

BANK REGULATIONS, FISCAL POLICIES AND GROWTH

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ABSTRACT

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This dissertation studies the effects of economic policies on investment, growth and welfare. The first chapter examines the welfare implications of bank capital requirements in a general equilibrium model in which a dynamic banking sector endogenously determines aggregate growth. Due to government bailouts, banks engage in risk-shifting, thereby depressing investment efficiency; furthermore, they over-lever, causing fragility in the financial sector. Capital regulation can address these distortions and has a first-order effect on both growth and welfare. In the model, the optimal level of minimum Tier 1 capital requirement is 8%, greater than that prescribed by both Basel II and III. Increasing bank capital requirements can produce welfare gains greater than 1% of lifetime consumption.

The second chapter studies fiscal policy design in an economy in which endogenous growth risk and asset prices are a first-order concern. When (i) the representative household has recursive preferences, and (ii) growth is endogenously sustained through R&D investment, fiscal policy alters both the composition of intertemporal consumption risk and the incentives to innovate. Tax policies aimed at short-run stabilization may substantially increase long run tax and growth risks and reduce both average growth and welfare. In contrast, policies oriented toward asset price stabilization increase growth, wealth and welfare by lowering the slope of the term structure of equity yields.

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CHAPTER 1 : Bank Capital Requirements: A Quantitative Analysis

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Abstract

This paper examines the welfare implications of bank capital requirements in a general equilibrium model in which a dynamic banking sector endogenously determines aggregate growth. Due to government bailouts, banks engage in risk-shifting, thereby depressing investment efficiency; furthermore, they over-lever, causing fragility in the financial sector. Capital regulation can address these distortions and has a first-order effect on both growth and welfare. In the model, the optimal level of minimum Tier 1 capital requirement is 8%, greater than that prescribed by both Basel II and III. Increasing bank capital requirements can produce welfare gains greater than 1% of lifetime consumption.

1.1. Introduction

Following the recent financial crisis, a change to bank regulatory capital requirements has become one of the key regulatory reforms under consideration as well as the subject of an extensive academic debate (see [Admati, DeMarzo, Hellwig, and Pfleiderer \(2010\)](#)). There is a strong consensus among policymakers in favor of higher bank capital requirements. The benefit of increased requirements is clear: having more capital helps banks better absorb adverse shocks and thus reduces the probability of financial distress. More capital would also reduce bank risk-taking incentives and thus improve investment efficiency and overall welfare. The banking industry has adamantly pushed back the effort to increase capital requirements however, arguing that an increase in the bank capital requirement could adversely affect bank lending and leads to lower economic growth. For effective policy making, it is thus vital to determine which effect dominates by quantitatively assessing the welfare implications of higher bank capital requirements.

To contribute to the current debate, this paper analyzes the welfare implications of bank equity capital requirements in a model with endogenous growth and a dynamic banking sector. The endogenous growth framework is important because it allows bank regulation to affect the growth rate of the economy. Banks play an important role in financing capital production, which in turn is used to produce final goods. In the model, sustained growth results from capital accumulation ([Romer \(1986\)](#)); therefore, any distortion in bank lending will have an effect on aggregate activities. This paper focuses on the distortions that bank bailouts cause and the role that bank capital requirements play in mitigating these distortions.¹

To this end, banks in the model economy are taken to be big banks, which entails the assumption that the government bails out banks with a high probability ex-post. This

¹There are other motivations for regulating banks, for example, to prevent contagious effects of bank failures on other banks or prevent asset fire sale that could cause additional failures. This paper focuses on bailout distortions because I think it is important and has first order effects. The role of bank capital regulation on containing financial contagion and asset fire sale are left for future research.

can be motivated from the recent financial crisis: many large institutions were bailed out through programs such as the Troubled Asset Relief Program (TARP) and the emergency Federal Deposit Insurance Corporation (FDIC) Temporary Liquidity Guarantee Program. This FDIC program guarantees bank debt and business checking accounts, which are not normally covered under the FDIC's deposit insurance. Nonetheless, the fall of Lehman Brothers, Washington Mutual and Wachovia has shown that governments can and do permit big banks to fail. The proposed model captures both dynamics.

The high probability of bailout implies that ex-ante bank depositors expect to be compensated even if banks default, and hence banks do not have to remunerate depositors entirely for bank default risk. Thus deposits are a cheap source of funding for banks. This causes banks to over-lever. Moreover, given the option to default due to limited liability, banks have incentives to risk-shift, lending to risky and less productive firms. This lending practice allows banks to reap the benefits when they succeed but escape costs when they fail. Risk-shifting by bankers has welfare implications because funds are used inefficiently. In addition to prospective government bailouts, other factors that determine bank capital structure in the model are bank default cost and equity issuance cost.

When calibrated to match key moments in the distribution of U.S. banks as well as macroeconomic quantities, the model produces a hump-shape in welfare, with the optimum at an 8% minimum Tier 1 capital requirement. This is 2 percentage points higher than the level of Tier 1 capital ratio recommended by Basel III in 2010, a measure that was adopted by U.S. regulators in July 2013, and 4 percentage points higher than the Basel II requirement. Relative to the 4% Basel II minimum Tier 1 capital ratio, the 8% level improves welfare by 1.1% of lifetime consumption. That is, requiring banks to hold a minimum of 8% in equity capital is equivalent to giving the representative agent with a 4% minimum capital requirement a 1.1% increase in consumption every period. What is more important is that welfare gains remain sizable even at very high levels of capital requirement.

The intuition for the result is as follows. At low levels of bank capital requirements, banks

raise funds from depositors to exploit the subsidy implicit in government bailouts. Banks, therefore, can provide more credit for capital production, which results in more capital being produced, leading in turn to higher growth. However, at low levels of bank capital requirements, because banks have the default option and do not have enough “skin in the game,” they engage in risk-shifting, lending to risky-low-productivity firms. Consequently, the average investment productivity in the economy is low and the rate of bank default is elevated, which leads to high capital losses. Therefore, in order to attain high growth, since investment is inefficient, substantial resources are used for capital production, and little is left for consumption. The net effect is lower welfare despite higher growth.

As the minimum capital constraint increases, so does the shadow cost of funding for banks. Moreover, the extent to which banks can exploit the implicit subsidy using deposits reduces, and a larger proportion of banks have to issue equity, for which they have to pay issuance cost. Therefore, more banks exit the economy, aggregate credit is tightened, less capital is produced, and growth is lowered. At the same time, however, bank lower leverage and lower incentive for risk-shifting result in lower default and higher overall capital production productivity and consumption. The effect on increasing productivity and consumption dominates the lowered growth and leads to a graduate increase in welfare, reaching a maximum of 1.1% of lifetime consumption when the capital requirement is at 8%.

As the capital requirement increases above 8%, lower welfare gains result. The reasons are twofold. The first is equity flotation costs. Since banks must pay issuance costs and these are rebated back to households, the private cost of issuing equity is higher than the social cost. Therefore, the funds that are raised are lower than those in a centralized economy. This leads to lower lending, lower capital production, and hence lower growth. The second reason is the presence of the “learning-by-doing” spillover that is inherent in the [Romer \(1986\)](#) endogenous growth model. In this class of models, capital accumulation improves overall final good production productivity, and because this is external to each individual final good producer, decentralized allocations entail under-investment and lower capital

accumulation. Consequently, any policy that further discourages investment lowers welfare. In the current setup, higher bank capital requirements increase the private cost of capital for banks, causing a reduction in lending and thus a lower accumulated stock of capital. This brings the decentralized allocations further away from the first-best allocation and lowers welfare gains.

To the best of my knowledge, the proposed model is the first, in a fully specified dynamic general equilibrium setting, to quantitatively investigate the impact of capital requirements on deterring moral hazard, on financing and hence growth.

1.1.1. Related Literature

This paper is at the intersection of a large literature on banking and macroeconomics. On the macroeconomic side, this study is related to a burgeoning strand of literature started by [Kung and Schmid \(2011\)](#) that uses endogenous growth models to generate long-run consumption growth risk, a feature that is essential for explaining asset market data ([Bansal and Yaron \(2004b\)](#)). [Croce, Nguyen, and Schmid \(2012\)](#) examine the link between fiscal policies and pessimism in the spirit of [Hansen and Sargent \(2010\)](#). [Croce, Nguyen, and Schmid \(2013\)](#) analyze fiscal policy design when there is a tradeoff between short-run stabilization and long-run growth risk. More closely related to the setup in the present paper, [Opp \(2010\)](#) focuses on the role of the financial sector in amplifying shocks in a Schumpeterian growth model.

On the banking side, there are many theoretical studies on moral hazard due to public guarantees. In the context of deposit insurance, [Merton \(1977\)](#) shows that deposit insurance provides banks with a put option, and thus without any regulation banks would find it privately optimal to take on more risk. Furthermore, [Mailath and Mester \(1994\)](#) analyze bank closure policy and show that over a wide region of parameters, “too-big-to-fail” banks arise in equilibrium and can lead to excessive risk-taking. There is also a strand of literature that predicts a reduction in risk-taking following such guarantees. Bailouts raise the

charter value for banks because banks then benefit from the lower cost of funding. This induces banks to be more conservative in lending, because they have more to lose in default (Keeley (1990)). Cordella and Yeyati (2003) and Hakenes and Schnabel (2010) show that the net effect on risk-taking depends on which channel dominates. Consistent with these theoretical predictions, in the present paper banks risk-shift only when their charter values are sufficiently low, and they do not engage in risk-shifting otherwise.

The main instrument used by regulators to restrict bank risk-shifting incentive is minimum capital requirements, and there are many theoretical studies on the effectiveness of this instrument. For example, Hellmann, Murdock, and Stiglitz (2000), Repullo (2004), and Morrison and White (2005) analyze the role of capital in disciplining bank moral hazard. Allen, Carletti, and Marquez (2011) study capital regulation in the case in which credit market competition induces banks to hold capital in excess of the regulatory constraint, a fact that is robust in the data. The authors show that the decentralized solution entails banks' holding a level of capital higher than the regulatory solution. In a similar vein, Mehran and Thakor (2011) argue that there is a positive link between bank capital and bank value because bank capital encourages monitoring; the authors also provide empirical support for their theoretical prediction. Acharya, Mehran, and Thakor (2012) study bank capital requirements when banks face asset substitution by shareholders and rent-seeking by managers, and they analyze the trade-offs of the use of capital regulation to reduce risk-taking vs. allowing debt to discipline managerial rent-seeking. Harris, Opp, and Opp (2013) examine the effectiveness of bank capital requirements in the existence of competition between regulated banks and unregulated investors. They show that when competition is sufficiently strong, bank capital regulation becomes ineffective. The extant literature thus far has not focused on the impact of capital requirements on growth, however; the present paper addresses this gap in the literature.

Empirical studies related to the impact of higher bank capital requirements on lending and costs of capital are limited. Kashyap, Stein, and Hanson (2010) estimate that, for a 10

percentage point increase in the capital ratio, the long-run steady-state weighted average cost of capital for banks increases by 25–45 basis points. [Baker and Wurgler \(2013\)](#) estimate the impact on average cost of capital of the same policy to be 60–90 basis points. In an interesting study exploiting data on a costly loophole used to bypass the capital requirement, [Kisin and Manela \(2013\)](#) show that a 10 percentage point increase in the capital ratio leads to at most a three basis points increase in banks’ cost of capital. These studies shed light on the potential impact of capital requirements on real activities; however, it is difficult to conclude whether such a policy would be beneficial due to the uncertain and potentially nonlinear general equilibrium effects from a substantial increase in the capital ratio. My paper complements these studies in this respect.

Quantitative studies on the welfare impact of bank capital requirements are even more limited. [Van den Heuvel \(2008\)](#) was the first to quantitatively study the welfare cost of bank capital requirements. Using yield spread data, he shows that U.S. regulation at the time was too high due to a reduction in liquidity creation. [Corbae and D’Erasmus \(2012\)](#) study capital requirements when there is competition between big and small banks. They find that an increase in the capital requirement leads to a fall in the loan supply and a rise in the interest rate. However, neither [Van den Heuvel \(2008\)](#) nor [Corbae and D’Erasmus \(2012\)](#) address the concern on the effect of capital regulation on growth, which is at the heart of the current policy debate.

In this paper, banks optimally determine their capital structure by trading off bank default costs, the benefit of implicit guarantees, and equity issuance costs, all while operating in an endogenous growth environment. Thus, the present study complements the literature on understanding the welfare implications of capital regulations. This paper is the first, to the best of my knowledge, to quantitatively investigate the impact of capital requirements on growth and risk-shifting in a fully specified dynamic general equilibrium banking model.

More broadly, my paper is related to the macro literature in which models contain financial intermediaries. [He and Krishnamurthy \(2012, 2013\)](#) study the nonlinear behavior of risk

premia and asset volatility in crises in a setup in which financial intermediary capital plays an important role in pricing assets. [He and Krishnamurthy \(2011\)](#) and [Brunnermeier and Sannikov \(2013\)](#) focus on the amplification of shocks, where in equilibrium the economy can enter systemic crisis states. [Adrian and Boyarchenko \(2012\)](#) study leverage cycles in a model in which financial intermediaries can produce capital more efficiently than households and intermediary leverage is restricted by a value-at-risk constraint. They show that this constraint plays an important role in amplifying shocks; moreover, varying the tightness of the value-at-risk constraint produces an inverted U-shape in households' welfare. As the authors pointed out, however, this result depends on the assumption that intermediaries finance themselves only with debt. Moreover, as is common in this literature, [Adrian and Boyarchenko's](#) paper relies on heterogeneity in preferences between financial intermediaries and households. This makes it somewhat difficult to analyze welfare effects. In my model, homogeneous households own all productive assets, and welfare is readily comparable between different levels of capital constraint. Importantly, in my model financial intermediaries hold financial assets—giving loans to firms, instead of directly investing in capital projects. This makes it easier to interpret these intermediaries as banks and examine bank capital regulations.

In a different setup, [Gertler and Kiyotaki \(2013\)](#) examine bank instability in a model where households are subject to liquidity shocks, leading to bank runs as in [Diamond and Dybvig \(1983\)](#). [Gertler, Kiyotaki, and Queralto \(2011\)](#) consider a model with financial intermediation in which the intermediaries can issue outside equity as well as short term debt, making intermediary risk exposure an endogenous choice. In a DSGE model with financial intermediaries, as in [Holmstrom and Tirole \(1997\)](#), [Meh and Moran \(2010\)](#) study the role of intermediary capital in the propagation of shocks. Similarly, [Angeloni and Faia \(2013\)](#), using a financial sector as in [Diamond and Rajan \(2000, 2001\)](#), analyze capital regulation and monetary policy. In [Angeloni and Faia's](#) work, growth is *exogenously* determined, however, and it is not clear why banks should be regulated in the first place.

The rest of the paper is organized as follows. Section 1.2 reviews evidence on bank risk-shifting. Section 2.2 discusses the model, and Section 1.4 gives a quantitative assessment of bank capital requirements. Section 1.5 concludes.

1.2. Evidence on Bank Risk-Shifting

In the model described in this paper bailouts cause banks to risk-shift; this prediction is well known within existing banking theories and has ample empirical support. As this is a prominent feature of my model, I nonetheless review these evidence here. [Gropp, Gruendl, and Guettler \(2013\)](#) use a natural experiment in the removal of government guarantees for German savings banks; they show that after guarantees are removed, banks reduce credit risk and adjust their liabilities away from risk-sensitive debt instruments. Moreover, their bond yield spreads increase significantly. The authors conclude that public guarantees result in substantial moral hazard effects. Furthermore, [Dam and Koetter \(2012\)](#) use a data set of actual bailouts of German banks from 1995–2006 and show that increases in bailout expectations significantly heighten bank risk-taking.

In a recent study on risk-shifting, [Duchin and Sosyura \(2013\)](#) use data on bank applications for government assistance under the TARP and show that banks make riskier loans and shift investment portfolios toward riskier securities after being approved for government assistance. This is consistent with the moral hazard story, as an approved for assistance through TARP signals government support going forward. In a related study, [Black and Hazelwood \(2012\)](#) compare the risk ratings of commercial loan originations of TARP recipient and non-recipient banks and show that loan originations risk increases at large TARP-recipient banks. On a related note, [Drechsler, Drechsel, Marques-Ibanez, and Schnabl \(2013\)](#) use a unique data set from the European Central Bank (ECB) and show evidence that during the recent financial crisis, of banks that borrow from the Lender of Last Resort—the ECB in this case—those with lower financial strength borrowed more and pledged increasingly risky collateral. The authors test four different theories and show that risk-shifting by banks is most consistent with this fact.

There is also ample evidence of risk-shifting owing to another form of public guarantee: deposit insurance. [Grossman \(1992\)](#) uses a data set of insured and uninsured thrifts in the 1930s and documents that after several years, insured thrifts engaged in relatively riskier lending activities as measured by the foreclosures-to-assets ratio. [Wheelock and Wilson \(1995\)](#) show that deposit insurance membership increases the probability of bank failure. From cross-country evidence, using differences in the presence and design of deposit insurance schemes, [Demirguc-Kunt and Detragiache \(2002\)](#) find that countries with explicit deposit insurance are more likely to have banking crises. All in all, existing empirical evidence suggests that when there are public guarantees, banks engage in risk-shifting.

1.3. Model

The model consists of four types of agents: (1) households, who consume and save, (2) final good producers, who produce the consumption good, (3) capital-producing firms, who produce capital, and (4) banks, who raise funds from households and lend to capital-producing firms. I will now describe each of the agents in turn.

1.3.1. Households

The economy is populated by a measure one of identical households who have CRRA preferences over consumption C_t ,

$$U_0 = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-1/\psi} - 1}{1 - 1/\psi},$$

where ψ is the intertemporal elasticity of substitution and $\beta \in (0, 1)$ the subjective discount factor. In every period, households are also endowed with one unit of labor, $L_t = 1$, and since they do not value leisure, they supply labor inelastically. The discount factor can be written as usual:

$$M_{t+1} = \beta \left(\frac{C_{t+1}}{C_t} \right)^{-1/\psi}.$$

Households are owners of capital-producing firms, banks, and final good producers. In

addition to equity shares, they hold deposits issued by banks. I assume that they can split their deposits and equity shares equally among all banks, so that the law of large numbers applies and all idiosyncratic risks, as will be specified in subsection 1.3.3 and 1.3.4 below, are diversified away. All proceeds are returned to the household at the end of the period.

1.3.2. Final Good Production

There is a measure one of final good producers. Producer $u \in [0, 1]$ has technology

$$y_{ut} = A_t k_{ut}^\alpha (K_t l_{ut})^{1-\alpha}, \quad (1.1)$$

where A_t is total factor of productivity, k_{ut} is producer u 's capital, l_{ut} is labor demand, and K_t is the aggregate level of capital, which producer u takes as given. This is a simple way to generate endogenous growth as in Romer (1986) via the “learning-by-doing” externality. Aggregate capital and labor are then simply

$$\int_0^1 k_{ut} du = K_t \quad (1.2)$$

and

$$\int_0^1 l_{ut} du = L_t = 1. \quad (1.3)$$

Since all producers function at the same capital-effective labor ratio, aggregate output can be written as

$$Y_t = \int_0^1 y_{ut} du = A_t K_t L_t^{1-\alpha} = A_t K_t. \quad (1.4)$$

In aggregate, therefore, there is no diminishing return to capital despite diminishing return at the individual final good producer level. This is the source of growth in the model. Capital accumulation by an individual final good producer increases productivity by all other producers through aggregate capital K_t , but since this is taken as external to the producer, in the decentralized allocations there is under-investment. This externality on the production side will have important implication for bank capital regulations.

Let p_t^I be the relative price of capital. The final good producer u chooses investment i_{ut}^d and dividend d_{ut} to maximize shareholders' value

$$v(k_{u,t-1}, K_t, A_t) = \max_{i_{ut}^d, d_{ut}, l_{ut}} d_{ut} + \mathbb{E}_t M_{t+1} v(k_{ut}, K_{t+1}, A_{t+1}), \quad (1.5)$$

subject to

$$d_{ut} = y_{ut} - W_t l_{ut} - p_t^I \cdot i_{ut}^d - \frac{a}{2} \left(\frac{i_{ut}^d}{k_{u,t-1}} \right)^2 k_{u,t-1} \quad (1.6)$$

$$k_{ut} = (1 - \delta) k_{u,t-1} + i_{ut}^d, \quad (1.7)$$

where δ is the depreciation rate of capital and W_t the equilibrium wage rate. The last term in (1.6) captures investment adjustment costs, a standard assumption in the macrofinance literature. Aggregate demand for the capital good is then

$$I_t^d = \int_0^1 i_{ut}^d du = i_{ut}^d,$$

where I am considering the symmetric equilibrium in which all final good producers behave identically. The first-order condition with respect to capital implies that, in the symmetric equilibrium, the price of capital satisfies the condition

$$p_t^I = A_t \alpha L_t^{1-\alpha} - a \frac{I_t^d}{K_{t-1}} + \mathbb{E}_t M_{t+1} \left[p_{t+1}^I (1 - \delta) + \frac{a}{2} \left(\frac{I_{t+1}^d}{K_t} \right)^2 + a \left(\frac{I_{t+1}^d}{K_t} \right) (1 - \delta) \right]. \quad (1.8)$$

In equilibrium, aggregate capital demand must equal aggregate capital supply produced by capital-producing firms. Since in the model financial frictions mainly affect the capital supply, this is the channel through which bank regulations affect the whole economy.

1.3.3. Capital-Producing Firms

The economy consists of islands indexed by j . One can think of an island as an industry or a state; what is important, as will become clear, is that there is an idiosyncratic shock specific

to j that cannot be diversified away. On each island, at the beginning of each period, a large number of infinitesimal capital-producing firms is born. These firms are short-lived.

Each firm is endowed with a project with a required investment of i_t today for production tomorrow. i_t is taken as given by all agents in the economy. Those firms that get financing invest today and then produce capital, settle payments, and exit the economy tomorrow. Those that do not get financing exit the economy immediately. Then new firms are born.

Firms on any island are of two types: *normal firms* and *risky-low-productivity firms*. For the normal firm, investing i_t today produces $z_{j,t+1} \cdot i_t$ units of capital tomorrow, where z_{jt} is an island-specific persistent shock:

$$\log z_{j,t+1} = \rho_z \log z_{jt} + \sigma_z \epsilon_{zj,t+1}, \quad \forall j.$$

As for the risky-low-productivity firm, investing i_t today produces $z_{j,t+1} \epsilon_{jf,t+1} \cdot i_t$ units of capital tomorrow, where $\epsilon_{jf,t+1}$ is specific to firm f in island j . This shock is independent and identically distributed across firms, that is,

$$\log \epsilon_{jft} \sim \mathcal{N} \left(-\mu - \frac{1}{2} \sigma_\epsilon^2, \sigma_\epsilon \right) \quad \forall j, f, t.$$

Therefore, risky-low-productivity firms are both riskier because they are exposed to an additional shock, and on average less productive, $\mu \geq 0$, than normal firms. The technology for both type of firms can be written compactly as

$$z_{j,t+1} \cdot [\chi \epsilon_{jf,t+1} + (1 - \chi)] \cdot i_t,$$

where χ is an indicator function equal to one if the firm is a risky-low-productivity firm and zero if it is a normal firm. To economize on notation, I drop the subscript j where there is no risk of confusion.

To invest, firms must pay a small constant marginal operating cost o . This operating cost is

however can be raised within the households that own the firms, that is, for each firm, the internal equity is enough to cover operating cost. As for the funds that must be invested into the firms, i_t , because of unmodeled commitment or moral hazard frictions they cannot borrow directly from other households. They can, however, approach banks for funds because banks have a monitoring technology that solves the moral hazard problem.² Since there is a large number of firms on each island, firms behave competitively, and the lending rate R^l is determined by firms' zero profit condition, taking into account the default option and whether firm f is a risky firm:

$$\mathbb{E}_t M_{t+1} \underbrace{\max\{0, p_{t+1}^I z_{t+1} [\chi \epsilon_{f,t+1} + (1 - \chi)] - R^l(\chi, z_t)\}}_{\text{Firm's default option}} \cdot i_t = \underbrace{o \cdot i_t}_{\text{Operating cost}} \quad (1.9)$$

Recall that p_t^I is the market price of capital. Thus the left hand side of equation (1.9) is firm f 's expected discounted revenue net of loan repayment. The 'max' operator captures the fact that firm has the option to default on its loan if the proceeds from the sale of capital are not enough to cover the loan repayment. The firm's default option implies that there exists a firm-specific cutoff in terms of the shock tomorrow $\bar{z}_{t+1}(z_t, \chi, \epsilon_{f,t+1})$ such that firm f will default if the productivity z_{t+1} on the island falls below that level.

1.3.4. Banks

On each island, banks differ in the net cash, denoted by π_t , that they have on hand at the beginning of the period. If not exiting the economy, each bank must choose one firm to

²For example, because the capital-producing firms are short-lived, they cannot commit to paying back their loans. Banks, however, can enforce their claims better than households because of their expertise and thus make lending possible (Diamond and Rajan (2000, 2001)). Another possibility is that firms can invest in bad projects and get private benefits from these bad projects. Because of this moral hazard problem, financing from households is not feasible. Banks however can monitor these firms, and thus financing become possible through banks (Holmstrom and Tirole (1997)). The goal of this paper is to study the quantitative implications of bank capital requirements, and so the emergence of bank is abstracted away.

finance.^{3,4} A bank's revenues realized next period from lending this period are then

$$\begin{aligned} \hat{\pi}_{t+1}(\chi_t, z_t, z_{t+1}, \epsilon_{f,t+1}) = i_t & \left[R^l(\chi_t, z_t) \cdot \mathbf{1}_{\{z_{t+1} \geq \bar{z}_{t+1}\}} \right. \\ & \left. + \underbrace{\eta \cdot p_{t+1}^I z_{t+1} [\chi_t \epsilon_{f,t+1} + (1 - \chi_t)]}_{\text{Liquidated asset value}} \cdot \mathbf{1}_{\{z_{t+1} < \bar{z}_{t+1}\}} \right], \end{aligned} \quad (1.10)$$

where η is the fraction of capital that could be recovered from the firm if it defaults, and with a slight abuse of notation, where χ_t denotes the bank's choice of the type of firm to finance this period. This also means that there is no asymmetric information, and banks know the type of firms to which they give loans.

If it finances a firm, a bank must spend resources to monitor it. In particular, I assume the monitoring cost is m per unit of investment. One could think of this cost as the intermediation cost of providing credit.

Each bank could finance its loan using a mixture of debt and equity. Let b_t be the amount of deposits outstanding and R_t^b the required deposit rate. Further, let d_t be the net equity issuance. The bank's budget constraint is

$$\underbrace{\hat{\pi}_t - R_t^b b_t}_{\equiv \pi_t} - m \cdot i_t + b_{t+1} = i_t + d_t, \quad (1.11)$$

where the net cash, π_t , is revenues from lending last period net of current deposit liabilities. The left-hand side of (1.11) is the source of funding and the right hand-side is the use. In addition to new debt b_{t+1} issued, the bank's resources come from lending last period, net of interest payments on deposits and monitoring costs. Funding is used for financing a firm

³One could think that each bank finances a portfolio of firms, which have a firm-level idiosyncratic shock. By the law of large numbers, the firm-level idiosyncratic risk is diversified away, but because all firms are in the same island, the island-specific shock is not. Therefore, allowing banks to hold a portfolio of firms is equivalent to the current setup. Notice that when a bank wants to risk-shift, it wants exposure to a firm specific shock, and so it is optimal for a bank *not* to diversify this risk away.

⁴Either financing or exiting is equivalent to giving banks the option to not finance any firm, but they have to pay a fixed operating cost that is the same as an entry cost, to be described later. Thus not financing any firm and paying the fixed operating cost is equivalent to exiting the economy today and re-enter next period after paying the entry cost.

this period and for paying dividends.

If the bank issues equity, i.e., $d_t < 0$, it has to pay a flotation cost. To better match quantity, as is common in the dynamic corporate literature, I assume that equity issuance costs are proportional to the amount issued ([Gomes \(2001\)](#); [Hennessy and Whited \(2005, 2007\)](#); [Gomes and Schmid \(2010b\)](#)). In particular,

$$\Phi(d_t) = -\phi \cdot d_t \mathbb{1}_{\{d_t < 0\}}. \quad (1.12)$$

The indicator function means that this cost is only applied when the bank issues equity. Distributions to bank shareholders are then just the equity payout net of issuance costs:

$$d_t - \Phi(d_t). \quad (1.13)$$

1.3.4.0.1 Bank equity valuation. Bank equity value is defined as the discounted sum of all future distributions. If the prospect of operating is sufficiently bad, equity holders will choose to close down the bank, i.e., the bank exits the economy. Conditional on the bank exiting the economy, there are two distinct cases. The first is when lending revenue is not enough to cover deposit liabilities. In this case, the bank will stop servicing its deposits and exit; that is, the bank defaults. In the second case, the bank's revenue is greater than deposit liabilities, but economic prospects are sufficiently low that it is optimal for the bank to close down and pay out its residual cash after servicing its depositors. The value of the bank upon exit is then $V_{xt} = \max\{0, \pi_t\}$. The equity value of the bank is thus the solution to the problem

$$V_t(z_t, \pi_t) = \max\{V_{xt}, \max_{b_{t+1}, x_t, d_t} d_t - \Phi(d_t) + \mathbb{E}_t M_{t+1} V_{t+1}(z_{t+1}, \pi_{t+1})\} \quad (1.14)$$

subject to the loan demand schedule (1.9), the budget constraint (1.11), and the minimum bank equity capital requirement

$$\frac{\pi_t - m \cdot i_t - d_t}{i_t} \geq \bar{e}, \quad (1.15)$$

where the net cash next period is

$$\pi_{t+1} = \hat{\pi}_{t+1}(\chi_t, z_t, z_{t+1}, \epsilon_{f,t+1}) - R_{t+1}^b b_{t+1}. \quad (1.16)$$

The denominator in (1.15) is the loan given to the firm, and that represents the bank's total assets. In the numerator, the first two terms are retained earnings and the last term is the dividend payout (d_t is positive) or the equity raised (d_t negative); thus, the numerator represents the total equity that the bank uses to finance its assets. The minimum capital requirement imposes that at least a fraction \bar{e} of the bank assets must be financed by the bank equity capital.

1.3.4.0.2 Bank deposit valuation. When a bank decides to stop servicing its deposits, depositors are bailed out with probability λ . To keep the analysis focus, bailouts are assumed to be financed using a lump-sum tax, so that no additional distortion is introduced. If not bailed out, depositors recover a fraction θ of the bank's revenues.⁵ The market price of the bank deposits satisfies the condition

$$b_{t+1} = \mathbb{E}_t M_{t+1} \left[\begin{array}{c} \text{Bank does not default} \quad \text{Bank defaults--bailed out} \\ \overbrace{R_{t+1}^b b_{t+1} \cdot \mathbb{1}_{\{V_{t+1}>0\}}} + \overbrace{\lambda R_{t+1}^b b_{t+1} \cdot \mathbb{1}_{\{V_{t+1}=0\}}} \\ + \underbrace{(1-\lambda)\theta \hat{\pi}_{t+1} \cdot \mathbb{1}_{\{V_{t+1}=0\}}}_{\text{Bank defaults--not bailed out}} \end{array} \right]. \quad (1.17)$$

⁵There are various ways to generalize this model to capture other aspects of bank capital regulation. For example, the probability of bailout λ could be a function of the number of failed banks. This captures the phenomenon of too-many-to-fail (Acharya and Yorulmazer (2007)). The recovery parameter θ could also be a *decreasing* function of the number of failed banks; this captures asset fire sale externality. The bank capital requirement is then also a device to contain fire sale externality.

Because of the probability of bailout, the bank does not have to compensate depositors fully for the risk that it undertakes. Moreover since the bank has the option to default when its loan goes bad, the bailout creates incentives for the bank to finance risky-low-productivity firms. This is the typical risk-shifting that has been highlighted in the theoretical banking literature discussed in sections 1.1.1 and 1.2.

1.3.4.0.3 Entry and exit. Every period, banks enter and exit the economy. As discussed earlier, banks exit when the prospect of operating is sufficiently low, that is, when

$$V_t = V_{xt}.$$

Each period a mass of potential new banks arrives in the economy. Entering entails a setup cost that is proportional to asset size $e \cdot i_t$. Since in this model growth is endogenous, all quantities, including the equity value of the bank, grow at the same rate. The entry cost is modeled proportional to investment to make sure it will not vanish in the long run relative to trend and hence will stay relevant. The potential new bank observes the aggregate state of the economy, but before knowing which island it will be on, it has to pay the setup cost. Once the setup cost is paid, the potential new bank draws the initial shock from the stationary distribution of z_t . Thus, entry occurs if and only if

$$e \cdot i_t \leq \mathbb{E}_z V_t(z_t, \pi_t = 0), \quad (1.18)$$

where the expectation is taken with respect to the long-run distribution of z_t . The free-entry condition (1.18) holds with equality when entry is positive.

1.3.4.0.4 Distribution of banks. The behavior of each bank is completely characterized by its individual state (z_t, π_t) . We can thus summarize the aggregate distribution of banks with a measure defined over this state space. Let $\Gamma(z_t, \pi_t)$ denote the mass of banks

with state (z_t, π_t) . The law of motion for the measure of banks is given by

$$\Gamma_{t+1}(z_{t+1}, \pi_{t+1}) = T((z_{t+1}, \pi_{t+1})|(z_t, \pi_t)) [\Gamma_t(z_t, \pi_t) + B_t(z_t, \pi_t = 0) + E_t(z_t, \pi_t = 0)]. \quad (1.19)$$

Here B_t is the mass of banks that defaults and gets bailed out. They continue to operate with zero net cash. E_t is the measure of new banks, and they enter with no cash. Moreover, for any set $\Theta_{t+1} \subset Z \times \Pi$, the space of possible combination of (z, π) , $T(\Theta_{t+1}|(z_t, \pi_t))$ the transition function is defined as

$$T(\Theta_{t+1}|(z_t, \pi_t)) = \int_Z \int_{\Omega} \mathbb{1}_{\{(z_{t+1}, \pi_{t+1}) \in \Theta_{t+1} | \epsilon_{t+1}\}} \mathbb{1}_{\{V_t > V_{xt}\}} dP(\epsilon_{t+1}) dQ(z_{t+1}|z_t), \quad (1.20)$$

where Ω is the state space for ϵ , the additional risk exposure for the risky-low-productivity firm. The first indicator is one if given ϵ_{t+1} , the pair (z_{t+1}, π_{t+1}) belongs to Θ_{t+1} , and zero otherwise. The second indicator function takes into account the bank's endogenous exit decision. Q is the transition function for the exogenous shock z , and P is the cumulative distribution function of the ϵ shock.

1.3.4.0.5 Bank capital structure and risk-shifting. In addition to the bank's charter value, which is endogenous in the model, bank capital structure is determined by three forces: the equity issuance cost, the bailout probability, and the bank bankruptcy cost. Fig. 1 shows how risk-shifting is manifested in the model and how banks finance their loans when they risk-shift. This figure plots the bank's policy functions on a particular island, where island-specific productivity is low. Because of low productivity, the bank's charter value is sufficiently low, and this leads all banks on the island to engage in risk-shifting (top right panel). If they do not exit (when the exit decision is zero in the top left panel of Fig. 1), they lever up as much as they can, reaching the minimum capital constraint (bottom left panel), and pay out all their cash as dividends (bottom right panel). This is intuitive. Because banks have the option to default, if they want to risk-shift, they do not want to put in any of their own funds, so that if they succeed they can reap the benefit,

whereas if they fail they will lose the minimum amount of their own equity capital. This is where one can see how minimum capital requirements could curb the banks' risk-shifting incentives. Imposing greater capital requirements makes banks internalize the downside of risky lending, since they stand to lose more in the event that their loans default. Therefore, capital regulations induce banks to be more conservative in their lending.

On the island where productivity is high, the charter value of banks is high, and therefore they do not have the incentive to risk-shift (top left panel, Fig. 2). On this island, the Myers and Majluf (1984) pecking-order theory of capital structure holds for banks. Banks use internal funds if they have any (equity payout is zero, bottom right panel of Fig. 2), then issue deposits, and only issue equity as a last resort (equity payout is negative), when the minimum capital constraint binds them. When internal funds are more than enough to finance loans, banks issue dividends. Bank capital structure in this model is thus rich due to heterogeneity in investment opportunities, captured by the island-specific shocks that banks face on different islands.

1.3.5. Aggregation

Aggregate capital produced can be computed from the following expression:

$$I_{t+1}^s = i_t \int \int z_{t+1} [\chi_t \epsilon_{f,t+1} + (1 - \chi_t)] \left[\begin{array}{c} \text{Firm defaults--Bank not} \\ \mathbb{1}_{\{z_{t+1} \geq \bar{z}_{t+1}\}} + \eta \underbrace{\mathbb{1}_{\{z_{t+1} < \bar{z}_{t+1}\}} \mathbb{1}_{\{V_{t+1} > 0\}}}_{\text{Both default}} \\ + \eta(\lambda + (1 - \lambda)\theta) \underbrace{\mathbb{1}_{\{z_{t+1} < \bar{z}_{t+1}\}} \mathbb{1}_{\{V_{t+1} = 0\}}}_{\text{Both default}} \end{array} \right] \times dP(\epsilon_{t+1} | z_{t+1}, \pi_{t+1}) d\Gamma_{t+1} \quad (1.21)$$

This aggregation takes into account shocks that firms get next period and the losses due to firms defaulting, banks defaulting, and government bailouts.

In equilibrium, aggregate savings S_t must satisfy

$$S_t = (1 + o + m) i_t \int d\Gamma_t.$$

That is, aggregate savings must equal total lending plus operating costs invested in capital-producing firms by their owners and total costs of financial intermediation. Finally, the aggregate resource constraint is

$$C_t = Y_t - S_t - E_t e \cdot i_t. \quad (1.22)$$

Recall that E_t is the measure of new banks and $e \cdot i_t$ is entry cost. Notice that unlike in the dynamic corporate finance literature, equity issuance costs are rebated to the households. Therefore, bank equity regulations will not increase the deadweight loss due to equity issuance costs. This assumption is made to isolate the welfare effect of private incentives in bank equity issuance from any possible social cost due to deadweight losses.

1.3.6. *Equilibrium growth*

The aggregate capital accumulation in the model reads

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

Capital market clearing implies that $I_t^d = I_t^s$; moreover, from (1.4), growth in equilibrium is

$$\frac{Y_{t+1}}{Y_t} = \frac{A_{t+1}}{A_t} \frac{K_{t+1}}{K_t}.$$

Thus, growth in the model comes from either growth in TFP or growth in capital. When TFP is stationary, as it is in the current setup, economic growth is endogenously determined by capital accumulation. Furthermore, since banks play a crucial role in the financing of investment, regulatory capital requirements will affect growth. The goal of the next section is to quantify the overall effect.

1.4. Quantitative Assessment

1.4.1. Regulation and bank data

1.4.1.0.6 Regulation. In July 2013, the Federal Reserve Board approved the final rules to implement in the United States bank capital regulations proposed by the Basel Committee on Banking Supervision known as Basel III.⁶ These rules include, among other requirements, an increase in the Tier 1 minimum capital requirement from 4% to 6% for all banks. In this paper, loans to capital-producing firms are best matched to commercial and industrial loans in the data, and it is natural to interpret capital in the model as Tier 1 capital since these are all common equity and retained earnings. Hence I will calibrate the model to previous regulation, i.e. 4%, to best match macro quantities as well as bank data counterparts from the Reports of Condition and Income, commonly known as the Call Reports and consider welfare implications of different levels of capital requirements relative to this benchmark.

1.4.1.0.7 Bank data. Data for banks comes from Call Reports 1984Q1-2010Q4, the FDIC failed bank list and the Federal Reserve Bank of Chicago Mergers and Acquisitions database. Consistent time series are constructed as is standard in the literature ([Kashyap and Stein \(2000\)](#); [den Haan, Sumner, and Yamashiro \(2007\)](#); [Corbae and D’Erasmus \(2012\)](#)). See Appendix [A.1](#) for details. Banks in the model are mapped to big banks in the data, and since it is not clear what the cutoff in size should be, I report statistics for different percentiles in terms of bank total assets. Bank size is not determined in the model; thus, for consistency, failure and exit in the data are calculated not in terms of frequencies but in terms of total bank assets. It is important to note that, in the model, the bank stops servicing its deposits and then depositors get bailed out. However, in the data, in many cases, banks get bailed out before they become insolvent.⁷ These bailouts are not recorded

⁶For details, see <http://www.federalreserve.gov/newsevents/press/bcreg/20130702a.htm>

⁷During a private interview with the Financial Crisis Inquiry Commission, Federal Reserve Chairman Ben Bernanke said “out of maybe ... 13 of the most important financial institutions in the United States, 12 were at risk of failure within a period of a week or two.” Moreover, many banks that were approved for

Table 1: Benchmark Calibration

Description	Symbol	Value	Source/Target
TFP level	A	0.11	Match consumption growth
Income share of capital	α	0.45	Cooley and Prescott (1995)
Subjective discount factor	β	0.987	Cooley and Prescott (1995)
Capital depreciation rate	δ	0.025	Jermann and Quadrini (2012)
Intertemporal elasticity of substitution	ψ	1.1	Bansal, Kiku, and Yaron (2013)
Loan recovery parameter	η	0.8	Gomes and Schmid (2010b)
Investment adjustment cost	a	5	Gilchrist and Himmelberg (1995)
Monitoring cost	m	0.02	Philippon (2012)
Bank deposit recovery parameter	θ	0.7	James (1991)
Equity issuance cost	ϕ	0.025	Gomes (2001)
Probability of bailout	λ	0.9	Koetter and Noth (2012)
Firm's operating cost	o	0.023	Average return on loan
Standard deviation of ϵ	σ_ϵ	0.363	x-std return on loan
Bank entry cost	e	0.06	Exit rate
Reduction in productivity of risky firm	μ	0.02	Average net interest margin
Persistence of island specific shock	ρ_z	0.95	x-std net interest margin
Volatility of island specific shock	σ_z	0.011	Failure rate

Notes – This table reports the benchmark quarterly calibration of the model. See subsection 1.4.2 for detail discussion.

in the data set that I use. Therefore, to give the model the best chance of matching bank failure rate data, failure rate is calculated as a fraction total assets of banks that defaulted and did not get bailed out (banks that were not assisted by the FDIC) to total assets of all banks.

1.4.2. Calibration

One period is a quarter. In the model, all quantities grow at the same rate, so to preserve balanced growth, capital-producing firms' investment size, i_t , must grow at this same rate. I assume that this investment size is equal to one relative to trend, that is $i_t = K_t$. In this paper, I consider the case where there is no aggregate uncertainty, so A_t is constant and chosen to match consumption growth. The effect of aggregate uncertainty is left for future work. α , β , δ and η are set to standard values in the dynamic corporate literature as well as values traditionally used in macroeconomics. The coefficient on the quadratic adjustment cost, a , is 5, based on a study by Gilchrist and Himmelberg (1995). The intertemporal government assistance through TARP could have become insolvent.

elasticity of substitution is calibrated according to the long-run risk literature, in particular, it takes a value of 1.1 (Bansal and Yaron (2004b); Bansal, Kiku, and Yaron (2013)). θ is set consistent with a study by James (1991), who documented that upon default the average loss on bank assets is about 30 percent. The marginal equity issuance cost ϕ is chosen similarly to Gomes (2001), Hennessy and Whited (2005) and Gomes and Schmid (2010a). The monitoring cost m is set at .02 based on a study by Philippon (2012) who estimated that the intermediation cost is about two percent of outstanding assets. The probability of bailout λ is set at .9 consistent with a study by Koetter and Noth (2012) who estimated the bailout expectations for U.S. banks to be between 90 to 93 percent. In a data set of German banks during the period 1995-2006, Dam and Koetter (2012) documented that bailout frequency is about 76.4 percent. In this paper, banks are mapped to big banks in the data, so one would expect the bailout expectation to be higher.

This left us with six parameters: α , e , ρ_z , σ_z , σ_ϵ and μ . Since there is not much guidance on these parameters, they are chosen to best match six moments in the cross-section of U.S. banks distribution. The final calibration is summarized in Table 3.

Table 2 reports the main statistics given the benchmark minimum Tier 1 capital requirements of 4%. All cross-section moments are calculated from the stationary distribution of banks. The model does a reasonable job describing macro quantities as well as key cross-sectional moments of the U.S. banking industry. The model has a hard time matching exit rate however. One reason for this is that in the model, if banks want to exit they can just walk away with no cost. However, in the data, banks are big banks and so liquidating the whole bank is very costly. Therefore, outside options for banks in reality are much lower than in the model, and so then is exit. Importantly however the model does a good job at matching bank capital structure. Notice that the leverage ratio (the ratio of Tier 1 capital over total assets) and Tier 1 capital ratio (the ratio of Tier 1 capital over risk-weighted assets) are the same in the model, whereas in the data they are different. In the benchmark calibration, more than 4% of banks risk-shift in equilibrium.

Table 2: Main Statistics

<i>Macro moments</i>		Data		Model ($\bar{e} = .04$)
		Δc	0.49	0.49
		c/y	0.76	0.69
<i>Bank moments</i>		Data		Model ($\bar{e} = .04$)
		Top 1%	Top 5%	Top 10%
Targeted moments				
Return on loan				
mean	4.33	4.63	4.92	4.01
x-std	2.95	3.51	3.99	5.23
Net interest margin				
mean	2.89	3.18	3.43	1.95
x-std	3.05	3.55	4.03	6.09
Failure	0.33	0.29	0.28	1.07
Exit rate	1.02	1.17	1.20	4.27
Other moments				
Net charge-off rate				
mean	2.70	0.93	0.76	2.86
x-std	17.94	13.74	11.00	10.09
Fraction risk-shifting				4.14
Leverage ratio	7.74	8.29	8.51	11.63
Tier 1 capital ratio	10.25	12.18	12.62	11.63
Number of banks	113	564	1129	

Source: Bank data comes from Call Reports 1984-2010. Top x% column indicates statistics calculated from the top x% banks in term of total assets. ‘mean’ is the time-series average of cross-sectional mean, and ‘x-std’ is the time-series average of cross-sectional standard deviation. Macro data is from BEA 1947-2010. Output is defined as consumption plus investment. All figures are in percent, except for consumption-output ratio. For more details on data construction, see Appendix [A.1](#).

1.4.3. Welfare implications

Let c_t be the consumption-capital ratio. That is,

$$c_t = \frac{C_t}{K_{t-1}}.$$

In the stationary equilibrium with no aggregate uncertainty in consideration, the consumption-capital ratio and the growth rate are constant, so that $c_t = c$. Then starting from any initial

level of aggregate capital K_0 , the level of consumption is

$$C_t = c_t K_{t-1} = c \cdot \Delta k^{t-1} \cdot K_0, \quad (1.23)$$

where Δk denotes K_t/K_{t-1} . Thus, higher consumption could come from a higher growth (Δk) or a higher initial level of consumption ($c \cdot K_0$). Therefore, welfare is not only a function of growth but also depends on the initial level of consumption. Bank equity capital regulation ultimately alters both the consumption-capital ratio and growth.

Fig. 3 depicts welfare as a function of different levels of minimum capital requirements but with the same initial level of capital K_0 . Relative to Basel II, which requires 4% of Tier 1 capital, welfare peaks at a minimum capital requirement of 8%, and the welfare gains reach 1.1 percent of lifetime consumption. What is more important is that welfare benefits remain sizable at very high levels of minimum capital requirement, consistent with analysis by [Admati, DeMarzo, Hellwig, and Pfleiderer \(2010\)](#) and [Admati and Hellwig \(2013\)](#). From a policy perspective, erring on the side of high requirements is safe in the context of this model.

The intuition for the result is as follows. At low levels of the bank equity capital requirements, banks raise funds from depositors to exploit the subsidy implicit in government bailouts. Banks, therefore, can provide more credit to capital-producing firms, which results in more capital being produced (bottom left panel of Fig. 4). More capital produced means that growth is higher (bottom right panel of Fig. 4). Higher growth normally would promote welfare. However, as is clear from equation (1.23), growth is not the whole story; the starting point of growth is no less important. At low levels of the bank equity capital requirements, because banks have the default option and do not have enough “skin in the game,” they engage in risk-shifting, lending to risky-low-productivity firms. As a result, not only is bank bankruptcy high (top right panel, Fig. 5), which leads to high capital losses, average productivity is also low (top left panel of Fig. 5). Since investment is inefficient, to attain high growth, substantial resources are used for capital production and too few

resources are left for consumption (bottom right panel, Fig. 5). The net effect is lower welfare.

As the minimum capital constraint rises, the shadow cost of funds for banks becomes higher. More banks exit because now *private* bank profitability is low (top left panel, Fig. 4). As a result, the total measure of banks is now lower (top right panel, Fig. 4). Consequently, aggregate credit supply tightens, less capital is produced, and growth is lower. At the same time, however, banks' incentive for risk-shifting is also lower. Moreover, mandating lower leverage through high capital requirements leads to lower bankruptcy rates (top right panel, Fig. 5) and hence less capital is lost due to default. The overall effect brings about higher capital production productivity (bottom left panel of Fig. 5) and higher consumption (bottom right panel, Fig. 5). This leads to an increase in welfare, which peaks at 1.1 percent of lifetime consumption when the capital requirement is at 8%.

There are two reasons why requiring minimum equity capital higher than 8% leads to lower welfare gains. The first is the equity flotation cost. Because banks must pay issuance costs and since these costs are rebated back to households, the private cost of issuing equity is higher than the social cost. Therefore, the funds that are raised are lower than those in a centralized economy. This leads to lower lending, lower capital production and hence lower growth. The second reason is because of the presence of the “learning-by-doing” spillover that is inherent in the [Romer \(1986\)](#) endogenous growth model. In this class of models, capital accumulation improves overall final good production productivity and because this is external to each individual final good producer, decentralized allocations entail under-investment and low capital accumulation. In the current setup, higher bank capital requirements increase the cost of capital for banks, causing a reduction in lending leading to low capital production and hence a lower accumulated capital stock. This brings the decentralized allocations further away from the first-best allocation, and lowers welfare gains as seen in Fig. 3.

1.4.4. Sensitivity Analysis

1.4.4.0.8 Role of probability of bailout λ . Fig. 6 plots the welfare analysis for a higher level of bailout probability, increasing from 0.9 in the benchmark calibration to 0.95. As expected, the welfare gain increases at the optimal level of capital requirement from 1.1% to 1.8% of lifetime consumption, and the optimal minimum capital requirement increases from 8% to 9%. This is intuitive since the likelihood of bailout is the source of distortions. The more likely a bailout is, the more severe these distortions are, and so correcting these distortions is more beneficial. Not only are welfare gains higher, the optimal level of the minimum capital requirement is also higher. This is because the social cost of high bank capital remains unchanged but the benefit of correcting distortions is now higher.

1.4.4.0.9 Role of equity issuance cost ϕ . Fig. 7 compares welfare results when there is no equity issuance cost with the benchmark calibration. Not surprisingly the welfare gains are higher in the case where equity issuance is costless. The result comes from the fact that now the cost of funds for banks is lower, and as a consequence, relative to the benchmark case, more funds are raised, more investment is undertaken, and more capital is produced (right panel, Fig. 7).

What is more interesting is that there is still a hump-shape in welfare as one varies the minimum capital requirement \bar{e} . As discussed in subsection 1.4.3, the hump-shape comes from not only the issuance cost but also the under-investment in the decentralized allocations. As more equity capital is required, banks can not exploit the implicit subsidy using deposits and have to use a relatively more expensive form of funds from a *private* perspective; therefore, equilibrium credit supply is lower, resulting in lower capital produced. Overall high capital requirements still lead to lower welfare gains.

1.4.4.0.10 Role of productivity loss μ . Fig. 8 depicts welfare results for a lower μ at .01 instead of .02 as in the benchmark case. Recall that μ is the average percentage loss in productivity when a bank finances a risky-low-productivity firm. A lower μ affects

equilibrium outcome in two ways. On the one hand, lower μ leads to lower productivity loss and makes investment more efficient. This tends to improve welfare.

On the other hand, lower μ encourages more banks to risk-shift, because now the private cost of risk-shifting is lower due to a *higher* productivity in risky-low-productivity firms relative to the benchmark calibration. More risk-shifting by banks implies that more banks will default relative to the benchmark (top right panel, Fig. 8). The net result is a reduction in the average investment productivity (bottom panel). Hence, welfare is higher despite lower productivity loss in risk-shifting (top left panel, Fig. 8). Moreover, the optimal level of minimum bank capital requirement is now higher at 8.5%, attaining almost 1.5 percent of lifetime consumption, while in the benchmark calibration the optimal level is 8%. This result is due to the fact that in spite of lower μ , the net negative effect of bank distortions is higher (lower average productivity, Fig. 8), and so the benefits of bank regulation is higher while the cost of regulation has not changed.

1.4.4.0.11 Role of additional risk exposure σ_ϵ . Fig. 9 compares welfare results in the benchmark case with the case where the additional risk exposure due to risk-shifting is higher. With higher risk exposure due to risk-shifting, the welfare gain is higher at the optimal level of capital requirement, 1.35% versus 1.1%. Moreover, the optimal capital ratio is also higher at 9% compared to 8% in the benchmark case. This is intuitive since the upside potential of risk-shifting is higher, but the downside is unchanged, banks have more incentives to risk-shift when risk exposure is higher. This leads to more capital losses due to bank default and hence lowers investment productivity. Thus, from a social perspective, the cost of risk-shifting is higher, and so is the benefit of higher bank capital requirements. Since the cost of regulating banks is the same, this results in higher welfare gains and higher optimal level of minimum capital requirement.

1.5. Conclusion

This paper quantitatively studies the welfare implications of bank capital requirements in a dynamic general equilibrium banking model. In the proposed model, because of government bailouts, banks have incentives to risk-shift, leading to inefficient lending to risky-low-productivity firms. Bank capital requirements reduce risk-shifting incentives and improve welfare. The calibrated version of the model suggests that an 8% minimum Tier 1 capital requirement brings about a significant welfare improvement of 1.1% of lifetime consumption. This capital requirement is 2 percentage points *higher* than the level under Basel III and current U.S. regulation. Moreover, from a social perspective, the bank cost of equity in this model is not expensive. Welfare gains remain sizable even at a 25 percent minimum capital requirement. Overall, my results highlight the need to re-examine current bank capital regulations.

Further research should consider the impact of aggregate uncertainty on the optimal level of minimum capital requirement as well as welfare implications of countercyclical bank capital requirements policies. Moreover, the roles of other externalities such as contagious bank failures and asset fire sale, should be analyzed. Intuition suggests that these externalities would further strengthen the benefit of bank capital regulation now that the social cost of bank failure is higher. The optimal level of capital ratio would therefore be even higher than the 8% suggested by the proposed model.

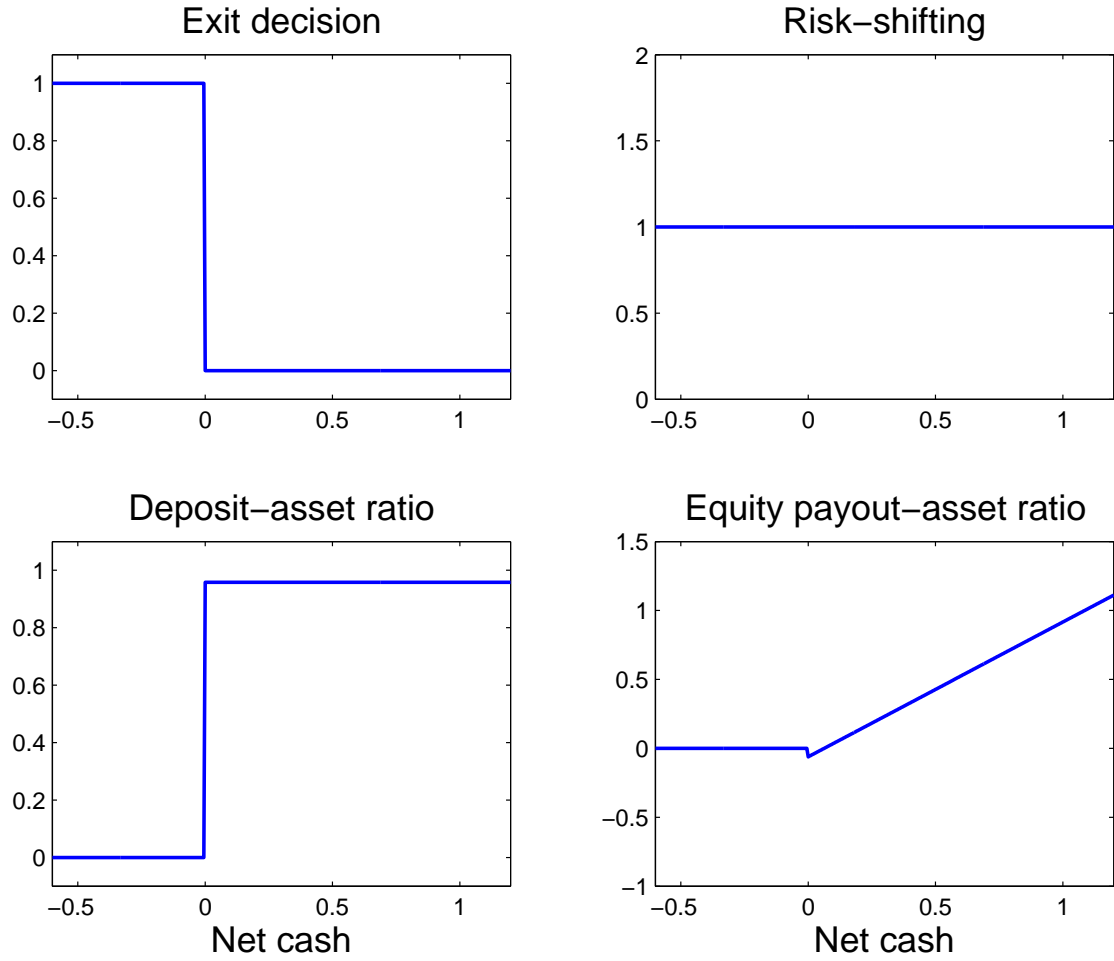


Figure 1: Policy functions: risk-shifting

Notes – This figure shows a bank's policy functions, on an island where banks risk-shift, as functions of a bank's net cash position. The policy functions are calculated under the benchmark calibration discussed in subsection 1.4.2.

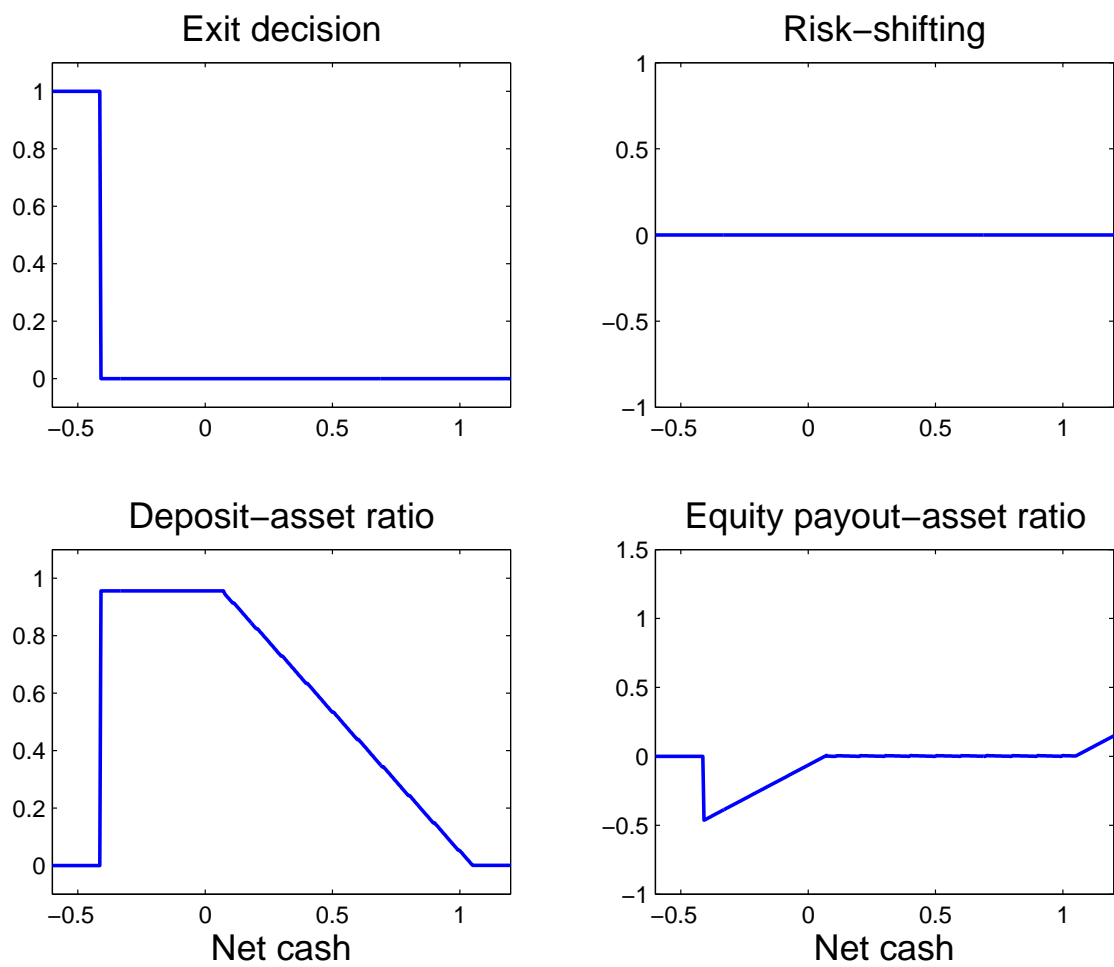


Figure 2: Policy functions: no risk-shifting

Notes – This figure shows bank's policy functions, on an island where banks do not risk-shift, as functions of bank's net cash position. The policy functions are calculated under the benchmark calibration discussed in subsection 1.4.2.

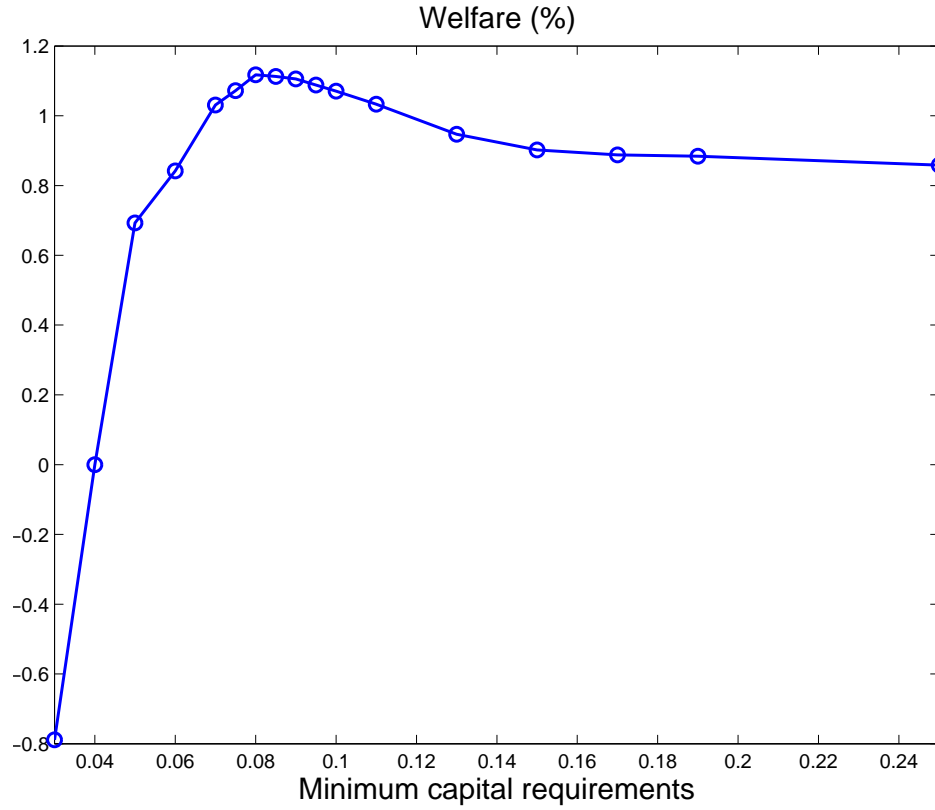


Figure 3: Welfare benefits

Notes – This figure shows the welfare result as a function of the minimum capital requirement \bar{e} relative to the benchmark calibration with $\bar{e} = .04$. Welfare is expressed in lifetime consumption units. All other parameters are calibrated as in Table 3. The x-axis indicates different levels of the minimum capital requirement.

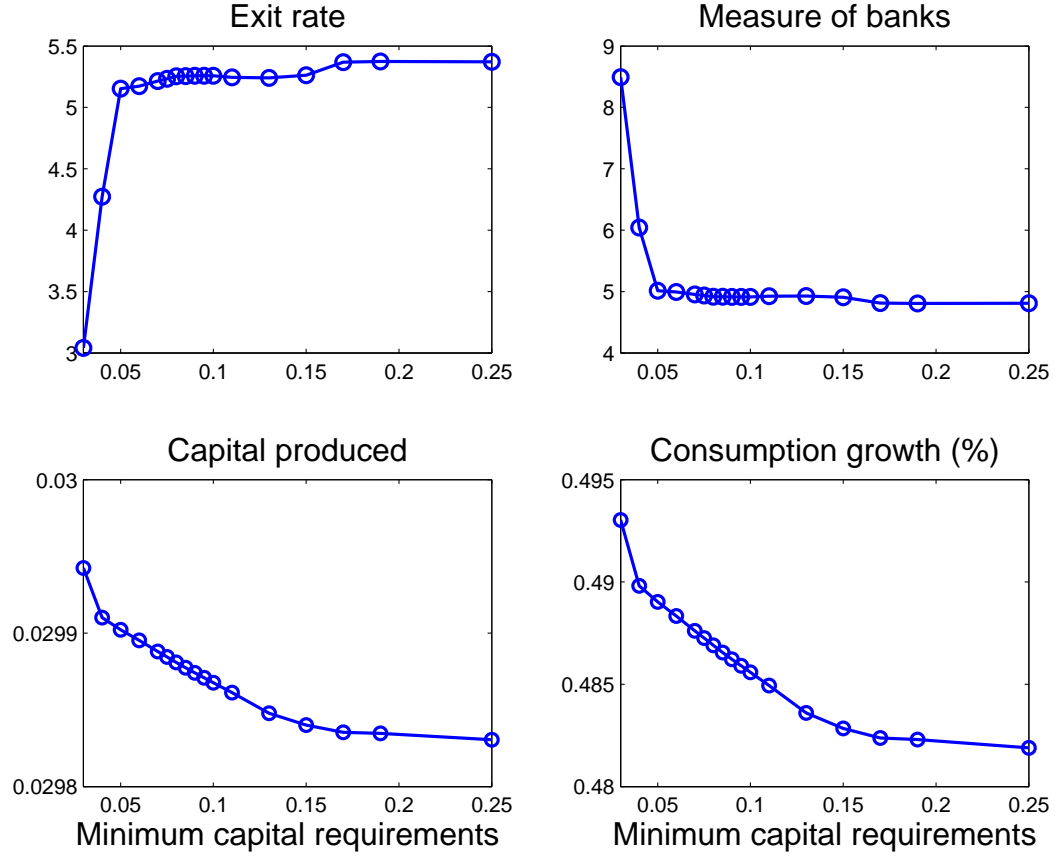


Figure 4: Consumption growth and distribution of banks

Notes – This figure shows exit rate, the measure of banks, capital produced and consumption growth as a function of the minimum capital requirement \bar{e} . All other parameters are calibrated as in Table 3. The x-axis indicates different levels of the minimum capital requirement.

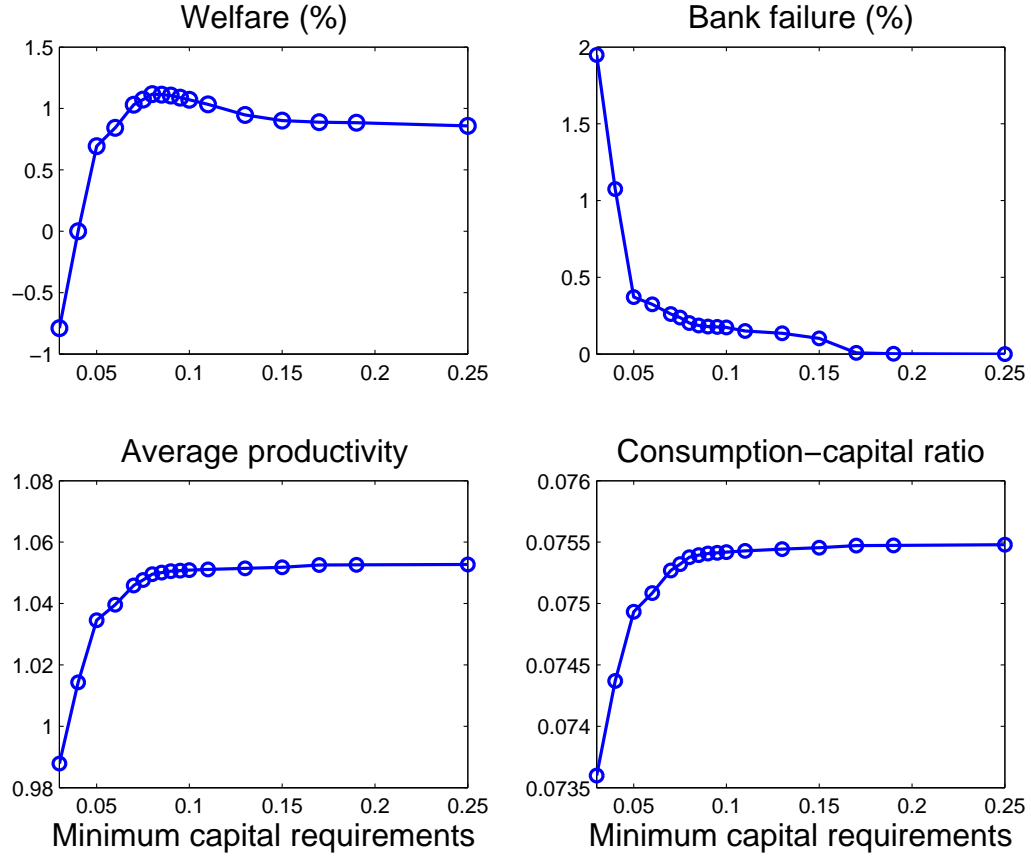


Figure 5: Welfare benefits, consumption and productivity

Notes – This figure shows the welfare result as a function of the minimum capital requirement \bar{e} relative to the benchmark calibration with $\bar{e} = .04$. The welfare figure is reproduced here for ease of references. All other parameters are calibrated as in Table 3. The x-axis indicates different levels of the minimum capital requirement.

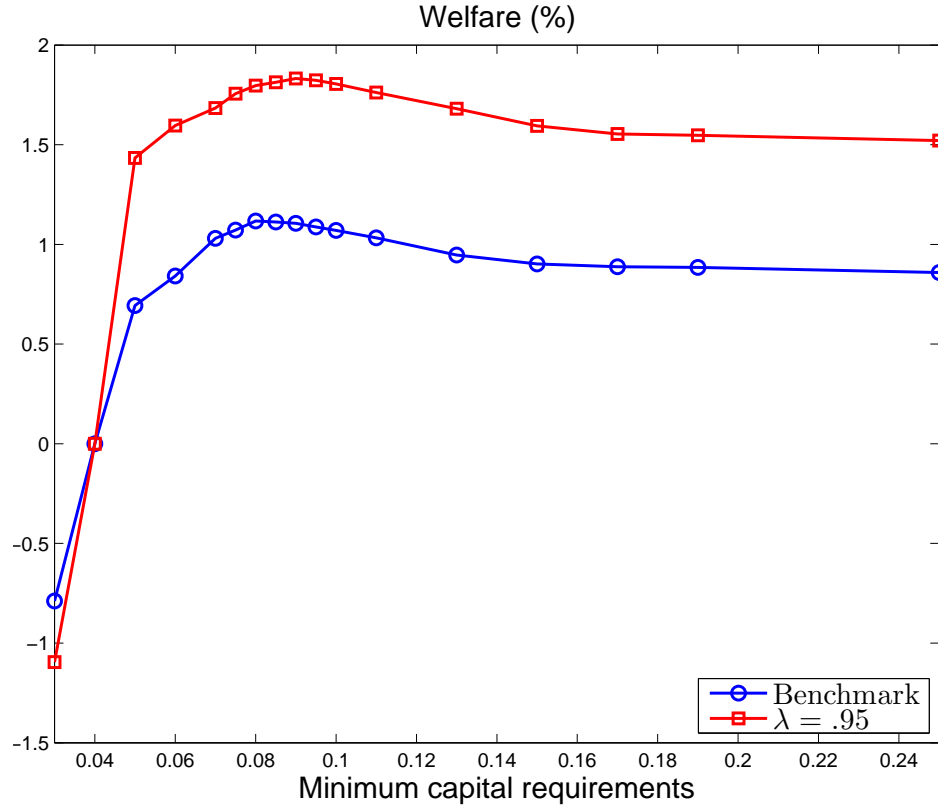


Figure 6: Role of probability of bailout λ

Notes – This figure shows the welfare result as a function of the minimum capital requirement \bar{e} relative to the benchmark calibration with $\bar{e} = .04$. Welfare is expressed in lifetime consumption units. The blue-circle line is welfare in the benchmark case ($\lambda = .9$), and the red-square line is for the case with bailout probability $\lambda = .95$. All other parameters are as calibrated in Table 3. The x-axis indicates different levels of the minimum capital requirement.

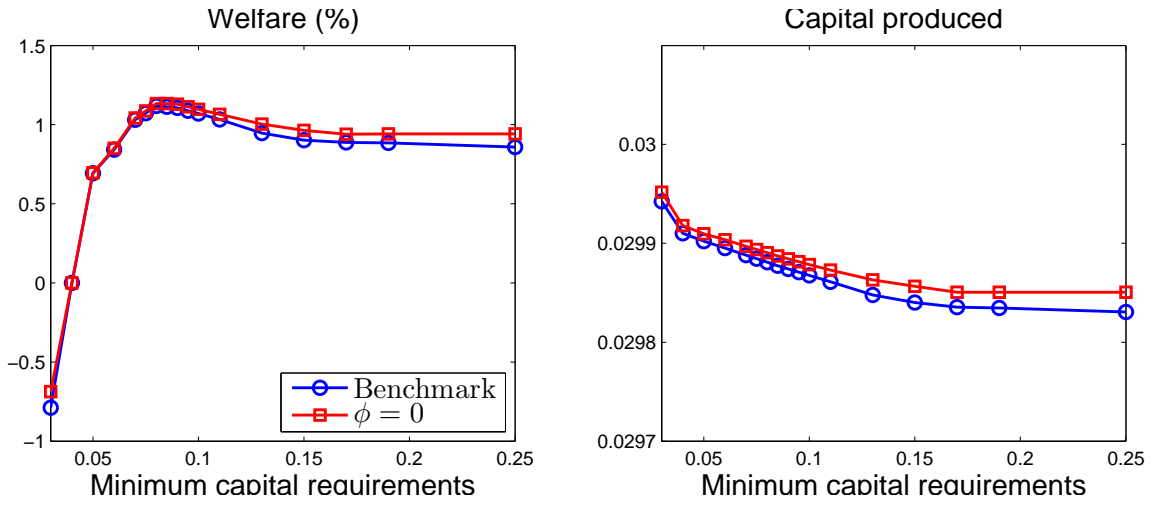


Figure 7: Role of equity issuance cost ϕ

Notes – This figure shows the welfare result as a function of the minimum capital requirement \bar{e} relative to the benchmark calibration with $\bar{e} = .04$. Welfare is expressed in lifetime consumption units. The blue-circle line is welfare in the benchmark case ($\phi = .025$), and the red-square line is for the case with no issuance cost $\phi = 0$. All other parameters are as calibrated in Table 3. The x-axis indicates different levels of the minimum capital requirement.

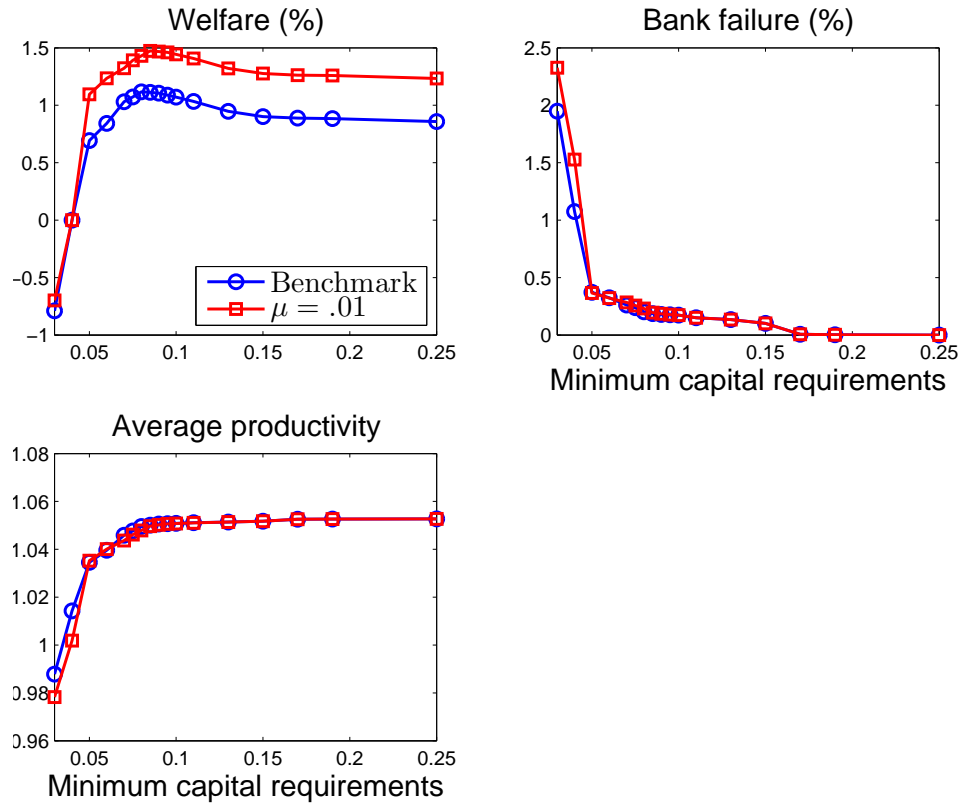


Figure 8: Role of productivity loss due to risk-shifting μ

Notes – This figure shows the welfare result as a function of the minimum capital requirement \bar{e} relative to the benchmark calibration with $\bar{e} = .04$. Welfare is expressed in lifetime consumption units. The blue-circle line is welfare in the benchmark case ($\mu = .02$), and the red-square line is for the case with $\mu = .01$. All other parameters are as calibrated in Table 3. The x-axis indicates different levels of minimum capital requirement.

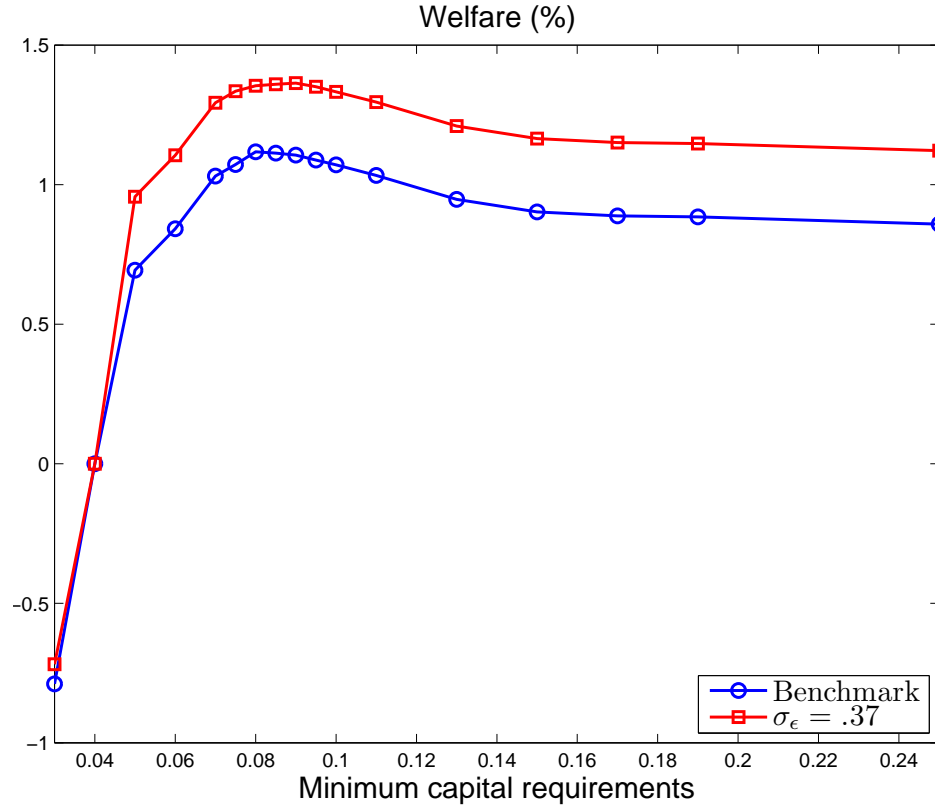


Figure 9: Role of additional risk exposure due to risk-shifting σ_ϵ

Notes – This figure shows the welfare result as a function of the minimum capital requirement \bar{e} relative to the benchmark calibration with $\bar{e} = .04$. Welfare is expressed in lifetime consumption units. The blue-circle line is welfare in the benchmark case ($\sigma_\epsilon = .363$), and the red-square line is for the case with $\sigma_\epsilon = .37$. All other parameters are as calibrated in Table 3. The x-axis indicates different levels of minimum capital requirement.

CHAPTER 2 : Fiscal Policy and the Distribution of Consumption Risk

Mariano Massimiliano Croce and Thien T. Nguyen and Lukas Schmid

Abstract

This paper studies fiscal policy design in an economy in which endogenous growth risk and asset prices are a first-order concern. When (i) the representative household has recursive preferences, and (ii) growth is endogenously sustained through R&D investment, fiscal policy alters both the composition of intertemporal consumption risk and the incentives to innovate. Tax policies aimed at short-run stabilization may substantially increase long run tax and growth risks and reduce both average growth and welfare. In contrast, policies oriented toward asset price stabilization increase growth, wealth and welfare by lowering the slope of the term structure of equity yields.

2.1. Introduction

Since the onset of the fall 2008 financial crisis, the world has witnessed government interventions on a unprecedented scale aimed at preventing a major global depression. While the return of the world economy to positive growth suggests that these policies may have been successful at short-run stabilization, their long-term effects are still uncertain.

Indeed, sharp increases in projected government debt go hand in hand with such fiscal stimulus packages. The 2012 Congressional Budget Office Outlook, for example, suggests that the US debt-output ratio may follow an unstable path in the coming years, reaching as high as 200% within the next three decades. These forecasts raise considerable uncertainty about the future stance of fiscal policy required for debt stabilization. Given the distortionary nature of tax instruments, current deficits may have substantial effects on the long-term prospects of the economy. In particular, short-run economic stabilization may come at the cost of dimmer and uncertain long-term growth.

In this paper, we examine fiscal policy design in an environment in which the government faces an explicit trade-off between short-run stabilization and long-run growth through an asset pricing channel. As in [Barro \(1979\)](#), our proposed government finances an exogenous expenditure stream through a mix of taxes and noncontingent debt. Government expenditure is stochastic and only labor income taxes are available, as in [Lucas and Stokey \(1983\)](#). We extend this classic benchmark through two relevant economic mechanisms.

On the technology side, our economy grows at an endogenous and stochastic rate determined by firms' incentives to innovate ([Romer 1990](#)). By altering labor supply through tax dynamics, fiscal policy can affect the market value of innovative products and ultimately long-run growth.

On the household side, we adopt the recursive preferences of [Epstein and Zin \(1989\)](#) so that agents care about the intertemporal distribution of growth risk, as in [Bansal and Yaron \(2004a\)](#). Specifically, agents are sensitive to the timing of taxation because they are averse

to tax policies that amplify long-run growth risk.

In this setting, the government’s financing policy effectively serves as a device to reallocate consumption risk across different horizons. We find that tax smoothing is welfare enhancing if it is oriented toward long-run stabilization. Tax policies promoting short-run stabilization, in contrast, increase long-run risk and depress both average growth and welfare. We thus identify a relevant and novel tension between short-run stabilization and long-term growth.

Our results are driven by two complementary channels that reinforce each other and enrich the welfare implications of common tax smoothing prescriptions. In the [Lucas and Stokey \(1983\)](#) economy, the cost of future tax distortions can be summarized exclusively by their effect on short-run consumption growth (the short-run consumption smoothing margin). In our setting, in contrast, we need to consider both an asset price and an intertemporal distortion margin.

The asset price channel is related to endogenous growth. In a stochastic version of the [Romer \(1990\)](#) economy, indeed, growth depends on the risk-adjusted present value of expected future profits. In our setting, the tax system can directly affect long-term growth by altering the risk characteristics of both profits and the consumption-based discount factor. Equivalently, the shadow cost of future tax distortions depends also on its impact on the market value of patents.

Since with standard time-additive preferences agents are sensitive to short-run growth risk only, tax smoothing oriented toward short-run stabilization produces welfare benefits through both the short-run consumption-smoothing and the asset price channels. That is, welfare improves because of both lower short-run volatility in consumption and higher average growth. With standard preferences, therefore, there is no tension between long-term growth and short-run stabilization.

With recursive preferences, however, the entire intertemporal distribution of future tax distortions becomes welfare relevant, as news about future long-run taxation affects continua-

tion utility. This implicit preference for the timing of taxation stems from the intertemporal distortion margin. When agents have a preference for early resolution of uncertainty, they care about continuation utility smoothing in addition to consumption smoothing. Since continuation utility reflects expected long-run consumption, the tax system should take into account long-run consumption stabilization.

In contrast to the time-additive case, we show that short-run-oriented tax smoothing can produce substantial welfare costs as high as of 1.5% of lifetime consumption. Intuitively, upon the realization of adverse exogenous shocks the use of deficits can reduce the short-run drop in output and consumption, but the subsequent financing needs associated with long-run budget balancing produce bad news about future distortionary taxation. When tax distortions endogenously affect growth rates, this leads to more uncertainty about long-term growth prospects. Hence, in asset pricing language, a reduction in the extent of short-run growth risk comes at the cost of increased exposure to long-run risk. We view these results as quantitatively significant, as our model is calibrated to reproduce key features of both consumption risk premia and wealth-consumption ratios as measured by [Lustig, Van Nieuwerburgh, and Verdelhan \(2013\)](#) and [Alvarez and Jermann \(2004\)](#).

Under aversion to long-run uncertainty, the reallocation of consumption risk from the short- to the long-run can further depress welfare because of the asset price channel. With recursive preferences, indeed, the agent prices both short- and long-run profit risk. By increasing long-run growth risk, short-run-oriented fiscal policies lead to a drop in the market value of patents, research and development (R&D) investment, and growth. This interaction between the asset-price and intertemporal-distortion channels explains both (i) our high welfare costs for fiscal policies aimed at short-term stabilization and (ii) the sizeable benefits created by policies seeking to stabilize long-term growth prospects by responding to asset prices and their determinants.

At a broader level, our study conveys the need to introduce risk considerations into the current fiscal policy debate. More precisely, our analysis suggests that asset prices should

be an important determinant of tax systems and that long-term risk considerations should be included in fiscal policy design. In an economy with uncertain growth, ignoring the timing of taxes and the implied intertemporal composition of consumption risk can substantially bias the welfare cost-benefit analysis of fiscal interventions. Our risk-based endogenous growth model shows a relevant and novel tension between short-run stabilization and long-term growth that has not been highlighted before. We show that the fiscal debate, rather than focusing exclusively on the average level of taxation, should be concerned with long-term tax uncertainty as well, since tax risk can be as welfare-relevant as average tax pressure.

Our study highlights relevant costs associated with short-term oriented financing policies, but it abstracts away from various channels through which fiscal intervention may generate significant welfare benefits. Even though our analysis is silent about the net welfare effects of fiscal intervention, our quantitative results suggest that these financing costs are economically relevant.

The remainder of this paper is organized as follows. In the next section we discuss related literature. We present our model in section 2.2, summarize our calibration strategy in section 2.3, and discuss the quantitative results in sections 2.4 and 2.5. In section 2.6 we show that our results are robust to the introduction of subsidies. Section 2.7 concludes.

2.1.1. Related Literature

Several recent studies have focused on evaluating fiscal policies in asset pricing settings. [Gomes, Michaelides, and Polkovnichenko \(2010\)](#) calculate the distortionary costs of government bailouts in a model that is consistent with basic asset market data. [Gomes, Michaelides, and Polkovnichenko \(2012\)](#) analyze fiscal policies in an incomplete markets economy with heterogeneous agents. [Gomes, Kotlikoff, and Viceira \(2012\)](#) and [Pastor and Veronesi \(2012, 2013\)](#) examine the effects of policy uncertainty on economic outcomes and stock returns; [Glover, Gomes, and Yaron \(2012\)](#) conduct a series of fiscal policy experiments in order to assess the links between the preferential tax treatment of debt, default risk, and

aggregate fluctuations. In complementary work, [Sialm \(2006, 2009\)](#) examines the link between tax risk and asset returns both empirically and theoretically from a household-income perspective. All of these studies abstract away from the endogenous technological progress highlighted in [Papanikolaou \(2011\)](#), [Kung and Schmid \(2012\)](#), and [Kogan, Papanikolaou, and Stoffman \(2013\)](#). None of these papers addresses taxation and welfare costs in a long-term risk-sensitive environment similar to ours.

A number of papers have documented strong empirical linkages between fiscal policy, innovative activity, and asset prices. For example, [Backus, Henriksen, and Storesletten \(2008\)](#) and [Da, Warachka, and Yun \(2013, 2014\)](#) empirically examine the effects of fiscal policy on stock returns. [Belo, Gala, and Li \(2013\)](#), [Belo and Yu \(2013\)](#) and [Kelly, Pastor, and Veronesi \(2013\)](#) document significant links between government policies and financial markets more broadly. On the other hand, [Kogan, Papanikolaou, Seru, and Stoffman \(2012\)](#) show that an innovation measure based on patent grants and stock returns predicts economic growth. [Lin \(2012\)](#) analyzes the empirical impact of innovation and endogenous technological progress on the cross-section of stock returns.

We quantitatively examine the significance of fiscal risk channels by means of simple and implementable rules linking fiscal policy stance to macroeconomic conditions, in the spirit of [Dotsey \(1990\)](#); [Ludvigson \(1996\)](#); [Schmitt-Grohe and Uribe \(2005, 2007\)](#); [Leeper, Plante, and Traum \(2010\)](#); [Leeper, Traum, and Walker \(2011\)](#). In contrast to these papers, our fiscal rules account for asset prices and expectations of future tax distortions as in the monetary policy studies of [Gallmeyer, Hollifield, and Zin \(2005\)](#) and [Gallmeyer, Hollifield, Palomino, and Zin \(2011\)](#). We see our tax smoothing policies as devices to quantitatively trace the risk trade-off frontier faced by the fiscal authority. This is an important contribution, since with non-time-separable preferences the quantitative assessment of optimal fiscal policies is challenging, even in much simpler economic setups ([Karantounias 2011, 2012](#)).

[Barlevy \(2004\)](#) finds that the costs of business cycles can be substantial in stochastic models with endogenous growth. The present study differs from this important contribution in two

respects. First, we explicitly consider fiscal stabilization in a framework in which risk premia are a critical element. In this respect, our analysis is closely related to the work of [Tallarini \(2000\)](#) and [Alvarez and Jermann \(2005\)](#), who link the welfare costs of aggregate consumption fluctuations to asset prices. Secondly, because we adopt recursive preferences, the intertemporal reallocation of consumption risk is central to our results.

[Croce, , Nguyen, and Schmid \(2012\)](#) study the link between fiscal policies and pessimism in the sense of [Hansen and Sargent \(2009\)](#).¹ In contrast to [Croce, , Nguyen, and Schmid \(2012\)](#), we provide a broad and general analysis of the interaction between risk preferences and fiscal policy design. Specifically, we show that the benefits of stabilization are horizon-dependent and are crucially related to the term structure of growth risk. Our positive analysis demonstrates that obtaining welfare benefits through tax smoothing is possible, provided that fiscal policy stabilizes long-run investment. Furthermore, we show that our stabilization results do not hinge on market failures and remain significant even after the introduction of appropriate subsidy policies.

More broadly, our analysis is related to the literature on production-based asset pricing. A nonexhaustive list of papers includes [Jermann \(1998, 2010, 2013\)](#), [Zhang \(2005\)](#), [Backus, Routledge, and Zin \(2007, 2010\)](#), [Kaltenbrunner and Lochstoer \(2010\)](#), [Chen and Zhang \(2011\)](#), [Gourio \(2012, 2013\)](#), [Kuehn, Petrosky-Nadeau, and Zhang \(2013\)](#), [Favilukis and Lin \(2013b,a\)](#), [Belo, Bazdresch, and Lin \(2011\)](#), [Belo and Lin \(2013\)](#), [Croce \(2014\)](#).

2.2. Model

We use a stochastic version of the [Romer \(1990\)](#) model in which the fiscal system affects all moments of the distribution of consumption growth, including its unconditional mean. Since our representative agent has recursive preferences, she cares about the intertemporal composition of consumption risk and is sensitive to both current and future taxation. Even

¹The article by [Croce, , Nguyen, and Schmid \(2012\)](#) has been solicited for the Carnegie-Rochester-NYU Conference Series on Public Policy ‘Robust Macroeconomic Policy’ as a contribution to the robustness literature.

though stylized, our model enables us to conduct a rich and detailed quantitative analysis of the link between growth risk and fiscal dynamics.

On the production side, the only source of sustained growth in the economy is the accumulation of patented intermediate goods (henceforth patents) that facilitate the production of a final consumption good. Patents are created through an innovation activity requiring investment in research and development (R&D) and can be stored. In this model, therefore, patents represent an endogenous stock of intangible capital. For simplicity, we abstract away from both tangible capital accumulation and capital taxation and allow the government to finance its expenditures only by a mix of deficit and labor income taxes, as in [Lucas and Stokey \(1983\)](#).

In this class of models, the speed of patent accumulation, i.e., the growth rate of the economy, depends on the risk-adjusted present value of the additional cash-flow stream generated by such innovations. The fiscal system affects growth through two channels. First, by distorting the labor supply through taxation, fiscal policy affects future expected profits (the cash-flow channel). Second, since we assume that the representative household has Epstein-Zin preferences, the market value of a patent is sensitive to both short-run and long-run risk adjustments (the discount rate channel). Asset pricing considerations are therefore required to understand the impact of a given tax system on the equilibrium growth rate of the economy.

Specifically, we show that smoothing distortional taxation using public debt affects the riskiness of patents' cash flow over both the short and long horizons, thereby altering the equilibrium growth rate of the economy. In this sense, choosing a tax system is equivalent to choosing a specific intertemporal distribution of growth risk.

In what follows, we start by describing the household's problem, the production sector, and the government and fiscal policy. We then provide a description of the equilibrium link between asset prices and aggregate growth.

2.2.1. Household

The representative household has [Epstein and Zin \(1989\)](#) preferences,

$$U_t = \left[(1 - \beta) u_t^{1 - \frac{1}{\psi}} + \beta (\mathbb{E}_t U_{t+1}^{1 - \gamma})^{\frac{1 - \frac{1}{\psi}}{1 - \gamma}} \right]^{\frac{1}{1 - \frac{1}{\psi}}}, \quad (2.1)$$

defined over a CES aggregator, u_t , of consumption, C_t , and leisure, $1 - L_t$:

$$u_t = \left[\theta_c C_t^{1 - \frac{1}{\nu}} + (1 - \theta_c) [A_t (1 - L_t)]^{1 - \frac{1}{\nu}} \right]^{\frac{1}{1 - \frac{1}{\nu}}}.$$

We let L_t , γ , ψ , and ν denote labor, relative risk aversion (RRA), intertemporal elasticity of substitution (IES), and degree of complementarity between leisure and consumption, respectively. Leisure is multiplied by A_t , our measure of standards of living, to guarantee balanced growth when $\nu \neq 1$.

When $\psi = \frac{1}{\gamma}$, these preferences collapse to the standard time-additive CRRA case. When, instead, $\psi \neq \frac{1}{\gamma}$, the agent cares about the timing of the resolution of uncertainty, meaning that long-run growth news affects her marginal utility differently than does short-run growth news. In what follows, we always assume that $\psi \geq \frac{1}{\gamma}$ so that when the agent cares about the intertemporal composition of consumption risk, she dislikes uncertainty about the long-run growth prospects of the economy.

In each period, the household chooses labor; consumption; equity shares, Z_{t+1} ; and public debt holdings, B_t ; to maximize utility according to the following budget constraint:

$$C_t + Q_t Z_{t+1} + B_t = (1 - \tau_t) W_t L_t + (Q_t + D_t) Z_t + B_{t-1} (1 + r_{t-1}^f), \quad (2.2)$$

where D_t denotes aggregate dividends (to be specified in equation (2.21)), Q_t is the market value of an equity share, and r_t^f is the short-term risk-free rate. Wages, W_t , are taxed at a rate τ_t .

In our setup the stochastic discount factor in the economy is given by

$$M_{t+1} = \beta \left(\frac{u_{t+1}}{u_t} \right)^{\frac{1}{\nu} - \frac{1}{\psi}} \left(\frac{C_{t+1}}{C_t} \right)^{-1/\nu} \left(\frac{U_{t+1}^{1-\gamma}}{\mathbb{E}_t[U_{t+1}^{1-\gamma}]} \right)^{\frac{1/\psi - \gamma}{1-\gamma}}, \quad (2.3)$$

where the last factor captures aversion to continuation utility risk, i.e., long-run growth risk. Optimality implies the following asset pricing conditions:

$$\begin{aligned} Q_t &= \mathbb{E}_t[M_{t+1}(Q_{t+1} + D_{t+1})] \\ \frac{1}{1 + r_t^f} &= \mathbb{E}_t[M_{t+1}]. \end{aligned}$$

In equilibrium, the representative agent holds the entire supply of both bonds and equities. The latter is normalized to be one, i.e., $Z_t = 1 \quad \forall t$. The intratemporal optimality condition on labor takes the following form:

$$\frac{1 - \theta_c}{\theta_c} A_t^{(1-1/\nu)} \left(\frac{C_t}{1 - L_t} \right)^{1/\nu} = (1 - \tau_t) W_t \quad (2.4)$$

and implies that the household's labor supply is directly affected by the government's financing policy.

2.2.2. Production

The production process involves three sectors. The final consumption good is produced in a competitive sector using labor and a bundle of intermediate goods. Intermediate goods are produced by firms that have monopoly power and hence realize positive profits. Intermediate good producers use these rents to acquire the right of production from innovators. Innovators create new patents through R&D investment and are subject to a free-entry condition.

2.2.2.0.12 Final good Firm. A representative and competitive firm produces the economy's single final output good, Y_t , using labor, L_t , and a bundle of intermediate goods,

X_{it} . We assume that the production function for the final good is specified as follows:

$$Y_t = \Omega_t L_t^{1-\alpha} \left[\int_0^{A_t} X_{it}^\alpha di \right], \quad (2.5)$$

where Ω_t denotes the exogenous stationary stochastic productivity process

$$\log(\Omega_t) = \rho \cdot \log(\Omega_{t-1}) + \epsilon_t, \quad \epsilon_t \sim N(0, \sigma^2),$$

and A_t is the total measure of intermediate goods in use at date t .

Our competitive firm takes prices as given and chooses intermediate goods and labor to maximize profits as follows:

$$\max_{L_t, X_{it}} Y_t - W_t L_t - \int_0^{A_t} P_{it} X_{it} di,$$

where P_{it} is the price of intermediate good i at time t . Profit maximization thus implies

$$\begin{aligned} X_{it} &= L_t \left(\frac{\Omega_t \alpha}{P_{it}} \right)^{\frac{1}{1-\alpha}}, \\ W_t &= (1-\alpha) \frac{Y_t}{L_t}. \end{aligned} \quad (2.6)$$

2.2.2.0.13 Intermediate good firms. Each intermediate good $i \in [0, A_t]$ is produced by a monopolistic firm. Each firm needs X_{it} units of the final good to produce X_{it} units of its respective intermediate good i . Given this assumption, the marginal cost of an intermediate good is fixed and equal to one. Taking the demand schedule of the final good producer (equation (2.6)) as given, each firm chooses its price, P_{it} , to maximize the following operating profits, Π_{it} :

$$\Pi_{it} \equiv \max_{P_{it}} P_{it} X_{it} - X_{it}.$$

At the optimum, monopolists charge a constant markup over marginal cost:

$$P_{it} \equiv P = \frac{1}{\alpha} > 1.$$

Given the symmetry of the problem for all the monopolistic firms, we obtain

$$\begin{aligned} X_{it} &\equiv X_t = L_t(\Omega_t \alpha^2)^{\frac{1}{1-\alpha}}, \\ \Pi_{it} &\equiv \Pi_t = \left(\frac{1}{\alpha} - 1\right)X_t. \end{aligned} \tag{2.7}$$

In view of this symmetry, in what follows we drop the subscript i . Equations (2.5) and (2.7) allow us to express final output in the following compact form:

$$Y_t = \frac{1}{\alpha^2} A_t X_t = \frac{1}{\alpha^2} A_t L_t (\Omega_t \alpha^2)^{\frac{1}{1-\alpha}}. \tag{2.8}$$

Since both labor and productivity are stationary, equation (2.8) implies that the long-run growth rate of output is determined by the expansion of the variety of intermediate goods, A_t . This expansion stems from endogenous innovation conducted in the R&D sector, which we describe next.

2.2.2.0.14 Research and development. Innovators develop blueprints for new intermediate goods and obtain patents on them. At the end of the period, these patents are sold to new intermediate-goods firms in a competitive market. Starting from the next period on, the new monopolists produce the new varieties and make profits. We assume that each existing variety becomes obsolete with probability $\delta \in (0, 1)$. In this case, its production is terminated. Given these assumptions, the cum-dividend value of an existing variety, V_{it} , is equal to the present value of all future expected profits and can be recursively expressed as follows:

$$V_t = \Pi_t + (1 - \delta) E_t [M_{t+1} V_{t+1}]. \tag{2.9}$$

Let $1/\vartheta_t$ be the cost of producing a new variety. The free-entry condition in the R&D sector implies that at the optimum

$$\frac{1}{\vartheta_t} = E_t [M_{t+1} V_{t+1}], \quad (2.10)$$

i.e., the cost of producing a variety must equal the market value of the new patents. Equation (2.10) is central in this class of models because it implicitly pins down the optimal level of investment in R&D, S_t , and ultimately the growth rate of the economy.

Specifically, our stock of patents, A_t , evolves as follows:

$$A_{t+1} = \vartheta_t S_t + (1 - \delta)A_t, \quad (2.11)$$

and hence

$$\frac{A_{t+1}}{A_t} = 1 - \delta + \vartheta_t \frac{S_t}{A_t}.$$

In the spirit of [Jermann \(1998\)](#), we assume that the innovation technology ϑ_t involves a congestion externality effect capturing decreasing returns to scale in the innovation sector,

$$\vartheta_t = \chi \left(\frac{S_t}{A_t} \right)^{\eta-1} \quad \eta \in (0, 1), \quad (2.12)$$

where $\chi > 0$ is a scale parameter and $\eta \in [0, 1]$ is the elasticity of new intermediate goods with respect to R&D. This specification captures the idea that concepts already discovered make it easier to come up with new ideas, $\partial\vartheta/\partial A > 0$, and that R&D investment has decreasing marginal returns, $\partial\vartheta/\partial S < 0$.

Combining equations (2.10)–(2.12), we obtain the following optimality condition for investment in R&D:

$$\frac{1}{\chi} \left(\frac{S_t}{A_t} \right)^{1-\eta} = E_t \left[\sum_{j=0}^{\infty} M_{t+j|t} (1 - \delta)^j \Pi_{t+j} \right], \quad (2.13)$$

²This dynamic equation is consistent with our assumption that new patents survive for sure in their first period of life. If new patents are allowed to immediately become obsolete, equations (2.10) and (2.11) must to be replaced by $A_{t+1} = (1 - \delta)(\vartheta_t S_t + A_t)$ and $\frac{1}{\vartheta_t} = E_t [M_{t+1}(1 - \delta)V_{t+1}]$, respectively. Our results are not sensitive to this modeling choice.

where $M_{t+j|t} \equiv \prod_s^j M_{t+s|t}$ is the j -steps-ahead pricing kernel and $M_{t|t} \equiv 1$. Equation (2.13) suggests that the amount of innovation intensity in the economy, S_t/A_t , is directly related to the discounted value of future profits. When agents expect profits above (below) steady state, they have an incentive to invest more (less) in R&D, ultimately boosting (reducing) long-run growth. In section 2.2.5, we further discuss this point, since it is essential to the understanding of long-term stabilization.

2.2.3. Government

2.2.3.0.15 Expenditure to be financed. The government faces an exogenous and stochastic expenditure stream, G_t , that evolves as follows:

$$\frac{G_t}{Y_t} = \frac{1}{1 + e^{-gy_t}}, \quad (2.14)$$

where

$$gy_t = (1 - \rho)\overline{gy} + \rho_g gy_{t-1} + \epsilon_{G,t}, \quad \epsilon_{G,t} \sim N(0, \sigma_{gy}^2).$$

This specification ensures that $G_t \in (0, Y_t) \quad \forall t$, and it enables us to replicates key features of the expenditure-to-output ratio observed in the U.S. data. In most of our analysis, we focus only on the expenditure component of total public liabilities and abstract away from entitlements. We also abstract away from the volatility shocks documented by [Fernandez-Villaverde, Guerron-Quintans, Kuester, and Rubio-Ramirez \(2013\)](#). Results reported in [A.3](#) suggest that adding further liabilities in the form of lump-sum transfers to the household would enhance our results.

2.2.3.0.16 Financing rules. In order to finance these expenditures, the government can use tax income, $T_t = \tau_t W_t L_t$, or public debt according to the following budget constraint:

$$B_t = (1 + r_{f,t-1})B_{t-1} + G_t - T_t, \quad (2.15)$$

with

$$B_0 = 0.$$

The government chooses the mix between taxation and deficit by means of simple, implementable and plausible fiscal rules, in the spirit of Favero and Monacelli (2005), Schmitt-Grohe and Uribe (2007), Bi and Leeper (2010), and Leeper, Plante, and Traum (2010).

We focus on two tax regimes. Under the first regime, the government commits to a zero-deficit policy and sets the tax rate, τ_t^{zd} , as follows:

$$\tau_t^{zd} = \frac{G_t/Y_t}{1 - \alpha}.$$

In this case, there is no tax smoothing and the tax rate perfectly mimics the properties of our exogenous government expenditure process. We take this zero-deficit policy as a benchmark case in our welfare analysis.

Under the second regime, we allow for tax smoothing and let the government adjust its fiscal stance according to prevailing macroeconomic conditions. We focus on two aspects of tax smoothing, namely the persistence and intensity of swings in the tax rate. We specify the government's policy in terms of a debt management rule, with tax rates implied by the budget constraint, as follows:

$$\frac{B_t}{Y_t} = \rho_B \frac{B_{t-1}}{Y_{t-1}} + \phi_B \cdot \epsilon_t^B, \quad (2.16)$$

where ϵ_t^B is an endogenous, stationary, and zero-mean variable summarizing the state of the economy; ϕ_B determines the intensity of the government response to shocks; and $\rho_B \in (0, 1)$ is a measure of the speed of repayment of debt, i.e., the higher the value of ρ_B , the slower the repayment of debt relative to output.³

This parsimonious specification has two main advantages. First, the condition $\rho_B < 1$

³Given this policy specification, we have $E[B_t] = B_0 = 0$. In our analysis, we abstract away from a non-zero target for the debt-output ratio.

guarantees stationarity of the debt-output ratio. In the language of [Bi and Leeper \(2010\)](#), our rule in equation (2.16) anchors expectations about future debt and rules out unstable paths. Overall, this specification replicates key empirical properties of the U.S. debt-output ratio.

Second and most importantly, the tax system is fully characterized by just two parameters, (ρ_B, ϕ_B) . To better illustrate this point, we combine equations (2.15) and (2.16) to obtain the following expression for the tax rate:

$$\tau_t(\rho_B, \phi_B) = \tau_t^{zd} - \phi_B \frac{\epsilon_t^B}{1 - \alpha} + \frac{1}{1 - \alpha} \left(\frac{1 + r_{f,t-1}}{Y_t/Y_{t-1}} - \rho_B \right) \frac{B_{t-1}}{Y_{t-1}}. \quad (2.17)$$

The second term on the right-hand side of this equation refers to the departure of the tax rate from its zero-deficit counterpart in response to economic shocks. The parameter ϕ_B determines the intensity of this response. The last term in equation (2.17), in contrast, captures the persistent effect that debt repayment has on taxes. This term generates a positive monotonic mapping between ρ_B and the persistence of the tax rate, i.e., choosing a higher ρ_B is equivalent to increasing the degree of tax smoothing.

2.2.3.0.17 Tax smoothing horizons. In our analysis, we consider two different specifications for ϵ_t^B . We first focus on the case in which the government uses tax smoothing to reduce short-run fluctuations in labor. In this case, we set

$$\epsilon_t^B \equiv \log L_{SS} - \log L_t, \quad (2.18)$$

where L_{SS} denotes the steady-state level of labor. Under this specification, the government cuts labor taxes (increases debt) when labor is below steady state and increases them (reduces debt) in periods of boom for the labor market. As we show in the next section, reducing short-run labor volatility implies a reduction of the short-run volatility of the whole consumption bundle. For this reason, we refer to this specification as *short-run-oriented* tax smoothing.

Under our second specification, in contrast, we consider a government concerned about stabilizing the economy's long-term growth prospects. In our innovation-driven model of endogenous growth, long-term growth closely mirrors the dynamics of investment in R&D, S_t . As suggested by equation (2.13), long-run stabilization can be achieved by responding to fluctuations in expected profits. In particular, we set

$$\epsilon_t^B \equiv E_t[\Delta \log A_{t+1} \Pi_{t+1}] - \Delta \log A \Pi_{SS}, \quad (2.19)$$

so that when expected aggregate profit growth is below average the government increases current taxation in order to create expectations of lower future tax rates. Under this policy, therefore, the government counterbalances bad long-run profit news with good long-run tax rate news. We refer to this specification as *long-run-oriented* tax smoothing.

2.2.4. Market Clearing

We complete the description of our model by discussing our market clearing conditions. In the labor market, the following holds:

$$\left(\frac{C_t}{A_t(1 - L_t)} \right)^{1/\nu} = (1 - \tau_t(\rho_B, \phi_B)) \frac{(1 - \alpha)Y_t}{A_t L_t}. \quad (2.20)$$

The market clearing condition for the final good is given by

$$Y_t = C_t + S_t + A_t X_t + G_t,$$

implying that final output is used for consumption, R&D investment, production of intermediate goods, and public expenditure.

Given the multisector structure of the model, various assumptions on the constituents of the stock market can be adopted. We assume that the stock market is a claim to the net payout from all the production sectors described above, namely, the final good, the intermediate goods, and the R&D sector. Taking into account the fact that both the final good and the

R&D sector are competitive, aggregate dividends are simply equal to monopolistic profits net of investment:

$$D_t = \Pi_t A_t - S_t. \quad (2.21)$$

2.2.5. Growth, Asset Prices, and Risk Distribution

2.2.5.0.18 Growth and asset prices. Combining equations (2.10)–(2.13), we obtain the following expression for growth rate in the economy:

$$\begin{aligned} \frac{A_{t+1}}{A_t} &= 1 + \delta + \chi^{\frac{1}{1-\eta}} E_t [M_{t+1} V_{t+1}]^{\frac{\eta}{1-\eta}} \\ &= 1 + \delta + \chi^{\frac{1}{1-\eta}} E_t \left[\sum_{j=1}^{\infty} M_{t+j|t} (1-\delta)^{j-1} \left(\frac{1}{\alpha} - 1 \right) (\Omega_{t+j} \alpha^2)^{\frac{1}{1-\alpha}} L_{t+j} \right]^{\frac{\eta}{1-\eta}}. \end{aligned} \quad (2.22)$$

The relevance of equation (2.22) is twofold, as it enables us to discuss both the interaction between recursive preferences and endogenous growth, and the role played by the tax system.

First, we point out that in this framework, growth is a monotonic transformation of the discounted value of future profits. This implies that the average growth in the economy is endogenously negatively related to both the discount rate used by the household and the amount of perceived risk. When the household has standard time-additive preferences, only short-run profit risk matters for the determination of the value of a patent. When the agent has recursive preferences, however, optimal growth depends also on the endogenous amount of volatility in expected long-run profits. A characterization of the entire intertemporal distribution of risk is required.

Second, since profits are proportional to labor, and labor supply is sensitive to the tax rate (equation (2.20)), a fiscal system (ϕ_B, ρ_B) based on tax smoothing ultimately introduces long-lasting fluctuations in future profits. Depending on the dynamic properties of current and future taxes, tax smoothing can depress or enhance long-term growth and ultimately welfare.

Our study shows that in an economy calibrated to match key asset pricing facts, short-run-oriented tax smoothing comes at the cost of reduced long-run growth, whereas long-run-oriented tax smoothing can produce benefits. This tension is at the core of our welfare analysis.

2.2.5.0.19 A simple log-linear environment. We find it useful to study the asset pricing properties of both patent value and pricing kernel in a simple log-linear setting. This analysis provides simple economic intuition on the impact of both recursive preferences and tax uncertainty on long-run growth. To this aim, assume for the moment that log profits, $\ln \Pi_t$, and log consumption bundle growth, Δc_t , are jointly linear-gaussian and embody a predictable component:

$$\begin{aligned}
\Delta c_{t+1} &= \mu + x_{c,t} + \sigma_c^{SR} \varepsilon_{t+1}^c \\
\ln \Pi_{t+1} &= \bar{\Pi} + x_{\Pi,t} + \sigma_{\Pi}^{SR} \varepsilon_{t+1}^{\pi} \\
x_{c,t+1} &= \rho_c x_{c,t} + \sigma_c^{LR} \varepsilon_{t+1}^{xc} \\
x_{\Pi,t+1} &= \rho_{\Pi} x_{\Pi,t} + \sigma_{\Pi}^{LR} \varepsilon_{t+1}^{x\Pi} \\
\varepsilon_{t+1} &\equiv \begin{bmatrix} \varepsilon_{t+1}^c & \varepsilon_{t+1}^{\pi} & \varepsilon_{t+1}^{xc} & \varepsilon_{t+1}^{x\Pi} \end{bmatrix} \sim i.i.d.N.(\vec{0}, \Sigma),
\end{aligned} \tag{2.23}$$

where Σ has ones on its main diagonal. In the spirit of [Bansal and Yaron \(2004a\)](#), we think of ε^c and ε^{π} as short-run shocks to consumption growth and profits, respectively. The predictable components x_{Π} and x_c , in contrast, are long-run risks.

To stay as close as possible to the [Bansal and Yaron \(2004a\)](#) framework, assume also that $C_t/(A_t(1 - L_t))$ is constant. Given these simplifying assumptions, we obtain the following approximate solution for the pricing kernel:

$$\ln \Lambda_{t+1} - E_t[\ln \Lambda_{t+1}] = \begin{cases} -\gamma \sigma_c^{SR} \varepsilon_{t+1}^c & \text{CRRA} \\ -\gamma \sigma_c^{SR} \varepsilon_{t+1}^c - \kappa_c \frac{\gamma-1/\psi}{1-\rho_c \kappa_c} \sigma_c^{LR} \varepsilon_{t+1}^{xc} & \gamma \neq 1/\psi, \end{cases} \tag{2.24}$$

where $\kappa_c = \overline{P/C}/(1 - \overline{P/C})$ is an approximation constant and P/C is the average wealth-

consumption ratio. By no arbitrage, the log return of a patent, $r_{V,t+1} = \ln(V_{t+1}/(V_t - \Pi_t))$, satisfies the following condition:

$$r_{V,t+1} - E_t[r_{V,t+1}] \approx \kappa_2 \sigma_{\Pi}^{SR} \epsilon_{t+1}^{\Pi} - \frac{\kappa_1}{1 - \kappa_1 \rho_c} \sigma_c^{LR} \epsilon_{t+1}^{xc} + \frac{\kappa_2}{1 - \kappa_1 \rho_{\Pi}} \sigma_{\Pi}^{LR} \epsilon_{t+1}^{x\Pi}, \quad (2.25)$$

where $\kappa_1 = (\bar{V} - \bar{\Pi})/\bar{V}$ and $\kappa_2 = \bar{\Pi}/\bar{V}$ are approximation constants.

Since the average value of a patent is decreasing in the risk premium of its return, $E_t[r_{V,t+1} - r_t^f] \approx -cov_t(\ln \Lambda_{t+1}, r_{V,t+1})$, these equations help us to make three relevant points. First, with CRRA preferences, the reduction of short-run consumption risk, σ_c^{SR} , is sufficient to reduce the market price of risk and hence the riskiness of the patents, i.e., short-run stabilization promotes growth.

Second, with recursive preferences, the market price of risk strongly depends on both the persistence, ρ_c , and the volatility, σ_c^{LR} , of the long-run component in consumption. For sufficiently high values of $\gamma - 1/\psi$, growth is pinned down mainly by long-run consumption risk, as opposed to short-run risk.

Third, in contrast to the endowment economy of [Bansal and Yaron \(2004a\)](#), in our setting all cash-flow parameters are endogenous objects sensitive to the fiscal system (ϕ_B, ρ_B) . After calibrating the model, we explore the role of ϕ_B and ρ_B in (i) varying the amount of short- and long-run risk, and (ii) altering long-run growth.

2.2.5.0.20 Link to optimal policy. In [A.4](#), we report the Ramsey problem associated with our economy. In order to reduce the set of constraints faced by the planner, we assume availability of state-contingent debt. [Croce, Karantounias, Nguyen, and Schmid \(2013\)](#) provide sufficient conditions for the existence of a well-defined Ramsey problem, but they do not assess the trade-offs faced by Ramsey. With recursive preferences, the multiplier on the promise-keeping constraint is an endogenous state that evolves as a log-martingale whose characterization is challenging even in simpler settings ([Karantounias 2011, 2012](#)). Our exogenous fiscal policy rules, in contrast, are a simple and useful device to trace the

risk trade-off frontier faced by the government in our rich production setting.

Specifically, in our setting the marginal utility of consumption from a Ramsey perspective, λ_t , can be decomposed in the following way:

$$\lambda_t = \lambda_t^{LS} \cdot \underbrace{M_t^{\frac{\zeta}{\zeta-1}} + u_{ct}\xi_t - M_t^{\frac{\zeta}{\zeta-1}}}_{\substack{\text{Intertemporal Distorsion} \\ \text{Channel}}} \cdot \underbrace{u_{cc,t}\Phi(\rho_t - \rho_{t-1}\vartheta_{t-1}V_t - D_t)}_{\substack{\text{Asset Price} \\ \text{Channel}}}, \quad (2.26)$$

where $\lambda_t^{LS} := u_{ct} + \Phi\Omega_{c,t}$ is the shadow value of consumption in the [Lucas and Stokey \(1983\)](#) economy, $D_t := A_t\Pi_t - S_t$ are the aggregate dividends, and ξ_t evolves as a martingale with respect to $\pi_t M_t$ with $\xi_0 = 0$ and $\text{StD}_t[\xi_{t+1}] \propto \zeta$.

Relative to [Lucas and Stokey \(1983\)](#), our setup adds two margins. The first margin concerns the second term in equation (2.26) and accounts for the impact that current taxation has on future utility (the intertemporal distortion margin). In our risk-based analysis, the term has a simple interpretation: it defines the link between short-run consumption smoothing and continuation utility smoothing that arises under recursive preferences. Since continuation utility is a reflection of future expected consumption, this term introduces a tension between short-run and long-run consumption stabilization. This term enables us to meaningfully interpret fiscal policy as a device to alter the intertemporal distribution of consumption risk.

The second margin relates to the last term in equation (2.26) and arises because of endogenous growth. This term captures the impact that future labor taxation distortions have on the riskiness of future labor supply, profits, and the market value of innovation (the asset price channel). Consistent with our analysis of equation (2.22), assessment of the impact of taxation on the value of patents is essential to the understanding of long-term growth.

Intuitively, for any given tax system, the planner takes into account both the asset-price and the intertemporal-distortion channel trying to balance short-run consumption smooth-

ing, long-run consumption stabilization, and growth. In our setup, these two channels are complementary and reinforce each other in the determination of novel and rich fiscal policy implications, which we discuss next.

2.3. Calibration

We report our benchmark calibration along with the implied main statistics of our model in table 3. Our benchmark calibration refers to the case of a zero-deficit policy. Since the main focus of the paper is on the implications of fiscal policy for long-run consumption dynamics, we calibrate our productivity process to match the unconditional volatility of consumption growth observed in the U.S. over the long sample 1929–2008.

The parameters for the government expenditure-output ratio are set to have an average share of 10% and an annual volatility of 4%, consistent with U.S. annual data over the sample 1929–2008. Using post–World War II data would make expenditure risk even larger; hence we regard our calibration as conservative.

Relative risk aversion, IES, and subjective discount factor are set to replicate the low historical average of the risk-free rate and the consumption claim risk premium estimated by [Lustig, Van Nieuwerburgh, and Verdelhan \(2013\)](#). Replicating these asset pricing moments is important because it imposes a strict discipline on the way in which innovations are priced and average growth is determined.

The parameters ν and θ_c control the labor supply and are chosen to yield a steady-state share of hours worked of 1/3 and a steady-state Frisch elasticity of 0.7, respectively. These values are standard in the literature.

Turning to technology parameters, the constant α captures the relative weight of labor and intermediate goods in the production of final goods, and, by equation (2.7), controls the markup and hence profits in the economy. We choose this parameter to match the empirical share of profits in aggregate income. The parameter η , the elasticity of new intermediate

Table 3: Calibration and Main Statistics

Panel A: Parameters		
Description	Symbol	Value
<i>Preference Parameters</i>		
Consumption-Labor Elasticity	ν	0.7
Utility Share of Consumption	θ_c	0.095
Discount Factor	β	0.996
Intertemporal Elasticity of Substitution	ψ	1.7
Risk Aversion	γ	7
<i>Technology Parameters</i>		
Elasticity of Substitution Between Intermediate Goods	α	0.7
Autocorrelation of Productivity	ρ	0.96
Scale Parameter for R&D Externalities	χ	0.45
Survival Rate of Intermediate Goods	$1 - \delta$	0.97
Elasticity of New Varieties wrt R&D Investment	η	0.8
Standard Deviation of Technology Shock	σ	0.006
<i>Government Expenditure Parameters</i>		
Log-level of Expenditure-Output Ratio (G/Y)	\overline{gy}	-2.2
Autocorrelation of G/Y	ρ_G	0.98
Standard Deviation of G/Y shocks	σ_G	0.008
Panel B: Moments		
	Data	Model
$E(\Delta c)$ (%)	2.05	2.04
$\sigma(\Delta c)$ (%)	2.34	2.14
$ACF_1(\Delta c)$	0.44	0.58
$E(L)$ (%)	33.0	35.63
$E(\tau)$ (%)	33.5	33.5
$\sigma(\tau)$ (%)	3.10	1.80
$E(r_f)$	0.93	1.48
$\sigma(m)$	—	0.43
$E(r^C - r_f)$	—	1.89

Notes - This table reports the benchmark quarterly calibration of our model along with the main moments computed under the zero-deficit policy ($\phi_B = 0$). $E(L)$ is the fraction of hours worked. All moments are annualized. All figures are multiplied by 100, except $ACF_1(\Delta c)$, the first-order autocorrelation of consumption growth. The log discount factor is denoted by m , and τ is the tax rate. r^C and r_f are the return of the consumption claim and the risk-free bond, respectively.

goods with respect to R&D, is within the range of the panel and cross-sectional estimates of [Griliches \(1990\)](#). Since the variety of intermediate goods can be interpreted as the stock of R&D (a directly observable quantity), we can then interpret δ as the depreciation rate of the R&D stock. We set $1 - \delta$ to 0.97, which corresponds to an annual depreciation rate of about 14%, i.e., the value assumed by the Bureau of Labor Statistics in its R&D stock

calculations. The scale parameter χ is chosen to match the average growth rate of the U.S. economy over the 1929–2008 sample.

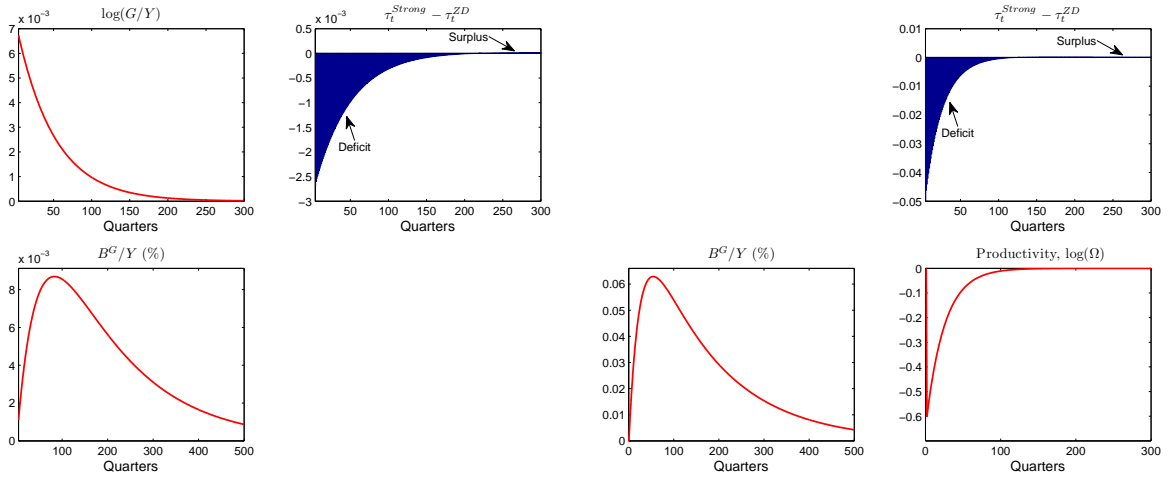
Under our benchmark calibration, the average tax rate is roughly 33.5%, consistent with the data. On the other hand, the implied volatility of taxes is moderate, in the order of 2.6%⁴. Our results, therefore, are not driven by an excessively volatile tax rate.

2.4. Short-Term-Oriented Tax Smoothing and the Distribution of Risk

In panels A and B of figure 10, we depict the response of the tax rate after a positive shock to government expenditures and a negative shock to productivity, respectively. Since these responses are qualitatively the same under time-additive preferences, for brevity we plot only the responses under our benchmark calibration. According to equations (2.17)–(2.18), in both cases the government responds to these shocks by initially lowering the tax rate below the level required to achieve a zero deficit. Over the long horizon, however, the government increases taxation above average in order to run surpluses and repay debt. Good news for short-run taxation levels always comes with bad news for long-run fiscal pressure. In our stochastic environment, this consideration explains the existence of a relevant trade-off between short- and long-run risk.

In what follows, we first describe the impact of this fiscal policy on macroeconomic aggregates by looking at impulse response functions. This step helps to explain the change in the distribution of consumption risk across policies and preferences. Second, we show that our simple countercyclical fiscal policy generates welfare benefits with respect to a simple zero-deficit rule when the agent has CRRA preferences. When the agent has recursive preferences, in contrast, the same policy creates significant welfare costs. Third, we relate these welfare results to the market value of patents and the term structure of profit risk. In the next section, we show that with recursive preferences welfare benefits can be obtained by means of a fiscal policy oriented toward long-term stabilization. Our welfare

⁴See Backus, Henriksen, and Storesletten (2008) for evidence on the time-series properties of tax rates in an international context.



a) Positive Expenditure Shock

b) Negative Productivity Shock

Figure 10: Impulse Response of Tax Rate and Debt

Notes - This figure shows quarterly log-deviations from the steady state for the government expenditure-output ratio (G/Y), debt-output ratio (B/Y), and labor tax (τ). Panel A refers to an adverse shock to government expenditure. Panel B refers to a negative productivity shock. All deviations are multiplied by 100. All the parameters are calibrated to the values in table 3. The fiscal system is determined by equations (2.17)–(2.18). The zero-deficit policy is obtained by imposing $\phi_B = 0$. The countercyclical policy is obtained by setting $\rho_B^4 = .98$ and $\phi_B = .4\%$.

cost computations are reported in A.5.

2.4.1. Dynamics

2.4.1.0.21 Time-additive preferences. We set $\psi = 1/\gamma = 1/7$ to study the time-additive preferences case, a useful benchmark to evaluate fiscal policy implications for consumption growth. All other parameters are kept constant at their benchmark values reported in table 3.

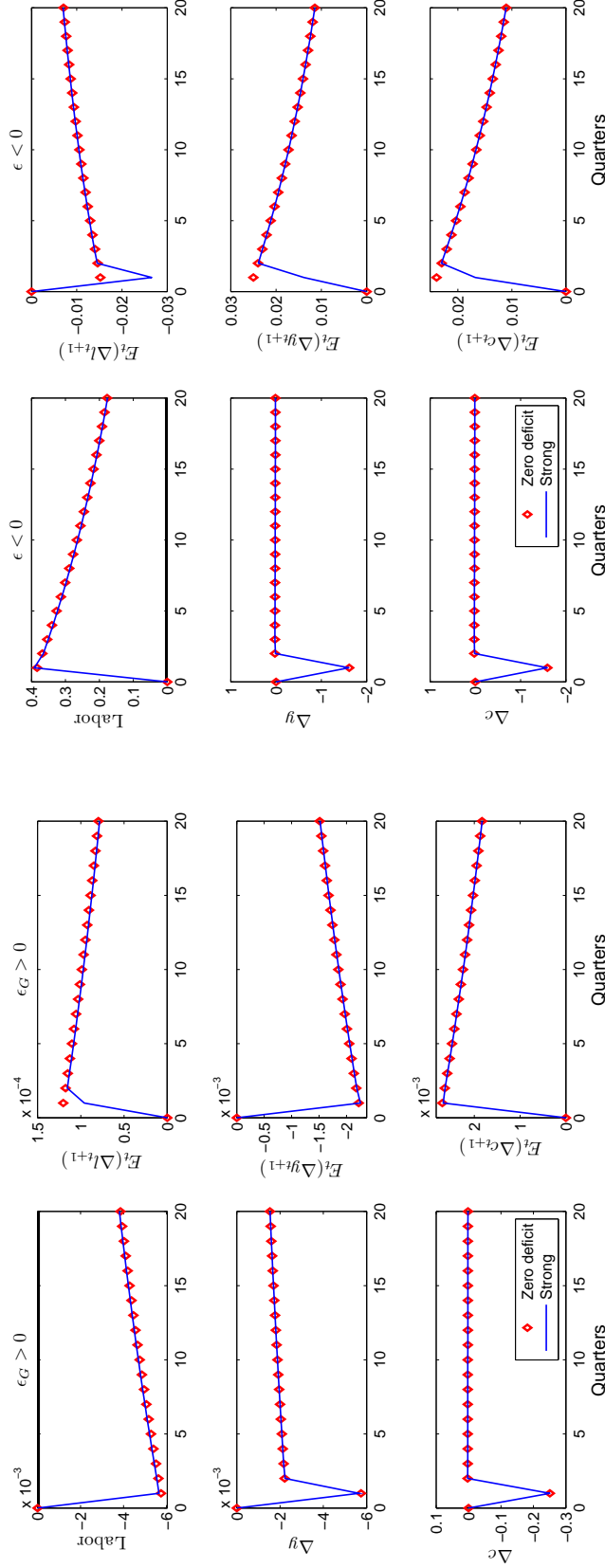
We depict the impulse response functions of key variables of interest upon the realization of adverse expenditure and productivity shocks in figures 11a and 11b, respectively. In each subfigure, the plots on the left-hand side refer to realized values of labor, output, and

consumption growth. The right-hand side panels, in contrast, refer to the dynamics of the one-period-ahead expectation about these variables.

We note two things about figure 11. First, under our active policy the short-run response of our variables of interest is less pronounced than under the zero-deficit policy. Although almost invisible, this different dynamic behavior is important, as it guarantees that our active policy does what it is supposed to do, i.e., it promotes short-run stabilization in consumption and leisure. Second, expectations are very similar across the zero-deficit and active policy cases, implying that our active policy does not radically change long-term dynamics in a model with CRRA. This result is in sharp contrast with that of the recursive preferences case.

2.4.1.0.22 Recursive preferences. Similarly to the case of time-additive preferences, in figure 12 we depict the impulse response of key variables of interest with recursive preferences. The top-left panel of figure 12a shows that when an adverse government shock materializes, labor tends to fall, as in the CRRA case. This is due to the substitution effect: a higher level of government expenditure requires a higher tax rate, which depresses the supply of labor services. When the government implements a strong tax smoothing policy, the immediate increase in the tax rate is less severe, and for this reason labor falls less than under the zero-deficit policy. Under this calibration, the short-run stabilization effect of our simple policy is sizeable and visible.

The top-right panel of figure 12a shows that this short-run stabilization comes at the cost of a lower expected recovery speed. At all possible horizons, indeed, the expected growth rate of labor under the tax-smoothing policy is lower than under the zero-deficit policy. This effect is due to the fact that over time the government keeps taxes at a higher level in order to repay public debt. In this sense, the government is trading off short-run labor volatility

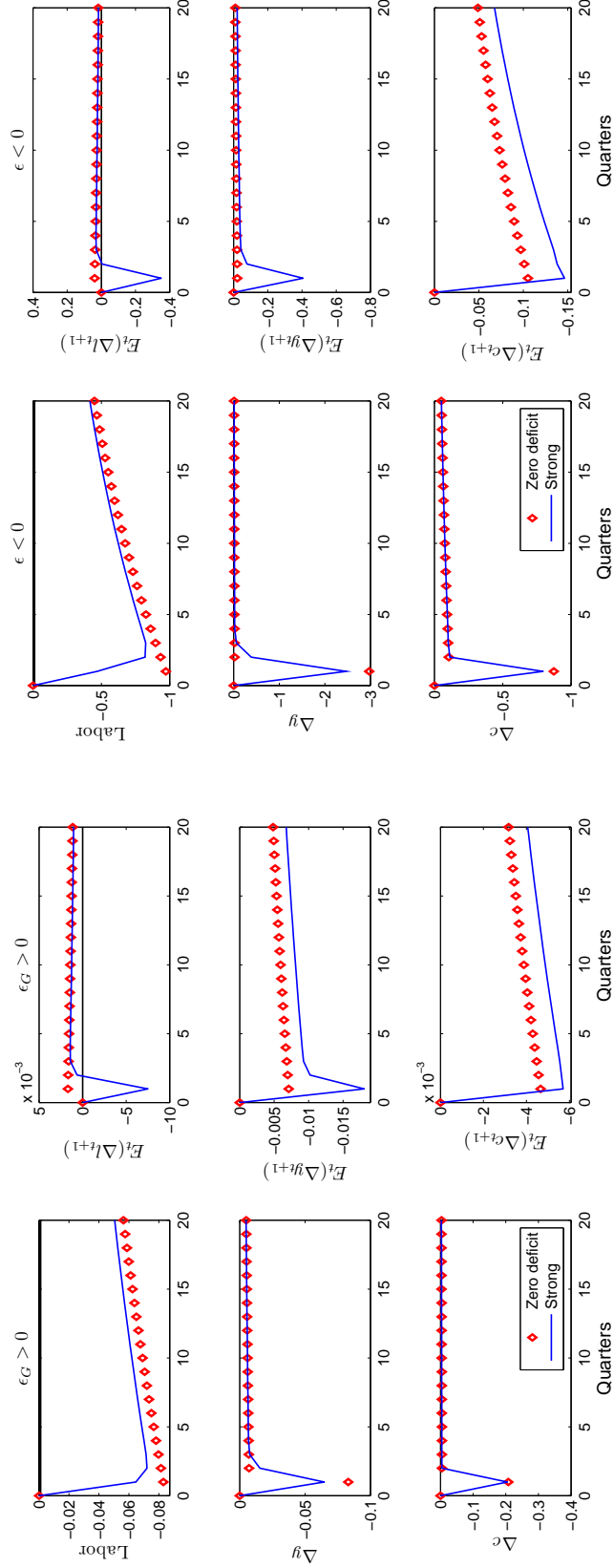


(a) Adverse Expenditure Shock

(b) Adverse Productivity Shock

Figure 11: Zero-deficit versus Strong Tax Smoothing: Impulse Responses in the CRRR Case

Notes - This figure shows quarterly log-deviations from the steady state. All deviations are multiplied by 100. All the parameters are calibrated to the values used in table 3, except the IES which is set to $1/\gamma = 1/7$. The fiscal system is determined by equations (2.17)–(2.18). The diamond-shaped markers refer to the zero-deficit policy ($\phi_B = 0$). The solid line is associated with a strong countercyclical fiscal policy ($\phi_B = .4\%$).



(a) Adverse Expenditure Shock

(b) Adverse Productivity Shock

Figure 12: Zero-deficit versus Strong Tax Smoothing: Impulse Responses in the EZ Case

Notes - This figure shows quarterly log-deviations from the steady state. All deviations are multiplied by 100. All the parameters are calibrated to the values used in table 3. The fiscal system is determined by equations (2.17)–(2.18). The diamond-shaped markers refer to the zero-deficit policy ($\phi_B = 0$). The solid line is associated with a strong countercyclical fiscal policy ($\phi_B = .4\%$).

for long-run labor volatility by making the effects of government expenditure shocks less severe on impact, but more long-lasting. In contrast to the case of time-additive preferences, this effect is quantitatively significant. In the next section, we show that this channel is responsible for relevant variations in both welfare and equilibrium growth.

Labor growth dynamics are relevant to the understanding of aggregate output growth adjustments over both the short- and long-run (equation (2.8)). The two middle panels of figure 12a show that under the short-term-oriented tax smoothing policy, the government is able to reduce the decrease in output growth when the shock materializes (left panel). This stabilization effect, however, comes at the cost of amplifying the reduction in expected long-run growth (right panel). Such a significant drop in output growth reflects not only labor growth dynamics, but also capital accumulation alterations. Specifically, the responses of output account for the fact that after an increase in government expenditure there are fewer resources allocated to R&D and hence a lower innovation speed, A_{t+1}/A_t , for the long-run.

What we have discussed so far is also true when the economy is subject to a negative productivity shock. As shown in figure 12b, the tax smoothing policy is able to reduce the short-run fall in employment and output only at the cost of a slower recovery for both of these variables.

Finally, the bottom two panels of both figures 12a and 12b show that our tax smoothing policy alters consumption growth exactly as it does for output growth: a reduction in short-run consumption adjustments comes at the cost of more pronounced movements in expected future growth upon the realization of both expenditure and productivity shocks.

Crucially, in table 4 we show that this kind of tax smoothing policy tends to make expected consumption growth more persistent, i.e., it makes the impact of the exogenous shocks on consumption more long-lasting. As ϕ_B increases, the volatility of consumption, $\sigma(\Delta c)$, declines, whereas the half-life of the consumption long-run component, $E_t[\Delta c_{t+1}]$, increases. Since the long-run component of consumption is relatively small, the half-life of long-term

Table 4: Short-Run Tax Smoothing and Consumption Distribution

	Data	Zero-deficit $\phi_B = 0$	Weak $\phi_B = .3\%$	Strong $\phi_B = .4\%$
$\sigma(\Delta c)$	2.34	2.14	2.08	2.07
$ACF_1(\Delta c)$	0.44	0.58	0.59	0.59
Half-life $E_t(\Delta c_{t+1})$		34.62	50.99	54.23
$E(\Delta c)$	2.03	2.04	2.01	1.99

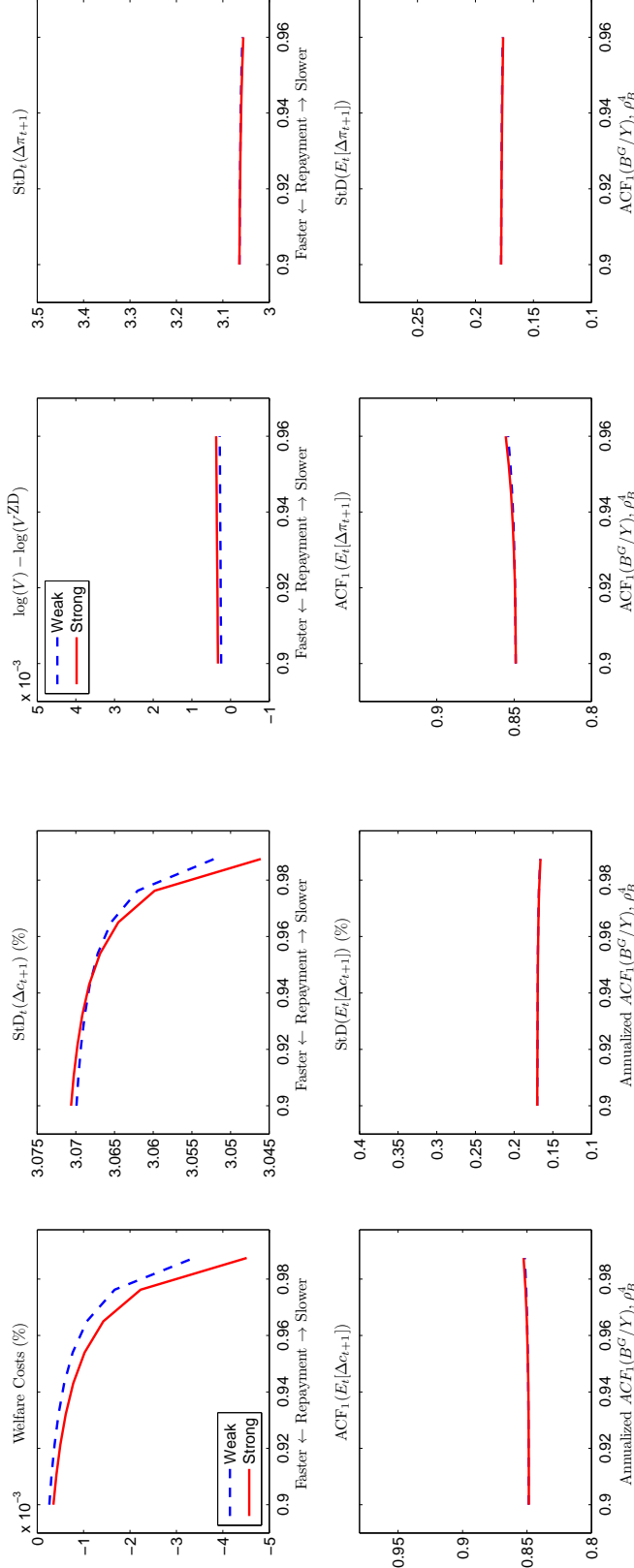
Notes - This table reports the summary statistics of our model as calibrated in Table (3). The half-life of $E_t[\Delta c_{t+1}]$ is expressed in quarters. All moments except the half-life and the autocorrelation of consumption growth, $ACF_1(\Delta c)$, are annualized and in percentages. Columns correspond to different levels of intensity of the countercyclical fiscal policy described in equations (2.17)–(2.18). The speed of debt repayment is determined by $\rho_B^4 = .98$.

consumption growth can increase substantially even though the persistence of consumption growth, $ACF_1(\Delta c)$, remains basically unchanged and consistent with the data. In the next section, we show that the trade-off between short-run volatility of consumption growth and amount of long-term growth risk is responsible for the decline of average growth.

2.4.2. Distribution of Risk, Patent Value, and Welfare

In this section, we explore the welfare implications of our simple short-term-oriented tax smoothing policy under both time-additive and recursive preferences (figures 13 and 14, respectively). For each preference setting, we depict welfare costs as well as our measure of short- and long-run consumption risk (subfigures 13a and 14a). Since welfare depends also on average growth and the latter is a reflection of patent value (equation (2.22)), we additionally plot variations in both average patent value and profit risks (subfigures 13b and 14b).

2.4.2.0.23 Time-additive preferences. Focusing on figure 13, we note three relevant results. First, our simple fiscal policy does what it is designed to do: it reduces short-term risk of both consumption and profits. This short-run stabilization is more pronounced when tax smoothing is more persistent (higher ρ_B) and in the case of a greater response to economic shocks (higher ϕ_B).



(a) Welfare Costs and Consumption Distribution

(b) Patent Value and Profits Distribution

Figure 13: Welfare Costs and Patent Value in the CRRRA Case

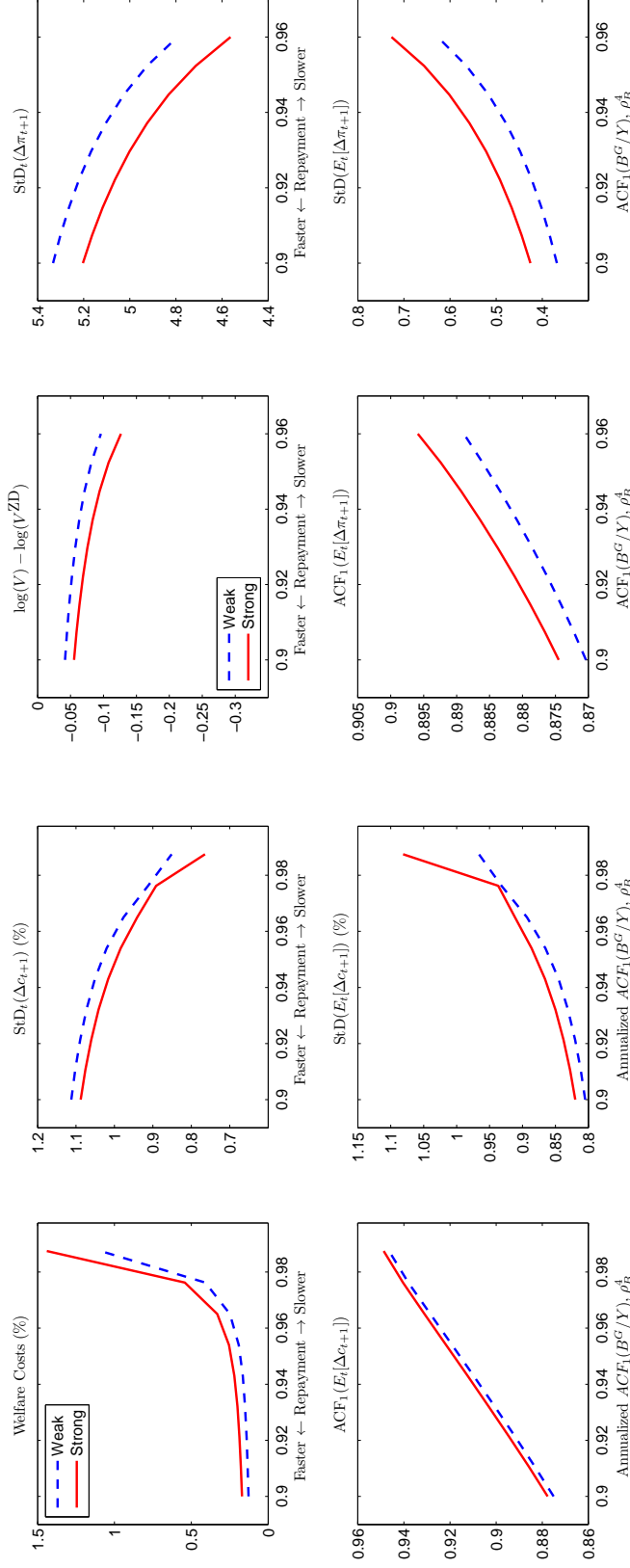
Notes - Panel A of this figure shows both the welfare costs and key moments of consumption growth associated with different fiscal policies specified by equations (2.17)–(2.18). Welfare is compared to the case of a zero-deficit fiscal policy and is expressed in lifetime consumption units. Panel B shows both the average value of patents and key moments of the profits distribution. All the parameters are calibrated to the values used in table 3, except the IES, which is set to $1/\gamma = 1/7$. The lines reported in each plot are associated to different levels of intensity of the countercyclical fiscal policy. Weak and strong policies are generated by calibrating ϕ_B to .3% and .4%, respectively. The horizontal axis corresponds to different annualized autocorrelation levels, ρ_B , of debt-to-output ratio, B^G/Y ; the higher the autocorrelation, the lower the speed of repayment.

Second, consistent with the results obtained when studying the impulse response functions of our model, short-run stabilization does not alter in any significant way the long-run properties of consumption and profits. Hence, with time-additive preferences there is no trade-off between short- and long-run risk.

Third, since the representative agent is sensitive only to short-run risk, and both short-run consumption growth and profits are less risky under our active fiscal policy, the average value of patents is higher than it would be under a zero-deficit tax policy. This result implies that the unconditional growth rate of consumption is higher under this tax smoothing scheme than under a zero-deficit rule. A higher average growth rate paired with less-severe short-run consumption fluctuations produces welfare benefits, as shown in the top-left panel of figure 13.

2.4.2.0.24 Recursive preferences. Our results change dramatically in the setting with recursive preferences. In sharp contrast to the time-additive preferences case, our short-run-oriented fiscal policy produces welfare costs. The source of these welfare costs is twofold. First of all, consistent with our previous analysis of the dynamics of consumption growth, short-run stabilization is accompanied by an increase in long-term growth risk. Specifically, as we increase the intensity of our policy, ϕ_B , or the extent of tax smoothing, ρ_B , the conditional expected growth rate of consumption becomes more persistent and volatile (bottom two panels of figure 14a). The reduction of short-run fluctuations comes at the cost of more sluggish long-term consumption dynamics. Since our agent has a preference for early resolution of uncertainty, these long-lasting consumption fluctuations depress welfare.

Further, our tax policy produces the same kind of trade-offs when we look at profits. As ϕ_B and ρ_B increase, short-run profit volatility declines, but at the cost of greater long-run profit risk. With recursive preferences, this trade-off ultimately depresses the average



(a) Welfare Costs and Consumption Distribution

(b) Patents Value and Profits Distribution

Figure 14: Welfare Costs and Patents' Value in the EZ Case

Notes - Panel A of this figure shows both the welfare costs and key moments of consumption growth associated with different fiscal policies specified by equations (2.17)–(2.18). Welfare is compared to the case of a zero-deficit fiscal policy and is expressed in lifetime consumption units. Panel B shows both the average value of patents and key moments of the profits distribution. All the parameters are calibrated to the values used in table 3. The lines reported in each plot are associated with different levels of intensity of the countercyclical fiscal policy. Weak and strong policies are generated by calibrating ϕ_B to .3%, and .4%, respectively. The horizontal axis corresponds to different annualized autocorrelation levels, ρ_B^G , of debt-to-output ratio, B^G/Y ; the higher the autocorrelation, the lower the speed of repayment.

value of patents with respect to the case of a zero-deficit policy. As a result, innovation is discouraged and long-term growth is lower than under the zero-deficit policy. Permanent growth losses paired with greater long-run consumption risk outweigh the reduction in short-run risk and produce welfare costs.

To better illustrate how our short-term-oriented tax policy affects profit risk premia across different horizons, in figure 15 we depict the variation of the whole term structure of profit excess returns across the active and zero-deficit fiscal policies. Specifically, let $P_{n,t}^{\pi,Active}$ ($P_{n,t}^{\pi,ZD}$) denote the time t value of profits realized at time $t+n$ under our active (zero-deficit) fiscal policy. The one-period excess return of a zero-coupon claim to profits with maturity n is

$$R_{n,t}^{\pi,j} = E_t[P_{n-1,t+1}^{\pi,j}/P_{n,t}^{\pi,j}] - r_t^f, \quad j \in \{Active, ZD\}.$$

Under time-additive preferences, the variation in the excess returns of profits with different maturity is basically zero (left panel, figure 15). This explains why under time-additive preferences the improvement in the average value of patents is very small.

Under recursive preferences, in contrast, the fiscal system becomes a vehicle by which to significantly alter the shape of the term structure of profits. Specifically, under our benchmark calibration of the active policy, the value-weighted return of a strip of dividends paid over a maturity of up to 24 periods (6 years) is less risky than under the zero-deficit policy. This reduction of short-term risk, however, comes at the cost of greater risk over the long horizon. Since our representative agent is very patient and adverse to long-run risk, the increase in long-term risk premia compounded over the infinite horizon dominates and depresses patent values and growth.

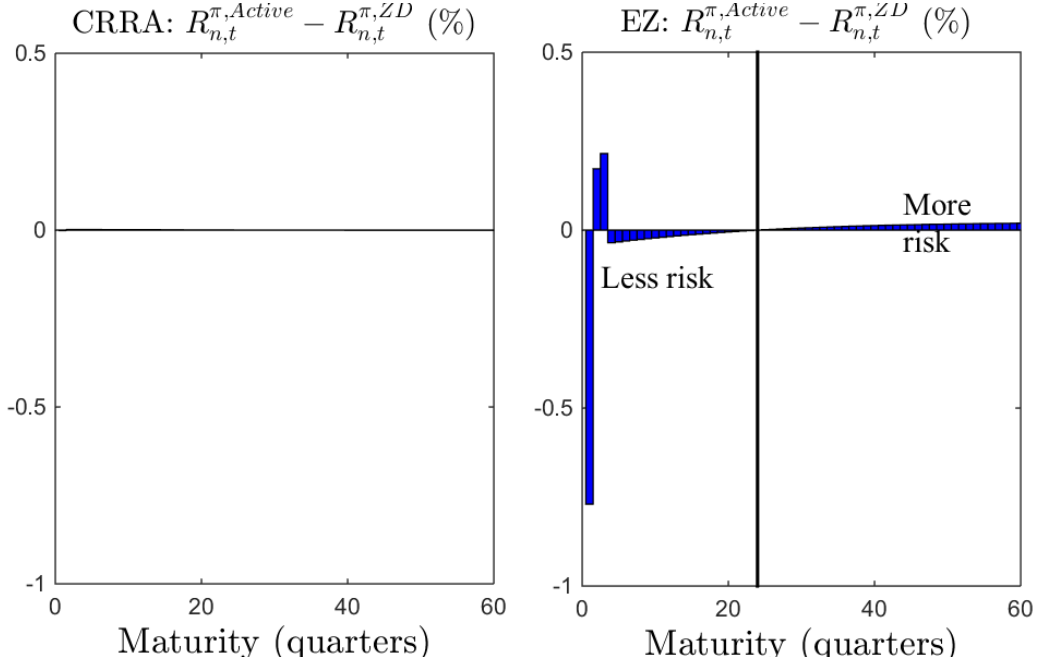


Figure 15: Fiscal Policies and Term Structure of Profits

Notes - This figure depicts the term structure of profit average excess returns under time-additive preferences (left panel) and recursive preferences (right panel). Let $P_{n,t}^{\pi,Active}$ ($P_{n,t}^{\pi,ZD}$) denote the time- t value of profits realized at time $t+n$ under our active (zero-deficit) fiscal policy. The one-period excess return of a zero-coupon claim to profits with maturity n is defined as:

$$R_{n,t}^{\pi,j} = E_t[P_{n-1,t+1}^{\pi,j}/P_{n,t}^{\pi,j}] - r_t^f, \quad j \in \{Active, ZD\}.$$

Excess returns are annualized and in percentages. All the parameters are calibrated to the values used in tables 3 and 4. In the case of CRRA preferences, we set $\psi = 1/\gamma = 1/7$. The countercyclical fiscal policy described in equations (2.17)–(2.18) is calibrated so that $\phi_B = .4\%$ and $\rho_B^4 = .97$.

2.4.3. Utility Mean-Variance Frontier and the Role of IES

In the previous section, we argued that the implications of fiscal policies aimed at short-run stabilization depend critically on whether we adopt time-additive or recursive preferences. In this section, we show that these results are driven by the IES, a parameter about which there is still substantial uncertainty. The early macroeconomic literature (see Hall (1988), among others) suggests a value for the IES of about 0.5; recent macro-finance studies, in contrast, suggest a value as high as 2 (see, e.g., Bansal and Yaron (2004a), Bansal, Kiku, and Yaron (2007), and Colacito and Croce (2011)).

To better highlight the impact of the IES on welfare, we focus on the following ordinally equivalent transformation:

$$\tilde{U}_t = \frac{U_t^{1-1/\psi}}{1-1/\psi}.$$

As in [Colacito and Croce \(2012\)](#), we obtain the following approximation:

$$\tilde{U}_t \approx (1-\beta) \frac{u_t^{1-1/\psi}}{1-1/\psi} + \beta E_t [\tilde{U}_{t+1}] - (\gamma - 1/\psi) \text{Var}_t [\tilde{U}_{t+1}] \kappa_t, \quad (2.27)$$

where $\kappa_t \equiv \frac{\beta}{2E_t[U_t^{1-1/\psi}]} > 0$. When $\gamma = 1/\psi$, the agent is utility-risk neutral and preferences collapse to the standard time-additive case. When the agent prefers early resolution of uncertainty, i.e., $\gamma > 1/\psi$, uncertainty about continuation utility, $\text{Var}_t [\tilde{U}_{t+1}]$, reduces welfare $E [\tilde{U}_t]$. With recursive preferences, therefore, welfare is determined not only by short-run consumption smoothing, but also by continuation utility smoothing.

In the left panel of figure [16](#), we depict the utility mean-variance frontier generated by our short-run-oriented policy when the IES is set to 1.7. We plot two different lines associated with different values of the intensity parameter ϕ_B . Each line is traced by varying the persistence of debt ρ_B^4 from .9 to .96. As tax smoothing increases, long-term utility risk increases and depresses the average continuation utility, as stated in equation [\(2.27\)](#).⁵ Adopting a stronger intensity, ϕ_B , makes this trade-off more severe by shifting the frontier up (greater long-run utility risk) and to the left (lower average welfare). We do not report the frontier with time-additive preferences, as it essentially collapses to just a point.

In the middle panel of figure [16](#), we depict welfare costs as a function of the IES. All other parameters are fixed at their benchmark values. We make two observations. First, varying the IES changes the welfare results of our short-run-oriented fiscal policy both qualitatively

⁵Along our frontier, in equilibrium, the expected value and volatility of continuation utility are linked through two channels. The first channel is a direct one implied by equation [\(2.27\)](#). The second channel is indirect and relates to the simultaneous reduction in the aggregate growth rate discussed in the previous section.

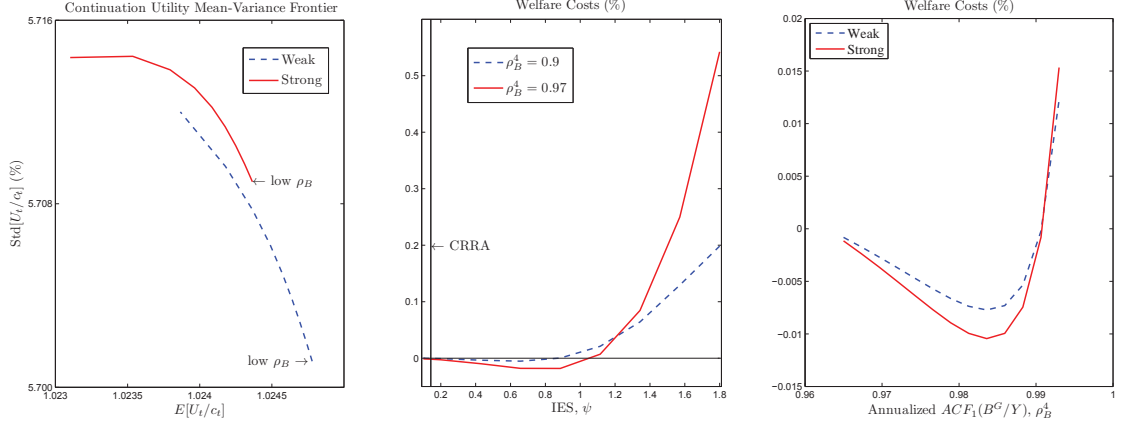


Figure 16: Utility Mean-Variance Frontier and the Role of IES

Notes - The left panel shows the utility mean-variance frontier (equation (2.27)) generated by our short-run-oriented policy (equations (2.17)–(2.18)) when we vary ϕ_B and ρ_B , and all other parameters are set to their benchmark values reported in table 3. In the middle panel, we plot welfare costs as a function of the IES. All other parameters are set to their benchmark values and $\phi_B = .4\%$. In the right panel, all parameters are calibrated as in table 3, except for the IES, which is set to unity. Weak and strong refer to setting ϕ_B to .3% and .4%, respectively.

and quantitatively. From a qualitative point of view, when the IES is smaller than one, short-run stabilization is welfare enhancing, whereas the opposite is true when the IES is set to higher values. From a quantitative point of view, our welfare cost function decreases only marginally for low values of the IES, but it rises sharply as the IES becomes greater than one. An asset-pricing-driven calibration of the IES in excess of unity, therefore, unveils a very different perspective on fiscal policy design.

Second, welfare costs are not monotonic in the IES because this parameter alters simultaneously the intertemporal smoothing attitude and the preference for early resolution of uncertainty. As the IES increases, welfare tends to increase as the effective degree of patience increases. This implies that both the risk-free rate and the average return of the patents decline, promoting more growth and hence welfare benefits. But as the IES increases, the aversion to long-run utility risk, $\gamma - 1/\psi$, rises as well. Under our benchmark calibration, when the IES becomes greater than one, the increased amount of long-term risk produced by our active policy dominates and generates welfare losses.

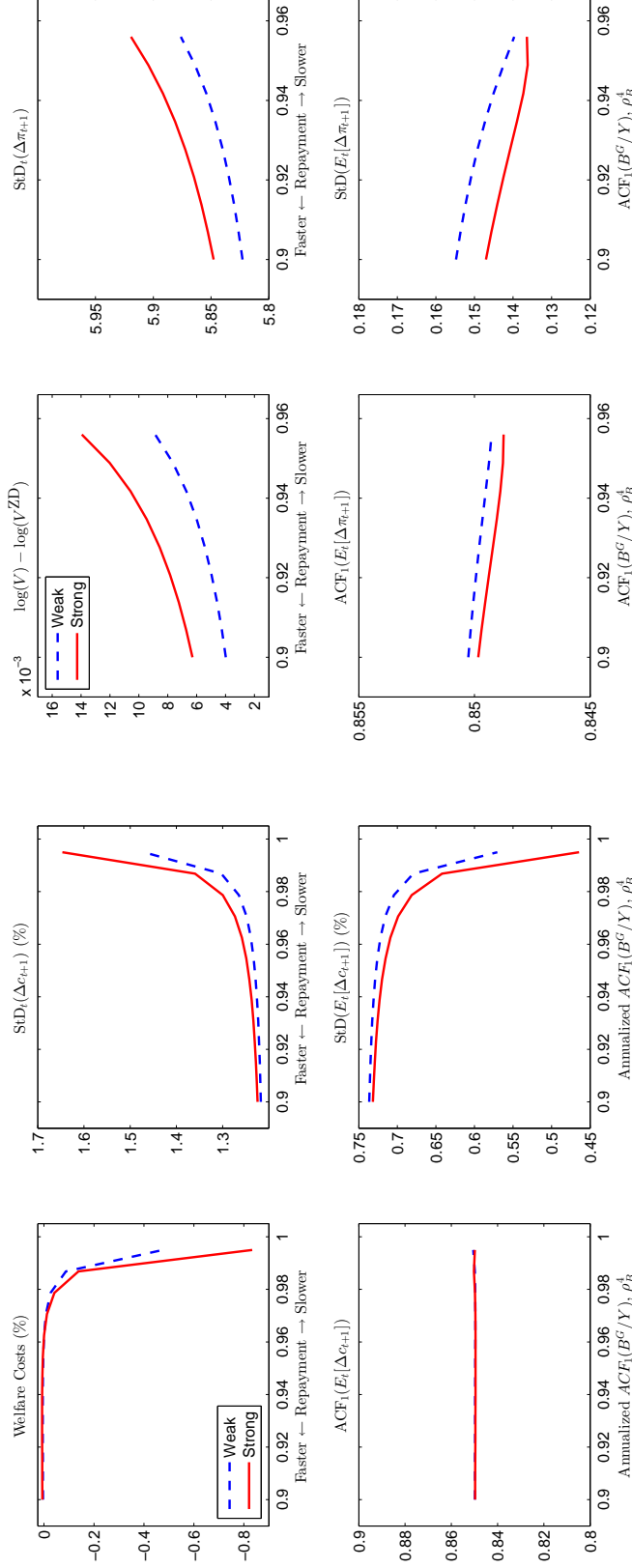
In the right panel of figure 16, we examine welfare costs as a function of the fiscal parameters (ϕ_B, ρ_B) while simultaneously keeping fix the IES to unity. This is a particularly interesting experiment for at least three reasons: (i) this value stands in between those assumed in the asset pricing and macroeconomic literatures; (ii) this calibration corresponds to the log case, i.e., a benchmark in several real-business-cycle models; and (iii) the results can be interpreted in terms of fear of model misspecification, as in Hansen and Sargent (2007).

We highlight two key results. First, under this calibration, aversion to long-term risk is lower than under our benchmark calibration, and hence it plays a more moderate role. For this reason, short-term stabilization is able to produce welfare benefits even if preferences are not of the time-additive form. Second, benefits are non-monotonic with respect to speed of debt repayment, ρ_B . In particular, tax smoothing maximizes welfare benefits for $\rho_B \approx .985$. As the persistence of debt starts to exceed this value, the welfare benefits decline and eventually turn into losses, consistent with the intuition obtained under our benchmark calibration: excessive short-term-oriented tax smoothing produces welfare costs.

2.5. Long-Term-Oriented Tax Smoothing

So far we have focused on financing policies aimed at stabilizing short-run fluctuations, and we have seen that they are welfare-inferior to a simple zero-deficit policy. In this section we focus on a different way to approach stabilization. Specifically, we study the effects of a financing policy aimed at stabilizing future expected profit growth, consistent with equations (2.17) and (2.19). Since in our economy there is a positive link between expected profits and patent values, the government rule is now designed to stabilize the stock market, as opposed to the labor market.

In this setting, the government increases current taxation (reduces current debt) with respect to the zero-deficit case when expected profits are below average. Specifically, if profits are expected to grow at a rate below average, the government counterbalances these negative long-run profit expectations with lower future tax rates. In order to remain solvent,



(a) Welfare Costs and Consumption Distribution

(b) Patent Value and Profits Distribution

Figure 17: Welfare Benefits from Long-Run Stabilization

Notes - Panel A of this figure shows both the welfare costs and key moments of consumption growth associated with different fiscal policies. Welfare is compared to the case of a zero-deficit fiscal policy and is expressed in lifetime consumption units. Panel B shows both the average value of patents and key moments of the profits distribution. All the parameters are calibrated to the values used in table 3. The lines reported in each plot are associated with different levels of intensity of the fiscal policy described in equations (2.17) and (2.19). Weak and strong policies are generated by calibrating ϕ_B to .3% and .4%, respectively. The horizontal axis corresponds to different annualized autocorrelation levels, ρ_B^G , of debt-to-output ratio, B^G/Y ; the higher the autocorrelation, the lower the speed of repayment.

the government has to increase taxation in the short-run.

We illustrate the implications of this policy for both welfare and the distribution of consumption and profits in figure 17. In contrast to short-run stabilization, long-term stabilization produces welfare benefits. On the one hand, this policy is costly because it increases short-run volatility. On the other hand, our simple policy in equation (2.19) enables the government to reduce long-run risk in both consumption and profits. Since long-term stabilization enhances the market value of patents, the average growth is greater as well. Under our benchmark calibration, higher growth and lower long-term risk outweigh the increase in short-term risk and produce welfare benefits.

The relevance of this result is twofold. First, it shows that zero-deficit is not an optimal financing policy. Hence, our previous results are not driven by the fact that we have chosen an economy in which any fiscal policy is bound to produce welfare costs compared to a simple zero-deficit rule. Second, this experiment shows that the financing of public debt with a mix of taxes and deficit can be beneficial, provided that it is aimed at long-term stabilization.

2.6. R&D Subsidy and Expenditure Risks

2.6.0.0.25 Subsidy risk. The decentralized equilibrium in our economy is far from the first-best for two reasons beyond the fact that taxation is distortionary. Specifically, average investment is below its own first-best level because (i) intermediate producers have monopoly power, and (ii) innovators do not take into account the positive externality that current innovation has on future productivity in the R&D sector (equation (2.12)).

In the previous section we have abstracted away from the welfare implications of fiscal policies aimed simultaneously at reducing market imperfections and stabilizing fluctuations. In this section, we consider the case in which the government offers a subsidy proportional to investment in order to bolster accumulation of technologies and growth.

Specifically, the total liability of the government includes both government expenditure and the total transfer granted to innovators, $SUB_t = \tau_t^{sub} S_t$. Given this subsidy, the free-entry condition takes the form

$$(1 - \tau_t^{sub}) \frac{1}{\vartheta_t} = E_t[M_{t+1} V_{t+1}],$$

and debt evolves as follows:

$$B_t = B_{t-1}(1 + r_t^f) + (G_t + SUB_t - T_t).$$

In this section, we consider the short-term-oriented fiscal policy described in equations (2.17)–(2.18) extending it with the following short-term-oriented subsidy policy:

$$\begin{aligned} \tau_t^{sub} &= \frac{\exp\{\tilde{\tau}_t^{sub}\}}{1 + \exp\{\tilde{\tau}_t^{sub}\}} \in (0, 1) \\ \tilde{\tau}_t^{sub} &= \tilde{\tau}_0^{sub} + \tilde{\tau}_1^{sub}(\log L_{ss} - \log L_t), \end{aligned} \tag{2.28}$$

so that the government increases subsidies when the labor market is weak and reduces them when labor is above steady state.

In figure 18, we compare welfare obtained under our active policy with subsidies and under the zero-deficit policy without subsidies ($SUB_t = 0$ and $G_t = T_t, \forall t$). We highlight two results. First, the introduction of subsidies creates welfare benefits, despite the fact that it requires more distortionary financing. There is hence scope for fiscal rules that improve upon the zero-deficit policy studied in section 2.4.

Second, subsidies can improve the level of welfare, but they do not resolve the tension between short- and long-run stabilization. As shown in figure 18, a short-term-oriented subsidy policy can reduce short-term consumption volatility, but only at the cost of substantially increasing long-term risk and depressing growth. A strong counter-cyclicality in the subsidy rate can make the subsidy-induced welfare benefits null.

Previous literature has focused almost exclusively on the determination of the optimal

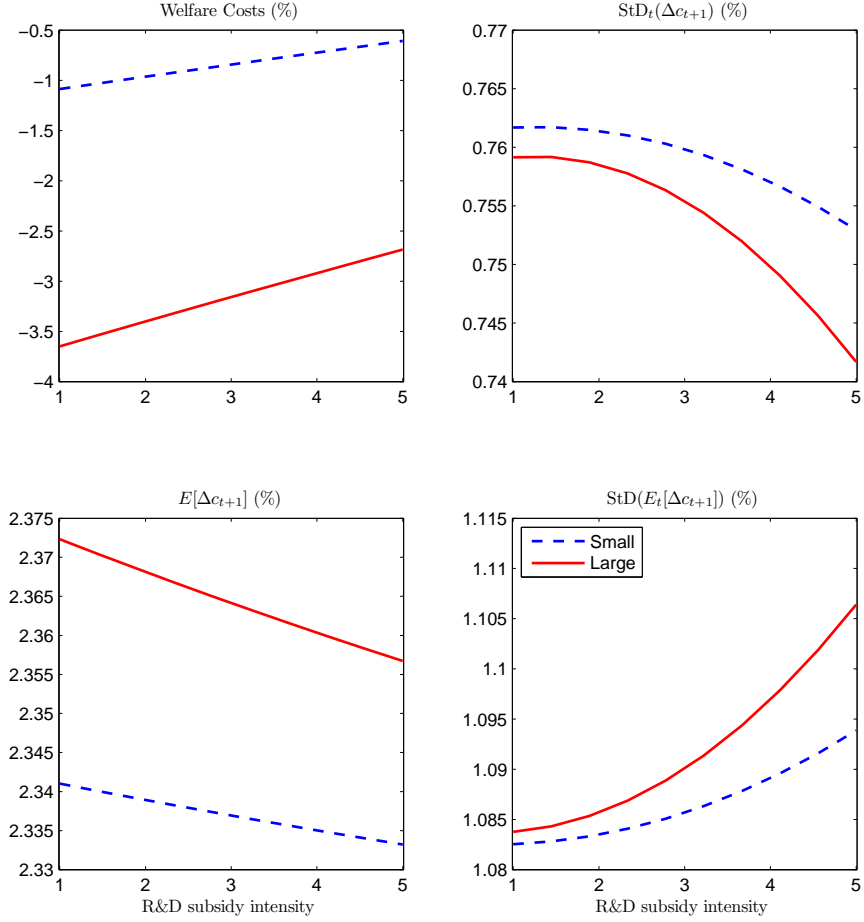


Figure 18: Welfare Costs with R&D Subsidy

Notes - This figure shows both the welfare costs and key moments of consumption growth associated with different fiscal policies. Welfare is compared to the case of a zero-deficit fiscal policy and is expressed in lifetime consumption units. All the parameters are calibrated to the values reported in table 3. The subsidy policy is described by equation (2.28). Small and large policies are generated by calibrating $\tilde{\tau}_0^{sub}$ to .1% and .2%, respectively. The horizontal axis corresponds to different levels of R&D subsidy intensity, $\tilde{\tau}_1^{sub}$. The financing policy is short-term-oriented, as described in equations (2.17)–(2.18). We set $\phi_B = .4\%$ and $\rho_B^4 = .99$.

average subsidy rate. In contrast to previous literature, this experiment suggests that a complete study of welfare must take into consideration both short- and long-run subsidy rate uncertainty.

2.6.0.0.26 Expenditure risk. An analogous statement can be made about the exogenous source of fiscal risk in our economy, i.e., government expenditure. As shown in figure 19, small increases in the volatility or the half-life of expenditure shocks can produce sub-

stantial declines in welfare regardless of the presence of a subsidy and regardless of the average size of government expenditure.

Our study is the first to highlight the strong link between different forms of fiscal risks and long-term potential growth and to show that with recursive preferences these risks play a major role. Specifically, our analysis proves that different financing schemes can substantially alter the transmission mechanism linking exogenous shocks to the distribution of consumption risk. In a model with endogenous growth and recursive preferences, long-run fiscal risks are a first-order determinant of the economy's long-term potential.

2.7. Conclusion

Recent fiscal interventions have raised concerns about U.S. public debt, future fiscal pressure, and long-run economic growth. This paper studied fiscal policy design in an economy in which (i) the household has recursive preferences and is averse to both short- and long-run uncertainty, and (ii) growth is endogenously sustained through innovations whose market value is sensitive to the intertemporal distribution of consumption and profit risk.

In this setting, long-term tax dynamics affect the risk-adjusted present value of future profits. By reallocating the timing of tax distortions, tax smoothing alters the intertemporal composition of growth risk and hence the incentives to innovate, thereby affecting long-term growth and welfare.

We find that countercyclical tax policies promoting short-run stabilization substantially increase long-run uncertainty, causing a costly decline in innovation incentives and growth. In contrast, tax smoothing policies aimed at stabilizing long-term growth can significantly increase growth and welfare, even though short-run consumption risk remain substantial.

Our analysis thus identifies a novel and significant tension between short-run stabilization and long-run growth and welfare. This tension is driven by risk considerations quantified through the lens of a general equilibrium asset pricing model with endogenous growth.

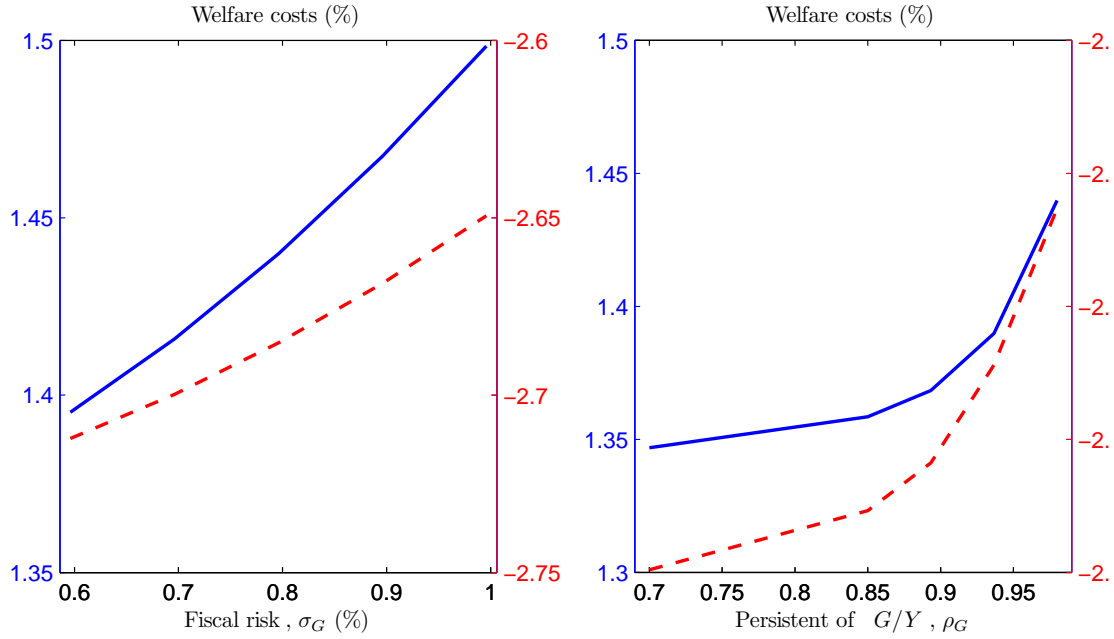


Figure 19: Welfare Costs and Expenditure Risks

Notes - This figure shows the welfare costs associated with different dimensions of expenditure risk. Welfare is compared to the case of a zero-deficit fiscal policy and is expressed in lifetime consumption units. All the parameters are calibrated to the values used in table 3. The lines reported in each plot are associated with different levels of fiscal risks, σ_G (left panel), and different levels of persistence of government expenditure, ρ_G (right panel). In both panels, the solid line (left scale) is associated with the short-term-oriented tax smoothing policy described in equations (2.17)–(2.18). We set $\phi_B = .4\%$ and $\rho_B^4 = .99$. The dashed line (right scale) refers to the same short-term-oriented tax smoothing policy, augmented with the subsidy policy detailed in equation (2.28). We set $\tilde{\tau}_0^{sub} = .2\%$ and $\tilde{\tau}_1^{sub} = 5$.

Given the magnitude of our welfare results, we regard long-term fiscal risk as a first-order determinant of fiscal policy design. Since our study abstracts away from various channels through which fiscal stabilization may generate significant welfare benefits, future research should focus on the net welfare effects of fiscal intervention.

On a broader level, our analysis conveys the need to introduce risk considerations into the

current fiscal policy debate. Rather than exclusively focusing on average tax pressure, fiscal authorities should be concerned with the timing of and the uncertainty surrounding fiscal policy decisions.

Further research should consider the impact of policy uncertainty and learning ([Pastor and Veronesi 2012, 2013](#)) on asset prices and growth. It will be important to examine to what extent the government has incentives to resort to monetization of debt as a fiscal policy instrument ([Diercks 2013](#)) when growth is endogenous and prices are sticky ([Kung 2014](#)). In addition, future studies should also investigate the role of labor market frictions ([Favilukis and Lin 2013b, Kuehn, Petrosky-Nadeau, and Zhang 2013](#)).

APPENDIX

A.1. Data

Quarterly macro data comes from the BEA 1947-2010. Bank data comes from the Call Reports available at <https://cdr.ffiec.gov/public/> and also available through the Wharton Research Data Services under the Bank Regulatory database. I screen and construct the time series used in this paper following [Kashyap and Stein \(2000\)](#); [den Haan, Sumner, and Yamashiro \(2007\)](#); [Corbae and D'Erasmus \(2012\)](#). In particular, I use U.S. commercial banks and define

- Return on loans = $\ln(1 + \text{Interest Income from C\&I loans} / \text{C\&I loans}) - \text{Inflation}$
- Net interest margin = Return on loans - Cost of deposits
- Cost of deposits = $\ln(1 + \text{Interest Expense from Deposits} / \text{Deposits}) - \text{Inflation}$
- Net charge-off rate = $(\text{C\&I charge-offs} - \text{C\&I recoveries}) / \text{C\&I loans}$

Tier 1 capital is constructed as suggested by the Federal Reserve Bank of Chicago.¹ Tier 1 capital ratio is Tier 1 capital over risk weighted assets, and leverage ratio is Tier 1 capital over total assets. Failure and exit are weighted by assets and calculated from the FDIC fail bank list and the Federal Reserve Bank of Chicago Mergers and Acquisitions database.^{2,3} Failure is when a bank failed and was not assisted by the FDIC. Exit includes failure and any bank that has its charter discontinued (merger code 1 and 50).

¹See http://www.chicagofed.org/digital_assets/others/banking/financial_institution_reports/regulatory_capital.pdf

²Details at <http://www2.fdic.gov/hsob/SelectRpt.asp?EntryTyp=30>

³See http://www.chicagofed.org/webpages/publications/financial_institution_reports/merger_data.cfm

A.2. Solution Method

The numerical solution for the model is similar to [Gomes \(2001\)](#) and proceeds in the following steps:

1. Guess a pricing kernel
2. From the guess in step 1, retrieve the growth rate of the economy and hence the total capital demanded by final good producers. This also gives the price of capital from equation (1.8).
3. Solve the bank's problem.
4. Check the free-entry condition (1.18), assuming positive entry. Update and repeat step 1 until convergence.
5. The mass of new banks, E_t are determined by the capital market clearing condition

$$I_t^d = I_t^s.$$

6. From the policy functions, one can derive the transition matrix defined in equation (1.20). For the net cash π_{t+1} that falls between grid points, I use linear interpolation to allocate the probability mass between the two adjacent points.
7. The stationary distribution of banks comes from inverting equation (1.19).
8. Once one has the stationary distribution, all variables are readily computed.

A.3. Distortions versus Crowding Out

Thus far we have assumed that the government uses taxes to finance an unproductive government expenditure. This assumption, however, introduces uncertainty about both the substitution effect and the crowding-out effect, i.e., the negative income effect generated

by government expenditure. In order to disentangle the crowding-out effect from the pure intertemporal redistribution of consumption risk, in this section we assume that the government uses taxes to finance a mandatory lump-sum transfer to the household, TR_t , that replaces G_t in equation (2.14). The consumer and government budget constraints and the resource constraint become, respectively:

$$\begin{aligned} C_t + Q_t Z_{t+1} + B_t &= (1 - \tau_t) W_t L_t + (Q_t + \mathcal{D}_t) Z_t + (1 + r_{f,t-1}) B_{t-1} + TR_t, \\ B_t &= (1 + r_{f,t-1}) B_{t-1} + TR_t - T_t \\ Y_t &= C_t + S_t + A_t X_t. \end{aligned}$$

This specification allows us to keep all marginal distortions in the first-order conditions without having to deal with the change in the allocation generated by changes in G_t .

Figure 20 confirms our previous findings: it is the persistent alteration of the tax rate that changes the long-run behavior of consumption and produces welfare costs with recursive preferences. The crowding-out effect produced by government expenditure is relevant, but it explains just a small fraction of the welfare costs that we found in the previous section.

Since U.S. entitlements are larger than public expenditure, considering a model with both transfers and expenditure would amplify both the amount of public liabilities and our welfare results.

A.4. Optimal Labor Taxation

In this section, we briefly summarize the determinants of optimal labor taxation in our setup. These results are based on [Croce, Karantounias, Nguyen, and Schmid \(2013\)](#) and are obtained assuming access to state-contingent debt. For the sake of simplicity, we use the following monotonic transformation of our utility function:

$$\tilde{U}_t = \tilde{u}_t + \beta (E_t \tilde{U}_{t+1}^{1-\zeta})^{\frac{1}{1-\zeta}},$$

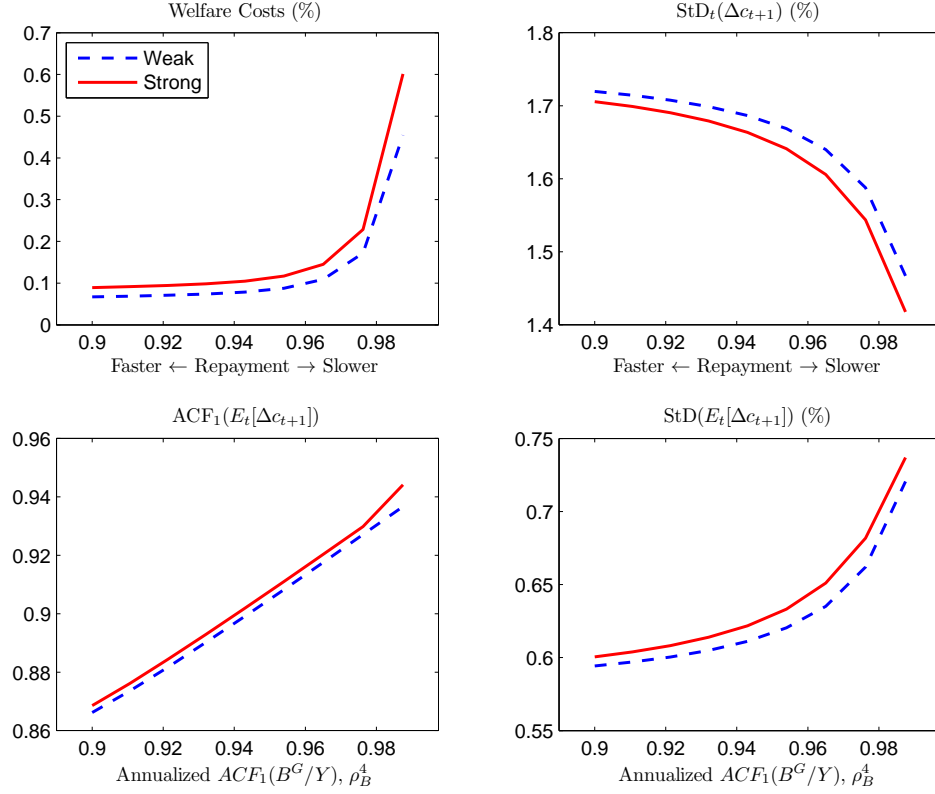


Figure 20: Welfare Costs and Consumption Distribution with Transfers

Notes - This figure shows the welfare costs and key moments of consumption growth. All the parameters are calibrated to the values in table 3, except for the IES, $\psi = 1/\gamma = 1/7$. The lines reported in each plot are associated with different levels of intensity of the countercyclical fiscal policy described in equations (2.17)–(2.18). Weak and strong policies are generated by calibrating ϕ_B to .3% and .4%, respectively. The horizontal axis corresponds to different annualized autocorrelation levels, ρ_B^4 , of debt-to-output ratio, B^G/Y ; the higher the autocorrelation, the lower the speed of repayment. Welfare costs are calculated as in A.5. In this figure, we assume taxes are used to finance a lump-sum transfer to the representative consumer.

where $\tilde{U}_t = \frac{U_t^{1-\frac{1}{\psi}}}{1-1/\psi}$, $\tilde{u}_t = (1-\beta)\frac{u_t^{1-\frac{1}{\psi}}}{1-1/\psi}$, and $\zeta = \frac{\gamma-\frac{1}{\psi}}{1-\frac{1}{\psi}}$. For the sake of notation, in what follows we drop the $\tilde{\cdot}$.

Let

$$M_t := \Pi_{i=1}^t m_i$$

be a martingale with increment

$$m_{t+1} := \frac{U_{t+1}^{1-\zeta}}{E_t U_{t+1}^{1-\zeta}},$$

where we normalize $M_0 = m_0 = 1$. Given these definitions, the stochastic discount factor in our model can be written as

$$\Lambda_{t+1} = \beta m_{t+1}^{\frac{\zeta}{\zeta-1}} \frac{u_{ct+1}}{u_{ct}}.$$

Finally, define

$$\begin{aligned} \Omega(C, l) &= \Omega(C, 1 - L) \\ &= u_c(C, 1 - L)C - U_l(C, 1 - L)L. \end{aligned}$$

The time-zero Ramsey problem consists in maximizing the household's lifetime utility subject to the following constraints, with multipliers reported in parentheses:

$$(\Phi) \quad E_0 \sum_{t=0}^{\infty} \beta^t M_t^{\frac{\zeta}{\zeta-1}} \left[\Omega(C_t, 1 - L_t) - u_{ct} \left(A_t \left(\frac{1}{\alpha} - 1 \right) X_t - S_t \right) \right] = u_{c0} B_0 \quad (\text{A.1})$$

$$(\beta^t \pi_t \lambda_t) \quad G_t + C_t + A_t X_t + S_t = Y_t \quad (\text{A.2})$$

$$(\beta^t \pi_t \mu_t) \quad A_{t+1} = \vartheta_t S_t + (1 - \delta) A_t \quad (\text{A.3})$$

$$(\beta^t \pi_t \rho_t) \quad \frac{1}{\vartheta_t} = E_t \beta m_{t+1}^{\frac{\zeta}{\zeta-1}} \frac{u_{ct+1}}{u_{ct}} V_{t+1} \quad (\text{A.4})$$

$$(\beta^{t+1} \pi_{t+1} \nu_{t+1}) \quad M_{t+1} = \frac{U_{t+1}^{1-\zeta}}{E_t U_{t+1}^{1-\zeta}} M_t \quad (\text{A.5})$$

$$(\beta^t \pi_t \xi_t) \quad U_t = u_t + \beta (E_t U_{t+1}^{1-\zeta})^{\frac{1}{1-\zeta}}. \quad (\text{A.6})$$

The implementability constraint (A.1) and the resource constraints (A.2) are standard, as they are present even in the simple setup of Lucas and Stokey (1983). Our problem, however, has to take into account also the physical accumulation of varieties (A.3) and the free-entry condition (A.4) prescribed by the Romer model. Furthermore, since we adopt recursive preferences, we need to keep track of both the martingale (A.5) and the future

utility (A.6) evolution.

Given these constraints, the shadow-value of consumption from a Ramsey perspective, λ_t , is

$$\lambda_t = \lambda_t^{LS} \cdot \underbrace{M_t^{\frac{\zeta}{\zeta-1}} + u_{ct}\xi_t - M_t^{\frac{\zeta}{\zeta-1}}}_{\substack{\text{Intertemporal Distorsion} \\ \text{Channel}}} \cdot u_{cc,t} \underbrace{\Phi(\rho_t - \rho_{t-1}\vartheta_{t-1}V_t - D_t)}_{\substack{\text{Asset Price} \\ \text{Channel}}}, \quad (\text{A.7})$$

where $\lambda_t^{LS} := u_{ct} + \Phi\Omega_{c,t}$ is the shadow value of consumption in the [Lucas and Stokey \(1983\)](#) economy, $D_t := A_t\Pi_t - S_t$ are the aggregate dividends, and ξ_t evolves as a martingale with respect to $\pi_t M_t$ with $\xi_0 = 0$ and $\text{StD}_t[\xi_{t+1}] \propto \zeta$.

With time-additive preferences, $\zeta = 0 \rightarrow \xi_t = 0$, and $M_t^{\frac{\zeta}{\zeta-1}} = 1$. With exogenous endowment growth, $\rho_t = 0$ and $D_t = 0$, as investment and profits vanish. Without endogenous growth and recursive preferences, our multiplier corresponds to that found by [Lucas and Stokey \(1983\)](#). Equation (A.7), therefore, enables us to disentangle two important channels. First, with innovation-driven growth, the tax system can alter the growth of the economy by affecting the private valuation of patents, V_t . In this setup, risk and asset prices become important determinants of tax systems (the asset price channel).

Second, in contrast to the time-additive preferences case, our Ramsey planner must consider the entire intertemporal distribution of risk. This intertemporal dimension relates to the martingales ξ_t and M_t . These forward-looking elements imply that the entire intertemporal distribution of future tax distortions becomes a determinant of the optimal tax system (the intertemporal distortions channel). [Croce, Karantounias, Nguyen, and Schmid \(2013\)](#) provide sufficient conditions for the existence of an equilibrium but do not characterize the dynamics of ξ_t and M_t . We study the role of long-run tax distortions through simple and implementable tax rules.

A.5. Solution Method and Welfare Costs

A.5.0.0.27 Solution method and computations. We solve the model in `dynare++4.2.1` using a third-order approximation. The policies are centered about a fix-point that takes into account the effects of volatility on decision rules. In the `.mat` file generated by `dynare++` the vector with the fix-point for all our endogenous variables is denoted as `dyn_ss`. All conditional moments are computed by means of simulations with a fixed seed to facilitate the comparison across fiscal policies.

A.5.0.0.28 Welfare costs. Consider two consumption bundle processes, $\{u^1\}$ and $\{u^2\}$. We express welfare costs as the additional fraction λ of the lifetime consumption bundle required to make the representative agent indifferent between $\{u^1\}$ and $\{u^2\}$:

$$U_0(\{u^1\}) = U_0(\{u^2\}(1 + \lambda)).$$

Since we specify U so that it is homogenous of degree one with respect to u , the following holds:

$$\frac{U_0(\{u^1\})}{u_0^1} \cdot u_0^1 = \frac{U_0(\{u^2\})}{u_0^2} \cdot u_0^2 \cdot (1 + \lambda).$$

This shows that the welfare costs depend both on the utility-consumption ratio and the initial level of our two consumption profiles. In our production economy, the initial level of consumption is endogenous, so we cannot choose it. The initial level of patents, A_0^i $i \in \{1, 2\}$, in contrast, is exogenous:

$$\frac{U_0(\{u^1\})}{u_0^1} \cdot \frac{u_0^1}{A_0^1} \cdot A_0^1 = \frac{U_0(\{u^2\})}{u_0^2} \cdot \frac{u_0^2}{A_0^2} \cdot A_0^2 \cdot (1 + \lambda).$$

We compare economies with different tax regimes but the same initial condition for the stock of patents: $A_0^1 = A_0^2$. After taking logs, evaluating utility- and consumption-productivity ratios at their unconditional mean, and imposing $A_0^1 = A_0^2$, we obtain the following expres-

sion:

$$\lambda \approx \overline{\ln U^1/A} - \overline{\ln U^2/A},$$

where the bar denotes the unconditional average which is computed using the `dyn_ss` variable in `dynare++`.

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