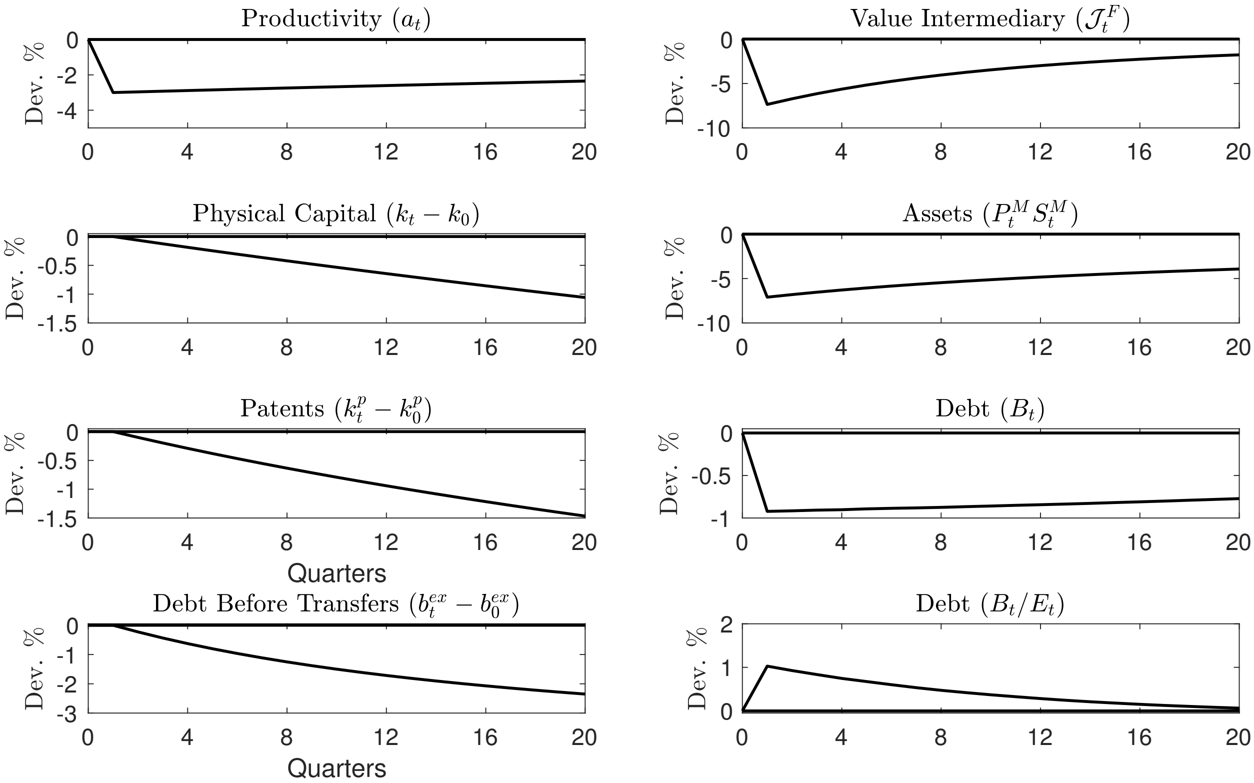

Figure 1: Impulse Response Functions - Overview

This figure depicts impulse response functions for state variables and control variables describing changes in the capital structure of the firm following a one standard deviation shock to productivity for the BM calibration. The left column displays the cumulated growth of state variables physical capital ($k_t - k_0$), the stock of blueprints ($k_t^p - k_0^p$), and the amount of debt before transfers ($b_t^{ex} - k_0^{ex}$). The right column displays the change in the value of the intermediary ($\mathcal{J}^F$), the value of aggregate assets ($P^M S^M$), the amount of firm debt (B), and firm leverage (B/E).

Figure 1 shows impulse response functions for a one standard deviation adverse shock to productivity for variables related to the capital structure in the economy. At the impact of the shock, leverage increases and the firm slowly deleverages in subsequent periods. While this happens a low rate of investment shifts capital stocks permanently to a lower level and the economy shrinks.

The BM calibration, in spite of a parametrization inducing a weaker accelerator than for example in Gertler and Karadi (2011) and Bocola (2016), generates countercyclical and sizable risk premia and persistent dynamics of consumption growth similar to what we observe in the data, while the WA calibration and, as also shown in Section 5 a model completely waiving a financial accelerator (NA), do not. While in the standard business cycle models with a financial accelerator countercyclical risk premia, or the wedge between the risk-free rate and a return on assets, can be fully attributed to the shadow price associated with the constraint on acquiring financing, in our model the inequality constraint that limits borrowing (see Equation (8)) rarely ever binds. Therefore, the risk premium can be fully attributed to the mere expectation of the limitation on borrowing. As stated in Equation (49), the equity *risk* premium is made up of two parts: One part that accounts for the covariance of the return with the pricing kernel (I), and one part that accounts for the cost induced by the leverage constraint (II).

$$E_t\left[R_{t+1} - R_t^f\right] = \underbrace{-R_t^f Cov_t\left(\tilde{\mathcal{M}}_{t,t+1} R_{t,t+1}\right)}_{\mathrm{I}} + \underbrace{\lambda_t \omega_d}_{\mathrm{II}}$$

However, in a purely linear (or log-linear) approximation covariance terms, or more generally, all risk considerations of agents will be neglected. Consequently, the excess return of the asset over the default-free bond is not due to its riskiness, but solely to the financing constraint. On the other hand, in our model, which is solved with a global algorithm, the constraint rarely ever binds. Consequently, the premium is driven by (I), and thus, is a true risk premium. In the following sections we show that the risk premium is mostly driven by the probability of becoming financially constrained in future periods and thus it increases in economic downturns. When being financially constrained, the inability to finance investments

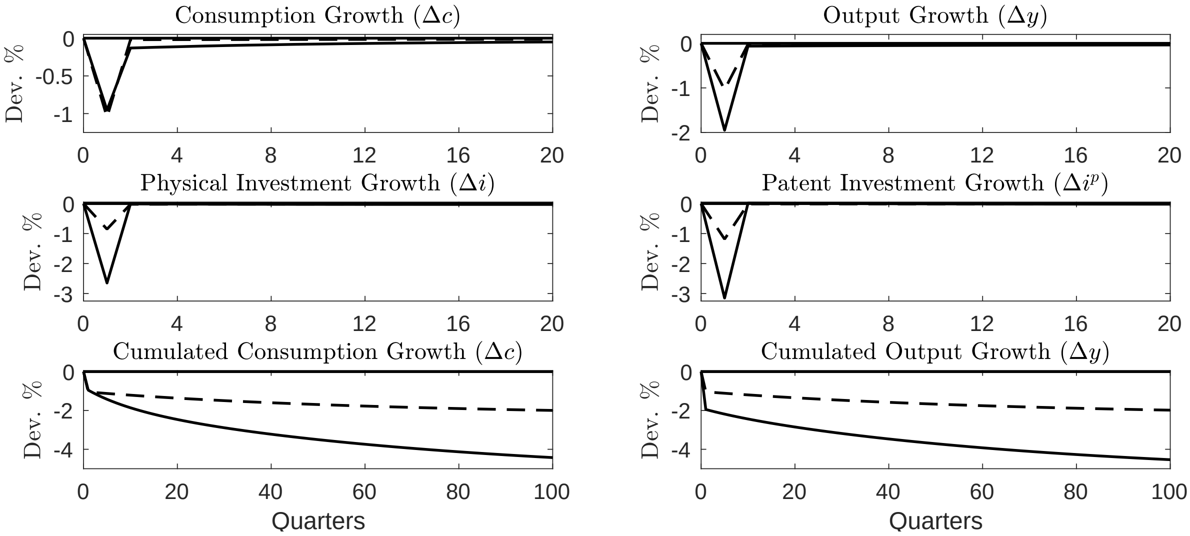

Figure 2: Impulse Response Functions - Growth Rates
This figure depicts impulse responses after a one standard deviation negative shock to productivity for consumption growth (Δc), output growth (Δy), growth of investment in physical capital (Δi), and growth of investment in blueprints (Δi^p) for the BM and the WA calibration. The impulse response functions in the upper four panels display reactions for a horizon of 5 years. Additionally, the two lower panels depict impulse response functions for cumulated consumption growth ($\sum \Delta c$), and output growth ($\sum \Delta y$) for the BM calibration and the WA calibration. The impulse response functions for the lower two panels display reactions for a horizon of 25 years. The solid line indicates the BM model and the dashed line the WA model.

lowers the prices and thus the expected returns. This increases the (negative) covariance of the stochastic discount factor and returns and therefore impacts the risk premium even when the constraint is not active.

4.1 Implied Growth Dynamics

In our economy, growth is a result of the introduction of the sector for developed goods and the innovation sector. In short, monopolistic profits in the sector for developed goods attract investments in research to enter this market. Positive externalities of the overall level of developed goods in the economy on the development of new technologies lead to positive growth in equilibrium. When productivity rises above its steady state level, production and demand for developed goods increases. A boom in profits attracts more research activity and turns a transitory rise in productivity into prolonged growth of *measured TFP*, *output*, and *consumption*.

Figure 2 depicts impulse response functions for consumption, output, and investment growth following a 2 standard deviation shock to productivity. Due to the simplicity of the model construction the implied dynamics for consumption and for output growth are very limited. At first sight, the effect of a decrease in productivity does not adversely impact the agents in the BM calibration as much as the agents in the economy facilitating only the *weak accelerator*. But as consumption is defined as the residual of output and investment this is a direct result of a sharper decline in investment and research activity at the arrival of the innovation. As agents in our economy cannot adjust capital utilization or labor input in the economy, output in $t = 1$ is left unaltered. As laid out in more detail in Section 4.2, the risk-free rate drops much sharper in the benchmark calibration as households retrieve the debt held by them to buffer short-run downward effects in consumption. For the entrepreneurs the initial shock deteriorates their net wealth. Their only sources to compensate these losses and finance further investments in their assets is either an equity transfer from the household or an expansion of debt. Households pulling out and retrieving their capital will thus stall investment and long-run growth. The impulse response function of consumption is a lot more persistent due to the effects of the financial accelerator. The two lower panels of Figure 2 depict the long-run effects of the adverse productivity shock. Even though the initial impact on consumption might have not been as severe due to the construction of the model economy, the negative impact on accumulated consumption growth in the baseline calibration surpasses the one for the calibration with the weak accelerator. A negative productivity shock is thus followed by prolonged negative consumption growth accompanied by a negative effect on real interest rates and a high risk premium.

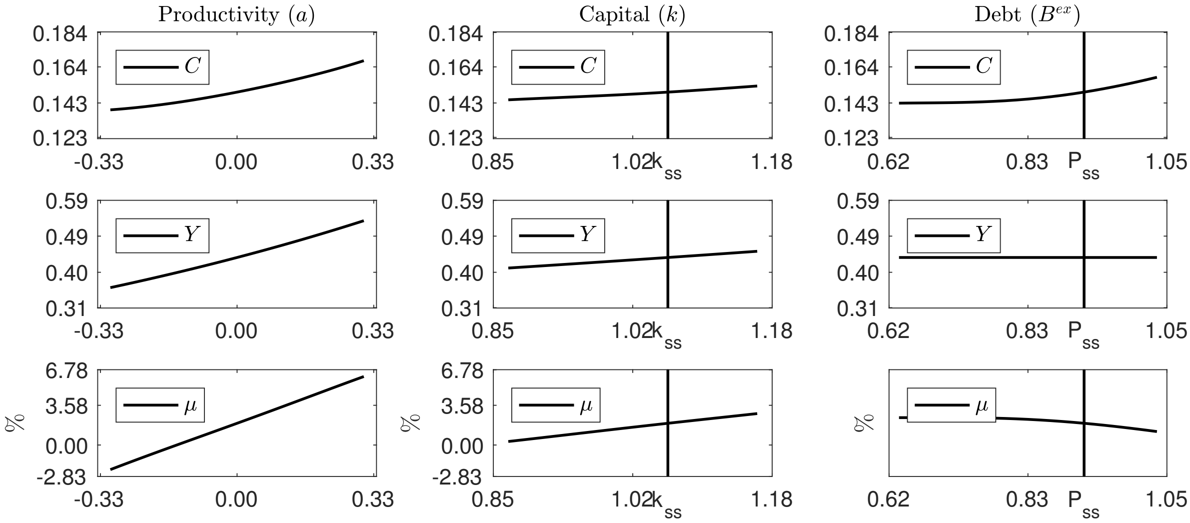

Figure 3: Macroeconomic Variables

This figure depicts macroeconomic control variables as functions of the three state variables productivity (a) in the left column, physical capital (k) in the middle column, and accumulated debt before transfers (B^{ex}) in the right column for the benchmark model. The upper row displays consumption (C). The middle row displays output (Y). The bottom row displays the expected growth rate of the level of blueprints (μ). The vertical line indicates the stochastic steady state of predetermined state variable. The bounds of the grid of approximation for the endogenous state variables are chosen such that the outer bounds are never violated when simulating. For the exogenous component of productivity the bounds are $\pm$ 3.25 unconditional standard deviations of the process.

To complement the results from the impulse response functions Figure 3 depicts consumption, output and expected productivity growth as functions over the state space for the BM calibration. High levels of productivity and physical capital imply high output, consumption, and an expansion of the stock of developed goods resulting in long-run growth of consumption. The effects of the level of accumulated debt is somewhat more intricate. Clearly, the level of debt does not directly affect output, but it increases contemporaneous consumption. Households withdraw money from the intermediary, which in turn will not be invested in physical capital and in acquiring new technologies. Consequently, a high level of debt may allow for high consumption today, but it also induces low growth in the future.

4.2 Countercyclicality

As documented in empirical and theoretical asset pricing literature risk premia are counter- while interest rates are procyclical. This pattern can be well replicated in a recursive equilibrium by introducing the financial accelerator to an otherwise standard (or plain vanilla) general equilibrium asset pricing framework as offered in Kung and Schmid (2015). A negative innovation in productivity leads to an increase in risk premia, whilst the risk-free rate decreases as a compensation for state variable risk. Figure 4 shows the market risk premium and the risk-free rate after a negative one standard deviation shock to productivity. The asset pricing implications can be divided into the risk-free rate component, incentivizing to shift consumption from today to the future, and the equity premium component, governing shifts between debt and equity financing.

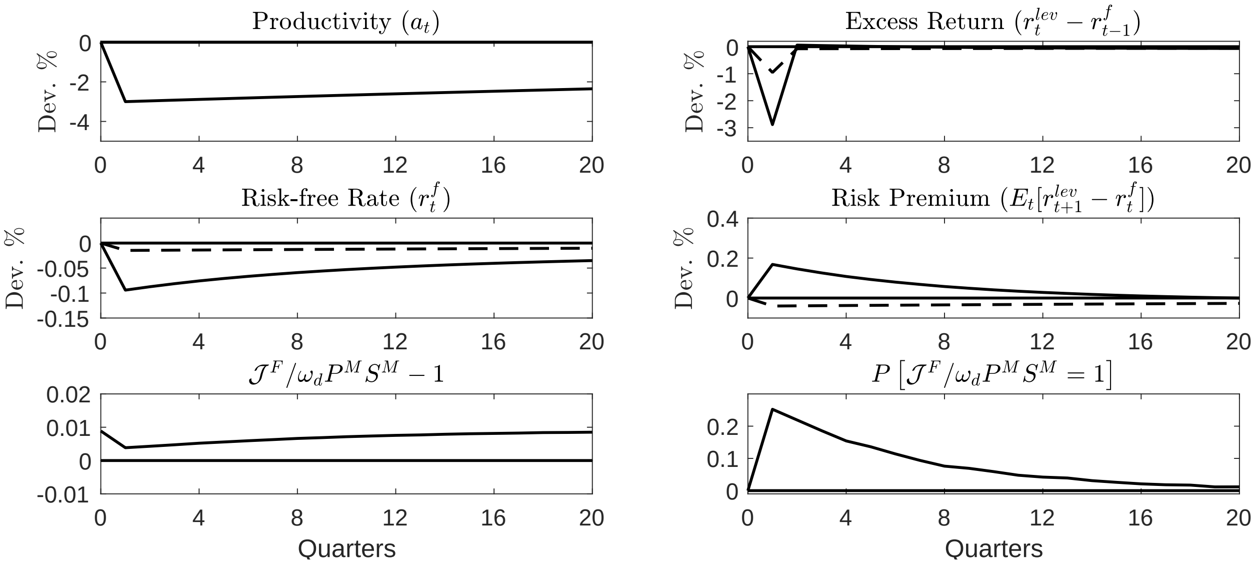

Figure 4: Impulse Response Functions - Premia
This figure depicts impulse responses after a one standard deviation negative shock to productivity for the (levered) market excess return $(r_t^{lev} - r_{t-1}^f)$, the risk-free rate (r_t^f), and the (levered) market risk premium $(E_t\left[r^{lev_{t+1}}\right])$ for the BM and the WA calibration. This lower two panels of the figure depict impulse responses after a one standard deviation negative shock to productivity for excess intermediary value $(\mathcal{J}^{FI}/\omega_d P^M S^M - 1)$ and the probability of being financially constrained $(P\left[(\mathcal{J}^{FI}/\omega_d P^M S^M = 1\right])$ only for the BM calibration.The impulse response functions display reactions for a horizon of 5 years. The solid line indicates the BM model and the dashed line the WA model.

First, at the impact of the adverse productivity shock, excess returns in both calibrations (BM and WA) react negatively; in the BM calibration more than three times as much as in the WA calibration. To understand this reaction better, we turn to Equation (28). As discussed in more detail in Section 3.2, neither entrepreneurs nor households can actively decide on the amount of equity in the intermediary sector. While for a WA calibration each period equity is replenished proportionally to assets in place, in the BM model equity in the intermediary sector is mainly adjusted via price changes of equity. As we will demonstrate in the following paragraphs, the lack of equity in the BM model cannot be covered by simply resorting to outside finance as the leverage constraint tightens when equity value drops. However, as the amount of physical and innovation capital is unchanged (even though productivity has dropped) prices of those real assets need to drop such that they can still be financed with the available funding. Following the initial negative return the risk premium in the WA calibration reacts negatively to a decline in the economic conditions. In the BM calibration on the other hand the the risk premium increases, in line with the expression given in Equation (49). But interestingly, as illustrated in Figure 4, the constraint on debt financing does not need to bind for this result to hold. On average, the value of the intermediary ($\mathcal{J}^{FI}$) is about 1% higher than what is required for borrowing ($\omega_d \left(P_t^F S_t^F + P_t^I S_t^I\right)$). During the downturn it drops by about half. Risk premia in the economy with the financial accelerator are determined by the intermediary, which anticipates an increase in demand for equity to compensate for the increased risk of becoming financially constrained. Even though we say that the intermediary determines prices and returns, this is still done with respect to the pricing kernel determined by consumers (all household members) optimality. Asset prices are determined by the intermediary as households do not have access to direct real investment in productive assets, neither the sector for final goods, nor the intermediate production sector for developed goods.

Second, the risk-free rate decreases in both calibrations. In the BM calibration more than three times as much as in the model with the *weak accelerator*. In both cases, the risk-free rate is driven by one simple mechanism. When the economy is in a good state, the income effect triggers households to raise consumption immediately. To counteract this effect and still motivate agents to save and transfer wealth to the future the risk-free rate needs to increase. As laid out in Section 4.1 the long-run impact of a transitory shock to productivity weighs much more heavily in the benchmark calibration. As a result, the movements in the risk-free rate in the BM calibration tend to be more pronounced than in the calibration with the *weak accelerator*. Above we argued that a lack of safe assets increases the price households are willing to pay for the default-free bond. One can also bring an argument in the fashion of the long-run risk literature. For recursive preferences and a preference for early resolution of uncertainty more long-run consumption risk (meaning more persistence) will shift the risk-free rate downward. Consequently, the financial friction does not only cause that investment is reduced more in downturns in the BM calibration than in the WA calibration inducing long-run consumption dynamics. It also justifies a lower and more volatile risk-free rate from the perspective of the household. In a pure exchange economy asset prices adjust to exogenously given consumption dynamics. In general equilibrium all quantities are determined at the same time, such that we con not only analyze how the financial friction affects asset prices, but also how this simultaneously affects consumption growth dynamics.

Combining above impressions, Figure 5 displays *the risk premium*, the *risk-free rate* and *conditional return volatility* as functions of the state variables *productivity*, *physical capital* and *accumulated debt before transfers* for the *Benchmark Model*.[16] Indeed, the risk premium depends negatively on the level of productivity in the economy, while the risk-free rate increases in the level of productivity. The figure also allows to trace this dynamic back to an increased risk the equity holder is exposed to as conditional return volatility increases in anticipation of being financially constrained. A second very important impression is given when considering the same variables as functions of the level of debt the intermediary faces at the beginning of the period. Very intuitively, *ceteris paribus*, the risk-free rate drops and the equity premium increases when debt levels are high. This in turn gives

[16] For the same figure for the WA calibration see Figure 9 in Appendix D.

an incentive to decrease debt levels (only low incentive to supply outside capital for the household) and build up net worth of the entrepreneurs. As laid out above, households will increase today's consumption and concurrently lower future growth as a result of shrinking investment. In parallel, and supporting above mechanics, high levels of debt increase the level of return volatility as a high leverage-ratio also increases the probability of becoming financially constrained.

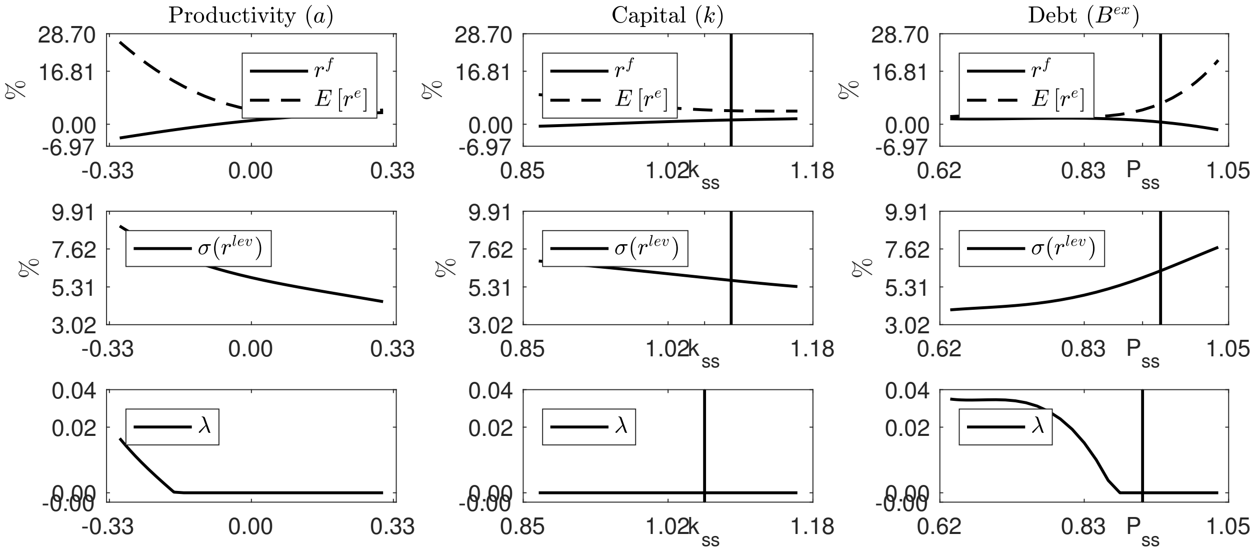

Figure 5: Asset Pricing

This figure depicts asset pricing control variables as functions of the three state variables productivity (a) in the left column, physical capital (k) in the middle column, and accumulated debt before transfers (B^{ex}) in the right column. The upper row displays the log risk-free rate (r^f) and the expected log unlevered risk premium ($E\left[r - r^f\right]$). The middle row displays the volatility of the unlevered return ($\sigma(r)$). The bottom row displays the shadow price of the leverage constraint (λ). The vertical line indicates the stochastic steady state of predetermined state variable. The bounds of the grid of approximation for the endogenous state variables are chosen such that the outer bounds are never violated when simulating. For the exogenous component of productivity the bounds are ± 3.25 unconditional standard deviations of the process.

5 Inspecting the Channels

To further carve out the impact of each channel in the economy, we present two additional models: one waiving the financial accelerator but allowing for endogenous growth and one model in which we eliminate the innovation sector but still allow for a financial accelerator.

Variable	Description	Benchmark Model BM	Constant Growth CG	No Accelerator NA
Panel A	Means			
$E[\Delta y]$	GDP %	1.86%	1.90%	1.92%
Panel B	Standard Deviations			
$\sigma[\Delta c]/\sigma[\Delta y]$	Ratio volatilities	0.53	0.73	0.70
$\sigma[\Delta i]/\sigma[\Delta y]$	Ratio volatilities	1.34	1.57	1.17
$\sigma[\Delta c]$	Consumption %	1.03%	1.04%	1.01%
$\sigma[\Delta y]$	Output %	1.95%	1.41%	1.44%
$\sigma[\Delta i]$	Investment %	2.61%	2.21%	1.69%
Panel C	Autocorrelations			
$\rho[\Delta c]$	Consumption	0.20	0.04	0.05
$\rho[\Delta y]$	Output	0.03	0.01	0.02
$\rho[\Delta i^k]$	Investment	-0.00	-0.01	0.02

Table VI: Macroeconomic Moments - Nested Models

This table depicts moments for the most relevant macroeconomic quantities for the Benchmark Model (BM), the Constant Growth model (CG), and the no Accelerator model (NA). Values are stated on an annualized basis. The upper panel (A) states the mean growth rate of output ($E[\Delta y]$) and its growth rate in deterministic steady state ($SS[\Delta y]$). The middle panel (B) reports volatilities for the growth rates of consumption (Δc), output(Δy), dividends (Δd), investment in capital (Δi), and investment in blueprints (Δi^p). The lower panel (C) reports autocorrelations the same variables.

The former model is referred to as the *No Accelerator* (NA) model and the latter one as the *Constant Growth* model (CG). As above, we reduce exogenous volatility in productivity with the aim to get similar consumption growth volatilities across all models.

5.1 Quantitative Implications

Table VI presents macroeconomic moments for both additional model calibrations, NA and CG, and the BM calibration. Essentially, there are two important observations. First, leaving out one of the model characteristics, increases consumption growth volatility by 20% as measured relative to output growth volatility. Second, the autocorrelation of consumption growth is slashed to about 5%, when excluding one of the channels. In other words, this means, that investment reacts less sensitive to changes in productivity. This increases the volatility of consumption growth and reduces its autocorrelation.

From Table VII we learn that for the CG model the leverage implications are not signif-

Variable	Description	Benchmark Model BM	Constant Growth CG	No Accelerator NA
Panel A	Means			
$E[\mathcal{J}^{FI}/\omega_d P^M S^M - 1]$	Excess firm value	0.89%	0.91 %	–
$p[\mathcal{J}^{FI}/\omega_d P^M S^M = 1]$	Probability of const.	9.24%	6.83%	–
$E[B/E]$	Debt-equity ratio	1.06	1.06	–
$E[B/(E+B)]$	Debt-asset ratio	0.51	0.51	–
Panel B	Deterministic Steady States			
$SS[\mathcal{J}^{FI}/\omega_d P^M S^M]$	Excess firm value	1.00	1.00	–
$SS[B/E]$	Debt-to-equity ratio	1.10	1.10	–
$SS[B/(E+B)]$	Debt-to-asset ratio	0.52	0.52	–
Panel C	Standard Deviations			
$\sigma[B/E]$	Debt-to-equity ratio	6.40%	6.73%	–
$\sigma[B/(E+B)]$	Debt-to-asset ratio	1.51%	1.58%	–
Panel D	Autocorrelations			
$\rho[B/E]$	Debt-to-equity ratio	0.88	0.88	–
$\rho[B/(E+D)]$	Debt-to-asset ratio	0.88	0.88	–

Table VII: Financial Moments - Nested Models

This table reports values for financial quantities for the Benchmark Model (BM), the Constant Growth model (CG), and the no Accelerator model (NA). All values are stated on an annualized basis. Panel A of the table reports means for the excess firm value over the required fraction of overall assets ($E[\mathcal{J}^{FI}/\omega_d P^M S^M]$), the probability of a financial crisis/being financially constrained ($p[\mathcal{J}^{FI}/\omega_d P^M S^M = 1]$), the average debt-to-equity ($E[B/E]$) and debt-to-asset ($E[B/(E+B)]$) ratio. Panel B reports corresponding values or deterministic steady states. The deterministic steady state is indicated by SS. Panel C reports volailities for debt-to-equity and debt-to-asset ratios. Panel D reports autocorrelations for debt-to-equity and debt-to-asset ratios.

Variable	Description	Benchmark Model BM	Constant Growth CG	No Accelerator NA
Panel A	Means			
$E[r^f]$	Risk-free rate	1.35%	2.02%	1.68%
$E[r^A]$	Unlevered return	2.65%	2.77%	1.94%
$E[r^{lev}]$	Levered return	3.99%	3.55%	2.24%
$E[r^{lev} - r^f]$	Levered ex. return	2.64%	1.56%	0.56%
Panel B	Deterministic Steady States			
$SS[r^f]$	Risk-free rate	1.80%	2.03%	2.35%
$SS[r^A]$	Unlevered return	2.45%	2.66%	2.35%
$SS[r^{lev}]$	Levered return	3.16%	3.34%	2.35%
Panel C	Standard Deviations			
$\sigma[r^f]$	Risk-free rate	0.26%	0.06%	0.13%
$\sigma[r^A]$	Unlevered return	1.79%	1.51%	0.89%
$\sigma[r^{lev}]$	Levered return	3.67%	3.11%	1.92%
Panel D	Correlations			
$\rho\left[W/C_t, E_t\left[r^{lev}_{t+1} - r^f_t\right]\right]$	–	-0.47	0.00	1.00
$\rho\left[\Delta c, E_t\left[r^{lev}_{t+1} - r^f_t\right]\right]$	–	-0.62	-0.48	0.37

Table VIII: Asset Pricing - Nested Models

This table depicts the most relevant asset pricing quantities for the Benchmark Model (BM), the Constant Growth model (CG), and the no Accelerator model (NA). All values are stated on an annualized basis. Panel A states stochastic means for the risk-free rate ($E[r^f]$), the unlevered return on assets ($E[r^A]$), and the levered market return ($E[r^{lev}]$). Panel B states values for a deterministic economy. The deterministic steady state value is indicated by SS. Panel C reports volatilities for the same variables. Panel D reports correlations of the levered excess return with the wealth-consumption ratio and consumption growth.

icantly different from the BM model. This comes as a surprise since the economy contains considerably less risk. Finally, turning to Table VIII we see that shutting down either channel increases the risk-free rate as well as the levered market returns. Keeping the subjective discount factor constant if we eliminate the endogenous growth mechanism the risk-free rate increases by about half to 2% and increases by a quarter in the model without the financial friction. This, together with a lower levered market return, implies a reduction of the equity premium to about 1.5% for the CG model and to less than 1% for the NA model. Both models have problems in replicating countercyclicality in the equity risk premium. However, at least the CG model implies a countercyclical risk premium with respect to consumption growth.

5.2 Qualitative Implications

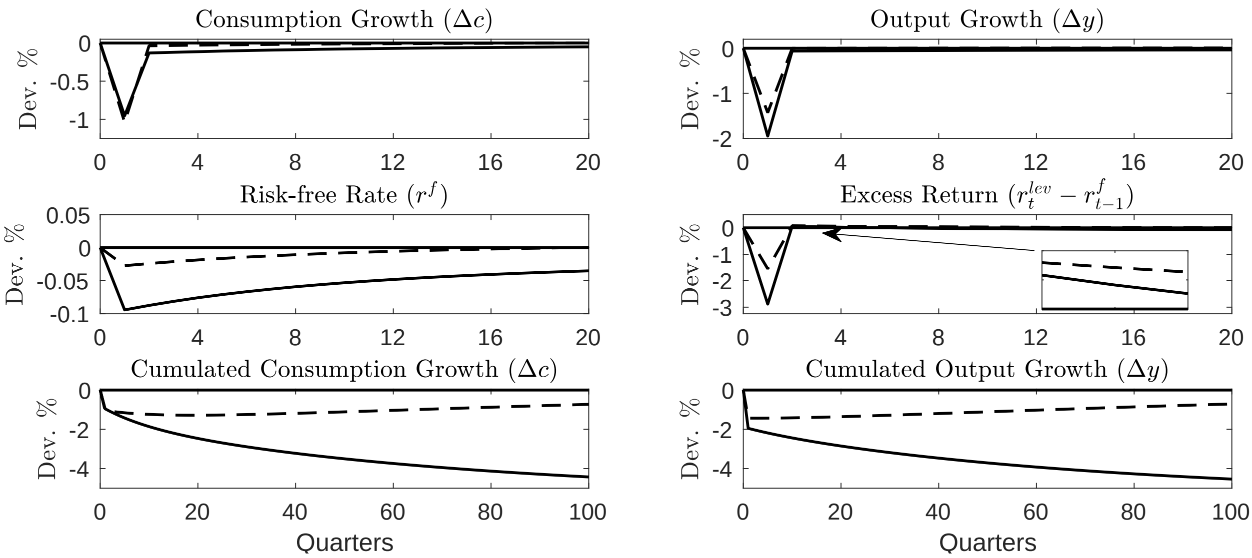

Figure 6: IRF Nested Models - I

This figure depicts impulse responses after a one standard deviation negative shock to productivity for consumption growth (Δc), output growth (Δy), the (levered) market excess return ($r_t^{lev} - r_{t-1}^f$), and the risk-free rate (r_t^f) for the BM and the CG calibration. The impulse response functions in the upper four panels display reactions for a horizon of 5 years. Additionally, the two lower panels depict impulse response functions for cumulated consumption growth ($\sum \Delta c$), and output growth ($\sum \Delta y$) for the BM calibration and the CG calibration. The impulse response functions for the lower two panels display reactions for a horizon of 25 years. The solid line indicates the BM model and the dashed line the CG model.

Another assessment of the role of various channels can be obtained using the impulse response functions following a one standard deviation adverse productivity shock. Figure 6 compares impulse response functions for the CG economy and Figure 7 for the NA model. While consumption growth rates remain low fairly long in the BM model, in both nested models consumption growth reverts back to its steady state value quite fast. A more informative insight can be obtained when turning to the impulse responses of cumulated growth rates. The model with constant exogenous growth produces a *dent* in consumption growth for the first 15 quarters but will slowly catch up with the level of consumption given by the exogenous growth rate of productivity. On the other hand, in the NA model, still facilitating endogenous growth, consumption will persistently keep shrinking, but still not as much as in the BM model. Finally, turning to the implications for asset prices, we observe a much

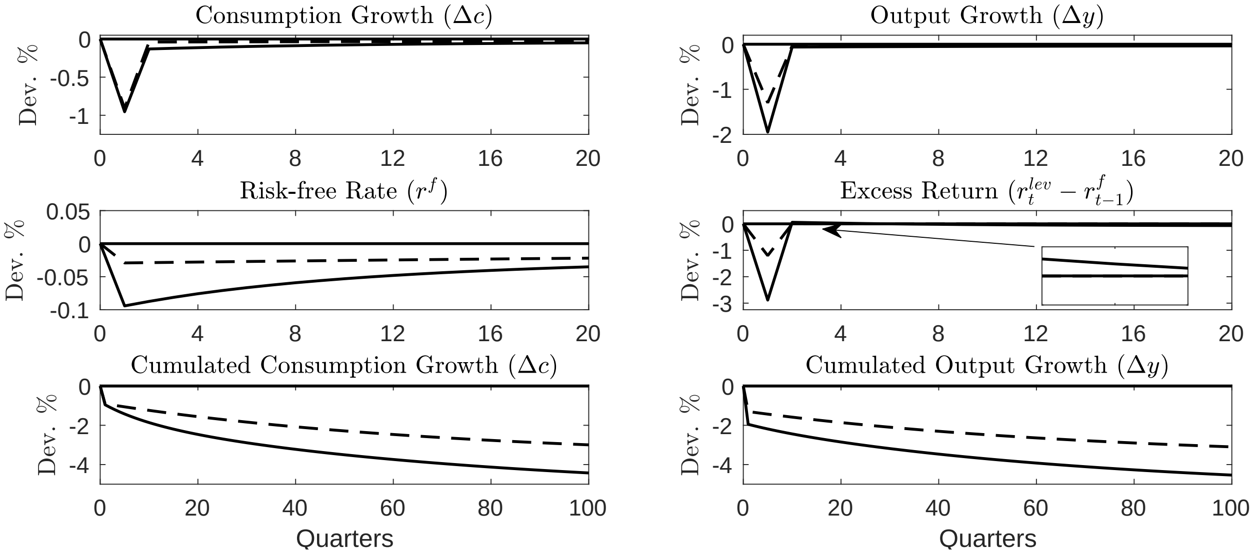

Figure 7: IRF Nested Models - II

This figure depicts impulse responses after a one standard deviation negative shock to productivity for consumption growth (Δc), output growth (Δy), the (levered) market excess return ($r_t^{lev} - r_{t-1}^f$), and the risk-free rate (r_t^f) for the BM and the NA calibration. The impulse response functions in the upper four panels display reactions for a horizon of 5 years. Additionally, the two lower panels depict impulse response functions for cumulated consumption growth ($\sum \Delta c$), and output growth ($\sum \Delta y$) for the BM calibration and the CG calibration. The impulse response functions for the lower two panels display reactions for a horizon of 25 years. The solid line indicates the BM model and the dashed line the NA model.

smoother drop of the risk-free rate for both nested models. And, as already discussed above, after an initial drop of the excess levered market return only the model without endogenous growth (CG) can generate a countercyclical (positive) excess return in subsequent periods.

6 Conclusion

We developed a quantitative DSGE framework combining features from state-of-the-art general equilibrium asset pricing models with a standard financial friction. We find that this framework is able to explain countercyclicality of the risk premium and highlights how this influences the interplay of the deleveraging of the firm and expected consumption growth in the economy.

In our economy the constraint on firm leverage is not always binding. Hence, we rely on global methods to solve for the equilibrium. We show that the mere expectation of being financially constrained leads to an increase in the risk premium and makes the risk-free rate reacting more pronouncedly than in an economy without a financial friction.

Our model illustrates a simple mechanism: when the economy is hit by an adverse shock the probability of firms becoming financially constrained increases, which in turn leads stock market volatility and the risk premia to go up. As riskless assets become scarce, the risk-free rate drops. The closer a firm is to be financially constrained, the harder it is to acquire outside finance. When risk premia are high the firm can deleverage, while the economy experiences a prolonged period of low growth rates due to a lack of financing.

This paper only discusses the case of exogenous shocks to productivity and analyzes how a financial sector can amplify its effects. It would be worthwhile to also include shocks in the financial sector and evaluate the impact of central banks' policies on spreading the risk.

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A Additional Derivations

A.1 The Stochastic Discount Factor

$$\mathcal{M}_{t,t+1} = \frac{\mathcal{U}_{c_{t+1}}}{\mathcal{U}_{c_t}} = e^{-\delta}\left(\frac{C_{t+1}}{C_t}\right)^{-\frac{1}{\psi}}\left(\frac{\mathcal{U}_{t+1}}{\mathcal{R}_t}\right)^{\frac{1}{\psi}-\gamma} \tag{51}$$

A.2 The Financial Intermediary

After plugging in affine guess for financial intermediaries value and changing to state space notation[17]

$$\mathcal{J}^{FI}(E_j, X) = \max_{S_j^F, S_j^I} E_X\left[\mathcal{M}\left(X, X^{'}\right)\left[(1-p^b)+p^b\hat{\mathcal{J}}^{FI}(X')\right]E_j'\right] \tag{52}$$

$$E_j^{'} = \sum_{i\in\{F,I\}}\left(R^i\left(X, X'\right)-R^f\left(X\right)\right)P_j^i\left(X\right)S_j^i\left(X\right)+R^f\left(X\right)E_j' \tag{53}$$

$$\omega_d\left[\sum_{i\in\{F,I\}}P_j^i\left(X\right)S_j^i\left(X\right)\right] \leq \hat{\mathcal{J}}^{FI}(X')\ E_j' \tag{54}$$

$$X' = \Gamma\left(X\right) \tag{55}$$

Substituting for the law motion for E_j
Reshuffle

$$\begin{aligned}
\mathcal{J}^{FI}(E_j, X) &= \max_{S_j^F, S_j^I} E_X\left[\mathcal{M}\left(X, X^{'}\right)\left[(1-p^b)+p^b\hat{\mathcal{J}}^{FI}(X')\right]\sum_{i\in\{F,I\}}\left(R^i\left(X, X'\right)-R^f\left(X\right)\right)P_i^jS_j^i+R^f\left(X\right)E_j'\right]\\
\mathcal{J}^{FI}(E_j, X) &= \max_{S_j^F, S_j^I} E_X\left[\mathcal{M}\left(X, X^{'}\right)\left[(1-p^b)+p^b\hat{\mathcal{J}}^{FI}(X')\right]\sum_{i\in\{F,I\}}\left(R^i\left(X, X'\right)-R^f\left(X\right)\right)P_i^j\left(X\right)S_j^i\left(X\right)\right]\\
&+E_X\left[\mathcal{M}\left(X, X^{'}\right)\left[(1-p^b)+p^b\hat{\mathcal{J}}^{FI}(X')\right]\right]R^f\left(X\right)E_j'
\end{aligned} \tag{56}$$

First Order Conditions
S_j^F: $E_X\left[\mathcal{M}\left(X, X^{'}\right)\left[(1-p^b)+p^b\mathcal{J}^{FI}, X')\right]\left(R^F\left(X, X'\right)-R^f\left(X\right)\right)\right]\cancel{Q^F}-\omega_d\cancel{Q^F}\lambda\left(X\right)=0$
S_j^I: $E_X\left[\mathcal{M}\left(X, X^{'}\right)\left[(1-p^b)+p^b\mathcal{J}^{FI}, X')\right]\left(R^P\left(X, X'\right)-R^f\left(X\right)\right)\right]\cancel{Q^P}-\omega_d\cancel{Q^P}\lambda\left(X\right)=0$
$\lambda\left(X\right)$:$\lambda\left(X\right)\left(\omega_d\sum_{i\in\{F,I\}}P_j(X')S_j^i(X')-\hat{\mathcal{J}}^{FI}(X')E_j\right)=0$
For later use:

$$\max_{S_j^F, S_j^I} E_X\left[\mathcal{M}\left(X, X^{'}\right)\left[(1-p^b)+p^b\hat{\mathcal{J}}^{FI}(X')\right]\sum_{i\in\{F,I\}}\left(R^i\left(X, X'\right)-R^f\left(X\right)\right)P_i^jS_j^i\right]=\lambda\left(X\right)\hat{\mathcal{J}}^{FI}(X')E_j \tag{57}$$

and define

$$\tilde{\mathcal{M}}\left(X, X^{'}\right)=\mathcal{M}\left(X, X^{'}\right)\left[(1-p^b)+p^b\hat{\mathcal{J}}^{FI}(X')\right] \tag{58}$$

[17] The derivations closely follow Bocola (2016).

as the pricing kernel of the financial intermediary. We can plug into Equation 56 and obtain

$$\hat{\mathcal{J}}^{FI}(X')E_i = \lambda(X)\,\hat{\mathcal{J}}^{FI}(X')E_i + E_X\left[\tilde{\mathcal{M}}\left(X, X^{'}\right)\right] R^f(X)\,E_i \tag{59}$$

Solving for the value of one unit of equity

$$\hat{\mathcal{J}}^{FI}(X) = \frac{E_X\left[\tilde{\mathcal{M}}\left(X, X^{'}\right)\right] R^f(X)}{1-\lambda(X)} = \frac{R^f(X)}{\tilde{R}^f(X)}\left(1-\lambda(X)\right)^{-1} \tag{60}$$

Complementary slackness as given in Equation (A.2) implies:

A.2.1 Case 1 Constraint doesn't bind

When the constraint doesn't bind complementary slackness implies

$$\lambda(X) = 0, \tag{61}$$

which gives us

$$\begin{aligned}
E_X\left[\mathcal{M}\left(X, X^{'}\right)\left[(1-p^b)+p^b\hat{\mathcal{J}}^{FI}(X')\right]\left(R^j(X,X')-R^f(X)\right)\right] &= 0 & (62)\\
E_X\left[\mathcal{M}\left(X, X^{'}\right)\left[(1-p^b)+p^b\hat{\mathcal{J}}^{FI}(X')\right]\right] & \\
+E_X\left(R^j(X,X')-R^f(X)\right) & \\
+Cov_t\left(\tilde{\mathcal{M}}\left(X, X^{'}\right)R^j(X,X')\right) &= 0 & (63)\\
\tilde{R}^f(X)^{-1} - Cov_t\left(\tilde{\mathcal{M}}\left(X, X^{'}\right)R^j(X,X')\right) &= E_X\left(R^j(X,X')-R^f(X)\right) & (64)
\end{aligned}$$

with

$$\begin{aligned}
\tilde{\mathcal{M}}\left(X, X^{'}\right) &= \mathcal{M}\left(X, X^{'}\right)\left[(1-p^b)+p^b\hat{\mathcal{J}}^{FI}(X')\right] & (65)\\
\tilde{R}^f(X)^{-1} &= E_X\left[\tilde{\mathcal{M}}\left(X, X^{'}\right)\right] & (66)
\end{aligned}$$

A.2.2 Case 2 Constraint does bind

For the case when the constraint binds we can solve for she Lagrange multiplier

$$\lambda(X) = 1 - \frac{R^f(X)}{\tilde{R}^f(X)}\frac{E_i}{\left(\omega_d\sum_{i\in\{F,I\}}P^jS_{j,i}\right)} = 1 - \frac{R^f(X)}{\tilde{R}^f(X)}\frac{E}{\left(\omega_d\sum_{i\in\{F,I\}}P^i(X)\,S^i(X)\right)}, \tag{67}$$

where we make use of the fact that in distress the leverage of all firms is the same.

A.2.3 Together

$$\lambda(X) = max\left\{1 - \frac{R^f(X)}{\tilde{R}^f(X)} \frac{E_i}{\left(\omega_d \sum_{i\in\{F,I\}} P^i(X) S^i(X)\right)}, 0\right\} < 1 \tag{68}$$

A.2.4 Law of Motion for Aggregate Net Worth

The law of motion for net worth of the individual intermediary is

$$E'_j = R^F(X,X') P^F(X) S^F_j(X) + R^I(X,X') P^I(X) S^I_j(X) - R^f(X) B_j(X) \tag{69}$$

$$= \left(R^F(X,X') - R^f(X)\right) P^F(X) S^F_j(X) + \left(R^I(X,X') - R^f(X)\right) P^I(X) S^I_j(X) + R^f(X) E_j \tag{70}$$

Each period p^b of bankers remain in business and new bankers are endowed with $\omega \sum_{i\in\{F,I\}} P_{j,t} S^i_j$

$$E' = p^b\left[\left(R^F(X,X') - R^f(X)\right) P^F(X) S^F(X) + \left(R^I(X,X') - R^f(X)\right) P^I(X) S^I(X) + R^f(X) E\right] \tag{71}$$

$$+\omega_b \sum_{i\in\{F,I\}} P^i(X) S^i(X') \tag{72}$$

A.3 The Final Good Producer

The final good producer has a Cobb-Douglas production function

$$Y(X) = \left((AN)^{1-\alpha} K^\alpha\right)^{1-\omega_p} (G(X))^{\omega_p} \tag{73}$$

$$G(X) = \left(\int_0^{K^p} \zeta_i^\nu(X)\, di\right)^{1/\nu}. \tag{74}$$

$$\tag{75}$$

And the inverse demand is given by

$$P^p_i(X) = \omega_p \left((AN)^{1-\alpha} K^\alpha\right)^{1-\omega_p} \left(\int_0^{K^p} \zeta_i(X)^\nu\, di\right)^{(\omega_p-\nu)1/\nu} \zeta_i(X)^{\nu-1} \tag{76}$$

A.4 R &D

A.4.1 Sector for Developed Goods

Monopolistic competition. The demand for a developed good of type i is given by

$$\zeta_i(X) = \left(P^p_i(X)\right)^{\frac{1}{\nu-1}} \left(\omega_p \left((AN)^{1-\alpha} K^\alpha\right)^{1-\omega_p} \left(\bar{\zeta}(K^p)^\nu\right)^{\omega_p-\nu}\right)^{\frac{1}{\nu-1}} \tag{77}$$

Producer of developed goods used one consumption good to produce one developed good. Profits are given by

$$\Pi_i = \max_{P_i^p} \zeta_i (X) P_i^p (X) - \zeta_i (X) \tag{78}$$

yields

$$P_i^p = \frac{1}{\nu} \tag{79}$$

Together with symmetrie amongst developed good producers this results in

$$\bar{\zeta} = (\nu \omega_p)^{\frac{1}{1-\omega_p}} K^\alpha (NA) (K^p)^{\frac{\frac{\omega_p}{\nu}-1}{1-\omega_p}} \tag{80}$$

Value of a blueprint is recursively defined

$$\mathcal{J}^p (X) = P_i^p (X) + (1 - p^o) E_X \left[\bar{\mathcal{M}} (X, X') \hat{\mathcal{J}}^p (X') \right] \tag{81}$$

A.4.2 Innovation sector

Entrepreneurs sell developed blueprints to the FI. Market is perfectly competitive

$$I^p (X) = E_X \left[\mathcal{M} (X, X') \mathcal{J}^p (X) \left(K^{p'} - K^p (1 - p^o) \right) \right] \tag{82}$$

With law of motion for blueprint stock

$$K^{p'} = \chi (X) I^p (X) K^p (1 - p^o) \tag{83}$$

and

$$\chi (X) = \frac{\bar{\chi} K^p}{(I^p (X))^{1-\eta} (K^p)^\eta} \tag{84}$$

Multiplying out

$$I^p (X) = K^p E_X \left[\bar{\chi} \mathcal{M} (X, X') \mathcal{J}^p (X) \right]^{\frac{1}{1-\eta}} \tag{85}$$

A.4.3 Production Function

Plugging in for G

$$
\begin{aligned}
Y(X) \quad &= \left((AN)^{1-\alpha} K^\alpha \right)^{1-\omega_p} (G_t)^{\omega_p} && (86)\\
&= \left((AN)^{1-\alpha} K^\alpha \right)^{1-\omega_p} && (87)\\
&\times \left(\left(\nu \omega_p \left((K)^\alpha (NA)^{1-\alpha} \right)^{1-\omega_p} (K^p)^{\frac{1}{\nu}(\omega_p - \nu)} \right)^{\frac{1}{1-\omega_p}} (K^p)^{\frac{1}{\nu}} \right)^{\omega_p} && (88)\\
&= (\nu \omega_p)^{\frac{\omega_p}{1-\omega_p}} (K)^\alpha (NA)^{1-\alpha} (K^p)^{\frac{\frac{\omega_p}{\nu} - \omega_p}{1-\omega_p}} && (89)
\end{aligned}
$$

Impose parameter restriction for stable growth: $\alpha + \frac{\frac{\omega_p}{\nu} - \omega_p}{1-\omega_p} = 1$

$$Y(X) = (\nu\omega_p)^{\frac{\omega_p}{1-\omega_p}} (K)^{\alpha} (NZ)^{1-\alpha} \tag{90}$$

$$Z(X) = AK^p \tag{91}$$

A.5 Budget Constraint Household

$$C = Y(X) - I(X) - I^p(X) - K^p\zeta(X) \tag{92}$$

B Equilibrium Conditions

This appendix presents the full set of equilibrium conditions and its de-trended version of our main model.

B.1 Collected Equilibrium

$$\mathcal{M}(X, X') = e^{-\delta} \left(\frac{C(X')}{C(X)}\right)^{-1/\psi} \left(\frac{\mathcal{U}(X')}{\mathcal{R}(X)}\right)^{\frac{1}{\psi}-\gamma} \tag{B.1.1}$$

$$\mathcal{U}(X) = \left(\left(1-e^{\delta}\right) C(X)^{1-\frac{1}{\gamma}} + e^{\delta}\mathcal{R}(X)^{1-\frac{1}{\psi}}\right)^{\frac{1}{1-\frac{1}{\psi}}} \tag{B.1.2}$$

$$\mathcal{R}(X) = E_X\left[\mathcal{U}(X')^{1-\psi}\right]^{\frac{1}{1-\psi}} \tag{B.1.3}$$

$$\bar{\mathcal{M}}(X, X') = \mathcal{M}\left(X, X'\right)\left[(1-p^b) + p^b \hat{\mathcal{J}}^{FI}(X')\right] \tag{B.1.4}$$

$$C(X) = F(X) - I(X) - I^p(X) - K^p\zeta(X) \tag{B.1.5}$$

$$F(X) = (\nu\omega_p)^{\frac{\omega_p}{1-\omega_p}} K_t^{\alpha} (Z(X))^{1-\alpha} \tag{B.1.6}$$

$$Z(X) = (AK^p) \tag{B.1.7}$$

$$0 = E_X\left[\bar{\mathcal{M}}(X, X')\left(R^F(X, X') - R^f(X)\right)\right] - \omega_d\lambda(X) \tag{B.1.8}$$

$$0 = E_X\left[\bar{\mathcal{M}}(X, X')\left(R^P(X, X') - R^f(X)\right)\right] - \omega_d\lambda(X) \tag{B.1.9}$$

$$1 = E_X\left[\mathcal{M}(X, X')\, R^f(X)\right] \tag{B.1.10}$$

$$1 = E_X\left[\bar{\mathcal{M}}(X, X')\, \bar{R}^f(X)\right] \tag{B.1.11}$$

$$R^p(X, X') = \frac{(1-p^o)\,\mathcal{J}^p(X')}{\mathcal{J}^p(X) - \Pi(X)} \tag{B.1.12}$$

$$R(X, X')^k = \Phi'(X)\left[\frac{\partial F(X)}{\partial K} + \frac{(1-p^k) + \Phi(X')}{\Phi'(X')} - \frac{I(X')}{K(X')}\right] \tag{B.1.13}$$

$$\frac{\partial F(X)}{\partial K_t} = (\alpha)(1-\omega_p)\frac{Y(X)}{K} \tag{B.1.14}$$

$$\Phi'(X) = a_2\left(\frac{I(X)}{K}\right)^{-\frac{1}{\xi}} \tag{B.1.15}$$

$$\Phi(X) = a_1 + \frac{a_2}{1-\frac{1}{\xi_k}}\left(\frac{I(X)}{K}\right)^{1-\frac{1}{\xi_k}} \tag{B.1.16}$$

$$\Pi(X) = \left(\frac{1}{\nu} - 1\right)\bar{\zeta}_t \tag{B.1.17}$$

$$\bar{\zeta} = (\nu\omega_p)^{\frac{1}{1-\omega_p}} K^{\alpha} (A) \tag{B.1.18}$$

$$\frac{1}{\chi(X)} = E_X \left[\mathcal{M}(X, X')\mathcal{J}^p(X')\right] \tag{B.1.19}$$

$$\mathcal{J}^p(X) = \Pi(X) + (1 - p^o)\,\mathcal{J}^p(X') \tag{B.1.20}$$

$$\chi(X) = \frac{\bar{\chi}K^p}{(I^p(X))^{1-\eta}\,(K^p)^{\eta}} \tag{B.1.21}$$

$$E(X) = p\left(\left[\frac{\partial F(\cdot)}{\partial K} + \frac{(1-p^k) + \Phi(X)}{\Phi'(X)} - \frac{I(X)}{K}\right] K + \mathcal{J}^p(X')(1-p^k)K^p - B^{ex}\right) \tag{B.1.22}$$

$$+\omega_b\left(\frac{1}{\Phi'(X)}K + (\mathcal{J}^p(X) - \Pi(X))\,K^p\right) \tag{B.1.23}$$

$$\hat{\mathcal{J}}^{FI}(X) = \frac{R^f(X)}{\tilde{R}^f(X)}\,(1 - \lambda(X))^{-1} \tag{B.1.24}$$

$$\lambda(X) = \max\left\{1 - \frac{R^f(X)}{\tilde{R}^f(X)}\frac{E(X)}{\omega_d\left[\frac{1}{\mathcal{J}^p(X)-\Pi(X)}K^{p'} + \frac{1}{\Phi(X)}K'\right]}, 0\right\} < 1. \tag{B.1.25}$$

State variables

$$a' = \rho_a a + \sigma_a \epsilon_a' \tag{B.1.26}$$

$$K' = (1-p^k)K + \Phi(X)K \tag{B.1.27}$$

$$B^{ex'} = R^f(X)\left(\frac{1}{\mathcal{J}^p(X) - \Pi(X)}K^{p'} + \frac{1}{\Phi(X)}K' - E\right) \tag{B.1.28}$$

$$K^{p'} = \chi(X)I^p(X) + (1-p^o)(K^p) \tag{B.1.29}$$

occasionally binding constraint on leverage

$$\omega_d\left[\frac{1}{\mathcal{J}^p(X) - \Pi(X)}K^{p'} + \frac{1}{\Phi(X)}p^{o'}\right] \leq \hat{\mathcal{J}}^{FI}(X) \times E \tag{B.1.30}$$

B.2 Collected Equilibrium Detrended

To solve the the model with global solution methods, we rewrite the model along the balanced growth path. For that we make use of the parameter restriction.

$$\mu(\hat{X}) = log\left(1 - p^o + \chi_t e^{i^p(\hat{X})}\right) \tag{B.2.1}$$

$$\Delta c(X, X') = \hat{c}(\hat{X}') - \hat{c}(\hat{X}) + \mu(\hat{X})) \tag{B.2.2}$$

$$\mathcal{M}\left(\hat{X}, \hat{X}'\right) = e^{\delta - \left(\frac{1}{\psi}\right)\Delta c(X,X')}\left(\frac{e^{\Delta\mu(X)}\hat{\mathcal{U}}(X)}{\hat{\mathcal{R}}(X)}\right)^{\frac{1}{\psi}-\gamma} \tag{B.2.3}$$

$$\mathcal{U}(\hat{X}) = \left(\left(1 - e^{\delta}\right)\hat{C}(\hat{X})^{1-\frac{1}{\psi}} + e^{\delta}\hat{\mathcal{R}}(\hat{X})^{1-\frac{1}{\psi}}\right)^{\frac{1}{1-\frac{1}{\psi}}} \tag{B.2.4}$$

$$\mathcal{R}(\hat{X}) = E_X\left[\left(e^{\Delta\mu(\hat{X})}\hat{\mathcal{U}}(\hat{X}')\right)^{1-\gamma}\right]^{\frac{1}{1-\gamma}} \tag{B.2.5}$$

$$\bar{\mathcal{M}}(\hat{X}, \hat{X}') = \mathcal{M}\left(\hat{X}, \hat{X}'\right)\left[(1-p^b) + p^b\hat{\mathcal{J}}^{FI}(X')\right] \tag{B.2.6}$$

$$C(\hat{X}) = F(\hat{X}) - I(\hat{X}) - I^p(\hat{X}) - \zeta(\hat{X}) \tag{B.2.7}$$

$$F(\hat{X}) = (\nu\omega_p)^{\frac{\omega_p}{1-\omega_p}} K^{\alpha}(A)^{1-\alpha} \tag{B.2.8}$$

$$0 = E_{\hat{X}}\left[\bar{\mathcal{M}}\left(\hat{X}, \hat{X}'\right)\left(R^F\left(\hat{X}, \hat{X}'\right) - R^f\left(\hat{X}\right)\right)\right] - \omega_d\lambda\left(\hat{X}\right) \tag{B.2.9}$$

$$0 = E_{\hat{X}}\left[\bar{\mathcal{M}}\left(\hat{X},\hat{X}'\right)\left(R^{P}\left(\hat{X},\hat{X}'\right) - R^{f}\left(\hat{X}\right)\right)\right] - \omega_d \lambda\left(\hat{X}\right) \tag{B.2.10}$$

$$1 = E_{\hat{X}}\left[\mathcal{M}\left(\hat{X},\hat{X}'\right) R^{f}(\hat{X})\right] \tag{B.2.11}$$

$$1 = E_{\hat{X}}\left[\bar{\mathcal{M}}\left(\hat{X},\hat{X}'\right) \bar{R}^{f}(\hat{X})\right] \tag{B.2.12}$$

$$R^{p}\left(\hat{X},\hat{X}'\right) = \frac{(1-p^{o})\,\mathcal{J}^{p}(\hat{X}')}{\mathcal{J}^{p}(\hat{X}) - \Pi(\hat{X})} \tag{B.2.13}$$

$$R^{F}\left(\hat{X},\hat{X}'\right) = \Phi'\left(\hat{X}\right)\left[\frac{\partial F(\hat{X})}{\partial \hat{K}} + \frac{(1-p^{k}) + \Phi\left(\hat{X}'\right)}{\Phi'\left(\hat{X}'\right)} - \frac{I(\hat{X}')}{K(\hat{X}')}\right] \tag{B.2.14}$$

$$\frac{\partial F(\hat{X})}{\partial \hat{K}^{k}} = (\alpha)\,(1-\omega_p)\,\frac{Y(\hat{X})}{\hat{K}^{k}} \tag{B.2.15}$$

$$\Phi'\left(\hat{X}\right) = a_2\left(\frac{I(\hat{X})}{\hat{K}^{k}}\right)^{-\frac{1}{\xi}} \tag{B.2.16}$$

$$\Phi\left(\hat{X}\right) = a_1 + \frac{a_2}{1-\frac{1}{\xi_k}}\left(\frac{I(\hat{X})}{\hat{K}^{k}}\right)^{1-\frac{1}{\xi_k}} \tag{B.2.17}$$

$$\Pi(\hat{X}) = \left(\frac{1}{\nu} - 1\right)\zeta(\bar{\hat{X}}) \tag{B.2.18}$$

$$\zeta(\bar{\hat{X}}) = (\nu\omega_p)^{\frac{1}{1-\omega_p}}\,\hat{K}^{\alpha}\,(A) \tag{B.2.19}$$

$$\frac{1}{\chi(\hat{X})} = E_{\hat{X}}\left[\mathcal{M}(\hat{X},\hat{X}')\mathcal{J}^{p}(\hat{X}')\right] \tag{B.2.20}$$

$$\chi(\hat{X}) = \frac{\bar{\chi}\hat{K}^{p}}{\left(I^{p}(\hat{X})\right)^{1-\eta}\left(\hat{K}^{p}\right)^{\eta}} \tag{B.2.21}$$

$$E(\hat{X}) = p\left(\left[\frac{\partial F(\hat{X})}{\partial \hat{K}^{k}} + \frac{(1-p^{k}) + \Phi\left(\hat{X}\right)}{\Phi'\left(\hat{X}\right)} - \frac{I(\hat{X})}{\hat{K}^{k}}\right]\hat{K}^{k} + \mathcal{J}^{p}(X')\,(1-p^{o})\,, -\hat{B}^{ex}\right) \tag{B.2.22}$$

$$+\omega_b\left(\frac{1}{\Phi'\left(\hat{X}\right)}\hat{K}^{k} + \left(\mathcal{J}^{p}(\hat{X}) - \Pi(\hat{X})\right)\hat{K}^{p}\right) \tag{B.2.23}$$

$$\mathcal{J}^{FI}(\hat{X}) = \frac{R^{f}\,(X)}{\tilde{R}^{f}\left(\hat{X}\right)}\left(1 - \lambda\left(\hat{X}\right)\right)^{-1} \tag{B.2.24}$$

$$\lambda\left(\hat{X}\right) = \max\left\{1 - e^{-\mu(X)}\frac{R^{f}\left(\hat{X}\right)}{\tilde{R}^{f}\left(\hat{X}\right)}\frac{E(\hat{X})}{\omega_d\left[\frac{1}{\mathcal{J}^{p}(\hat{X})-\Pi(\hat{X})}\hat{K}^{p\prime} + \frac{1}{\Phi(\hat{X})}\hat{K}^{k\prime}\right]}, 0\right\} < 1. \tag{B.2.25}$$

State variables

$$a' = \rho_a a + \sigma_a \epsilon_a' \tag{B.2.26}$$

$$\hat{k}^{k\prime} = log(1 - p^{k} + \Phi\left(\hat{X}\right)) + \hat{k}^{k} - \mu(\hat{X}) \tag{B.2.27}$$

$$log(B)^{ex\prime} = \log\left[R^{f}(\hat{X})\left(\left(\frac{1}{\mathcal{J}^{p}(\hat{X}) - \Pi(\hat{X})}\hat{K}^{p\prime} + \frac{1}{\Phi(\hat{X})}\hat{K}'\right)e^{\mu(\hat{X})} - E(\hat{X})\right)\right] - \mu(\hat{X}) \tag{B.2.28}$$

$$K^{p\prime} = gone \tag{B.2.29}$$

OccBin

$$e^{\mu(\hat{X})}\omega_d\left[\frac{1}{\mathcal{J}^{p}(\hat{X}) - \Pi(\hat{X})}\hat{K}^{p\prime} + \frac{1}{\Phi(\hat{X})}\hat{K}'\right] \leq \mathcal{J}^{FI}(\hat{X}) \times E(\hat{X}) \tag{B.2.30}$$

C Data and Additional Figures

C.1 Data Description

Financial leverage Our timeseries for financial leverage is defined as credit market debt as a percentage of the market value of corporate equities for nonfinancial corporate business. We use date from Board of Governors of the Federal Reserve System (US), Nonfinancial Corporate Business; Credit Market Debt as a Percentage of the Market Value of Corporate Equities [NCBCMDPMVCE], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/NCBCMDPMVCE, February 16, 2017. The series is transformed to debt over total assets. The timeseries is available on a quarterly basis ranging from 1952Q1 until 2016Q3.

Macroeconomic and financial uncertainty For macroeconomic and financial uncertainty we use data from Jurado et al. (2015). Their data is updated and can be downloaded from https://www.sydneyludvigson.com/data-and-appendixes/ and ranges from 1960Q3 until 2016Q2. The date is available in monthly frequency and is computed 1,3, and 12 months ahead. As the model and empirical data is quarterly we also use end of quarter uncertainty with a 3-month horizon.

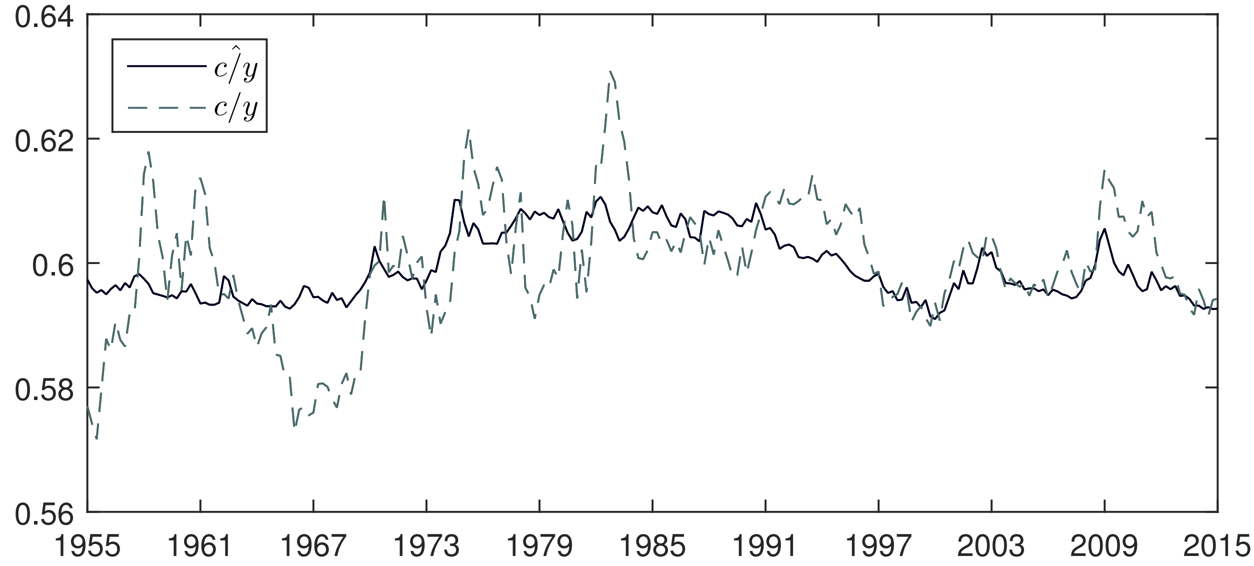
Risk-free rate The ex-ante real risk-free rate is computed according to Beeler and Campbell (2012) with the 90-day US treasury bill proxying for the risk-free rate and the CPI as provided by the CRSP database serving as the inflation measure. The data ranges from 1936Q1 until 2016Q4

Stock returns The real return on the market is proxied by the S&P 500 index including distributions [vwretd] as supplied by the CRSP database. Data is supplied on a monthly basis. It is time aggregated before computing volatilities (and means) and corrected for inflation by the consumer price index supplied by CRSP. The data ranges from 1926Q1 until 2016Q4.

Consumption growth Consumption is defined as real personal expenditures on non-durable consumption and services as reported in NIPA Table 7.1 downloadable from https://www.bea.gov/national/nipaweb/DownSS2.asp. Data is quarterly and ranges from 1947Q1 until 2016Q3.

Other macroeconomic variables All other variables are per capital values as reported in NIPA Table 7.1 downloadable from https://www.bea.gov/national/nipaweb/DownSS2.asp. Data is quarterly and ranges from 1947Q1 until 2016Q3.

C.2 Empirical Links



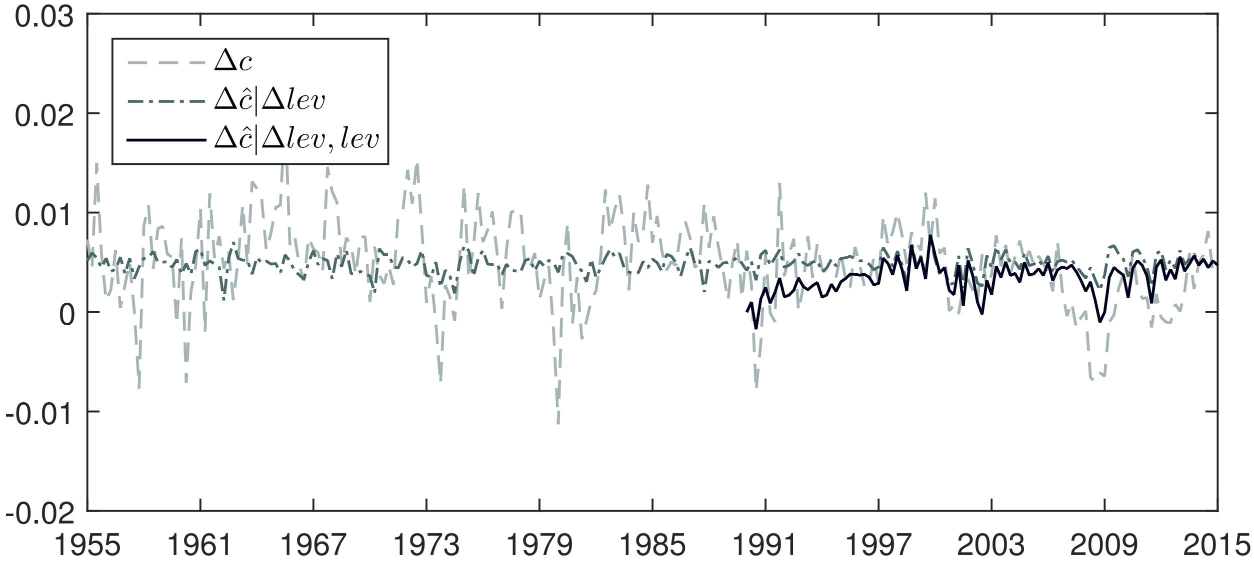


Figure 8: Predicted Consumption Growth

This figure depicts timeseries for consumption growth and the consumption-output ratio. Consumption is defined as per capital real expenditures on nondurable consumption and services. Output is real gross domestic product per capita. The upper panel depicts the realized consumption-output ratio and the consumption output ratio as predicted with leverage of non-financial corporate businesses in the US. The lower panel depicts realized real consumption growth and predicted consumption growth when predicted with financial leverage and financial leverage growth. As financial leverage is strongly influenced by high oil prices for the period from 1973 until 1990 we only include the level of financial leverage from 1990 on. The whole sample is quarterly U.S. data an ranges from 1955 until 2015.

	const.	Δlev_t	Δc_t	$\Delta\sigma_{mac,t}$	$\sigma_{mac,t}$	$\Delta\sigma_{fin,t}$	$\sigma_{fin,t}$	$\bar{R}^2$
1	0.005***	−0.018***						0.045
	[0.000]	[0.005]						
2	0.002***	−0.013***	0.511***					0.308
	[0.000]	[0.005]	[0.059]					
3	0.010***	−0.010**	0.451***	−0.026***	−0.010***			0.361
	[0.003]	[0.004]	[0.062]	[0.007]	[0.003]			
4	0.010***	−0.010**	−0.002	−0.025***	0.000	−0.010***	0.451***	0.355
	[0.003]	[0.005]	[0.006]	[0.008]	[0.003]	[0.004]	[0.062]	

Table IX: Regression Consumption Growth

This table depicts results for regressions predicting future consumption growth (Δc_{t+1}), defined as expenditures on non-durable consumption and services. The predicting variables are the the change of the debt-to-asset ratio of non-financial corporate businesses (Δlev_t), past consumption growth (Δc_t), macroeconomic uncertainty ($\sigma_{mac,t}$), the change in macroeconomic uncertainty ($\Delta\sigma_{mac,t}$), financial uncertainty ($\sigma_{fin,t}$), the change in financial uncertainty ($\Delta\sigma_{fin,t}$). The data for macroeconomic and financial uncertainty is taken from Jurado et al. (2015). All data is quarterly U.S data and ranges from 1965 until 2015. Standarderrors are reported in squared brackets and the adjusted R^2 is denoted by $\bar{R}^2$.

Figure 8 presents two relations that are the starting point of the theoretical model. It depicts the consumption-output ratio and consumption growth together with their predicted counterparts when using financial leverage as a regressor. The Figure illustrates firstly, agents tend to consume more when financial leverage is high, and secondly, consumption growth tends to be low when financial leverage increases. The key mechanism underlying these effects can be explained as follows: With high leverage, creditors reduce the money they lend out to firms. This money is used to increase consumption contemporaneously, but lowers *consumption growth* in the future due to a lack of funding of investment.

While these results are rather suggestive, Table IX presents a more quantitative assessment of this relation. When predicting consumption growth with a preceding change in firm leverage we obtain an adjusted R^2 of almost 5%. When including other variables into the regression the leverage change remains a significant predictor of future consumption growth. The influence of all other variables is as expected. High levels of macroeconomic uncertainty and an increase in financial uncertainty both significantly lower future consumption growth. Table X presents the impact of the level of leverage in the economy on future changes in leverage. A high level of leverage indicates negative future growth for financial leverage. This relationship still remains significant when controlling for the same variables as above. Finally, we also argue that financial leverage causes financial volatility to go up contemporaneously as shown in Table XI. While increases in macroeconomic uncertainty seem to spill over to the financial market the influence of financial leverage does not lose significance when including this variable or past growth in financial volatility. We argue that a relative increase in debt boosts the probability of financial distress. This in turn lowers the price of firm equity attracting investment and supporting organic growth, or in other words deleveraging of firms, while being in a low growth environment.

	const.	lev_t	Δc_t	$\Delta\sigma_{mac,t}$	$\sigma_{mac,t}$	$\Delta\sigma_{fin,t}$	$\sigma_{fin,t}$	$\bar{R}^2$
1	0.038	-0.106^{**}						0.015
	[0.019]	[0.053]						
2	0.035^{*}	-0.103^{*}	0.405					0.011
	[0.020]	[0.053]	[0.912]					
3	-0.053	-0.132^{**}	1.534		0.115^{**}	0.258^{***}		0.090
	[0.039]	[0.055]	[0.988]		[0.048]	[0.073]		
4	-0.052	-0.128^{**}	1.500	0.070	0.105^{*}	0.232^{***}	0.006	0.082
	[0.042]	[0.056]	[0.995]	[0.126]	[0.059]	[0.087]	[0.039]	

Table X: Regression Leverage Growth

This table depicts results for regressions predicting future leverage growth (Δlev_{t+1}), defined as the debt-to-asset ratio of non-financial corporate businesses. The predicting variables are the leverage (lev_t), past consumption growth (Δc_t), macroeconomic uncertainty ($\sigma_{mac,t}$), the change in macroeconomic uncertainty ($\Delta\sigma_{mac,t}$), financial uncertainty ($\sigma_{fin,t}$), the change in financial uncertainty ($\Delta\sigma_{fin,t}$). The data for macroeconomic and financial uncertainty is taken from Jurado et al. (2015). All data is quarterly U.S data and ranges from 1965 until 2015. Standarderrors are reported in squared brackets and the adjusted R^2 is denoted by $\bar{R}^2$.

	const.	Δlev_t	$\Delta\sigma_{mac,t}$	$\Delta\sigma_{fin,t-1}$	$\bar{R}^2$
1	0.001	0.339^{***}			0.045
	[0.003]	[0.061]			
2	0.001	0.234^{***}	0.640^{***}		0.308
	[0.003]	[0.056]	[0.088]		
3	0.001	0.207^{***}	0.558^{***}	0.167^{***}	0.361
	[0.003]	[0.056]	[0.093]	[0.064]	

Table XI: Regression Financial Uncertainty Growth

This table depicts results for regressions explaining contemporary changes in financial volatility ($\Delta\sigma_{fin,t}$). The predicting variables are the leverage (Δlev_t), the change in macroeconomic uncertainty ($\Delta\sigma_{mac,t}$), the change in financial uncertainty ($\Delta\sigma_{fin,t-1}$) in the previous period. The data for macroeconomic and financial uncertainty is taken from Jurado et al. (2015). All data is quarterly U.S data and ranges from 1965 until 2015. Standarderrors are reported in squared brackets and the adjusted R^2 is denoted by $\bar{R}^2$.

D Additional Figures

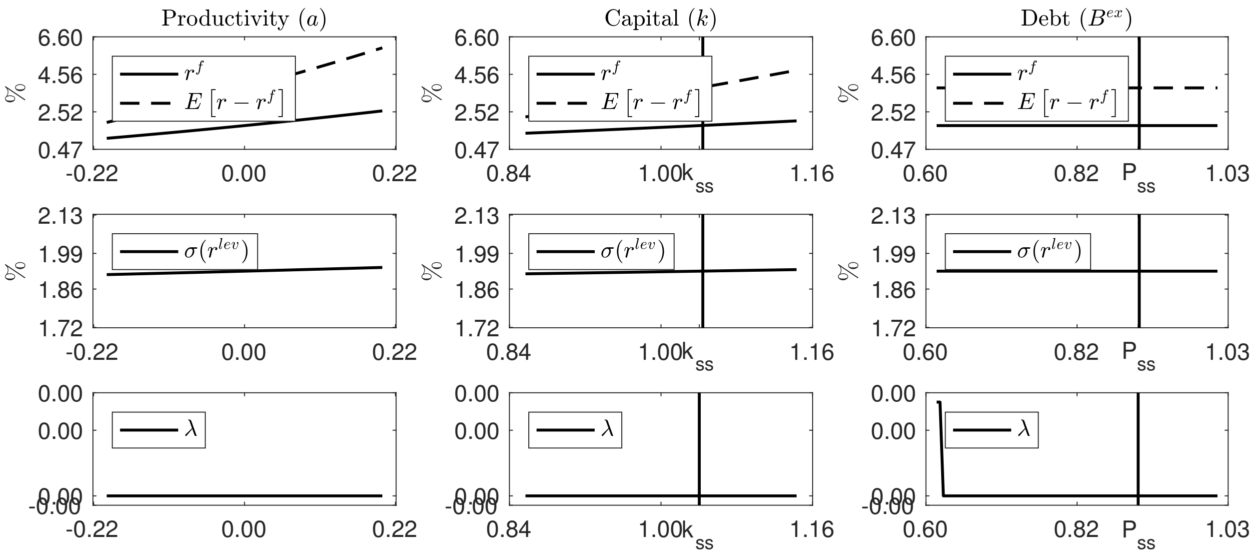


Figure 9: Asset Pricing - WA

This figure depicts asset pricing control variables as functions of the three state variables productivity (a) in the left column, physical capital (k) in the middle column, and accumulated debt before transfers (B^{ex}) in the right column for the WA calibration. The upper row displays the log risk-free rate (r^f) and the expected log unlevered risk premium $(E\left[r - r^f\right])$. The middle row displays the volatility of the unlevered return $(\sigma(r))$. The bottom row displays the shadow price of the leverage constraint (λ). The vertical line indicates the stochastic steady state of predetermined state variable. The bounds of the grid of approximation for the endogenous state variables are chosen such that the outer bounds are never violated when simulating. For the exogenous component of productivity the bounds are $\pm$ 3.25 unconditional standard deviations of the process.

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