Stabilization vs. Growth

Miguel Faria-e-Castro — FRB St. Louis
Pascal Paul — FRB San Francisco
Juan M. Sánchez — FRB St. Louis

April 2026*

Abstract

Should firms in financial distress be saved to stabilize an economy, even if less productive ones are kept alive, possibly reducing economic growth? To assess this fundamental stabilization-vs.-growth trade-off, we develop a new dynamic general equilibrium model with business cycles, endogenous growth, and innovation externalities. We discipline key parameters using microeconomic data and an instrumental-variable approach that links firm productivity growth to R&D expenditure. Based on the calibrated model, we find that economies that save distressed firms with credit guarantees, debt restructuring, or loan evergreening experience lower volatility but also slower growth. Even though welfare is higher in an economy without such interventions, the various "soft credit" regimes can still arise as equilibrium outcomes when a benevolent government intervenes in credit markets under discretion.

Keywords: business cycles, endogenous growth, financial frictions.
JEL Codes: E43, E44, E60, G21, G32.

*We thank our discussants Andrea Colciago, Federico Kochen, and Galina Vereshchagina, as well as Pablo d'Erasmo, Hugo Hopenhayn, Aakash Kalyani, Julian Kozlowski, Simone Lenzu, Yueran Ma, Alex Monge-Naranjo, Diego Restuccia, Sanjay Singh, and Stephen Terry for helpful conversations and suggestions. We also thank seminar and conference audiences at the 4th Workshop on Firm Heterogeneity and Macroeconomics, University of Rochester, the 4th xAmsterdam Macro Workshop, SED Copenhagen, CEBRA Boston, Chile-Becker-Friedman Workshop on Productivity, Rome Conference "Financial Stability and Regulation," Federal Reserve Board, and Federal Reserve Banks of Atlanta, St. Louis, San Francisco, and Kansas City for questions and suggestions. This research benefited from the computational resources provided by the CADRE Group at FRB Kansas City. We thank Wesley Wasserburger for excellent research assistance. The views expressed herein are those of the authors and do not reflect the views of the FRB San Francisco, the FRB St. Louis, or the Federal Reserve System.

1 Introduction

A number of policy interventions and lending practices in credit markets imply a fundamental trade-off: they can stabilize business cycle fluctuations at the expense of future economic growth. As a concrete example, consider the business funding programs during the COVID-19 recession, such as the Paycheck Protection Program in the United States. These programs aimed to save firms in financial distress and prevent them from going bankrupt, thereby stabilizing employment and economic activity. At the same time, the programs may have kept less productive firms alive, possibly reducing economic growth in the medium to long term. Thus, how should such firm credit programs be designed if a policymaker takes both short-run stabilization but also longer-term growth effects into account?

In this paper, we aim to answer this question, not only for business credit subsidies, but also for lending practices where a similar stabilization-versus-growth trade-off may be present. A restructuring or reorganization of distressed businesses reduces existing debt burden, as, for example, Chapter 11 in the United States, again possibly stabilizing an economy in downturns while also keeping less-productive firms alive. Similar effects can be associated with so-called "evergreening" or "zombie-lending" practices which allow struggling firms to roll-over their debt at possibly favorable terms (Peek and Rosengren, 2005; Caballero, Hoshi and Kashyap, 2008). To analyze the trade-off for various policy interventions and lending practices, a framework is needed that includes business cycles, financial intermediation that channels funds from savers to businesses, firm heterogeneity with endogenous exit and default decisions, as well as endogenous growth. Existing macroeconomic models typically fall short along at least one of these dimensions. We therefore develop a new framework that incorporates all of these features and remains tractable to account for firm heterogeneity in general equilibrium with aggregate shocks.

Our model has two important features. First, firms differ in their productivity, and some may choose to default and exit. However, lenders and policymakers can steer firms' default decisions by reducing their legacy debt (restructuring), easing credit conditions (evergreening), or by directly issuing credit guarantees to firms. We show that a lender's decision to evergreen or restructure distressed firms arises as the optimal solution to a profit-maximization problem. Intuitively, a lender would rather offer a distressed firm more favorable loan terms and thereby recover at least part of the outstanding debt than allow default and recover only the collateral backing the loan. Second, aggregate total factor productivity (TFP) is endogenous and shaped by firms' decision to exit and to invest in research and development (R&D). We posit that firms learn from or imitate each other, which is reflected in the fact that their R&D costs depend negatively on the average productivity of incumbent firms. As a result, if low productivity firms exit the economy, the R&D costs for all subsequent firms are affected, a mechanism similar to the "cleansing effect" that can lead to more innovation and growth (Schumpeter, 1939).

We tightly calibrate the model to various empirical moments for the U.S. economy, such as lending spreads, default rates, loan recovery rates, and the typical relative productivity of exiting versus continuing firms. Most importantly, we use firm-level data to pin down the elasticity of firm productivity growth to R&D investment and the innovation externalities that drive the learning between firms. To this end, we employ an instrumental-variable approach that instruments firm R&D expenditure with variation in state-level R&D tax credits (Wilson, 2009; Bloom, Schankerman and Van Reenen, 2013). We find that a 1% increase in R&D expenditure, or a 1% higher productivity of a firm's peers relative to its own productivity, each leads to firm productivity growth of around 0.3% over the next year.

Based on these parameter estimates, we first consider an economy where neither lenders nor policymakers intervene ex-post to save firms from default. In analogy to the "soft budget constraint" literature (Kornai, Maskin and Roland, 2003), we term this economy the "hard credit" economy. Relative to this benchmark, we consider three counterfactual economies where credit terms are softened after idiosyncratic firm productivities realize: an economy where lenders can write off a fraction of the firms' legacy debt ("restructuring economy"), an economy where lenders lower interest rates on new borrowing while leaving the legacy debt unchanged ("evergreening economy"), and an economy where firms receive credit guarantees from the government ("guarantee economy"). Each of these interventions is designed such that a firm that would default without additional support receives a subsidy just large enough for the firm to continue operating.

Across the various counterfactuals, one common pattern emerges. Each intervention reduces the share of firms exiting in each period, thereby raising output and employment all else equal. In turn, this reduces output growth volatility overall, as well as the response of output to adverse aggregate shocks. However, by keeping less productive firms alive, the average productivity of incumbents falls. Given the calibrated innovation externality, this raises the R&D costs for subsequent firms all else equal, lowering R&D investment and growth. As a result, the hard credit economy features around 0.33%-0.39% higher GDP growth per year compared with the counterfactual economies. To illustrate the importance of the differential growth rates, consider the number of years it takes to double GDP. In the hard credit economy, this milestone is achieved after around 30.5 years, while it takes around 5 to 6 years longer in the counterfactual economies.

To assess the stabilization-vs.-growth trade-off, we compute aggregate welfare for all four economies. To make the counterfactual economies comparable, we pick parameters to equalize the share of subsidized firms across the three economies and choose the same initial states. We find that welfare in the hard credit economy is largest due to higher economic growth. Relative to this benchmark, the restructuring and the guarantee economies deliver around 2.3% lower welfare in terms of consumption-equivalent variation, while the evergreening economy features 3% lower welfare. The relatively poor performance of the evergreening economy is explained by the fact that the relaxed credit terms in this economy distort firm labor choices, leading to relatively higher labor demand and increased wages. In turn, firm profits are lower, and firms invest less in R&D, further reducing economic growth.

We next decompose welfare into contributions from average levels and volatility. The bulk of the welfare differences is accounted for by higher average consumption levels of the hard credit economy, reflecting its stronger long-run growth. However, in the first few periods, average consumption and output levels are in fact higher in the soft-credit economies, as firm exit is reduced. Thus, stabilization policies also affect initial *levels*. Welfare rankings are therefore not solely driven by long-run growth and volatility, and can be sensitive to parameters. To illustrate this point, we show that soft credit regimes can deliver higher overall welfare when innovation externalities are smaller than implied by our estimation strategy.

Finally, we study the optimal design of credit regimes. We begin with a benevolent government that can commit to a constant policy. Across the counterfactual economies, the optimal ex-ante allocation features no ex-post interventions: a policymaker with commitment would choose the hard credit regime. This naturally raises the question: if hard credit is welfare-dominant, why are soft credit arrangements so prevalent in advanced economies? To answer this question, we turn to a policymaker who chooses the extent of ex-post intervention under discretion, re-optimizing period by period without commitment to future policy. We find that, in each soft-credit economy, such a policymaker chooses on average more aggressive ex-post interventions than under our baseline calibrated allocation, yielding even larger welfare losses of around 4.2 to 5.2 percent relative to the hard-credit economy. This exercise therefore provides an intuitive reason for the existence of soft credit regimes: in the absence of commitment, policymakers behave as if they were focused on short-term gains, since future policies will be re-optimized, leading them to favor saving distressed firms.

Related Literature. Our paper relates to an extensive literature at the intersection of innovation, growth, and corporate finance. Our main contribution to this literature is a tractable framework that includes business cycles, financial intermediation, firm heterogeneity with default, and endogenous growth with innovation externalities. The model allows us to study welfare and policy in a fully specified dynamic general equilibrium setting, and we show how to leverage micro data to carefully calibrate the model to important empirical moments.

Starting with the literature on innovation and growth, Aghion and Howitt (1992) provide the canonical Schumpeterian model of creative destruction in which growth is driven by quality-improving innovations that arrive endogenously through R&D and destroy incumbents' rents. In subsequent work, Klette and Kortum (2004), Lentz and Mortensen (2008), Luttmer (2011), and Akcigit and Kerr (2018) take this framework closer to the data by matching firm-level facts on R&D, patents, productivity, growth, entry and exit, as well as differences by size and age. What unites these and many other papers is that the pace of innovation and growth is determined by how quickly newer products or firms replace older ones. In contrast, our mechanism rests on the idea that firms learn from each other, and that the pace of innovation increases when low-productivity firms exit more frequently. In this sense, the direction of causality differs: the destruction of certain firms accelerates innovation in our framework, as opposed to the innovation by some firms leading to the destruction of others as in Aghion and Howitt (1992).

Building on these frameworks, several papers explore the interplay between finance and growth. For example, Aghion et al. (2010), Aghion, Howitt and Levine (2018), Celik (2023), and Ottonello and Winberry (2024) study the role of financial frictions for firm innovation and growth. While our framework incorporates financial frictions in the form of borrowing constraints and endogenous firm default, our focus is rather on the effects of ex-post interventions by lenders or governments to save firms in distress (Kornai, Maskin and Roland, 2003). This theme is shared by Aghion et al. (2025) who embed the soft budget constraint mechanism by Dewatripont and Maskin (1995) into a Schumpeterian growth model. They show that the reduction in interest expenses after the Great Financial Crisis can explain about 54% of the observed slowdown in French growth, as it crowded out the entry of skilled innovators. Compared to Aghion et al. (2025), (i) our modeling setup with heterogeneous firms and endogenous borrowing and default differs from their Schumpeterian setup, (ii) we incorporate productivity spillovers between firms, and (iii) we analyze the stabilization-vs.-growth trade-off of the various interventions we mention.

We also connect with the literature on the "cleansing effect of recessions," which holds the view that recessions intensify selection and reallocation by forcing low-productivity firms to contract or exit, potentially raising aggregate productivity due to an improved composition of surviving activity (Caballero and Hammour, 1994). Such a cleansing effect of downturns can be weakened if fewer high-quality job matches are created during recessions (Barlevy, 2002), if more productive and younger firms face tighter credit constraints or a lower chance of survival in downturns (Barlevy, 2003; Ouyang, 2009), or if job reallocation is reduced during recessions (Caballero and Hammour, 2005). We contribute to this literature by introducing a new mechanism for the cleansing view of recessions grounded in learning and imitation among firms, and we show how this mechanism can be muted by credit market interventions. Our main finding that credit market interventions can encourage the survival of less productive firms is also shared by Acemoglu et al. (2018) who show that broad R&D subsidies can have such effects.

Our analysis further relates to a long-standing question in macroeconomics: whether to prioritize business cycle stabilization or economic growth. Lucas (1987) famously showed that the welfare gains from reducing business cycle volatility are relatively small compared to the large gains from enhancing growth. While we arrive at the same conclusion, we start out quite differently: from a micro-founded model of firm heterogeneity and by posing the question whether distressed firms should be saved. Our approach reveals that stabilization policies not only have growth and volatility effects but also lead to differences in consumption levels on the transition, which matter for welfare rankings.

Turning to the empirical literature, a number of studies relate productivity gains to higher firm exit, consistent with our findings. For example, Bartelsman and Doms (2000) and Foster, Haltiwanger and Krizan (2001) highlight the importance of entry and exit for the aggregate economy, since they associate around a quarter of aggregate productivity growth with the exit and entry of firms. And, more recently, Adhami (2025) documents a positive relationship between industry productivity growth and firm exit rates.

Finally, we relate to an extensive literature that estimates rates of return to R&D investment and technology spillovers between firms. The most common approach starts with a production function that includes knowledge capital (see, e.g., Hall, Mairesse and Mohnen, 2010; Hall, 2011). Instead, we derive the relation between productivity growth and R&D from a cost function for R&D expenditures, and we find sizable effects based on our instrumental variable approach. Our empirical strategy also yields estimates for the speed of learning or technology adoption between firms, which complements earlier work by Bloom, Schankerman and Van Reenen (2013) on spillovers from R&D investment. Based on comparative statics, we highlight the importance of such knowledge spillovers for aggregate productivity and growth, a finding we share with Atkeson and Burstein (2019), Akcigit, Hanley and Stantcheva (2022), and Akcigit and Ates (2023).

2 Model

Time is discrete and infinite, $t = 0, 1, \ldots$. The economy consists of three types of agents: (i) a unit mass of firms that are heterogeneous within each period, (ii) a unit mass of lenders, each matched one-to-one with a firm, and (iii) a representative household that supplies labor, deposits with financial intermediaries, and ultimately owns all financial claims in the economy. Two central features characterize the model: (i) the institutional arrangement governing the lender-borrower relationship, which can give rise to ex-post interventions in equilibrium; and (ii) endogenous firm innovation decisions, which determine future productivity and economic growth.

2.1 Firms

There is a unit mass of firms that are identical across periods but heterogeneous within the period. This structure simplifies the interaction between firms and lenders, allowing for tractable modeling of firm heterogeneity in a dynamic, stochastic environment.

Technology. Firms produce using a decreasing returns-to-scale production function

$$y = x^{1-\eta}(\zeta k)^{\alpha} n^{\eta}, \tag{1}$$

where y denotes output, k is physical capital that depreciates at rate δ, ζ is an aggregate capital quality shock (as in Brunnermeier and Sannikov, 2014, for example), and n is labor. Firm-level productivity is given by $x = z\varepsilon$, where z represents fundamental productivity, which reflects firms' accumulated technological knowledge and can be improved through costly R&D investment, and ε is an i.i.d. shock across firms and time drawn from a distribution $F[0, \infty)$. Fundamental productivity evolves through R&D investment, where the next period z' is chosen subject to a cost given by:

$$\phi \times \left(\frac{z'}{z^{1-\rho}(x^*)^{\rho}} \right)^{\kappa}, \tag{2}$$

with ϕ denoting the level costs of R&D.[1] The parameter κ governs the curvature of R&D costs, and x^* is the average firm-level productivity of operating firms, that is, the average product of the fundamental and idiosyncratic component for firms that produced this

[1]The choice of future productivity subject to a cost is found, for example, in Greenwood, Han and Sánchez (2022) or Vereshchagina (2023). We assume that level costs scale with a measure of productivity; this is necessary for the existence of a balanced growth path as further explained in Section 2.8.

period.

The term x^* introduces a spillover effect in innovation. Higher average productivity for operating firms reduces R&D costs through a learning externality parameterized by $\rho \in [0, 1]$. This relates to the literature on learning, imitation, and growth, where the relative costs of innovation are tied to the productivity of other agents in the economy. Our setup is closest to Monge-Naranjo (2019), following a large tradition that emphasizes the importance of knowledge spillovers for economic growth (Jovanovic and MacDonald, 1994; Luttmer, 2007; Lucas, 2009; Perla and Tonetti, 2014; Lucas and Moll, 2014). Firms observe their own z and ε separately: while the latter affects production, it is not taken into consideration for investments going forward. However, firms cannot disentangle fundamental and idiosyncratic productivity of other firms, and only observe their realized productivity x. Thus, the cost of R&D does not depend on ε of the firm itself but on the average ε^*, as $x^* = Z\varepsilon^*$. Innovation is independent from average idiosyncratic productivity and depends only on internal factors when $\rho = 0$, while it depends only on average (external) economy-wide productivity when $\rho = 1$.

Financial frictions. Firms borrow in two types of debt: intraperiod debt ℓ and interperiod debt b. Intraperiod debt is risk-free and used to satisfy a working capital constraint on total payroll expenses (as in Christiano, Eichenbaum and Evans, 2005, for example):

$$\ell \geq wn. \tag{3}$$

Firms borrow and repay this loan in the same period, at the gross interest rate $1 + i$.

Interperiod debt finances physical capital and R&D investments. Firms borrow qb', and repay b' in the next period, where q^{-1} is the interest rate on interperiod debt. Borrowing in interperiod debt is subject to a collateral constraint defined over physical capital:

$$b' \leq \theta k'. \tag{4}$$

Finally, firms have limited liability and may default on interperiod debt and exit. This occurs at the beginning of each period after aggregate and idiosyncratic shocks are realized but before production takes place. In case of default, creditors recover a fraction of the firm's capital stock equal to $(1 - \lambda)\zeta' k'$, where λ represents the fraction of resources that is lost in default.

Interventions. Our model baseline is called *hard credit economy* (HC), in the spirit of Kornai, Maskin and Roland (2003), and is characterized by the absence of ex-post interven-

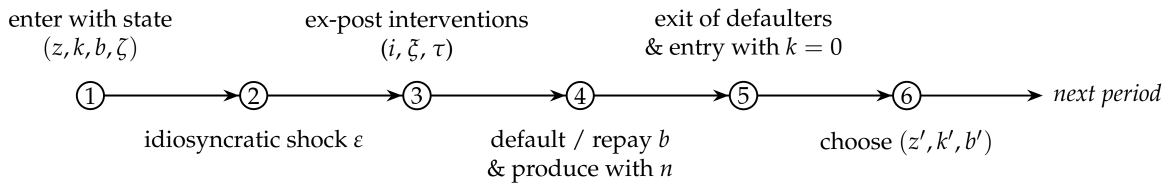

Figure 1: Intra-period timing of firm decisions and shocks.

tions and arrangements that may support firms in distress. We compare this benchmark to three soft-credit (SC) economies that each feature a different type of ex-post intervention: (i) the *evergreening economy*, where lenders may offer favorable interest rates on intraperiod debt i to distressed firms, (ii) the *restructuring economy*, where lenders can write off a fraction ξ of a firm's legacy debt b, and (iii) the *guarantee economy*, where the fiscal authority deploys credit guarantees τ to save distressed firms.

Timing. The model setup is such that, in equilibrium, all firms choose the same state variables across periods—capital, interperiod debt, and fundamental productivity—but may differ within a period. The exact timing assumptions are summarized in Figure 1.

Firms enter the period with endogenous states and a realization of the capital-quality shock $s \equiv (z, k, b, \zeta)$. At the beginning of each period, firms are hit with a purely idiosyncratic productivity shock $\varepsilon \sim F$. Additionally, they need to take on an intraperiod loan to finance labor hiring. Depending on the terms of this intraperiod loan and potential ex-post interventions by policymakers and lenders, they may choose to default on their interperiod debt and exit. If they choose not to exit and repay their debt b, firms hire labor n at a wage rate w to produce subject to the working capital constraint (3). Exiting firms are replaced by entrants with zero capital who do not produce in their period of entry. Surviving firms and entrants choose (z', k', b') subject to the collateral constraint (4).

These timing assumptions generate intraperiod heterogeneity, but heterogeneity within the period does not carry over to the final stage, when firms undertake dynamic decisions. Thus, the model ensures aggregation and identical dynamic choices (z', k', b') as long as all firms enter the period with the same s. This setup is similar to that of Gomes, Jermann and Schmid (2016) and reminiscent of models with a "day-and-night" market structure that allow for intraperiod heterogeneity while preserving aggregation across periods (Lagos and Wright, 2005).

Value functions. The firm takes as given the following objects, each determined by the aggregate state S, the firm's individual state s, and the idiosyncratic shock ε: the intraperiod interest rate $i(s, \varepsilon; S)$, the interperiod price of debt $q(s, S)$, and the share of debt write-off $\xi(s,\varepsilon;S)$ offered by the lender, the transfer $\tau(s,\varepsilon;S)$ provided by the government, the wage $w(S)$ in the labor market, the average productivity $x^*(S)$, the representative household's stochastic discount factor M, and the law of motion for the aggregate state, $S' = \Pi(S)$. To simplify notation, we suppress the dependence of these objects on the aggregate state S and on its transition $S' = \Pi(S)$. In equilibrium, all firms make identical choices, so the individual state coincides with the aggregate state, $s = S$. The value of the firm at the beginning of the period, after the idiosyncratic shock ε is realized, is

$$V_0(s,\varepsilon) = \max\{0,\ V^p(s,\varepsilon)\},$$

where 0 is the normalized value of default and exit, and V^p denotes the value of repaying interperiod debt b and continuing production. The continuation value is

$$V^p(s,\varepsilon) = \max_{n,\ell}\ (z\varepsilon)^{1-\eta}(\zeta k)^{\alpha} n^{\eta} - wn + \ell - (1+i)\ell - b(1-\xi) + (1-\delta)\zeta k - \nu + \tau + V_1(s)$$
$$\text{s.t.} \qquad \ell \geq wn.$$

The firm produces and sells output y, hires labor at cost wn, takes on a working-capital loan ℓ, and repays it with interest $(1+i)\ell$. It also repays legacy debt $b(1-\xi)$, sells the undepreciated portion of capital $(1-\delta)\zeta k$, incurs the fixed operating cost ν, and may receive a transfer τ if it benefits from a credit guarantee. All profits are paid immediately as dividends to the representative household, and there are no costs of issuing equity.

Finally, the continuation value $V_1(s)$ of the firm is

$$V_1(s) = \max_{z',k',b'} -\phi\left(\frac{z'}{z^{1-\rho}(x^*)^{\rho}}\right)^{\kappa} - k' + qb' + \mathbb{E}_{\zeta',\varepsilon'}[\,M \cdot\ V_0(s',\varepsilon')\,] \tag{5}$$
$$\text{s.t.} \quad b' \leq \theta k'.$$

The firm chooses next period's productivity z' through R&D investment, accumulates capital k', and selects its debt position b' subject to a collateral constraint. Future value depends on next period's state (s',ε') and is discounted using the household's stochastic discount factor, M.

Solution to the intraperiod problem. To solve the firm's problem, it is helpful to begin with the static decisions on labor and intratemporal debt. We assume that the working-capital constraint always binds.[2] Setting $\ell = wn$, the static decision on labor yields an

[2]This is guaranteed as long as $i \geq 0$. As we show later, $i < 0$ can arise in equilibrium, which requires us to impose this assumption so as to prevent unbounded borrowing.

optimal labor choice and an expression for sales minus labor costs as a function of (i, ξ, τ):

$$n(z,k,\varepsilon,i) = z\varepsilon \left[\frac{\eta(\zeta k)^{\alpha}}{w(1+i)}\right]^{\frac{1}{1-\eta}}$$

$$\Rightarrow \quad (z\varepsilon)^{1-\eta}(\zeta k)^{\alpha} n^{\eta} - wn(1+i) = z\varepsilon(\zeta k)^{\frac{\alpha}{1-\eta}} \left[\frac{\eta}{w(1+i)}\right]^{\frac{\eta}{1-\eta}} (1-\eta) \equiv z\varepsilon\, \pi(k,\zeta,i).$$

Given this expression, we can characterize the default decision as a threshold rule. A firm defaults if and only if $\varepsilon < \bar{\varepsilon}$, where the threshold value solves $V^p(s, \bar{\varepsilon}) = 0$ and is given by

$$\bar{\varepsilon}(s,i,\xi,\tau) = \frac{b(1-\xi) - (1-\delta)\zeta k + \nu - \tau - V_1(s)}{z\,\pi(k,\zeta,i)}. \tag{6}$$

2.2 Lenders

Each firm is matched with a risk-neutral lender. To fund interperiod lending, lenders raise deposits from households. For intraperiod lending, they have access to technology that allows them to raise funds at a linear cost of ω; we assume these are not true resource costs but are directly rebated to the representative household. Following the notation above, we denote by W_0 the lender's value at the beginning of the period when choosing intraperiod loan terms, and by W_1 the lender's value at the end of the period when making dynamic decisions. We assume free entry of lenders at both stages of lending.

Interperiod problem. The dynamic problem for interperiod lending is given by

$$\begin{aligned} W_1(s) &= \max_{q,d'} \mathbb{E}_{\zeta',\varepsilon'} \{\, M \cdot [\, W_0(s',\varepsilon') - d' \,] \,\} \\ \text{s.t.} \quad & qb' \leq Q^d d'. \end{aligned}$$

The lender maximizes its next-period value, which equals the expected payoff from the intraperiod stage minus the repayment of deposits raised today. The lender chooses the price of interperiod debt q and the amount of deposits d' to be raised. We assume that lenders hold no capital, so all lending must be fully deposit-funded. For simplicity, we also assume that the lender cannot commit to q when offering i, and vice versa.

Intraperiod problem. Lenders offer the intraperiod interest rate i and the debt write-off ξ after the idiosyncratic productivity ε is observed, but before the firm chooses to default on interperiod debt b. This timing assumption creates incentives to evergreen or restructure debt.[3] Lenders may choose to influence the firm's default decision to recover b. Intuitively, a lender may prefer this option to recovering the capital stock, as it yields a higher overall payoff. Lenders make take-it-or-leave-it offers which depend on ε. The problem for a lender at the intraperiod stage is

$$W_0(s,\varepsilon) = \max_{i \geq i^{reg}, \xi \leq \xi^{reg}} \mathbf{1}[\varepsilon \geq \bar{\varepsilon}(s,i,\xi,\tau)]\left\{ b(1-\xi) + (i-\omega) w\, n(z,k,\varepsilon,i) + W_1(s) \right\} + \mathbf{1}[\varepsilon < \bar{\varepsilon}(s,i,\xi,\tau)](1-\lambda)\,\zeta k. \tag{7}$$

We assume the firm is free to seek a new intraperiod lender and borrow at ω, which constrains the feasible set for the incumbent bank to be $i \leq \omega$. Given any guarantees and ex-post lender interventions, if the borrower survives and repays the legacy debt b, the firm takes on ℓ and the relationship continues. In contrast, if the borrower defaults, the lender recovers a fraction of the firm's capital at $(1-\lambda)\,\zeta k$.

In (7), i^{reg} is an exogenous lower bound for the interest rate that the lender is allowed to charge, and ξ^{reg} is the maximum amount of debt write-off. Such limits may exist for institutional or regulatory reasons, and we treat these limits as parameters for now. Later on, we consider how a benevolent policymaker chooses these limits without commitment. As previously explained, we term an economy without transfers and ex-post lender interventions the hard credit economy, where $i^{reg} = \omega$, $\xi^{reg} = 0$, and $\tau^{reg} = 0$, defined accordingly. Relative to this benchmark, the evergreening economy allows for $i^{reg} < \omega$, the restructuring economy permits $\xi^{reg} > 0$, and the guarantee economy features $\tau^{reg} > 0$. Thus, the parameters $(i^{reg}, \xi^{reg}, \tau^{reg})$ govern the strength of the ex-post interventions in the various economies. Note that, while we set up the general intraperiod problem for a lender in (7), we consider only one type of intervention at a time.

2.3 Intraperiod lending equilibrium

To solve the intraperiod lending equilibrium, it is useful to first examine the lender's interperiod problem. In equilibrium, the funding constraint binds, $d' = qb'/Q^d$. Free entry of banks at the interperiod lending stage implies that expected lender profits must be zero:

$$W_1(s) = 0 \quad \Rightarrow \quad q = \frac{\mathbb{E}_{\zeta',\varepsilon'}\{\, M \cdot W_0(s',\varepsilon')\,\}}{b'}. \tag{8}$$

This condition simplifies the intraperiod lending problem, which becomes static once we impose $W_1(s) = 0$.

[3] The timing assumption is similar to the one in Faria-e-Castro, Paul and Sánchez (2024), with the difference that lenders offer interest rates on new interperiod debt in that setting.

2.3.1 Hard Credit Economy

In the hard credit economy, lenders are not allowed to condition their offer of i on the firm's state, i.e. $i^{reg} = \omega = i$, and do not restructure debts, i.e. $\xi^{reg} = 0$. This allows us to characterize the firm's default decision as a threshold for the idiosyncratic shock ε, which depends only on the state variables s, by evaluating (6) at $i = \omega$:

$$\bar{\varepsilon}(s,\omega,0,0) = \left[\frac{b + \nu - (1-\delta)\zeta k - V_1(s)}{1-\eta}\right] \left[\frac{w(1+\omega)}{\eta}\right]^{\frac{\eta}{1-\eta}} \frac{1}{z(\zeta k)^{\frac{\alpha}{1-\eta}}}. \tag{9}$$

We refer to this object as the *distress threshold* and, to simplify notation, write it as $\bar{\varepsilon}(s)$. It corresponds to the default threshold in the hard credit economy and plays an important role in the other economies we analyze. Firms with $\varepsilon \geq \bar{\varepsilon}(s)$ are able to borrow at $i = \omega$, while firms with $\varepsilon < \bar{\varepsilon}(s)$ default and exit.

2.3.2 Evergreening Economy

In the evergreening economy, we allow lenders to condition their offer of i on the firm's state (s, ε). Free entry of lenders implies that $i \leq \omega$: lenders without an existing relationship break even by offering a rate equal to ω. Thus, if a lender were to offer an intraperiod rate above ω, the firm could switch to a new lender and borrow at ω, which defines an upper bound for i. Since we focus on one soft-credit mechanism at a time, when analyzing evergreening, we set $\xi = \tau = 0$ and write $\bar{\varepsilon}(s,i,0,0)$ simply as $\bar{\varepsilon}(s,i)$.

Given the stated conditions, we can rewrite the intraperiod lending problem in (7) as

$$W_0(s,\varepsilon) = \max_{i\in[i^{reg},\omega]} (1-\lambda)\zeta k + \mathbf{1}[\varepsilon \geq \bar{\varepsilon}(s,i)]\left\{b - (1-\lambda)\zeta k + (i-\omega)w\, n(z,k,\varepsilon,i)\right\}.$$

Crucially, in our model, the lender internalizes that the distress threshold $\bar{\varepsilon}(s,i)$ depends on i. The following proposition characterizes the intraperiod equilibrium under evergreening:

Proposition 1. *Let the liquidation threshold for the evergreening economy be given by:*

$$\underline{\varepsilon}_z(s) = \max\left\{\underline{\tilde{\varepsilon}}_z(s), \left[\frac{b + \nu - (1-\delta)\zeta k - V_1(s)}{1-\eta}\right] \left[\frac{w(1+i^{reg})}{\eta}\right]^{\frac{\eta}{1-\eta}} \frac{1}{z(\zeta k)^{\frac{\alpha}{1-\eta}}}\right\} \tag{10}$$

where

$$\tilde{\underline{\varepsilon}}_z(s) = \left[\frac{w(1+\omega)}{b-(1-\lambda)\zeta k + \frac{\eta}{1-\eta}\left[b+\nu-(1-\delta)\zeta k - V_1(s)\right]}\right]^{\frac{\eta}{1-\eta}} \times \left[\frac{b+\nu-(1-\delta)\zeta k - V_1(s)}{(1-\eta)(\zeta k)^{\alpha}}\right]^{\frac{1}{1-\eta}} \frac{1}{z}.$$

Then, the intraperiod equilibrium be characterized as:

1. *if* $\varepsilon < \underline{\varepsilon}_z(s)$, *the firm is liquidated.*
2. *if* $\varepsilon \in [\,\underline{\varepsilon}_z(s),\, \bar{\varepsilon}(s)\,]$, *the lender evergreens the firm's debt and* $i < \omega$.
3. *if* $\varepsilon > \bar{\varepsilon}(s)$, *the firm borrows at the competitive rate* $i = \omega$.

An evergreening region exists if and only if $b > (1-\lambda)\zeta k$.

The proof is in Appendix A.1. Figure 2 provides a graphical representation of the intraperiod equilibrium. Idiosyncratic productivity is on the horizontal axis. The blue dashed line represents ω, the competitive funding rate. The gray dot-dashed line is $i^{\min}$, the minimum interest rate at which the bank is willing to lend (i.e., such that the payoff of lending today and recovering legacy debt exceeds that of liquidation), and the solid black line is $i^{\max}$, the maximum interest at which the firm is willing to borrow and not default. For high enough ε, the firm borrows at the competitive rate. At some point, $i^{\max}$ falls below ω but is still higher than $i^{\min}$. This is the evergreening region, in which the lender is willing to lend at an intraperiod rate below the market rate. This happens because the difference between the value of repaid legacy debt and recovered capital in case of default exceeds any potential losses the lender may incur by lending below its funding cost. For low enough ε, however, the bank's minimum lending rate exceeds the maximum rate the firm is willing to pay, and so the lender prefers to liquidate the firm. The thick red line represents the rate that is offered in equilibrium as a function of ε.

One important consequence of evergreening is that the choice of i affects the amount of labor the firm hires. To the extent that some firms that would otherwise default are now supported by evergreening, total demand for labor expands, everything else constant. Moreover, not only total labor demand but also its distribution changes. Firms that have lower levels of productivity benefit from lower interest rates and thus demanding relatively more labor. Thus, evergreening is a source of static misallocation in the economy, as it expands input demand for less productive firms.

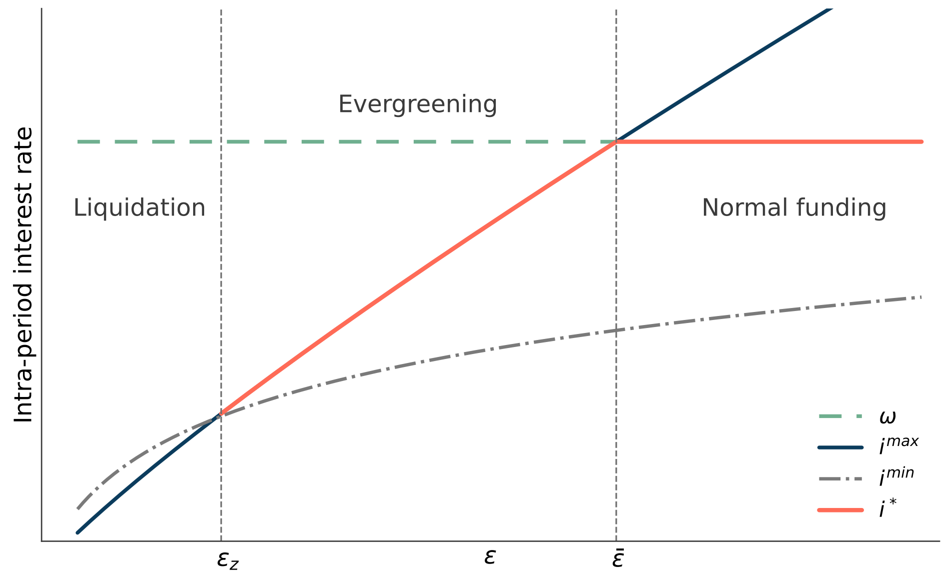

Figure 2: Intraperiod equilibrium for the evergreening economy as a function of idiosyncratic productivity ε. i^* denotes the equilibrium interest rate offered by the lender.

2.3.3 Restructuring Economy

We now consider the case in which lenders are allowed to write off a fraction $\xi(s,\varepsilon) \in [0,1]$ of past firm debt b. As in the evergreening economy, lenders may find it optimal to restructure debt ex-post whenever the recovered value under restructuring exceeds that obtained through liquidation.

We assume that while lenders can condition the size of restructuring on the firm's state, they cannot condition the intratemporal interest rate on those states; thus $i^{reg} = \omega = i$. As with evergreening, we impose regulatory limits on the extent of restructuring, requiring $\xi(s,\varepsilon) \leq \xi^{reg}$, where ξ^{reg} is an exogenous cap. The restructuring economy nests the hard credit economy when $\xi^{reg} = 0$, in which case no restructuring is allowed.

The proposition below characterizes the intraperiod equilibrium with restructuring:

Proposition 2. *Let the liquidation threshold for the restructuring economy be given by:*

$$\underline{\varepsilon}_x(s,\zeta) = \frac{\nu - (1-\delta)\zeta k - V_1(s) + b(1 - \min\{\xi^{\max}(k,b,\zeta),\, \xi^{reg}\})}{z\,\pi(k,\zeta,\omega)}. \tag{11}$$

where $\xi^{\max}$ is the maximum haircut the bank is willing to offer, given by

$$\xi^{\max}(k,b,\zeta) = 1 - \frac{(1-\lambda)\zeta k}{b}.$$

Then, the intraperiod equilibrium can be characterized by three regions for ε:

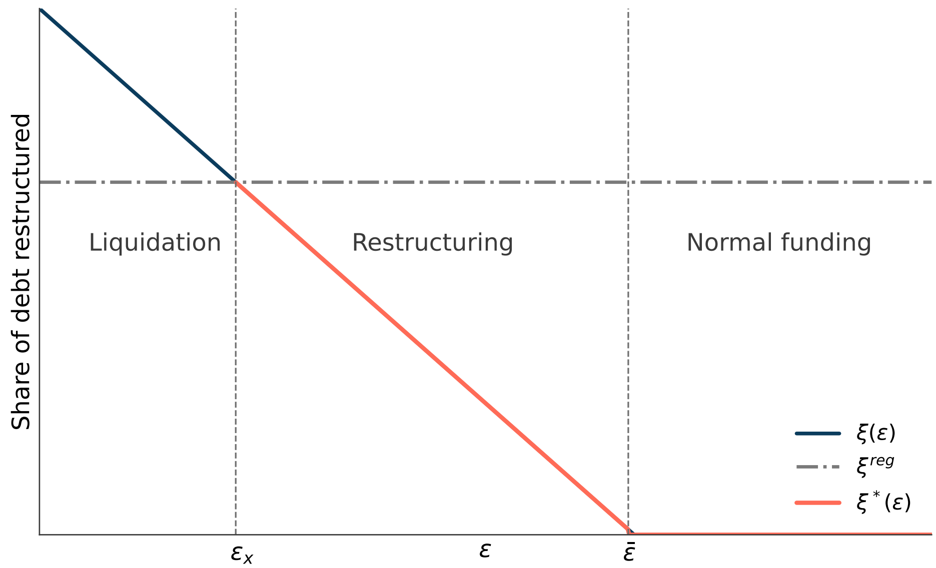

Figure 3: Intraperiod equilibrium for the restructuring economy as a function of idiosyncratic productivity ε.

1. *if* $\varepsilon > \bar{\varepsilon}(s,\zeta)$, *the firm receives normal funding and no restructuring occurs;*

2. *if* $\varepsilon \in [\,\underline{\varepsilon}_x(s,\zeta),\, \bar{\varepsilon}(s)\,]$, *the firm's debt is restructured,* $\xi > 0$*;*

3. *if* $\varepsilon < \underline{\varepsilon}_x(s,\zeta)$, *restructuring is not feasible and the firm is liquidated.*

The proof is again in Appendix A.1, and the equilibrium is depicted in Figure 3 as a function of the idiosyncratic shock ε. The horizontal dashed line represents the regulatory restructuring limit, the solid black line shows the unconstrained amount of restructuring the lender would choose, and the solid red line shows the resulting optimal restructuring policy given the constraints.

The three regions are similar to those of the evergreening economy, in the sense that restructuring supports distressed firms and helps prevent their exit, everything else constant. One key difference is that restructuring does not distort the intraperiod lending rate and, in turn, the labor demand decision.

2.3.4 Guarantee Economy

We also consider the case where a fiscal authority issues transfers to support businesses in distress in repaying their debts, thereby effectively offering credit guarantees. These transfers are financed with non-distortionary lump-sum taxes on households. Such a program resembles interventions at the onset of the COVID-19 pandemic, such as the Paycheck Protection Program (PPP). However, an important difference is that we consider an intervention that is directly targeted at firms in financial distress, with an amount just large enough to save a firm from default, and that occurs even outside of recessions.

We assume that firms in distress are eligible to receive a transfer that may depend on their own states, $\tau(s,\varepsilon)$. The size of the transfer is such that firms are indifferent between continuing and defaulting, with an upper bound τ^{reg} per firm. That is, the guarantee is exactly sufficient for the firm to repay the interperiod debt. Thus, this economy nests the hard credit economy when $\tau^{reg} = 0$.

As in the previous economies, firms that are not distressed with $\varepsilon > \bar{\varepsilon}(s)$ are not eligible for transfers (i.e., the guarantee does not trigger). The following proposition characterizes the equilibrium:

Proposition 3. *Let the liquidation threshold for the guarantee economy be given by:*

$$\underline{\varepsilon}_\tau(s,\zeta) = \frac{b + \nu - (1-\delta)\zeta k - V_1(s) - \tau^{reg}}{z\,\pi(k,\zeta,\omega)}. \tag{12}$$

Then, the intraperiod equilibrium can be characterized by three regions for ε:

1. *if $\varepsilon > \bar{\varepsilon}(s,\zeta)$, firms survive and receive no transfers;*
2. *if $\varepsilon \in [\,\underline{\varepsilon}_\tau(s,\zeta),\, \bar{\varepsilon}(s)\,]$, firms receive fiscal support and fully repay their debt;*
3. *if $\varepsilon < \underline{\varepsilon}_\tau(s,\zeta)$, the firm cannot survive without a transfer larger than the limit and therefore exits (without receiving a transfer).*

The equilibrium is shown in Figure 4 as a function of the idiosyncratic shock ε. The solid black line represents the unconstrained level of transfers the firm would require to survive. The horizontal red dashed line depicts the transfer limit, and the solid red line represents the transfer actually offered in equilibrium.

2.4 Dynamic Decisions

The full intraperiod equilibrium conditions and the dynamic decisions of lenders and firms are stated in Appendix A. Importantly, when choosing investment, innovation, and debt, the firm does not internalize any future states in which it is distressed, $\varepsilon' < \bar{\varepsilon}(s')$, even if it survives through evergreening, restructuring, or fiscal support. That is because in these states, the firm is indifferent to defaulting and its value function is therefore equal to zero.[4]

[4]We can further show that the firm's borrowing constraint (5) always binds in equilibrium. To see this, combine the expression for the price of intertemporal debt in (26) with the firm's first-order condition for

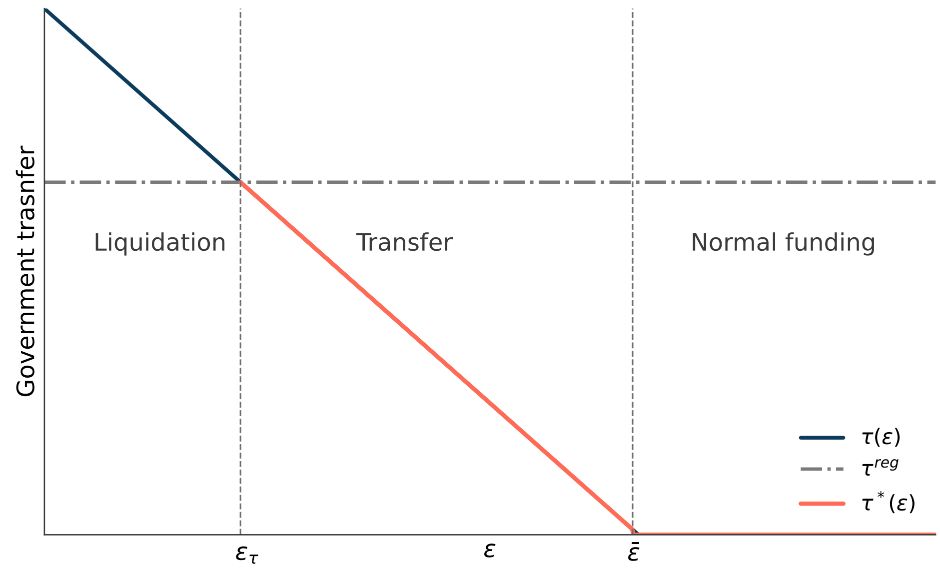

Figure 4: Intraperiod equilibrium for the guarantee economy as a function of idiosyncratic productivity ε.

2.5 Households

The representative household has preferences over consumption and labor as in King, Plosser and Rebelo (1988). Utility, in sequential form, is:

$$\mathcal{U} = \mathbb{E}_0 \sum_{t=0}^{\infty} (\beta)^t \frac{C_t^{1-\sigma} \left[1 + (\sigma - 1)\chi \frac{N_t^{1+\varphi}}{1+\varphi}\right]^{\sigma}}{1-\sigma}, \tag{13}$$

where σ is the inverse elasticity of intertemporal substitution, χ is a level disutility parameter for labor, and φ is the inverse Frisch elasticity. As discussed below, the model features balanced growth, which constrains the class of utility functions we can use. Importantly for our purposes, King, Plosser and Rebelo (1988) preferences are consistent with balanced growth and stable hours worked along the balanced growth path.[5] The household supplies labor and bank deposits, and is the ultimate owner of all financial claims in the economy, receiving net profits from both firms and financial intermediaries.

debt in (24). Since the firm and the lender share the same stochastic discount factor, the expected repayment cancels out, leaving a strictly positive expected recovery term, which implies that the Lagrange multiplier must be positive.

[5]Flow utility becomes equal to $\log C_t - \chi \frac{N_t^{1+\varphi}}{1+\varphi}$ in the limit $\sigma \to 1$. This is the only separable utility function over consumption and hours that is consistent with balanced growth and does not require a trend for the disutility of labor. See Boppart and Krusell (2020) for an extended discussion.

The household's period budget constraint is given by

$$C + Q^d D' = wN + D + \Psi - T,$$

where Ψ are net transfers from firms and financial intermediaries, and T are lump-sum taxes. We assume that the government runs a balanced budget, and so T equals total expenditures with credit guarantees. The household problem yields two optimality conditions: a labor supply condition and an Euler equation, given by

$$\sigma\chi C N^{\varphi} = w\left[1 + (\sigma - 1)\chi \frac{N^{1+\varphi}}{1+\varphi}\right],$$

$$Q^d = \beta\mathbb{E}\left\{\frac{\left[1 + (\sigma-1)\chi\frac{(N')^{1+\varphi}}{1+\varphi}\right]^{\sigma}(C')^{-\sigma}}{\left[1 + (\sigma-1)\chi\frac{N^{1+\varphi}}{1+\varphi}\right]^{\sigma}(C)^{-\sigma}}\right\} \equiv \mathbb{E}(M).$$

2.6 Aggregate Resource Constraint

Next, we derive the aggregate resource constraint. The joint intraperiod payoff for a firm-bank pair is given by:

$$(z\varepsilon)^{1-\eta}(\zeta k)^{\alpha} n^{\eta} - (1+\omega)wn + (1-\delta)\zeta k - \nu + \tau. \tag{14}$$

Liquidated firms yield a joint payoff equal to $(1-\lambda)\zeta k$. Let Λ denote aggregate joint payoffs plus labor income. We can write this term as:

$$\Lambda = \int_{\underline{\varepsilon}(s)}^{\infty}\left[(z\varepsilon)^{1-\eta}(\zeta k)^{\alpha} n^{\eta} - (1+\omega)wn + (1-\delta)\zeta k - \nu + \tau\right]\mathrm{d}F(\varepsilon)$$
$$+ \int_0^{\underline{\varepsilon}(s)}(1-\lambda)\zeta k\,\mathrm{d}F(\varepsilon) + (1+\omega)wN.$$

Total income to the household from labor and net transfers from the banking and corporate sectors is thus given by:

$$\Lambda + Q^d D' - D - K' - \phi\left[\frac{z'}{z(\varepsilon^*)^{\rho}}\right]^{\kappa}.$$

The aggregate resource constraint is obtained by combining this constraint with the household's budget constraint, and the government's balanced budget constraint, yielding:

$$C + K' + \phi\left[\frac{z'}{z(\varepsilon^*)^{\rho}}\right]^{\kappa} = \Lambda.$$

Consumption plus aggregate investment in physical capital and R&D equals labor earnings plus total net transfers from the corporate and financial sectors.

2.7 Equilibrium

A competitive equilibrium is a sequence of allocations $(C_t, N_t, D_{t+1}, z_{t+1}, k_{t+1}, b_{t+1}, n_t, \ell_t)$, prices (w_t, q_t, i_t), and thresholds for liquidation and distress $(\underline{\varepsilon}_t, \bar{\varepsilon}_t)$, such that for all t:

1. **Household optimization.** The representative household chooses $\{C_t, N_t, D_{t+1}\}$ to maximize lifetime utility subject to its budget constraint, taking prices and firm distributions as given.

2. **Firm optimization.** Firms choose intraperiod allocations (n_t, ℓ_t) and interperiod decisions $(z_{t+1}, k_{t+1}, b_{t+1})$ to maximize firm value, taking prices, lending policies, and thresholds as given.

3. **Lender optimization.** Lenders choose intraperiod contract terms and the interperiod price of debt $\{i_t, \xi_t, q_t\}$ to maximize profits subject to regulatory constraints, zero-profit/free-entry conditions, and funding constraints. The thresholds $(\underline{\varepsilon}_t, \bar{\varepsilon}_t)$ satisfy the firm's indifference conditions implied by optimal lending contracts.

4. **Market clearing.** The labor, goods, deposit, intraperiod debt, and interperiod debt markets clear.

5. **Consistency of laws of motion.** Aggregate states evolve according to the transition rules implied by firm decisions and the stochastic processes for shocks. In equilibrium, all firms make identical dynamic decisions, and so $s_t = S_t$.

2.8 Balanced Growth Path

Under suitable parameter restrictions, a balanced growth path exists with detrending factor $z_t^{\frac{1-\eta}{1-\alpha}}$. Accordingly, we express all equilibrium conditions in terms of detrended variables $x_t = \tilde{x}_t \cdot z_t^{\frac{1-\eta}{1-\alpha}}$. Letting $G_z \equiv z_{t+1}/z_t$ denote the growth rate of the common component of productivity, the growth rate of all real quantities in the economy—including output—equals $G_z^{\frac{1-\eta}{1-\alpha}}$. The complete set of detrended equilibrium conditions is provided in Appendix A.4.

An expression for the gross rate of productivity growth G_z can be obtained by rewriting the firms' dynamic decision (25), shown in Appendix A.3, in its detrended form as:

$$\frac{z'}{z} = (\varepsilon^*)^{\frac{\rho\kappa(1-\alpha)}{\kappa(1-\alpha)-(1-\eta)}} \times \left\{ \frac{\mathbb{E}[M \cdot \int_{\bar{\varepsilon}(s')}^{\infty} \frac{\partial V_0(s',\varepsilon')}{\partial z'} \mathrm{d}F(\varepsilon')]}{\kappa\tilde{\phi}} \right\}^{\frac{(1-\alpha)}{\kappa(1-\alpha)-(1-\eta)}} \equiv G_z \tag{15}$$

where

$$\frac{\partial V_0(s',\varepsilon')}{\partial z'} = \varepsilon'(\zeta'\tilde{k}')^{\frac{\alpha}{1-\eta}} \left[\frac{\eta}{\tilde{w}'(1+\omega)}\right]^{\frac{\eta}{1-\eta}} (1-\eta) + (1-\rho)\kappa\tilde{\phi} \left[\frac{G_z'}{(\varepsilon^{*\prime})^{\rho}}\right]^{\kappa}$$

Expression (15) determines the growth rate of the common productivity component z, showing that it is the product of two components. The first is a function of the average productivity of incumbents, ε^*, and highlights the key role of the innovation externality, governed by the parameter ρ: the more productive the surviving firms, the faster the common component of productivity grows. The second term reflects the private benefits of innovation relative to its costs. These benefits include the marginal profit from an extra unit of z', as well as the perceived reduction in the future cost of innovation, of which the firm privately internalizes only a fraction, $1-\rho$. Importantly, the benefits are only internalized in states of the world where $\varepsilon' \geq \bar{\varepsilon}(s')$. Thus, an expansion of the evergreening, restructuring, or transfer region that is associated with an increase in the distress threshold $\bar{\varepsilon}(s)$ can result in lower incentives to invest in R&D.

Equation (15) demonstrates that as long as there is an innovation externality, $\rho > 0$, the productivity of current incumbents directly impacts the growth rate of the economy. This resonates with the literature on creative destruction and imitation. For example, in Aghion and Howitt (1992), new entrants innovate over incumbent technology at fixed steps. In Perla and Tonetti (2014), firms learn from each other in equilibrium. With such relations, the average productivity of incumbents generates externalities that affect economy-wide productivity.

2.9 Key frictions

The model features four main inefficiencies from the perspective of a planner who maximizes household welfare subject only to technological constraints. We briefly summarize each of these distortions in turn.

The first inefficiency arises from the learning externalities governed by ρ. An unconstrained planner would internalize two effects that firms neglect in equilibrium. First, innovation undertaken today reduces the future cost of innovation one-for-one, rather than only by the private factor $1 - \rho$. Second, the planner internalizes the dynamic selection margin embedded in average productivity ε^*. The first channel suggests that firms underinvest in R&D in the decentralized equilibrium, because they do not fully appropriate the future benefits of their own innovation. The second implies that firm exit, and therefore the extent of selection, may also be inefficient.

The second inefficiency is related to congestion in input markets. This externality, emphasized by Caballero, Hoshi and Kashyap (2008) and studied more recently by Acharya et al. (2024), operates through factor prices. When more firms survive under soft credit regimes, labor demand rises, putting upward pressure on wages. Higher wages, in turn, raise liquidation thresholds and further weaken selection. At the same time, conditional on the innovation externality described above, firm exit is itself socially costly in this economy: exiting firms have already invested, yet their capital is no longer used in production, and it depreciates at rate λ, which we assume exceeds δ. Exit therefore generates both idle capital and additional depreciation losses.

The third inefficiency consists of standard financial frictions, namely limited liability and costly default (Cooley and Quadrini, 2001). Limited liability implies that firms do not fully internalize payoffs in states in which they default, or in which ex-post interventions prevent default by setting their payoff to zero. Because firms internalize returns only in a subset of states, they invest too little in both physical capital and R&D. This mechanism can also be interpreted through the lens of debt overhang: when firms understand that part of the return to current investment will accrue to lenders rather than equity holders in adverse states, they optimally scale back investment. This logic applies to both tangible capital accumulation and innovation effort.

The fourth and final inefficiency stems from the borrowing constraint, which distorts the composition of investment away from R&D and toward physical capital. Because the borrowing constraint is always binding – a consequence of costly default combined with imperfect but positive recovery – firms have an incentive to tilt investment toward assets that are pledgeable and expand borrowing capacity. From the standpoint of an unconstrained planner, for whom financing constraints are irrelevant, this creates an inefficient composition effect: firms invest too much in physical capital and too little in R&D.

3 Calibration and Solution

In this section, we describe our strategy for calibrating the model to annual U.S. data and the method we use to solve the model. Our framework encompasses a series of parameters that are standard in the macro-finance literature but a few parameters that are unique to our model. For this reason, we adopt a multi-step approach. First, we directly estimate the parameters governing the innovation cost function (2), κ and ρ, by combining theoretical relations derived from the model with firm-level micro data. Second, we externally calibrate parameters that are standard in the literature, or that have obvious counterparts in the data. Finally, we jointly calibrate all remaining parameters to match a series of empirical targets. Next, we describe these three steps in more detail.

3.1 Direct Estimation

To obtain estimates for ρ and κ, we start from the R&D investment cost function (2). To take this equation to the data, we rewrite the expression with time-, industry-, and firm-specific subscripts as

$$R\&D_{i,s,t} = \phi_t \left(\frac{z_{i,s,t+1}}{z_{i,s,t}^{1-\rho} (x_{i,s,t}^*)^{\rho}} \right)^{\kappa}, \tag{16}$$

where we associate the productivity and R&D costs with firms denoted by subscript i. We assume for now that the scale ϕ_t has the same time trend for all firms, whereas firms learn from the industry-specific average productivity x^* that is specific to their industry s, and we vary both restrictions below.[6] Taking logs and rearranging (16) yields the equation

$$\log z_{i,s,t+1} - \log z_{i,s,t} = \frac{1}{\kappa} \cdot (\log R\&D_{i,s,t} - \log \phi_t) + \rho \cdot \log \frac{x_{i,s,t}^*}{z_{i,s,t}}. \tag{17}$$

We transform this expression into a regression specification by using time fixed effects χ_t to absorb the time trend ϕ_t, predetermined values for the productivity terms to align those with the timing in the model, and by allowing for random variation $u_{i,s,t}$

$$\log z_{i,s,t+1} - \log z_{i,s,t-1} = \chi_t + \beta_1 \cdot \log R\&D_{i,s,t} + \beta_2 \cdot \log \frac{x_{i,s,t-1}^*}{z_{i,s,t-1}} + u_{i,s,t}, \tag{18}$$

where β_1 corresponds to $(1/\kappa)$ and β_2 to ρ, which measure the elasticity of firm productivity growth to log-variation of firm R&D expenses and the log-differences between a firm's peers' productivity relative to its own.

When estimating this regression on firm micro data, we would be concerned about the possible endogeneity of $\log R\&D_{i,s,t}$. For example, young firms may conduct less R&D since they have less skilled labor for such purposes at the beginning of their lifetime.

[6] When computing x^*, we omit a firm's own value, such that x^* is specific to firm i.

At the same time, younger firms exhibit higher productivity growth, leading to biased estimates of β_1 when firm age is omitted from the regression.

To address the possible endogeneity of log $R\&D_{i,s,t}$, we proceed with an instrumental variable approach. As an instrument, we use state-level R&D tax credit rates following Wilson (2009) and Bloom, Schankerman and Van Reenen (2013).[7] For the various regression specifications considered below, we find that firms headquartered in states with higher R&D tax credits report more R&D expenses, and that the instrument passes typical tests for weak instruments with first-stage F-statistics close to 20.

In contrast, the possible endogeneity of $\log(x^*_{i,s,t-1}/z_{i,s,t-1})$ is less central to our analysis since the associated coefficient simply measures the pace of convergence if ex-ante productivity levels diverge. To continue the example above: younger firms may have lower productivity levels than their peers, while they show higher productivity growth, leading us to find $\beta_2 > 0$, which measures the pace at which younger firms catch up. Thus, the age of the firm can explain why firms converge and we do not need to control for it in our regression. More importantly, we interpret such convergence as resulting from learning. Younger firms learn from their peers and *therefore* have relatively faster productivity growth. While we view learning as a broad explanation of productivity convergence, we test the robustness of our main findings to alternative values of ρ than the one we use for our baseline calibration below.

Data and TFP Estimation. We use annual firm data from S&P's Compustat database for publicly-traded corporations for the years 1982-2023.[8] We compute a firm's capital stock based on the perpetual inventory method as in Ottonello and Winberry (2020) and deflate the values using the nonresidential fixed investment good deflator from the NIPA tables. All other nominal variables are deflated using the GDP deflator. Given these data, and assuming a Cobb-Douglas production function of the form (1), we estimate the following regression

$$\log(\text{value added}_{i,t}) = \alpha + \beta_{1,s} \cdot \log(\text{capital}_{i,t-1}) + \beta_{2,s} \cdot \log(\text{employees}_{i,t}) + u_{i,t}, \quad (19)$$

[7]We use the updated data provided by Glaeser and Yoo (2025), available for the years 1982-2023. Bloom, Schankerman and Van Reenen (2013) document large cross-sectional variation in state-level R&D tax credits that is seemingly uncorrelated with economic and political variables, providing pseudo-random variation to R&D expenditures (see Appendix B.3 therein). We directly use the state-level R&D tax credit rate as an instrument as opposed to the user cost of R&D capital as in Wilson (2009), which we find yields nearly identical results.

[8]We restrict the sample to firms headquartered in the United States, that operate outside of the utilities and finance sectors (SIC codes 4900-4999 and 6900-6999), and do not show acquisitions larger than 5% of total assets per year.

Table 1: Estimates R&D Cost Function.

	(i) Baseline	(ii) Fixed Effects	(iii) TFP-Def.	(iv) Learning	(v) Capital	(vi) ACF-2015
β_1 $(= 1/\kappa)$	0.35***	0.52***	0.41***	0.53***	0.24***	0.22***
	(0.09)	(0.13)	(0.12)	(0.14)	(0.07)	(0.06)
β_2 $(= \rho)$	0.29***	0.39***	0.39***	0.39***	0.23***	0.40***
	(0.02)	(0.03)	(0.05)	(0.04)	(0.01)	(0.04)
Time FE	✓		✓	✓	✓	✓
Industry-Time FE		✓				
First-Stage F-Stat	19	18	15	16	24	15
R-squared	0.12	0.17	0.12	0.14	0.11	0.14
Observations	34,556	34,243	34,556	34,556	35,519	38,868
Number of Firms	4,847	4,823	4,847	4,847	5,380	5,010
Number of Industries	46	41	46	46	47	47

Notes: Estimation results for regression (18). Standard errors in parentheses are clustered by firm. Sample: 1982-2023. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

where we allow the coefficients β_1 and β_2 to vary by industry s using two-digit SIC codes. We recover the log-TFP estimates as

$$\log(TFP_{i,t}) = (\hat{\alpha} + \hat{u}_{i,t})/(1 - \eta). \tag{20}$$

Note that we divide by our calibration for $(1 - \eta)$, stated below, to align the estimates with our assumed production function in (1).[9]

Results. Equipped with the firm micro data and the TFP estimates, we estimate regression (18) using the outlined instrumental variable approach. The results are shown in Table 1. Column (i) portrays our baseline estimates of 0.35 for β_1 and 0.29 for β_2, which are both statistically significant at the 1 percent confidence level. Whereas β_2 directly corresponds to the parameter ρ, β_1 implies a value of around 3 for κ, and we use these numbers in our baseline calibration. These values imply that a 1% increase in R&D expenditure, or a 1% higher productivity of a firm's peers relative to its own productivity, each leads to firm productivity growth of around 0.3% over the next year.

[9] Since Compustat does not separately identify prices and quantities of goods sold, our TFP measure reflects both physical productivity and markups. However, as long as markups are slow-moving and do not strongly covary with physical productivity in the cross-section, the identified variation based on regression (18) can be associated with physical productivity.

Robustness. The remaining columns in Table (1) show the estimation results from various robustness checks. Column (ii) uses industry-time fixed effects to allow for the possibility that ϕ_t in equation (16) also varies by industry, which gets absorbed into these fixed effects.[10] Column (iii) uses an alternative TFP definition, which simply employs the calibration mentioned below to recover TFP, as opposed to estimating the parameters first and obtaining TFP based on these parameters as described above. Column (iv) assumes that firms learn not only from their industry peers but more broadly from all firms in the economy, such that $x^*_{i,t-1}$ does not vary by industry in (18). Column (v) uses net property, plant, and equipment as a measure of the firm's capital stock. And finally, in column (vi), we test the robustness of our findings to using the method by Ackerberg, Caves and Frazer (2015) to estimate production functions and hence TFP. Specifically, this approach deals with the concern that firms observe part of their own productivity when choosing inputs, rendering those inputs to be endogenous regressors that are correlated with the error term in (19).[11] Across the various robustness checks, we find estimates for β_1 and β_2 ranging between 0.22-0.52 and 0.23-0.40, respectively, with our baseline estimates falling roughly in the middle of those ranges.[12]

Comparison to Literature. How do our estimates compare to related findings in the literature? While previous studies have estimated spillover effects of R&D investment across various dimensions (see, e.g., Bloom, Schankerman and Van Reenen, 2013, Arqué-Castells and Spulber, 2022), we are not aware of any prior studies that have analyzed how firms learn from each other's productivity. In contrast, a large body of literature estimates the effects of R&D investment on firm productivity. However, prior studies have either used a firm's "R&D knowledge stock" accumulated through past R&D expenditures or a measure of R&D intensity, typically defined as R&D expenditures over firm output, to evaluate this relation. To assess the plausibility of our estimate for β_1, we therefore employ these alternative regressors, and separately report results based on the outlined

[10] Intentionally, we do not include firm fixed effects since $\log(R\&D_{i,s,t})$, as well as the state-level tax credit rates, have a positive time trend and the inclusion of such fixed effects imply a within-transformation that subtracts an average firm-specific value across periods, while the dependent variable in (18) is defined in log-differences.

[11] This method requires the choice of a dependent variable and we use value added in accordance with the production function in (19). Similarly, we choose employees as the labor input and the capital stock as the state variable. Importantly, we pick the costs of goods sold as the proxy variable, but obtain similar results for capital expenditures or net investment (difference of capital stock between two periods).

[12] Another potential concern may be that firms operate in multiple states and relocate their R&D expenditures to places with higher R&D tax credits without raising their overall expenditures (see, e.g., Wilson, 2009). However, in the presence of such R&D expenditure shifting, our instrument should not predict higher firm R&D spending, in contrast to our findings.

instrumental variable approach as well as simple OLS regressions in Appendix Table 8.[13]

To begin, columns (i) and (ii) compare our baseline IV results to an OLS approach of the same regression setup. This comparison shows that our IV approach yields a substantially larger coefficient for β_1 of 0.35 as opposed to 0.04 based on an OLS regression, underscoring the importance of the IV approach. Columns (iii) and (iv) instead use log-values of firms' R&D knowledge stocks as regressors, and again conduct IV and OLS estimations separately.[14] We obtain values for β_1 of 0.19 based on the IV approach, and 0.06 based on the OLS approach. The IV estimate lies at the upper end, but within the range, of prior estimates (see, e.g., Table 2 in Hall, Mairesse and Mohnen, 2010). Columns (v) and (vi) analogously report estimates for R&D intensity, giving us estimates of 0.55 for the IV approach and a coefficient that is close to zero for the OLS approach.[15] The IV estimate is again at the upper end of previous estimates in the literature (see, e.g., Table 3 in Hall, Mairesse and Mohnen, 2010). Thus, we view our identification approach as yielding similar effects of R&D investment on firm productivity growth and highlighting the importance of addressing the endogeneity of R&D expenditures via instrumental variables.

Further Evidence. Appendix Tables 9 and 10 provide further evidence. Columns (ii) and (iii) in Table 9 show the results from regressions that test for the dynamic response of firm productivity by changing the timing of the dependent variable to $(\log z_{i,s,t+2} - \log z_{i,s,t-1})$ and $(\log z_{i,s,t+3} - \log z_{i,s,t-1})$, respectively. The estimated coefficients β_1 and β_2 are slightly larger but close to our original estimates, illustrating that most of the productivity dynamics occur within the one-year horizon of our baseline specification, but also some thereafter. Column (iv) employs labor productivity—defined as value added/employees—instead of TFP, which has the advantage that it does not require a separate estimation step. While the estimate for β_2 remains close to our baseline, the estimate for β_1 differs quantitatively due to the alternative variable definitions. Column (v) addresses the concern that the regressor $\log(x^*_{i,s,t-1}/z_{i,s,t-1})$ is generated from a separate

[13]The regression specification (18) is derived from the R&D cost function (2), which implies that R&D $=$ 0 is associated with $z' = 0$. Firms reporting zero R&D are therefore not well characterized, and we implicitly exclude such observations by using log(R&D) as a regressor. Estimating (18) using $log(1 + \text{R\&D})$ instead yields similar results. However, as shown by Chen and Roth (2023), this transformation gives estimates that depend on the units of measurement when the underlying variable has a mass point at zero.

[14]We define the R&D knowledge stock as $K^{R\&D}_{i,t} = (1-\delta) \cdot K^{R\&D}_{i,t-1} + R\&D_{i,t}$ and set $\delta = 0.15$ as in Bloom, Schankerman and Van Reenen (2013).

[15]We define R&D intensity as firm R&D expenditures relative to value added. Such a regression specification could alternatively be derived from a R&D cost function that takes the form $R\&D_{i,s,t} = ValueAdded_{i,s,t} \cdot \log(\phi_t \cdot (z_{i,s,t+1}/(z^{1-\rho}_{i,s,t}(x^*_{i,s,t})^{\rho}))^{\kappa})$, and is therefore different than our original functional form (16).

estimation step, yielding possibly standard errors that are too low. To this end, we employ a bootstrap estimation by constructing new estimation samples through resampling with replacement. The estimation results show that the generated regressor does not pose a substantial concern, as the bootstrap-estimated standard errors are only slightly larger than those from the baseline estimation.

Columns (ii)-(iv) in Appendix Table 10 test the empirical estimates of ρ when firms are assumed to learn from other parts in the firm productivity distribution than the average. To this end, we posit that firms learn from the median, the 75th percentile, or the 90th percentile of the TFP distribution of firms within the same industry, yielding alternative definitions for $x^*_{i,s,t}$. For the various specifications, we obtain estimates of ρ in the range [0.34,0.37] and thus close to our baseline. And finally, column (v) in Table 10 weights the state-level tax credit rates by the R&D expenditure activity of firms across the states in which they are active. To this end, we use data on firms' patents from the NBER patent data project as a proxy for R&D activity.[16] We weight the tax credit rates by the patents firms filed in various states over the estimation sample for which the patent data is available. Again, we find that our results are robust to this alternative specification.

3.2 External Calibration

Table 2 presents the values for the externally calibrated parameters of the model. We assume a standard value for the Frisch elasticity, $\varphi = 1$, an inverse EIS equal to $\sigma = 2$, and a discount factor of $\beta = 0.98$: these are standard values in growth models (Acemoglu et al., 2018). For the firm production function (1), we set the factor shares α and η equal to 0.36 times a parameter that governs the degree of returns to scale ψ, and $0.64 \times \psi$, respectively. This is consistent with the standard assumption of a capital share of close to 1/3. The parameter ψ is internally calibrated in the next section to match the profit share. The depreciation rate is set, such that aggregate investment over the stock of capital is 8% at the annual level. We assume a borrowing constraint parameter equal to $\theta = 1$ to generate a ratio of debt to fixed-assets of 1 based on the empirical evidence in Faria-e-Castro, Paul and Sánchez (2024).

For financial intermediaries, we set the loss given default parameter to 0.35, which is in line with loss given default (LGD) rates reported by U.S. banks in the FR Y-14Q

[16]These data are available at: https://sites.google.com/site/patentdataproject/Home.

data.[17] Note that λ coincides with the LGD in equilibrium given our choice of $\theta = 1$.[18] We set the intraperiod lending cost to 2% annually, consistent with the average external bond premium reported by Gilchrist and Zakrajsek (2012). We view this as a reasonable target since it is a measure of the cost of borrowing that is purged of default risk, which corresponds to the risk-free intraperiod debt in our model.[19]

Table 2: Externally Calibrated Parameters.

Parameter	Description	Value	Target/Reason
	Households		
β	Discount factor	0.98	Acemoglu et al. (2018)
σ	Inverse EIS	2	Acemoglu et al. (2018)
φ	Inv. Frisch elasticity	1	Standard
	Firms		
α	Capital share	$0.36 \times \psi$	Standard
η	Labor share	$0.64 \times \psi$	Standard
δ	Depreciation rate	0.08	Standard
θ	Collateral constraint	1	Debt to fixed-assets of 1, FPS (2024)
	Financial Intermediaries		
λ	Loss given default	0.35	Y-14 data
ω	Lending cost	0.02	2% yearly, GZ (2012)

Notes: FPS (2024) refers to Faria-e-Castro, Paul and Sánchez (2024), GZ (2012) refers to Gilchrist and Zakrajsek (2012).

3.3 Internal Calibration

The next calibration step requires us to choose which of the economies is our calibration benchmark. Based on the empirical evidence in Faria-e-Castro, Paul and Sánchez (2024),

[17] The FR Y-14Q is a dataset maintained by the Federal Reserve for the purpose of stress-testing large bank holding companies. Specifically, our empirical moment is drawn from Schedule H.1, a quarterly loan-level dataset that contains detailed information on all credit facilities with balances over 1 million. For details, see https://www.federalreserve.gov/publications/fr-y-14-qas/y-14-qas.htm.

[18] More generally, and assuming a binding borrowing constraint, the LGD would be given by $\lambda \times \theta$. The implied recovery rate based on our LGD value is higher than the recovery rates for capital that are typically estimated in the literature, as in Kermani and Ma (2020), for example. Our goal of choosing this alternative target is to capture intermediaries' perceived expected losses from delinquency in the context of our model, rather than the physical recovery rates on liquidated capital.

[19] The target value is also consistent with the evidence in Philippon (2015), who reports an annual financial intermediation cost of 1.5%-2% for the U.S. economy over the past 130 years.

who show that U.S. banks have been evergreening loans even in normal times in recent years, we pick the evergreening economy as the main counterpart to the data.

Given the direct estimation and the external calibration, we jointly choose the seven remaining parameters such that simulated model averages are close to seven empirical target moments: the productivity of exiting firms relative to continuing firms, the typical historical firm exit rate, an average credit spread, the firm profit share, average GDP growth, as well as its annual persistence and conditional volatility. Table 3 describes the parameters and targets.

We assume that idiosyncratic productivity follows a lognormal distribution, and that its mean is equal to 1, hence $\log \varepsilon \sim \mathcal{N}(-0.5\sigma_\varepsilon^2, \sigma_\varepsilon^2)$. The dispersion parameter is set to $\sigma_\varepsilon = 0.406$, in order to match the evidence in Lee and Mukoyama (2015) regarding the productivity of exiting firms. Using one of their TFP measures, the authors find that the average TFP of exiting firms is about 65% of that of continuing firms. The fixed cost ν is set to -0.226, targeting an exit rate of 5% in the baseline economy with evergreening. Even though firm exit rates in the U.S. have been around 7.5% in recent decades (Crane et al., 2022), we target an exit rate of 5% since not all exits correspond to defaults in the data, whereas the two always coincide in our model. The average probability of loan default reported in the FR Y-14Q data is around 2.5% (Faria-e-Castro, Paul and Sánchez, 2024). We therefore take an average between these two rates as our target.

The lower bound on interest rates, i^{reg}, is set to -10.5% to match an average credit spread of 2% for variable-rate loans in the FR Y-14Q data. The level of returns to scale is chosen to match the average EBITDA-to-value-added ratio among Compustat firms, which is 30%.[20] The level cost of R&D $\tilde{\phi}$ is chosen to target a real GDP growth rate of 2%, roughly the average value of U.S. per capita GDP growth since 1960. Finally, the persistence and conditional volatility parameters for the exogenous process are set to match the persistence and conditional volatility of U.S. GDP growth since 1960.

[20] We define this ratio in the model as $(y - wn - \nu - \phi)/y$.

Table 3: Internally Calibrated Parameters.

Parameter	Description	Value	Moment	Source	Data	Model
σ_ε	Variance of iid prod.	0.406	Relative TFP exiters	LM (2015)	0.65	0.65
ν	Fixed cost	-0.226	Exit/default rate	See text	5.0%	4.9%
i^{reg}	Lower bound int. rate	-0.105	Credit spread	Y14 data	2.0%	2.0%
ψ	Returns to scale	0.860	EBITDA/Value Added	Compustat	30.0%	30.0%
$\tilde{\phi}$	Level cost of R&D	0.358	GDP pc growth	U.S. data	2%	2%
ρ_ζ	Capital quality persistence	0.736	GDP growth rate	U.S. data	0.16	0.16
σ_ζ	Capital quality volatility	0.035	GDP growth rate	U.S. data	0.02	0.02

Notes: LM(2015) refers to Lee and Mukoyama (2015).

3.4 Solution Method

We obtain a global nonlinear solution to the model via time iteration over a set of policy functions that depend on the model's state variables. We start by casting the equilibrium as a function of current states, a system of forward-looking difference equations that contain expectations over future shocks. We guess functional forms for the model's policy functions as a function of the (aggregate) endogenous and exogenous state variables: (k, ζ).[21] For each point in the grid, we solve for the values of policy functions at date t, interpolating over the guesses to compute expectations. We then update the interpolants with the updated policy functions and repeat the process until convergence. See, for example, Richter, Throckmorton and Walker (2014) and Faria-e-Castro (2024), for a detailed description and for applications of this method.

Our focus on higher-order moments and discretionary policy exercises requires a global nonlinear solution. Even so, the model's treatment of intraperiod heterogeneity and binding constraints is sufficiently tractable that it could be incorporated in a larger-scale DSGE model. The framework is potentially amenable to log-linearization around the deterministic steady state, allowing the mechanism to be incorporated into broader estimated models and analyzed with standard tools such as Dynare.

4 Quantitative Analysis

In this section, we compare the different economies in terms of simulation moments, responses to aggregate shocks, and their sensitivity to important parameters.

[21] Note that z is not a state variable for the detrended economy, and the fact that the borrowing constraint always binds implies that we do not need to keep track of k and b independently.

4.1 Aggregate Moments

To begin, we simulate the various economies and compute aggregate moments that are reported in Table 4. Our baseline calibration for the evergreening economy results in a share of saved firms equal to 5%. This is in line with the evidence in the dataset assembled by Albuquerque and Iyer (2024), which reports an average zombie share of 7.7% among US publicly listed firms since 2015, and an average zombie share of 2.2% among private firms. A simple average of these two values yields 5%. To make the different SC economies comparable, we calibrate ξ^{reg} and τ^{reg} for the restructuring and guarantee economies such that the share of firms that are saved is equalized to the one in the evergreening economy at 5%.[22] Of course, that share is zero in the HC economy where ex-post interventions are not permitted.

Exit and Growth. The absence of these interventions implies that the HC economy features almost twice as much firm exit relative to the various SC economies. In turn, more exit of low-productive firms raises the average productivity of all surviving firms ε^* which lowers the R&D costs of subsequent firms through the innovation externality. As a result, productivity growth rises, leading to GDP growth that is between 0.33 and 0.40 p.p. higher in the HC economy than in the SC economies. The evergreening economy lags behind in GDP growth, which is around 0.05 p.p. lower relative to the restructuring and the guarantee economy. The exit rate is slightly lower in the evergreening economy than in the other SC regimes, resulting in slightly lower GDP growth.

Volatility. However, higher growth in the HC economy comes at the cost of higher growth volatility. For example, relative to the evergreening economy, the standard deviation of GDP growth in the hard credit economy is almost 0.8 p.p. higher. This pattern also carries over to consumption, which shows similar differences across HC and SC economies, though these effects are less pronounced quantitatively.

Cost of credit. The possibility of saving distressed firms ex-post also affects the pricing of intertemporal credit. Across soft-credit economies, lenders charge a spread on intertemporal credit of around 2%, which partly reflects the flexibility to ease credit terms ex post. However, when this possibility is removed in the hard-credit economy, spreads almost double to 3.55%. As credit becomes less flexible, lenders more often face steeper losses when firms are in the default region, which is reflected in ex-ante credit pricing.

[22] The resulting values are $\xi^{reg} = 0.0198$ and $\tau^{reg} = 0.0413$.

Table 4: Model moments across credit regimes

	Hard Credit	Evergreening	Restructuring	Guarantee
Share of subsidized firms (%)	0.00	5.00	5.00	5.00
Exit rate (%)	8.86	4.91	4.92	4.96
ε^*	1.05	1.03	1.03	1.03
GDP growth	2.39	2.00	2.05	2.06
$\sigma(g_Y)$	2.81	2.03	2.27	2.25
$\sigma(g_C)$	2.70	2.50	2.62	2.58
Real interest rate, $1/Q^d - 1$	6.59	5.92	5.95	5.97
Lending spread, $(1/q - 1/Q^d)$	3.55	2.02	2.05	2.00
Detrended wage, $\tilde{w}$	0.73	0.78	0.78	0.78
K/Y	1.41	1.62	1.63	1.62
Avg. intraperiod rate, i (%)	2.00	1.69	2.00	2.00
Avg. debt restructured, ξ (%)	0.00	0.00	0.05	0.00
Guarantees over GDP (%)	0.00	0.00	0.00	0.08
$corr(R\&D, Y)$	0.69	0.90	0.85	0.90

Capital and wages. These differences in credit spreads, which by and large originate from changes in loan rates, affect firms' intertemporal capital choices. As the cost of borrowing declines, firms borrow more and invest more in physical capital in the SC economies. In turn, this increases the capital-to-output ratio in these economies relative to the hard credit economy. Thus, while the HC economy features higher productivity and GDP growth, physical capital investment relative to the same stock of capital is actually lower in this economy relative to the SC economies. Appendix Figure 12 visually illustrates these patterns by showing the firm policies for capital and productivity investment as a function of the stock of capital for various economies. In contrast to intertemporal credit, the rate on the working capital loan is the same across all economies at 2%, apart from the evergreening economy where this rate is used by lenders to influence firm default decisions.

When saving firms in distress, a larger set of firms produces, raising labor demand and pushing up wages all else equal. This effect is visible in Table 4 as the aggregate detrended wage is higher in the soft credit economies relative to the hard credit economy. A higher wage also reduces firm profits all else equal, partly depressing investment in R&D and physical capital. While this effect does not dominate the incentive to invest more in physical capital due to lower spreads in soft-credit economies, it does impact the liquidation and distress thresholds as shown in Appendix Figure 13. Relative to the hard-credit economy, the distress threshold in soft-credit economies is slightly higher for the idiosyncratic shock ϵ due to the wage effect that depresses firm profits.

Cyclicality of Innovation. The last line of Table 4 reports the measured correlation between the cyclical components of R&D expenditures and GDP growth, computed using a HP-filter. Notably, this correlation is significantly lower in the HC economy relative to the SC regimes. This is partly explained by the cleansing effects of recessions: since exit is countercyclical, so is ε^*. Thus, innovation becomes cheaper during recessions, and this effect is quantitatively more significant in the HC economy. This observation will be important for the welfare decompositions we conduct in section 5.

4.2 Responses to Aggregate Shocks

Having described the average behavior of each economy, we now examine how differences in credit regimes influence the economy's response to the aggregate shock: a disturbance to the capital quality level ζ. We first present and analyze the impulse response function to a capital-quality shock, and then discuss differences in the behavior of simulated economies.

4.2.1 IRF to a Capital Quality Shock

Since the model is nonlinear, with state-dependent responses to shocks, and because the various economies differ in their balanced growth paths, we compute generalized impulse response functions starting from the stochastic steady state of each respective economy. To this end, we simulate the various economies many times, and for each of the paths we compute a counterfactual where the capital quality level is perturbed with a given shock. Impulse responses are the average difference between the actual paths and the counterfactual paths across simulations.

Figure 5 plots the response of selected endogenous variables to a 10% shock to capital quality across the different economies. Since the economies have different balanced growth paths, we initialize them with $z_0 = 1$, and plot the simulated paths of the economy forward in levels, as opposed to reporting differences from the balanced growth paths. The first panel shows the response of the shock ζ. Panel (b) plots the path of measured TFP, defined as $Y/(K^\alpha N^\eta)$, and therefore comprising not only fundamental productivity z but also the effects of selection via ε^*. On impact, there is only a small effect on TFP. However, while TFP for the HC economy continues to grow at a similar rate, the SC economies experience a more pronounced slowdown. Panels (c) and (d) plot the paths of GDP and labor. At the time the shock realizes, both fall more in the HC economy compared with the SC economies. This difference is particularly pronounced for the evergreening economy, where labor does not even fall. However, over time, the HC economy catches up and its level of output surpasses that of the other economies as it grows faster. These panels showcase the stabilization/growth trade-off that arises across the different credit regimes, with the HC experiencing deeper recessions but better growth performance afterwards. Panels (e) and (f) shed light on why output and labor drop by less: while the exit rate rises on impact in all economies, it increases by less in the SC economies, as the share of firms that are saved by their lenders increases. These firms still produce and hire labor, unlike those that exit, which is reflected in the aggregate statistics of those variables. Thus, our model illustrates how different lending regimes can amplify or buffer the effects of business cycle shocks.

4.2.2 Simulation analysis

To complement the IRF analysis, it is also instructive to study a particular simulation path in which all economies experience the same sequence of aggregate shocks and start from the same level of capital and the same $z_0 = 1$.[23] The top panel of Figure 6 shows the GDP index for each economy (normalized so that it is equal to 100 in the first date), to illustrate differences in GDP dynamics. The bottom panel shows the HP-filter detrended GDP data that we use to compare business cycles across the different economies. The top panel shows that the HC economy grows faster, while the bottom panel shows that its business cycles are more volatile, with this economy experiencing stronger expansions but also deeper recessions relative to the SC economies. Both of these observations are consistent with the patterns inferred from the IRF in Figure 5.

We then study what an average recession looks like across the simulated paths. Specifically, we select recession episodes in which a one-period negative shock is large enough to generate a decline in GDP. Figure 7 plots the average shock as well as selected endogenous variables during these episodes. On impact (period 1), (detrended) GDP is lower in the HC economy relative to the SC economies as seen in panel (b). However, and consistent with the IRF evidence, the HC economy eventually catches up and surpasses the SC economies. Again, this figure prominently displays the stabilization vs. growth trade-off between hard and soft credit economies. Panels (c) and (d) again rationalize the differences in the behavior of output and employment at impact, as SC economies experience significant increases in the share of firms that receive some form of subsidy and would

[23] We set the starting point to be the stochastic steady state level of capital for the HC economy, as we later use the HC economy as the benchmark and starting point for welfare comparisons.

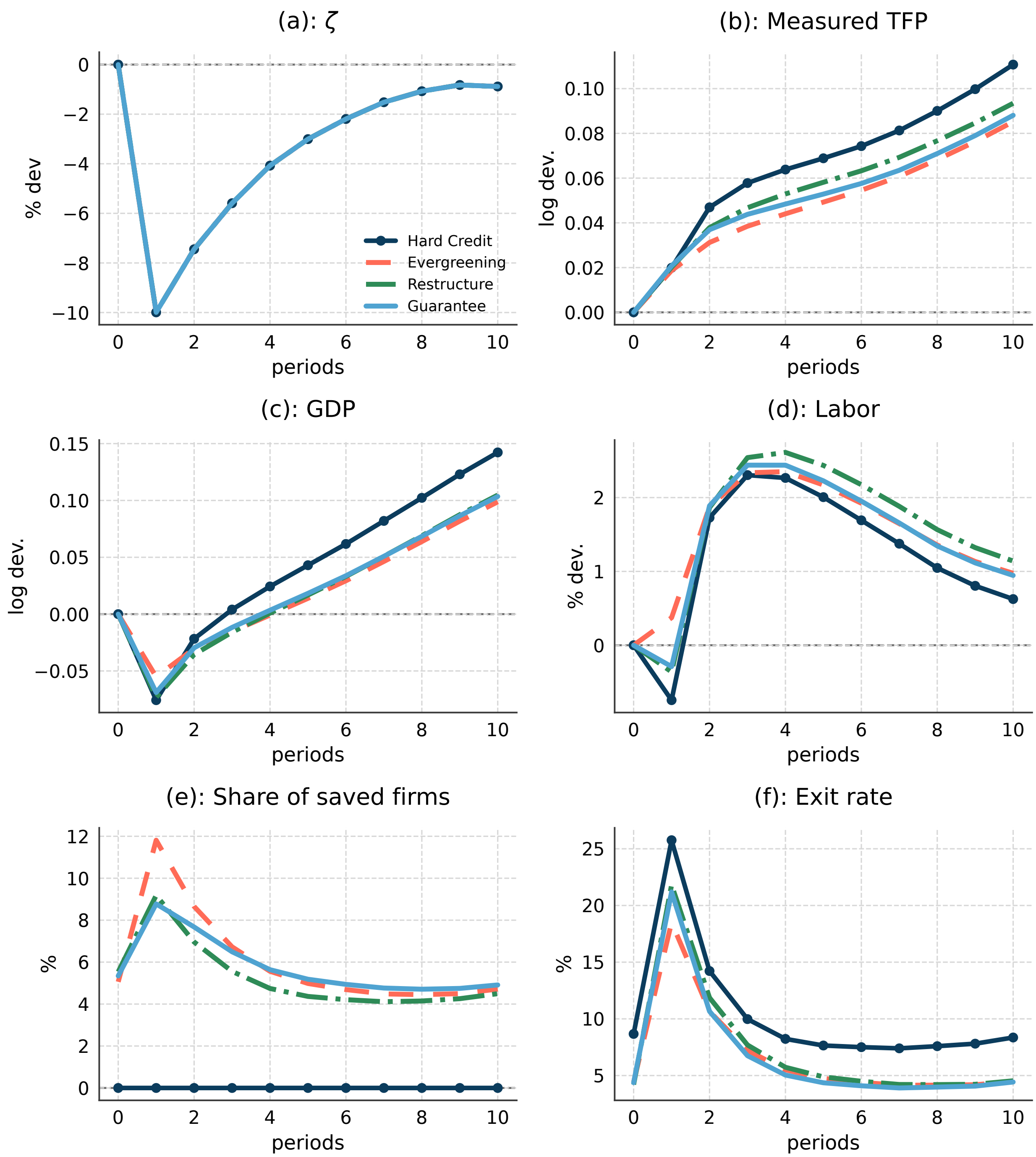

Figure 5: Generalized impulse response functions with respect to a 10% shock to capital quality for hard credit, evergreening, restructuring, and guarantee economies.

otherwise have had to exit.

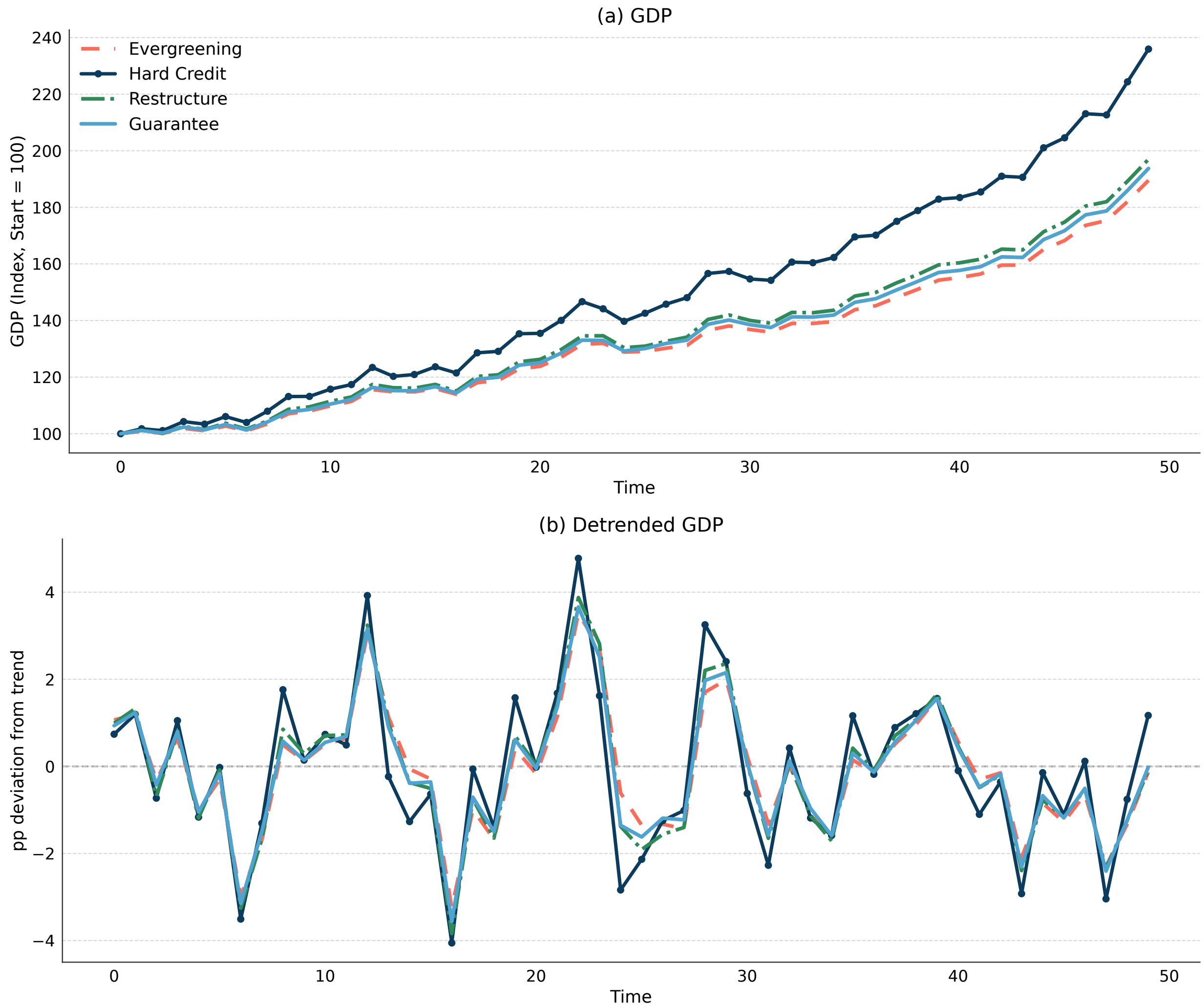

Figure 6: Illustration of GDP data simulation for hard credit, evergreening, restructuring, and guarantee economies. All economies start from the same point and experience the same sequence of shocks.

5 Welfare analysis

The key takeaway from the quantitative analysis is that the HC economy grows faster than the SC economies, but is also more volatile. In particular, recessions in the HC economy tend to be more severe for a shock of the same size, as clearly illustrated in Figures 5 and 7. In this section, we analyze the welfare implications of this growth vs. stabilization trade-off and present a decomposition of welfare differences across economies.

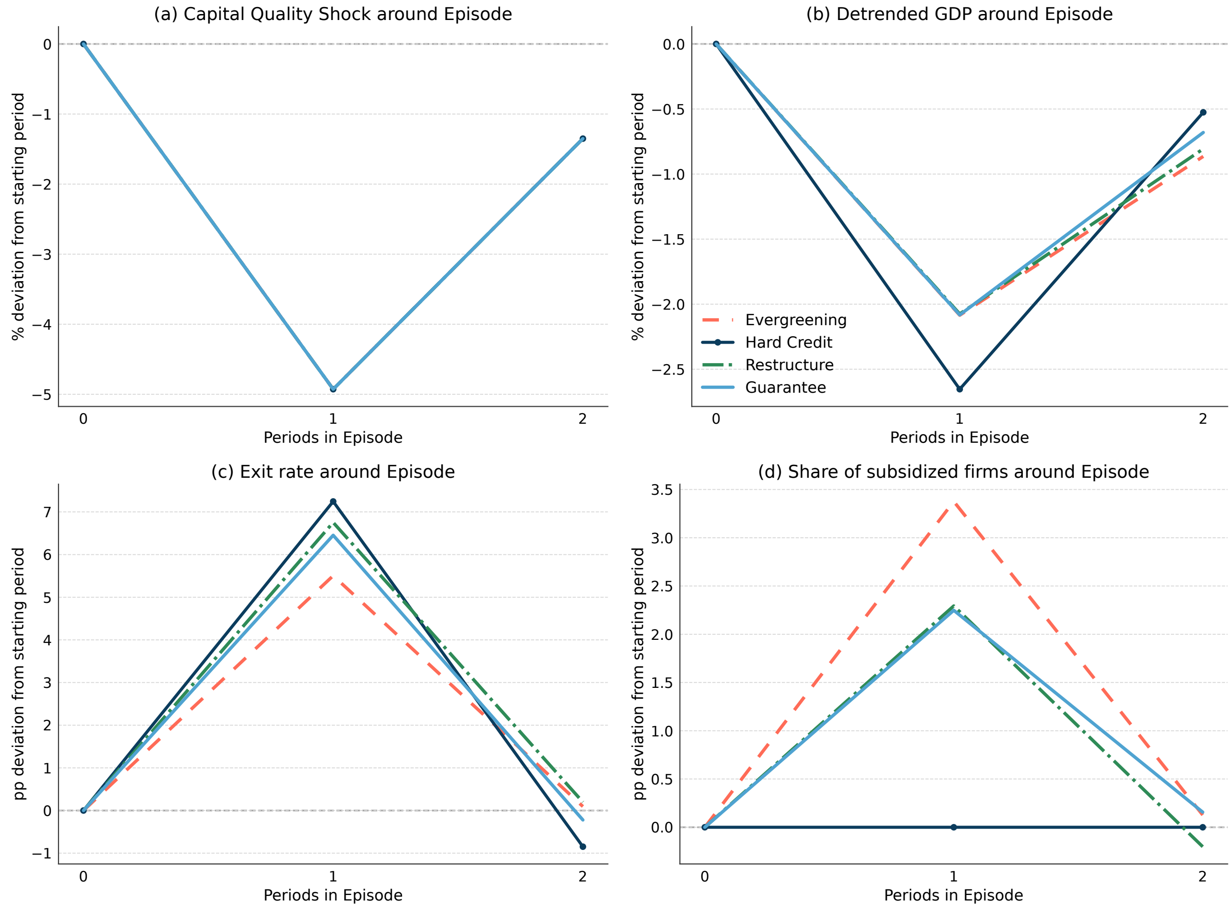

Figure 7: Recession analysis for hard credit, evergreening, restructuring, and guarantee economies. Note: We define a recession episode as a one-period decline in ζ, followed immediately by a one-period recovery, and retain only those episodes in which GDP declines for one period at the onset of the shock in all four economies.

5.1 Measuring welfare

Our main measure of welfare is the expected discounted sum of utility flows for the household in 13. Our welfare comparisons rely on a series of assumptions. First, we assume throughout that all economies start out with identical levels of fundamental TFP, which we normalize to $z_0 = 1$. This is a common assumption for welfare comparisons in endogenous growth models (e.g., Acemoglu et al., 2018). Second, to account for the impact of transitional dynamics, we assume that all economies start from the same set of states. Since most comparisons will be conducted using the HC economy as the benchmark/starting point, we assume that all economies begin at the mean shock value, $\zeta = 1$, and at the mean capital level in the HC economy's stochastic steady state.[24]

A recursive representation for detrended welfare is given by:

$$\tilde{\mathcal{U}} = u(\tilde{C}, N) + \beta G_z^{(1-\sigma)\frac{1-\eta}{1-\alpha}} \mathbb{E}[\tilde{\mathcal{U}}']$$

This is valid for $\sigma \neq 1$.[25]

5.2 A second-order approximation to welfare

While our global solution of the model allows us to compute welfare exactly using a recursive representation of detrended welfare, we focus on a second-order approximation of welfare as it allows for a simple and additive decomposition for the contributions of different factors.

As previously explained, we use the HC economy as the starting point for all welfare comparisons, and all economies start with the same set of states $(k_0, z_0, \zeta_0) = (\tilde{k}_*^{HC}, 1, 1)$. We can write ex-ante welfare for the benchmark and comparison economies $k \in \{HC, SC\}$ as

$$\mathcal{U}^k \equiv \mathbb{E}\left[\sum_{t=0}^{\infty} \beta^t u(X_t^k)\right]. \tag{21}$$

where X denotes the composite good in the KPR preferences:

$$X(C, N) = C\left(1 + (\sigma - 1)\frac{N^{1+\varphi}}{1+\varphi}\right)^{\frac{\sigma}{1-\sigma}},$$

This definition implies that the KPR utility function can be written a simple CRRA utility over this composite good, $u(X) = \frac{X^{1-\sigma}}{1-\sigma}$. As with other variables, the level of composite consumption $X_t = x_t z_t^{\frac{1-\eta}{1-\alpha}}$ is equal to the product of x_t, the stationary component of the composite good, and the stochastic trend $z_t^{\frac{1-\eta}{1-\alpha}}$. From our assumption that $z_0 = 1$, we can write the level of the stochastic trend as the product of all past growth rates:

$$z_t = \prod_{s=0}^{t-1} G_{z,s}.$$

[24] Welfare comparisons are robust to the choice of initial steady state. We compute consumption-equivalent welfare starting from both the hard-credit and soft-credit steady states. While transition dynamics differ—reflecting differences in initial capital and R&D investment—the resulting welfare decomposition is nearly identical.

[25] For $\sigma = 1$, we can write a recursive representation of welfare as $\tilde{\mathcal{U}} = \log(\tilde{C}) - \chi\frac{N^{1+\varphi}}{1+\varphi} + \frac{1-\eta}{1-\alpha}\frac{\beta}{1-\beta}\log G_z + \beta\mathbb{E}[\tilde{\mathcal{U}}']$.

For each economy k and period t, we employ a second-order Taylor expansion of $u(X_t^k)$ around $\mathbb{E}(X_t^k)$:

$$u(X_t^k) \approx u(\mathbb{E}[X_t^k]) + u'(\mathbb{E}[X_t^k])(X_t^k - \mathbb{E}[X_t^k]) + \frac{1}{2}u''(\mathbb{E}[X_t^k])(X_t^k - \mathbb{E}[X_t^k])^2.$$

Taking expectations allows us to write the expected utility flow in t as the sum of two terms, one that reflects the contribution of the mean of composite consumption to utility, and another that reflects the contribution of its variance:

$$\mathbb{E}[u(X_t^k)] \approx \underbrace{u(\mathbb{E}[X_t^k)}_{\text{mean}} + \underbrace{\frac{1}{2}u''(\mathbb{E}[X_t^k])\,\text{Var}(X_t^k)}_{\text{volatility}},$$

Since this decomposition is linear, we can approximate (21) as

$$\mathcal{U}^k \simeq \mathcal{U}^k_{\text{mean}} + \mathcal{U}^k_{\text{vol}}$$

Furthermore, note that the composite good X_t is the product of a stationary component x_t and a stochastic growth component. This means that its variance reflects both cyclical fluctuations in x_t as well as fluctuations in the stochastic trend $z_t^{\frac{1-\eta}{1-\alpha}}$. To quantify these contributions, we further write $\text{Var}(X_t^k)$ as the variance of a first-order approximation of X_t around $\mathbb{E}[x_t]$ and $\mathbb{E}[z_t^{\frac{1-\eta}{1-\alpha}}]$. This allows us to decompose the variance as:

$$\text{Var}(X_t) \approx \mathbb{E}[z_t^{\frac{1-\eta}{1-\alpha}}]^2\,\text{Var}(x_t) + \mathbb{E}[x_t]^2\,\text{Var}(z_t^{\frac{1-\eta}{1-\alpha}}) + 2\mathbb{E}[x_t]\mathbb{E}[z_t^{\frac{1-\eta}{1-\alpha}}]\,\text{Cov}(x_t, z_t^{\frac{1-\eta}{1-\alpha}}).$$

Since this decomposition is linear, we can further decompose the volatility component of ex-ante welfare into three components: a cyclical volatility component, a growth volatility component, and the covariance between the two.

$$\mathcal{U}^k_{\text{vol}} = \mathcal{U}^k_{\text{vol,x}} + \mathcal{U}^k_{\text{vol,z}} + \mathcal{U}^k_{\text{vol,cov}}$$

In the spirit of Lucas (2003), we report welfare differences in terms of consumption-equivalent variation (CEV) units. As previously mentioned, we treat the HC economy as the benchmark, so the CEV numbers should be interpreted as the permanent proportional change in consumption in the HC economy that makes households indifferent between remaining in the HC and transitioning to the SC economy. Given our parametrization of the coefficient of relative risk-aversion $\sigma = 2$, this CEV can be computed as:

$$\lambda = 100 \times \left(\frac{\mathcal{U}^{HC}}{\mathcal{U}^{SC}} - 1 \right)$$

Negative values indicate that the comparison economy delivers lower welfare than the HC economy.

5.3 Welfare results

Table 5 reports the results. The first line is the total CEV of transitioning from HC to each SC economy. These numbers are negative, meaning that the HC economy delivers higher welfare than any of the SC regimes. To understand why, the following lines perform the approximated decomposition. The bulk of welfare gains (76%) come from the mean component, primarily reflecting the higher growth rates in the HC economy, which tend to dominate welfare calculations. Interestingly, in light of our previous discussion, the volatility component is also negative, meaning that households prefer the overall volatility in the HC economy. This seemingly counterintuitive result is explained by further decomposing the volatility component: while SC economies deliver welfare gains due to lower cyclical volatility of x, they actually experience higher volatility of the stochastic growth trend, and the latter effect ends up dominating.

Table 5: Consumption-equivalent variation measures of moving from the HC economy.

	Evergreening	Restructuring	Guarantee
CEV, total	-3.13	-2.47	-2.32
CEV, mean	-2.39	-1.83	-1.64
CEV, volatility	-0.78	-0.66	-0.71
CEV, volatility from x	0.20	0.09	0.20
CEV, volatility from z	-0.43	-0.21	-0.43
CEV, volatility from $\text{Cov}(x, z)$	-0.19	-0.17	-0.13
CEV, exact	-3.09	-2.42	-2.30

Notes: CEV volatility components may not sum to the total volatility term due to approximation error and rounding. See text for details.

The stochastic growth trend is effectively less volatile in the HC economy. This observation was foreshadowed in the discussion of Table 4, as R&D expenditures are considerably less cyclical in the HC economy. How is this consistent with a lower volatility of GDP growth in the SC economies? Note that GDP growth can be written as the product of detrended GDP and the growth rate of Z:

$$\text{GDP growth}_t = \frac{\tilde{Y}_t}{\tilde{Y}_{t-1}} \times G_{z,t-1}^{\frac{1-\eta}{1-\alpha}} - 1$$

while G_z is more volatile in the SC economies, the cyclical growth component $\frac{\tilde{Y}_t}{\tilde{Y}_{t-1}}$ is much less so, which results in lower volatility of GDP growth in spite of a more volatile stochastic trend.

All things considered, while the growth component remains dominant, our model delivers nontrivial welfare gains from business cycle stabilization. Additionally, we identify risks to the economy's trend itself as having a significant impact on welfare.

Quality of the approximation. The last line of Table 5 displays the CEV computed using a value function that is computed using the globally solved policies, and evaluated at the initial transition states. The differences between these values and those in the first line, from the second-order approximation, are very small, suggesting that the approximation is valid in the context of our model.

Differences across SC economies. Welfare losses are larger in the evergreening versus restructuring and guarantee economies. This reflects the fact that the evergreening economy features more static misallocation of inputs than the other SC economies. Under restructuring and guarantees, firms' labor choices are not distorted, and each firm hires labor proportional to its idiosyncratic productivity, just as in the HC economy. Welfare losses in these economies arise primarily from dynamic effects: since exit is lower, ε^* is lower, and so is GDP growth. In contrast, the evergreening economy features distorted labor choices for firms that receive subsidized credit: they borrow at lower rates and thus face lower effective labor costs. This weakens the positive correlation between idiosyncratic productivity and the quantity of labor hired, as less productive firms hire relatively more labor, which contributes to making this economy more inefficient compared to the other SC regimes.

Mean component: levels vs. growth. Figure 8 plots the mean paths of $x_t, G_{z,t}, X_t$ along with one standard deviation bands for the HC and Evergreening economies. A few things in these figures are worth noting. First, panel (a) shows that the evergreening economy features a higher mean level for the stationary component x_t. This reflects lower exit, which is wasteful in our model, as it results in idle capital not employed in production and that effectively depreciates at a higher rate (λ rather than δ). Second, panel (b) shows that while the growth rate G_z is lower in the evergreening economy, it quickly accelerates during the first periods of the transition. Note that the paths of x and G_z in the evergreening economy exhibit a transition in the first 10 periods, since we start all economies in the same state. Combining panels (a) and (b) results in panel (c), which shows that the utility-relevant composite X is initially higher in the evergreening economy due to the higher stationary component x, but eventually the higher growth rate in the HC economy allows it to overtake in terms of X after around 15 years.

This discussion has two important implications. First, the mean component of our welfare decomposition nets two forces that offset each other: a higher detrended level in the SC economy, and a higher average growth rate in the HC economy. To the extent that the higher x reflects lower exit, it is related to stabilization. Thus the mean component does subsume some of the benefits of stabilization (or costs of lack of thereof). Second, this highlights the importance of time discounting in welfare comparisons between these two economies: for a fixed set of policy functions, sufficiently impatient households could prefer the evergreening economy for its front-loaded benefits in terms of X.[26]

6 The Role of Learning Externalities

The quantitative and welfare analyses reveal that the innovation externality via the R&D cost function (2) is an important mechanism in the model, shaping productivity differences and serving as a medium for the cleansing effect of recessions. The strength of this mechanism is determined by the parameter ρ. In this section, we study the effects of changing this parameter. First, we conduct pure comparative statics, where we study how changing this parameter in isolation affects key moments of the economy. We then analyze the impact of recalibrating the entire model for a different level of ρ.

6.1 Comparative statics

Our benchmark calibration uses $\rho = 0.3$, the value directly estimated in section 3.1. Figure 9 reports how selected moments of the different economies change for $\rho \in [0, 0.4]$. Panel (a) reports the CEV of moving from HC to each of the different economies, showing that this parameter is crucial to rank the different economies in terms of welfare: higher values of ρ amplify these differences, but lower levels of ρ can invert this ordering: the SC

[26]Appendix assesses the robustness of the results to changes in the discount factor β and the coefficient of relative risk aversion σ. An increase in patience magnifies the welfare differences between the economies, while an increase in risk aversion compresses them.

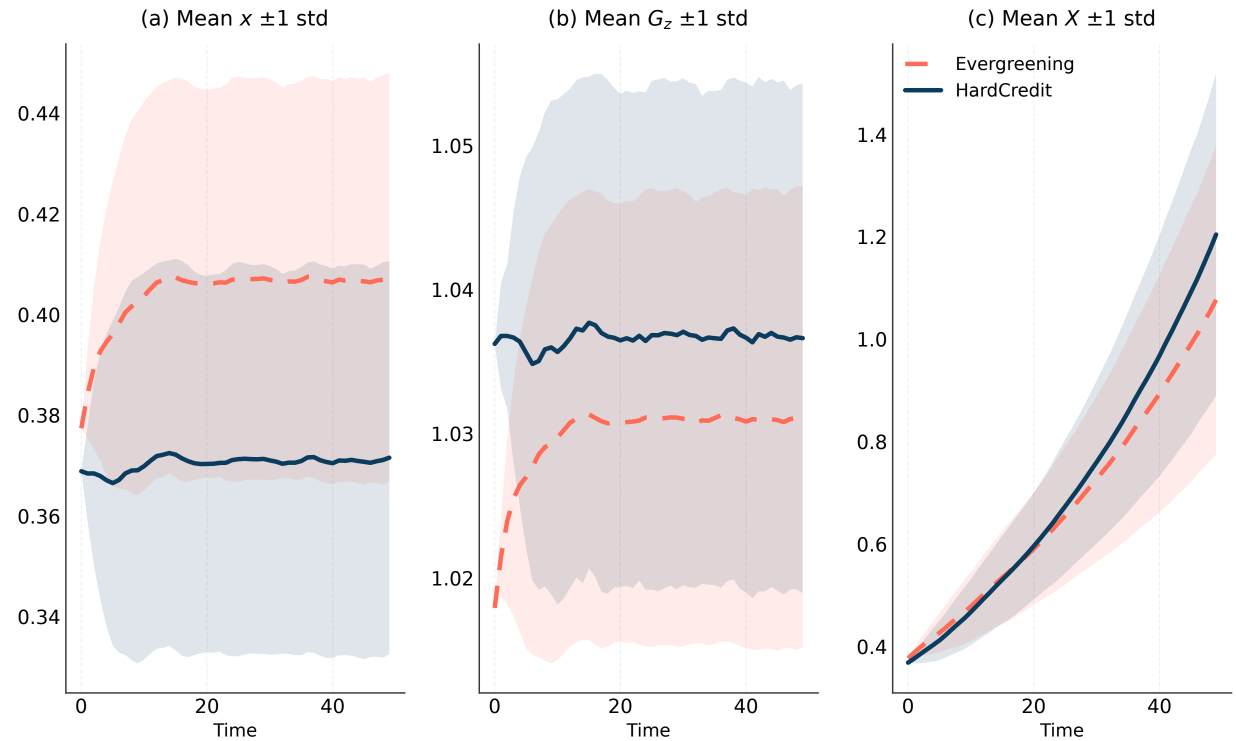

Figure 8: Simulations of composite consumption across HC and Evergreening economies, see text for details.

economies dominate the HC regime for levels of ρ roughly below 0.20. The following three panels help explain these changes in welfare rankings. Panel (b) plots GDP growth, which is decreasing in the value of this parameter. This is explained by a direct effect, which can be understood by analyzing equation (15): a lower ρ means that firms internalize a greater impact of their own innovation decisions in terms of reducing the cost of innovation tomorrow. Therefore, a lower ρ directly increases private incentives to innovate, which results in higher GDP growth. A lower value of ρ also means that the learning externality is less important, and thus ε^* matters less for the growth rate. To the extent that this is one of the channels through which aggregate conditions affect incentives to innovate, a lower ρ thus translates into less cyclical innovation and thus reduces the volatility of GDP growth. Finally, a lower ρ is associated with more firm exit, as firms tilt their investment away from physical capital and towards R&D. Since they operate at a smaller scale, they are more likely to exit due to the presence of fixed operating costs and fixed debt repayments. The fact that exit increases relatively less in the SC economies, while growth and its standard deviation increase and decrease at similar rates, contributes to flipping the welfare ordering.

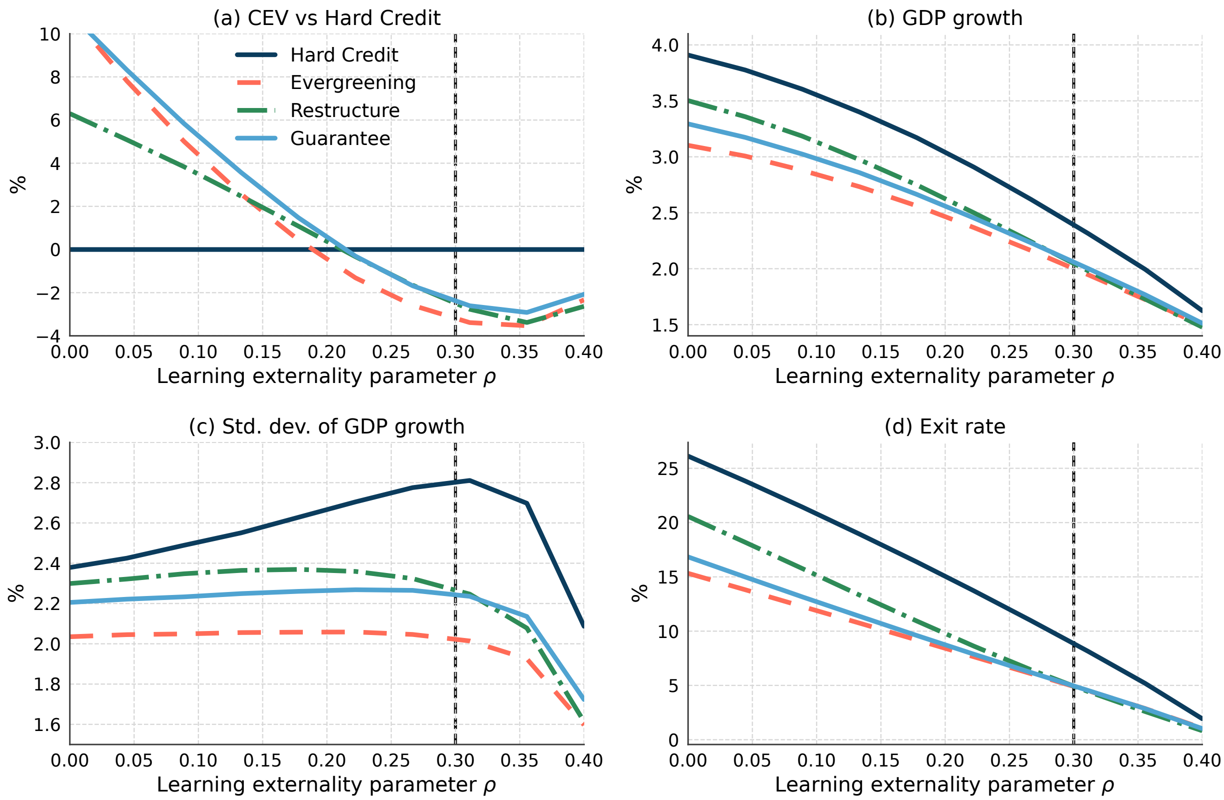

Figure 9: Comparative statics with respect to ρ.

6.2 Recalibrating the model

To further understand the changes in the welfare orderings, we also recalibrate the model for a value of ρ that is half of the baseline, $\rho = 0.15$. Table 6 summarizes aggregate moments and welfare statistics across the different credit regimes. Qualitatively, the moment rankings are similar, but noticeably, the growth differences between HC and SC are smaller, and the volatility differences are larger relative to the baseline. Additionally, the HC economy features more exit (9.5% vs. 8.9%), which reduces detrended levels and therefore pushes welfare differences in the opposite direction.

The bottom panel shows that the reverse welfare rankings survive the model recalibration, as positive CEV now mean that the HC economy delivers lower welfare. Comparison with Table 5 shows that SC economies now deliver higher mean welfare, reflecting the smaller differences in growth rates but larger differences in levels due to differences in exit rates. While the HC economy still delivers higher welfare from the volatility component, the CEV is smaller. Benefits from business cycle stabilization are similar to the benchmark case, but the benefits from lower volatility in the stochastic trend are now smaller. This is partly explained by R&D being more cyclical in the HC economy than

Table 6: Model moments and welfare across credit regimes, $\rho = 0.15$

	Hard Credit	Evergreening	Restructuring	Guarantee
Share of subsidized firms (%)	0.00	4.99	4.86	5.05
Exit rate (%)	9.49	4.96	5.09	4.96
ε^*	1.06	1.03	1.03	1.03
GDP growth	2.34	2.01	2.05	2.05
$\sigma(g_Y)$	2.97	2.03	2.29	2.24
$\sigma(g_C)$	2.81	2.51	2.68	2.58
Real interest rate, $1/Q^d - 1$	6.48	5.96	5.98	5.99
Lending spread, $(1/q - 1/Q^d)$	3.77	2.02	2.10	1.98
Detrended wage, $\tilde{w}$	0.68	0.73	0.73	0.73
K/Y	1.19	1.38	1.38	1.38
Intraperiod rate, i	2.00	1.68	2.00	2.00
Avg. debt restructured, ξ (%)	0.00	0.00	0.10	0.00
Guarantees over GDP (%)	0.00	0.00	0.00	0.18
$corr(R\&D, Y)$	0.74	0.91	0.85	0.92
CEV, total		2.24	2.53	2.81
CEV, mean		2.62	2.99	3.16
CEV, volatility		-0.36	-0.43	-0.32
CEV, volatility from x		0.22	0.09	0.23
CEV, volatility from z		-0.15	-0.03	-0.17
CEV, volatility from $\text{Cov}(x, z)$		-0.09	-0.12	-0.04
CEV, exact		2.26	2.57	2.83

Notes: CEV volatility components may not sum to the total volatility term due to approximation error and rounding.

in the benchmark, resulting in a slightly more volatile growth trend. Figure 10 replicates figure 8 for the case with $\rho = 0.15$, with panel (c) graphically illustrating the point about growth vs. levels: it takes now roughly twice as long for the HC economy to overtake the evergreening economy in terms of composite consumption levels. This is explained both by a larger difference in detrended levels (panel (a)) as well as a smaller difference in growth rates (panel (b)).

7 Optimal policy

Previous sections showed that the model calibrated to the data is such that a HC regime delivers higher welfare than any of the SC regimes. We now ask: what if the parameter

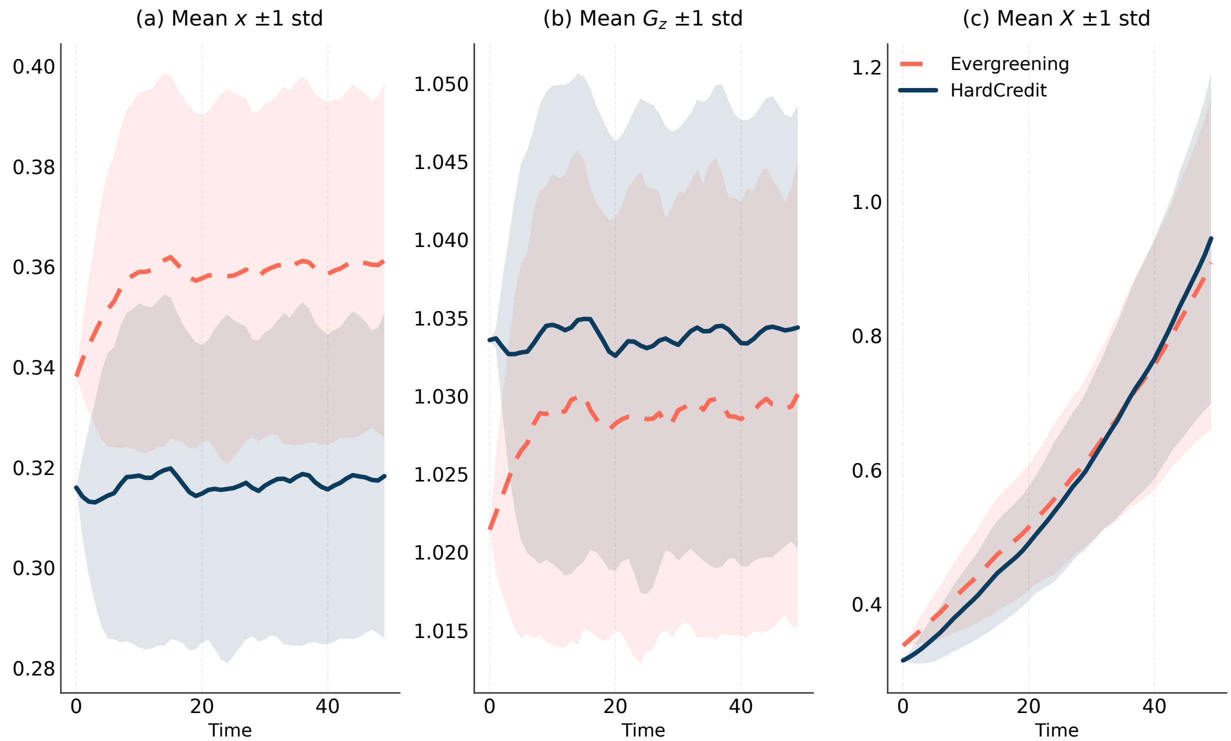

Figure 10: Simulations of composite consumption across HC and Evergreening economies for $\rho = 0.15$, see text for details.

that controls the extent of SC could be chosen by a benevolent government? We consider two possible implementations: one in which the government chooses a fixed degree of SC ex-ante, and another in which the government chooses it period-by-period under discretion. As we show below, each of these implementations delivers widely different policy prescriptions.

7.1 Optimal constant-policy with commitment

We first study an optimal policy with commitment that is constrained to be constant over time. In this problem, a perfectly benevolent government chooses at date 0 a single value of the policy instrument—either i^{reg}, ξ^{reg}, or τ^{reg}—that must remain fixed for all future periods. Following Sargent (2019), this can be interpreted as a "constant Ramsey" policy: the Ramsey planner maximizes welfare subject to the restriction that the policy instrument cannot vary with the state of the economy.

Figure 11 plots the results for this experiment. Since there is a monotonic relationship between each regulatory parameter and the share of subsidized firms, we plot different moments across credit regimes as a function of this share to make the analysis more comparable. The vertical dashed lines mark our calibration benchmark for this share as 5% in the SC economies. As i^{reg} becomes more negative or ξ^{reg} and τ^{reg} rise, the share of subsidized firms increases. In contrast, as these exogenous limits approach their values in the hard credit economy, the share of subsidized firms converges towards zero.

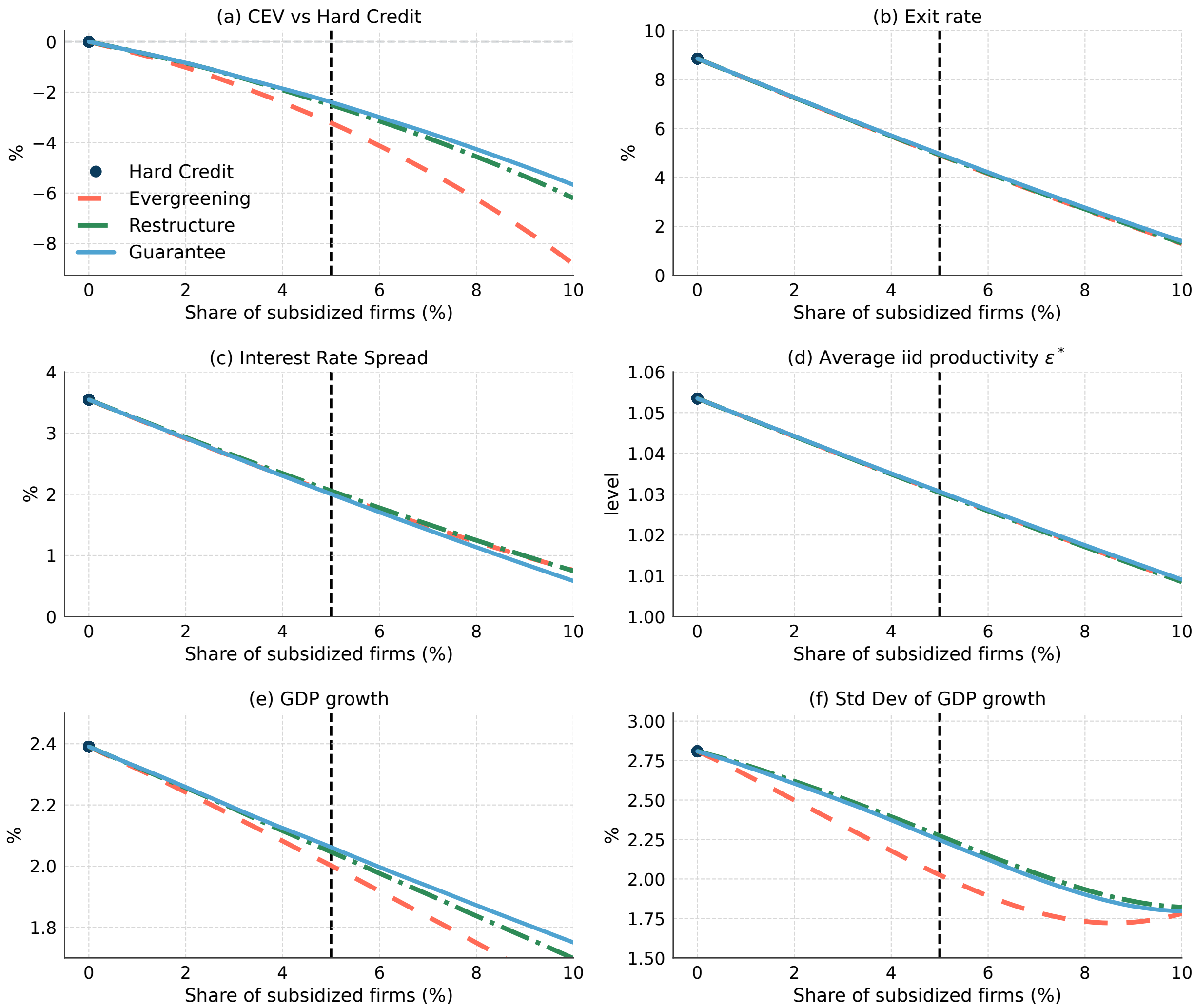

Figure 11: Key variables for alternative values of constant policies on i^{reg}, ξ^{reg}, and τ^{reg}.

Starting with the CEV welfare measure in panel (a), it is clear that the optimal constant policy is to set the share of subsidized firms to zero and replicate the HC economy. This is achieved by setting $i^{reg} = \omega$ or $\xi^{reg} = \tau^{reg} = 0$. Any other choice of value for each of these parameters entails welfare losses relative to the HC benchmark.

The remaining panels help explain the results. Panel (b) shows that the exit rate is monotonically and almost linearly decreasing on the share of subsidized firms. This is reflected in lower credit spreads in panel (c), but also in worse selection. Panel (d) plots the average idiosyncratic productivity ε^* of incumbents. As more distressed firms are saved,

ε^* falls, which raises the costs of innovation. This culminates with lower GDP growth, which is monotonically decreasing as shown in panel (e). Finally, panel (f) shows that the standard deviation of GDP growth also declines as ex-post interventions help stabilize economies. However, this reduction in volatility is insufficient to offset the decline in growth, thus explaining the welfare patterns.

7.2 Optimal policy without commitment

A natural question raised by our analysis is why SC policies are so prevalent in practice. As shown above, in the benchmark environment with commitment, a regime of HC—in which financially distressed firms are not supported through evergreening, restructuring, or transfers—delivers higher growth and welfare. If such a regime is socially preferable, why do policymakers frequently implement policies that relax credit discipline? To address this question, we study a policy problem without commitment. Specifically, a benevolent policymaker chooses the degree of intervention each period as a function of the current aggregate state, taking as given the continuation policy that will be chosen in future states. Specifically, letting $\varpi^{reg} \in \{i^{reg}, \xi^{reg}, \tau^{reg}\}$, we assume that the policymaker solves the following problem:

$$\begin{aligned} \tilde{\mathcal{U}}(\tilde{k}, \zeta) = & \max_{\varpi^{reg}} u(\tilde{C}, N) + \beta G_z^{(1-\sigma)\frac{1-\eta}{1-\alpha}} \mathbb{E}[\tilde{\mathcal{U}}(\tilde{k}', \zeta')] \\ & \text{s.t.} \quad (\tilde{C}, N, \tilde{k}', G_z) \in \mathcal{Y}(\tilde{k}, \zeta; \varpi^{reg}) \end{aligned}$$

where $\tilde{\mathcal{U}}$ is a recursive representation of the household's value function described in Section 5, and the constraint imposes that the tuple $(\tilde{C}, N, \tilde{k}', G_z)$ must be part of an equilibrium as defined in section 2.7, given states $\tilde{k}, \zeta$ and the chosen policy ϖ^{reg}.[27]

The equilibrium policy is characterized by a Markov-perfect equilibrium. In this environment, the policymaker internalizes the short-run benefits of supporting distressed firms but cannot commit to maintaining strict credit discipline in the future. As a result, policies that effectively generate soft credit may arise as the time-consistent outcome, even though the economy would be strictly better under a HC regime sustained by commitment. While the government is perfectly benevolent and maximizes household welfare, it cannot commit to future policies.

Table 7 reports the simulated aggregate moments under the optimal policy without commitment. In all three environments, the Markov-perfect policy implements substantial credit support to distressed firms, as reflected in the positive share of subsidized firms

[27]See Appendix A.4 for the full list of equilibrium conditions.

(between 7.2% and 7.5%) and the relatively low exit rates (2.9 to 3.2%). These policies effectively generate a SC regime. The resulting allocations display moderate growth rates and financial conditions consistent with sustained credit support, including relatively low spreads and default probabilities.

Table 7: Simulated aggregate moments: optimal policy without commitment.

	Hard Credit	i^{reg}	ξ^{reg}	τ^{reg}
Share of subsidized firms (%)	0.00	7.21	7.37	7.47
Exit rate (%)	8.86	3.22	2.98	2.94
ε^*	1.05	1.02	1.02	1.02
GDP growth	2.39	1.82	1.85	1.88
$\sigma(g_Y)$	2.81	2.03	2.01	1.99
$\sigma(g_C)$	2.70	2.49	2.52	2.54
Real interest rate, $1/Q^d - 1$	6.59	5.56	5.81	5.89
Lending spread, $(1/q - 1/Q^d)$	3.55	1.50	1.15	0.94
Detrended wage, $\tilde{w}$	0.73	0.80	0.80	0.80
K/Y	1.41	1.73	1.75	1.76
Avg. intraperiod rate, i (%)	2.00	1.34	2.00	2.00
Avg. debt restructured, ξ (%)	0.00	0.00	0.10	0.00
Guarantees over GDP (%)	0.00	0.00	0.00	0.18
$corr(R\&D, Y)$	0.69	0.77	0.76	0.75
CEV, total		-5.22	-4.59	-4.22

Importantly, despite being the time-consistent outcome of the policymaker's problem, these allocations remain welfare dominated by the HC regime. In fact, the optimal policy under discretion yields welfare lower than that of the equivalent SC economies. The last row of the table reports the CEV of moving from the HC economy to any of the discretionary policy SC economies. The welfare losses range between -4.2 and -5.2% of permanent consumption, larger than those in the baseline SC economies. This exercise shows that although SC emerges endogenously when policymakers are unable to commit, society would be strictly better off under a regime that enforces hard-credit discipline.[28]

[28] This result relates to the findings in Acharya, Lenzu and Wang (2021), who show that benevolent policymakers may find themselves "trapped" in low productivity equilibria due to excessive forbearance policies.

8 Conclusion

Policy interventions and lending arrangements that create "soft credit"—ex-post measures that keep distressed firms alive—are pervasive in advanced economies. In this paper, we develop a dynamic stochastic general equilibrium model with endogenous growth and business cycles to study the trade-offs embedded in such regimes. We consider three forms of soft credit: evergreening, restructuring, and credit guarantees. Motivated by evidence that evergreening is a feature of the U.S. financial system (Faria-e-Castro, Paul and Sánchez, 2024), we calibrate the model to the U.S. economy and use it to analyze counterfactual credit regimes. We also discipline two of the model's key parameters using firm-level microdata: the convexity of innovation costs and the strength of learning externalities.

A central benchmark is the hard credit economy, in which such ex-post interventions are absent. We find that hard credit delivers faster growth, but at the cost of greater growth volatility. This trade-off reflects the interaction of learning externalities, congestion in input markets, and financial frictions. Without ex-post support, more firms exit, improving selection and lowering future innovation costs through learning externalities, but also making the economy less stable. Our results echo the findings of Bergoeing et al. (2002), who analyze the growth performance of Chile vs. Mexico in the 1980s and write that "[...] Chile was willing to pay the costs of reforming its banking system and of letting inefficient firms go bankrupt; Mexico was not."

The hard credit economy also delivers the highest welfare, primarily because higher long-run growth dominates the welfare calculus. That ordering is not fully robust, however. When economies start from the same level of productivity, soft credit regimes can increase short-run consumption by stabilizing activity and reducing firm exits. For sufficiently impatient agents or for front-loaded welfare comparisons, these near-term-level effects may offset the long-run growth advantage of hard credit.

We then ask why soft credit interventions arise in practice if they are welfare-reducing. To address this question, we study optimal policy from the perspective of a benevolent but constrained government. A policymaker who can commit ex ante to a constant policy chooses not to intervene. By contrast, a policymaker operating under discretion chooses even softer credit than in our benchmark calibration, thereby further reducing welfare relative to the hard-credit economy. In the absence of commitment, future policies are re-optimized, so the policymaker behaves as if placing greater weight on current outcomes, leading to excessive support for distressed firms.

Our framework is tractable enough to be embedded in larger-scale DSGE models and flexible enough to address a broader set of questions about how financial regimes shape long-run growth and business-cycle stabilization. In particular, extensions of the model could be used to study the interaction of monetary policy, bank regulation, economic dynamism, and long-run growth. We leave these questions for future work.

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A Model Appendix

A.1 Proofs

A.1.1 Proposition 1

To solve the lender's problem under evergreening, it is helpful to define the objects $i^{\min}$ and $i^{\max}$. The interest rate $i^{\min}$ is the minimum rate at which the lender is willing to lend, rather than liquidate the firm. The rate $i^{\max}$ is the maximum interest rate at which the firm is willing to borrow, rather than default.

Equivalently, $i^{\min}(s,\varepsilon)$ is defined by the lender's indifference condition between liquidation and lending, for given (s,ε):

$$b - (1-\lambda)\zeta k + (i^{\min} - \omega)\, w\, n(z,k,\varepsilon,i^{\min}) = 0.$$

Importantly, $i^{\min} < \omega$ whenever $b > (1-\lambda)\zeta k$. In words, if the recovery value of collateral is below the legacy debt b, a lender has an incentive to offer a subsidized intraperiod loan to prevent default and recover the full amount b.

The rate $i^{\max}(s,\varepsilon)$, on the other hand, is defined as the rate i such that $\bar{\varepsilon}(s,i^{\max}) = \varepsilon$. This yields the closed-form solution

$$0 = z\varepsilon\, \pi(k,\zeta,i^{\max}) - b + (1-\delta)\zeta k - \nu + V_1(s)$$

$$\Rightarrow \qquad 1 + i^{\max} = \frac{\eta}{w}\,(z\varepsilon)^{\frac{1-\eta}{\eta}}(\zeta k)^{\frac{\alpha}{\eta}}\left(\frac{1-\eta}{b-(1-\delta)\zeta k + \nu - V_1(s)}\right)^{\frac{1-\eta}{\eta}}.$$

Given (s,ε), the intraperiod equilibrium can be characterized as follows:

1. if $i^{\min} < \omega < i^{\max}$, a firm is in the *normal funding region* and the lender offers $i^* = \omega$, the competitive rate set by outside lenders;

2. if $i^{\min} < i^{\max} < \omega$, a firm is in the *evergreening region* and the lender offers $i^* = i^{\max}$, a rate just low enough to prevent the firm from defaulting;

3. if $i^{\max} < i^{\min}$, there is no feasible contract and the firm is liquidated. Recall that $i^{\min} < \omega$, so the firm would default even if attempting to borrow from an outside lender.

Alternatively, one can more conveniently express these regions in terms of thresholds for the idiosyncratic shock ε. The threshold separating the normal funding region from the evergreening region corresponds to $i^{\max} = \omega$, which yields the same distress threshold as in (9).

The liquidation threshold $\underline{\varepsilon}_z(s)$ is the value of ε for which $i^{\max} = i^{\min}$:

$$b - (1-\lambda)\zeta k + (i^{\max} - \omega)\, w\, n(s, \underline{\varepsilon}_z(s), i^{\max}) = 0.$$

This implies

$$\tilde{\underline{\varepsilon}}_z(s) = \left[\frac{w(1+\omega)}{b - (1-\lambda)\zeta k + \frac{\eta}{1-\eta}\left[b + \nu - (1-\delta)\zeta k - V_1(s)\right]} \right]^{\frac{\eta}{1-\eta}} \times \left[\frac{b + \nu - (1-\delta)\zeta k - V_1(s)}{(1-\eta)(\zeta k)^{\alpha}} \right]^{\frac{1}{1-\eta}} \frac{1}{z}.$$

In practice, the interest rate is constrained below by i^{reg}, thus the relevant threshold is given by:

$$\underline{\varepsilon}_z(s) = \max\left\{ \tilde{\underline{\varepsilon}}_z(s), \left[\frac{b + \nu - (1-\delta)\zeta k - V_1(s)}{1-\eta} \right] \left[\frac{w(1+i^{reg})}{\eta} \right]^{\frac{\eta}{1-\eta}} \frac{1}{z(\zeta k)^{\frac{\alpha}{1-\eta}}} \right\} \tag{22}$$

A.1.2 Proposition 2

First, note that—as in the evergreening economy—lenders offer restructuring only to firms with productivity below the distress threshold, $\varepsilon < \bar{\varepsilon}(s)$. For such distressed firms, the lender prefers restructuring to liquidation if and only if

$$(1-\xi)\, b \;\geq\; (1-\lambda)\zeta k,$$

that is, when the amount recovered under restructuring exceeds the recovery of the collateral. This condition implies that the maximum feasible restructuring is independent of the idiosyncratic shock ε:

$$\xi^{\max}(k, b, \zeta) = 1 - \frac{(1-\lambda)\zeta k}{b}.$$

From the point of view of a distressed firm, restructuring ensures survival if and only if

$$\varepsilon z\, \pi(k, \zeta, \omega) - (1-\xi)\, b - \nu + (1-\delta)\zeta k + V_1(s) \;\geq\; 0,$$

which implies that the minimum share of debt write-off needed for the firm to survive is

$$\xi^{\min}(s,\varepsilon,\zeta) = \frac{b+\nu-(1-\delta)\zeta k - V_1(s) - \varepsilon z\,\pi(k,\zeta,\omega)}{b}.$$

We assume that the lender offers a restructuring program exactly equal to this amount, leaving the firm indifferent between exiting and continuing. Restructuring is therefore feasible for a distressed firm if (i) the lender is willing to offer the required write-off needed for survival, and (ii) this amount does not exceed the regulatory limit. That is, restructuring is feasible if and only if

$$\min\{\xi^{\max}(k,b,\zeta),\, \xi^{reg}\} \;\geq\; \xi^{\min}(s,\varepsilon,\zeta).$$

The right-hand side is monotonically decreasing in ε. Hence, there exists a threshold level of productivity above which restructuring is feasible, and below which it is not:

$$\underline{\varepsilon}_x(s,\zeta) = \frac{\nu-(1-\delta)\zeta k - V_1(s) + b(1-\min\{\xi^{\max}(k,b,\zeta),\, \xi^{reg}\})}{z\,\pi(k,\zeta,\omega)}.$$

The intraperiod equilibrium is therefore again characterized by three regions:

1. if $\varepsilon > \bar{\varepsilon}(s,\zeta)$, the firm receives normal funding and no restructuring occurs;

2. if $\varepsilon \in [\,\underline{\varepsilon}_x(s,\zeta),\, \bar{\varepsilon}(s)\,]$, the firm's debt is restructured;

3. if $\varepsilon < \underline{\varepsilon}_x(s,\zeta)$, restructuring is not feasible and the firm is liquidated.

A.1.3 Proposition 3

As in the previous economies, firms that are not distressed with $\varepsilon > \bar{\varepsilon}(s)$ are not eligible for transfers (i.e., the guarantee does not trigger). A distressed firm survives if and only if the transfer is large enough:

$$z\varepsilon\,\pi(k,\zeta,\omega) - b + (1-\delta)\zeta k - \nu + V_1(s) + \tau(s,\varepsilon) = 0,$$

which implies that the required transfer is

$$\tau(s,\varepsilon) = -\left[z\varepsilon\,\pi(k,\zeta,\omega) - b + (1-\delta)\zeta k - \nu + V_1(s)\right].$$

Note that the required transfer is decreasing in ε. Thus, there exists a threshold level of productivity below which a firm only survives with a transfer that exceeds the limit τ^{reg}.

This threshold is given by

$$\underline{\varepsilon}_\tau(s,\zeta) = \frac{b + \nu - (1-\delta)\zeta k - V_1(s) - \tau^{reg}}{z\,\pi(k,\zeta,\omega)}.$$

The equilibrium characterization is similar to that of the restructuring economy:

1. if $\varepsilon > \bar{\varepsilon}(s,\zeta)$, firms survive and receive no transfers;
2. if $\varepsilon \in [\,\underline{\varepsilon}_\tau(s,\zeta),\, \bar{\varepsilon}(s)\,]$, firms receive fiscal support and fully repay their debt;
3. if $\varepsilon < \underline{\varepsilon}_\tau(s,\zeta)$, the firm cannot survive without a transfer larger than the limit and therefore exits (without receiving a transfer).

A.2 Intraperiod equilibrium conditions

In this appendix, we provide a complete characterization of the intraperiod equilibrium for each of the four economies.

A.2.1 Hard credit

1. When $\varepsilon \geq \bar{\varepsilon}$, the firm finds itself in the normal funding region. The relevant intraperiod objects are:

$$\begin{aligned} i &= \omega \\ n &= z\varepsilon \left(\frac{\eta(\zeta k)^\alpha}{w(1+\omega)} \right)^{\frac{1}{1-\eta}} \\ V^p &= z\varepsilon(\zeta k)^{\frac{\alpha}{1-\eta}} \left(\frac{\eta}{w(1+\omega)} \right)^{\frac{\eta}{1-\eta}} (1-\eta) - b - \nu + (1-\delta)\zeta k + V_1(s) \\ W_0 &= b \end{aligned}$$

2. When $\varepsilon < \underline{\varepsilon}$, the firm is liquidated, and so i is not defined:

$$\begin{aligned} n &= 0 \\ V^p &= 0 \\ W_0 &= (1-\lambda)\zeta k \end{aligned}$$

A.2.2 Evergreening

1. When $\varepsilon \geq \bar{\varepsilon}$, the firm finds itself in the normal funding region. The relevant intraperiod objects are:

$$
\begin{aligned}
i &= \omega \\
n &= z\varepsilon \left(\frac{\eta(\zeta k)^{\alpha}}{w(1+\omega)} \right)^{\frac{1}{1-\eta}} \\
V^{p} &= z\varepsilon(\zeta k)^{\frac{\alpha}{1-\eta}} \left(\frac{\eta}{w(1+\omega)} \right)^{\frac{\eta}{1-\eta}} (1-\eta) - b - \nu + (1-\delta)\zeta k + V_1(s) \\
W_0 &= b
\end{aligned}
$$

2. When $\varepsilon \in [\underline{\varepsilon}_z, \bar{\varepsilon}]$, the firm is in the evergreening region:

$$
\begin{aligned}
i &= \left[\frac{\eta}{w} (z\varepsilon)^{\frac{1-\eta}{\eta}} (\zeta k)^{\frac{\alpha}{\eta}} \left(\frac{1-\eta}{b - (1-\delta)\zeta k + \nu - V_1(s)} \right)^{\frac{1-\eta}{\eta}} - 1 \right] (= i^{\max}) \\
n &= \left[\frac{b + \nu - (1-\delta)\zeta k - V_1(s)}{(1-\eta)(z\varepsilon)^{1-\eta}(\zeta k)^{\alpha}} \right]^{\frac{1}{\eta}} \\
V^{p} &= 0 \\
W_0 &= b + \frac{\eta}{1-\eta}[b + \nu - (1-\delta)\zeta k - V_1(s)] - (1+\omega) w \left[\frac{b + \nu - (1-\delta)\zeta k - V_1(s)}{(1-\eta)(z\varepsilon)^{1-\eta}(\zeta k)^{\alpha}} \right]^{\frac{1}{\eta}}
\end{aligned}
$$

3. When $\varepsilon < \underline{\varepsilon}_z$, the firm is liquidated, and so i is not defined:

$$
\begin{aligned}
n &= 0 \\
V^{p} &= 0 \\
W_0 &= (1-\lambda)\zeta k
\end{aligned}
$$

A.2.3 Restructuring

1. When $\varepsilon \geq \bar{\varepsilon}$, the firm finds itself in the normal funding region. The relevant intraperiod objects are:

$$
\begin{aligned}
i &= \omega \\
n &= z\varepsilon \left(\frac{\eta(\zeta k)^{\alpha}}{w(1+\omega)} \right)^{\frac{1}{1-\eta}}
\end{aligned}
$$

$$
\begin{aligned}
V^p &= z\varepsilon(\zeta k)^{\frac{\alpha}{1-\eta}} \left(\frac{\eta}{w(1+\omega)}\right)^{\frac{\eta}{1-\eta}} (1-\eta) - b - \nu + (1-\delta)\zeta k + V_1(s) \\
\xi &= 0 \\
W_0 &= b
\end{aligned}
$$

2. When $\varepsilon \in [\underline{\varepsilon}_x, \bar{\varepsilon}]$, the firm is in the restructuring region:

$$
\begin{aligned}
i &= \omega \\
n &= z\varepsilon \left(\frac{\eta(\zeta k)^{\alpha}}{w(1+\omega)}\right)^{\frac{1}{1-\eta}} \\
V^p &= 0 \\
\xi &= \frac{b + \nu - (1-\delta)\zeta k - V_1(s) - \varepsilon z \pi(k, \zeta; w, \omega)}{b} \\
W_0 &= \varepsilon z \pi(k, \zeta; w, \omega) + (1-\delta)\zeta k - \nu + V_1(s)
\end{aligned}
$$

3. When $\varepsilon < \underline{\varepsilon}_x$, the firm is liquidated, and so (i, ξ) are not defined:

$$
\begin{aligned}
n &= 0 \\
V^p &= 0 \\
W_0 &= (1-\lambda)\zeta k
\end{aligned}
$$

A.2.4 Guarantees

1. When $\varepsilon \geq \bar{\varepsilon}$, the firm finds itself in the normal funding region. The relevant intraperiod objects are:

$$
\begin{aligned}
i &= \omega \\
n &= z\varepsilon \left(\frac{\eta(\zeta k)^{\alpha}}{w(1+\omega)}\right)^{\frac{1}{1-\eta}} \\
V^p &= z\varepsilon(\zeta k)^{\frac{\alpha}{1-\eta}} \left(\frac{\eta}{w(1+\omega)}\right)^{\frac{\eta}{1-\eta}} (1-\eta) - b - \nu + (1-\delta)\zeta k + V_1(s) \\
\tau &= 0 \\
W_0 &= b
\end{aligned}
$$

2. When $\varepsilon \in [\underline{\varepsilon}_\tau, \bar{\varepsilon}]$, the firm benefits from the fiscal guarantee:

$$
\begin{aligned}
i &= \omega \\
n &= z\varepsilon \left(\frac{\eta(\zeta k)^\alpha}{w(1+\omega)} \right)^{\frac{1}{1-\eta}} \\
V^p &= 0 \\
\tau &= b + \nu - (1-\delta)\zeta k - V_1(s) - \varepsilon z \pi(k, \zeta; w, \omega) \\
W_0 &= b
\end{aligned}
$$

3. When $\varepsilon < \underline{\varepsilon}_\tau$, the firm is liquidated, and so i is not defined:

$$
\begin{aligned}
n &= 0 \\
V^p &= 0 \\
\tau &= 0 \\
W_0 &= (1-\lambda)\zeta k
\end{aligned}
$$

For reference, the total fiscal cost for this program can be computed as

$$
\text{cost}_\tau(s) = \int_{\underline{\varepsilon}_\tau(s)}^{\bar{\varepsilon}(s)} \tau(s, \varepsilon) \mathrm{d}F(\varepsilon) = z\pi(k, \zeta; w, \omega) \int_{\underline{\varepsilon}_\tau(s)}^{\bar{\varepsilon}(s)} [\bar{\varepsilon}(s) - \varepsilon] \mathrm{d}F(\varepsilon)
$$

A.3 Dynamic decisions

Given the solution to the intraperiod equilibrium, we can characterize the dynamic decisions and payoffs of lenders and firms.

Firms. Recall that the firm's dynamic problem is given by 5. Given the intraperiod equilibrium, we can derive the FOC for each of the firm's decisions as:

$$
\begin{aligned}
[k'] :\quad & \mathbb{E}_{\zeta'|\zeta} \left\{ M \cdot \int_{\bar{\varepsilon}(s')}^{\infty} \left[z'\varepsilon' \left[\frac{\eta}{w(1+\omega)} \right]^{\frac{\eta}{1-\eta}} \alpha (\zeta' k')^{\frac{\alpha+\eta-1}{1-\eta}} \zeta' + (1-\delta)\zeta' \right] \mathrm{d}F(\varepsilon') \right\} \\
& + \lambda\theta - 1 = 0 && (23) \\
[b'] :\quad & q - \mathbb{E}_{\zeta'|\zeta} \left\{ M \cdot \int_{\bar{\varepsilon}(s')}^{\infty} \mathrm{d}F(\varepsilon') \right\} - \lambda = 0 && (24)
\end{aligned}
$$

$$[z']: \quad -\phi\left[\frac{z'}{z(\varepsilon^*)^\rho}\right]^\kappa \frac{\kappa}{z'} + \mathbb{E}_{\zeta'|\zeta}\left\{M\cdot\int_{\bar{\varepsilon}(s')}^{\infty}\varepsilon'\left[\frac{\eta}{w'(1+\omega)}\right]^{\frac{\eta}{1-\eta}}(1-\eta)(\zeta'k')^{\frac{\alpha}{1-\eta}}\mathrm{d}F(\varepsilon')\right\}$$

$$+\mathbb{E}_{\zeta'|\zeta}\left\{M\cdot\int_{\bar{\varepsilon}(s')}^{\infty}(1-\rho)\kappa\phi'\left(\frac{z''}{z'(\varepsilon^{*\prime})^\rho}\right)^\kappa\frac{1}{z'}\mathrm{d}F(\varepsilon')\right\} = 0 \tag{25}$$

Notice that when choosing investment, innovation, and debt, the firm does not internalize any future states where $\varepsilon' < \bar{\varepsilon}(s')$, even if it survives through evergreening. Thus an increase in this threshold tends to be associated with underinvestment in both capital and R&D in partial equilibrium.

Lenders. For brevity, we report the lender's dynamic decisions for the evergreening economy. The equivalent conditions for the other economies are easy to derive given the expressions for the intraperiod equilibrium in A.2. Given the intraperiod equilibrium for the evergreening economy, we can write the value of the lender at the beginning of the period as:

$$\begin{aligned}
W_0(s,\varepsilon) = &\ \mathbf{1}[\varepsilon \geq \bar{\varepsilon}(s)]\cdot b \\
&+\mathbf{1}[\underline{\varepsilon}(s) \leq \varepsilon < \bar{\varepsilon}(s)]\cdot\left\{b + \frac{\eta[b+\nu-(1-\delta)\zeta k - V_1(s)]}{1-\eta}\right\} \\
&-\mathbf{1}[\underline{\varepsilon}(s) \leq \varepsilon < \bar{\varepsilon}(s)]\cdot\left\{w(1+\omega)\left[\frac{b+\nu-(1-\delta)\zeta k - V_1(s)}{(1-\eta)(z\varepsilon)^{1-\eta}(\zeta k)^\alpha}\right]^{\frac{1}{\eta}}\right\} \\
&+\mathbf{1}[\varepsilon < \underline{\varepsilon}(s)]\min\{(1-\lambda)\zeta k, b\}
\end{aligned}$$

This can be combined with 8 to write an expression for the equilibrium price of intertemporal debt:

$$\begin{aligned}
q = &\mathbb{E}_{\zeta'|\zeta}M\cdot\left\{\int_{\bar{\varepsilon}(s')}^{\infty}\mathrm{d}F(\varepsilon') + \int_{\underline{\varepsilon}(s')}^{\bar{\varepsilon}(s')}\frac{b'+\eta[\nu-(1-\delta)(\zeta'k')-V']}{b'(1-\eta)}\mathrm{d}F(\varepsilon')\right\} \\
&-\mathbb{E}_{\zeta'|\zeta}M\cdot\left\{\int_{\underline{\varepsilon}(s')}^{\bar{\varepsilon}(s')}\frac{w'(1+\omega)}{b'}\left(\frac{b'+\nu-(1-\delta)(\zeta'k')-V'}{(1-\eta)(z'\varepsilon')^{1-\eta}(\zeta'k')^\alpha}\right)^{\frac{1}{\eta}}\mathrm{d}F(\varepsilon')\right\} \\
&+\mathbb{E}_{\zeta'|\zeta}M\cdot\left\{\int_0^{\underline{\varepsilon}(s')}\min\left[1,\frac{(1-\lambda)\zeta'k'}{b'}\right]\mathrm{d}F(\varepsilon')\right\}
\end{aligned} \tag{26}$$

A.4 Full list of equilibrium conditions

Evergreening economy.

$$\tilde{\Theta} = (\zeta\tilde{k})^{\frac{\alpha}{1-\eta}} \left[\frac{\eta}{\tilde{w}(1+\omega)}\right]^{\frac{\eta}{1-\eta}} (1-\eta) \int_{\bar{\varepsilon}}^{\infty} \varepsilon \mathrm{d}F(\varepsilon) \tag{E.1}$$

$$1-\theta q = \mathbb{E}M' \left\{ \frac{\alpha}{1-\eta}\frac{\tilde{\Theta}'}{\tilde{k}'} + \int_{\bar{\varepsilon}'}^{\infty} \left[(1-\delta)\zeta' - \theta\right] \mathrm{d}F(\varepsilon') \right\} \tag{E.2}$$

$$\tilde{b}' = \theta\tilde{k}' \tag{E.3}$$

$$\tilde{V} = -\tilde{\phi}\left(\frac{G_z}{(\varepsilon^*)^\rho}\right)^{\kappa} + (G_z)^{\frac{1-\eta}{1-\alpha}} \left[-\tilde{k}' + q\tilde{b}' + \mathbb{E}M'\left\{\tilde{\Theta}' + \int_{\bar{\varepsilon}'}^{\infty}[-\tilde{b}' + (1-\delta)\zeta'\tilde{k}' - \nu + \tilde{V}']\mathrm{d}F(\varepsilon')\right\}\right] \tag{E.4}$$

$$\sigma\chi\tilde{C}N^{\varphi} = \tilde{w}\left[1 + (\sigma-1)\chi\frac{N^{1+\varphi}}{1+\varphi}\right] \tag{E.5}$$

$$M' = \beta\frac{\left[1+(\sigma-1)\chi\frac{(N')^{1+\varphi}}{1+\varphi}\right]^{\sigma}(\tilde{C}')^{-\sigma}}{\left[1+(\sigma-1)\chi\frac{N^{1+\varphi}}{1+\varphi}\right]^{\sigma}\tilde{C}^{-\sigma}}(G_z)^{-\sigma\frac{1-\eta}{1-\alpha}} \tag{E.6}$$

$$Q^d = \mathbb{E}M' \tag{E.7}$$

$$N = \left[\frac{\eta(\zeta\tilde{k})^{\alpha}}{\tilde{w}(1+\omega)}\right]^{\frac{1}{1-\eta}} \int_{\bar{\varepsilon}}^{\infty}\varepsilon\mathrm{d}F(\varepsilon) + \left[\frac{\tilde{b}+\nu-(1-\delta)\zeta\tilde{k}-\tilde{V}}{(1-\eta)(\zeta\tilde{k})^{\alpha}}\right]^{1/\eta} \int_{\underline{\varepsilon}}^{\bar{\varepsilon}} \varepsilon^{-\frac{1-\eta}{\eta}}\mathrm{d}F(\varepsilon) \tag{E.8}$$

$$\begin{aligned} q =& \mathbb{E}M'\left\{\int_{\bar{\varepsilon}'}^{\infty}\mathrm{d}F + \int_{\underline{\varepsilon}'}^{\bar{\varepsilon}'}\frac{\tilde{b}'+\eta[\nu-(1-\delta)(\zeta'\tilde{k}')-\tilde{V}']}{\tilde{b}'(1-\eta)}\mathrm{d}F\right\} \\ &-\mathbb{E}M'\left\{\int_{\underline{\varepsilon}'}^{\bar{\varepsilon}'}\frac{\tilde{w}'(1+\omega)}{\tilde{b}'}\left(\frac{\tilde{b}'+\nu-(1-\delta)(\zeta'\tilde{k}')-\tilde{V}'}{(1-\eta)(\varepsilon')^{1-\eta}(\zeta'\tilde{k}')^{\alpha}}\right)^{\frac{1}{\eta}}\mathrm{d}F\right\} \\ &+\mathbb{E}M'\left\{\int_{0}^{\underline{\varepsilon}'}\min\left[1, \frac{(1-\lambda)(\zeta'\tilde{k}')}{\tilde{b}'}\right]\mathrm{d}F\right\} \end{aligned} \tag{E.9}$$

$$\bar{\varepsilon} = \frac{\tilde{b}+\nu-(1-\delta)\zeta\tilde{k}-\tilde{V}}{1-\eta}\left[\frac{\tilde{w}(1+\omega)}{\eta}\right]^{\frac{\eta}{1-\eta}}\frac{1}{(\zeta\tilde{k})^{\frac{\alpha}{1-\eta}}} \tag{E.10}$$

$$\underline{\varepsilon}_{unc} = \left[\frac{\tilde{w}(1+\omega)}{\max\{0, \tilde{b}-(1-\lambda)\zeta\tilde{k}\} + \frac{\eta}{1-\eta}(\tilde{b}+\nu-(1-\delta)\zeta\tilde{k}-\tilde{V})}\right]^{\frac{\eta}{1-\eta}}\left[\frac{\tilde{b}+\nu-(1-\delta)\zeta\tilde{k}-\tilde{V}}{(1-\eta)(\zeta\tilde{k})^{\alpha}}\right]^{\frac{1}{1-\eta}} \tag{E.11}$$

$$\underline{\varepsilon}_{con} = \frac{\tilde{b}+\nu-(1-\delta)\zeta\tilde{k}-\tilde{V}}{1-\eta}\left[\frac{\tilde{w}(1+i^{reg})}{\eta}\right]^{\frac{\eta}{1-\eta}}\frac{1}{(\zeta\tilde{k})^{\frac{\alpha}{1-\eta}}} \tag{E.12}$$

$$\underline{\varepsilon} = \max\{\underline{\varepsilon}_{unc}, \underline{\varepsilon}_{con}\} \tag{E.13}$$

$$\tilde{C} = \tilde{\Lambda} - (G_z)^{\frac{1-\eta}{1-\alpha}}\tilde{k}' - \tilde{\phi}\left(\frac{G_z}{(\varepsilon^*)^{\rho}}\right)^{\kappa} \tag{E.14}$$

$$\tilde{\Lambda} = \frac{\tilde{\Theta}}{1-\eta} + [F(\bar{\varepsilon})-F(\underline{\varepsilon})]\frac{\tilde{b}+\nu-(1-\delta)\zeta\tilde{k}-\tilde{V}}{1-\eta} + [1-F(\underline{\varepsilon})][(1-\delta)\zeta\tilde{k}-\nu] + F(\underline{\varepsilon})(1-\lambda)(\zeta\tilde{k}) \tag{E.15}$$

$$G_z = (\varepsilon^*)^{\rho\frac{\kappa(1-\alpha)}{\kappa(1-\alpha)-(1-\eta)}}\left\{\mathbb{E}M'\left[\frac{\tilde{\Theta}'}{\kappa\tilde{\phi}} + (1-\rho)\left(\frac{G_z'}{(\varepsilon^{*\prime})^{\rho}}\right)^{\kappa}[1-F(\bar{\varepsilon}')]\right]\right\}^{\frac{(1-\alpha)}{\kappa(1-\alpha)-(1-\eta)}} \tag{E.16}$$

$$\varepsilon^* = \frac{\int_{\underline{\varepsilon}}^{\infty} \varepsilon \mathrm{d}F(\varepsilon)}{1 - F(\underline{\varepsilon})} \tag{E.17}$$

Restructuring Economy. The equilibrium conditions for the restructuring economy are identical with the following exceptions. The equation numbering corresponds to the equations above.

$$N = \left[\frac{\eta(\zeta\tilde{k})^{\alpha}}{\tilde{w}(1+\omega)}\right]^{\frac{1}{1-\eta}} \int_{\underline{\varepsilon}_x}^{\infty} \varepsilon \mathrm{d}F(\varepsilon) \tag{R.8}$$

$$q = \mathbb{E}M' \left\{ \int_{\bar{\varepsilon}'}^{\infty} \mathrm{d}F + \int_{\underline{\varepsilon}_x'}^{\bar{\varepsilon}'} \frac{(\zeta\tilde{k})^{\frac{\alpha}{1-\eta}} \left[\frac{\eta}{\tilde{w}(1+\omega)}\right]^{\frac{\eta}{1-\eta}} (1-\eta)\varepsilon' - \nu + (1-\delta)(\zeta'\tilde{k}') + \tilde{V}'}{\tilde{b}'(1-\eta)} \mathrm{d}F \right\} \tag{R.9}$$

$$+\mathbb{E}M' \left\{ \int_0^{\underline{\varepsilon}_x'} \min\left[1, \frac{(1-\lambda)(\zeta'\tilde{k}')}{\tilde{b}'}\right] \mathrm{d}F \right\}$$

$$\underline{\varepsilon}_x = \frac{\nu - (1-\delta)\zeta\tilde{k} - \tilde{V} + \max\{(1-\xi^{reg})\tilde{b}, (1-\lambda)\zeta\tilde{k}\}}{(\zeta\tilde{k})^{\frac{\alpha}{1-\eta}} \left[\frac{\eta}{\tilde{w}(1+\omega)}\right]^{\frac{\eta}{1-\eta}} (1-\eta)} \tag{R.13}$$

$$\tilde{\Lambda} = (\zeta\tilde{k})^{\frac{\alpha}{1-\eta}} \left[\frac{\eta}{\tilde{w}(1+\omega)}\right]^{\frac{\eta}{1-\eta}} \int_{\underline{\varepsilon}_x}^{\infty} \varepsilon \mathrm{d}F(\varepsilon) + [1 - F(\underline{\varepsilon}_x)][(1-\delta)\zeta\tilde{k} - \nu] + F(\underline{\varepsilon}_x)(1-\lambda)(\zeta\tilde{k}) \tag{R.15}$$

Guarantee Economy. The equilibrium conditions for the guarantee economy are identical with the following exceptions. The equation numbering corresponds to the equations above.

$$N = \left[\frac{\eta(\zeta\tilde{k})^{\alpha}}{\tilde{w}(1+\omega)}\right]^{\frac{1}{1-\eta}} \int_{\underline{\varepsilon}_\tau}^{\infty} \varepsilon \mathrm{d}F(\varepsilon) \tag{G.8}$$

$$q = \mathbb{E}M' \left\{ \int_{\underline{\varepsilon}_\tau'}^{\infty} \mathrm{d}F + \int_0^{\underline{\varepsilon}_\tau'} \min\left[1, \frac{(1-\lambda)(\zeta'\tilde{k}')}{\tilde{b}'}\right] \mathrm{d}F \right\} \tag{G.9}$$

$$\underline{\varepsilon}_\tau = \frac{\tilde{b} + \nu - (1-\delta)\zeta\tilde{k} - \tilde{V} - \tau^{reg}}{(\zeta\tilde{k})^{\frac{\alpha}{1-\eta}} \left[\frac{\eta}{\tilde{w}(1+\omega)}\right]^{\frac{\eta}{1-\eta}} (1-\eta)} \tag{G.13}$$

$$\tilde{\Lambda} = (\zeta\tilde{k})^{\frac{\alpha}{1-\eta}} \left[\frac{\eta}{\tilde{w}(1+\omega)}\right]^{\frac{\eta}{1-\eta}} \int_{\underline{\varepsilon}_\tau}^{\infty} \varepsilon \mathrm{d}F(\varepsilon) + [1 - F(\underline{\varepsilon}_\tau)][(1-\delta)\zeta\tilde{k} - \nu] + F(\underline{\varepsilon}_\tau)(1-\lambda)(\zeta\tilde{k}) \tag{G.15}$$

Hard Credit Economy. The equilibrium conditions for the hard credit economy are identical with the following exceptions. The equation numbering corresponds to the equations above.

$$N = \left[\frac{\eta(\zeta\tilde{k})^{\alpha}}{\tilde{w}(1+\omega)}\right]^{\frac{1}{1-\eta}} \int_{\bar{\varepsilon}}^{\infty} \varepsilon \mathrm{d}F(\varepsilon) \tag{HC.8}$$

$$q = \mathbb{E}M' \left\{ \int_{\bar{\varepsilon}'}^{\infty} \mathrm{d}F + \int_0^{\bar{\varepsilon}'} \min\left[1, \frac{(1-\lambda)(\zeta'\tilde{k}')}{\tilde{b}'}\right] \mathrm{d}F \right\} \tag{HC.9}$$

$$\underline{\varepsilon} = \bar{\varepsilon} \tag{HC.13}$$

$$\tilde{\Lambda} = (\zeta\tilde{k})^{\frac{\alpha}{1-\eta}} \left[\frac{\eta}{\tilde{w}(1+\omega)}\right]^{\frac{\eta}{1-\eta}} \int_{\bar{\varepsilon}}^{\infty} \varepsilon \mathrm{d}F(\varepsilon) + [1-F(\bar{\varepsilon})][(1-\delta)\zeta\tilde{k} - \nu] + F(\bar{\varepsilon})(1-\lambda)(\zeta\tilde{k}) \tag{HC.15}$$

B Further Evidence on Direct Estimation

Table 8: Further Evidence (1) - Estimates R&D Cost Function.

	(i) Baseline (IV)	(ii) Baseline (OLS)	(iii) Knowledge Stock (IV)	(iv) Knowledge Stock (OLS)	(v) R&D Intensity (IV)	(vi) R&D Intensity (OLS)
$\beta_1 (= 1/\kappa)$	0.35***	0.04***	0.19***	0.06***	0.55***	0.00
	(0.09)	(0.00)	(0.05)	(0.01)	(0.12)	(0.03)
$\beta_2 (= \rho)$	0.29***	0.23***	0.30***	0.27***	0.17***	0.18***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Time FE	✓	✓	✓	✓	✓	✓
First-Stage F-Stat	19		51		227	
R-squared	0.12	0.12	0.15	0.15	0.09	0.09
Observations	34,556	34,556	21,406	21,409	69,908	70,028
Number of Firms	4,847	4,847	3,471	3,472	9,045	9,057
Number of Industries	46	46	46	46	50	50

Notes: Estimation results for regression (18). R&D intensity is defined as firm capital expenditures relative to value added and we exclude outlier by dropping observations larger than 10 and smaller than zero. Standard errors in parentheses are clustered by firm. See text for descriptions on each regression. Sample: 1982-2023. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 9: Further Evidence (2) - Estimates R&D Cost Function.

	(i) Baseline	(ii) h=2	(iii) h=3	(iv) LP	(v) Bootstrap
β_1 $(= 1/\kappa)$	0.35***	0.41***	0.51***	0.17***	0.36***
	(0.09)	(0.12)	(0.18)	(0.04)	(0.12)
β_2 $(= \rho)$	0.29***	0.34***	0.40***	0.33***	0.29***
	(0.02)	(0.03)	(0.04)	(0.03)	(0.03)
Time FE	✓	✓	✓	✓	✓
First-Stage F-Stat	19	15	11	19	19
R-squared	0.12	0.14	0.13	0.1	0.12
Observations	34,556	29,033	24,641	39,238	34,556
Number of Firms	4,847	4,518	3,824	5,789	4,847
Number of Industries	46	46	46	47	46

Notes: Estimation results for regression (18). Standard errors in parentheses are clustered by firm. See text for descriptions on each regression. Sample: 1982-2023. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 10: Further Evidence (3) - Estimates R&D Cost Function.

	(i) Baseline	(ii) P50	(iii) P75	(iv) P90	(v) Patents
β_1 $(= 1/\kappa)$	0.35***	0.49***	0.43***	0.41***	0.43***
	(0.09)	(0.13)	(0.11)	(0.11)	(0.12)
β_2 $(= \rho)$	0.29***	0.37***	0.36***	0.34***	0.30***
	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)
Time FE	✓	✓	✓	✓	✓
First-Stage F-Stat	19	16	17	18	15
R-squared	0.12	0.14	0.14	0.13	0.13
Observations	34,556	34,556	34,556	34,556	24,136
Number of Firms	4,847	4,847	4,847	4,847	2,857
Number of Industries	46	46	46	46	42

Notes: Estimation results for regression (18). Standard errors in parentheses are clustered by firm. See text for descriptions on each regression. Sample: 1982-2023. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

C Additional Figures

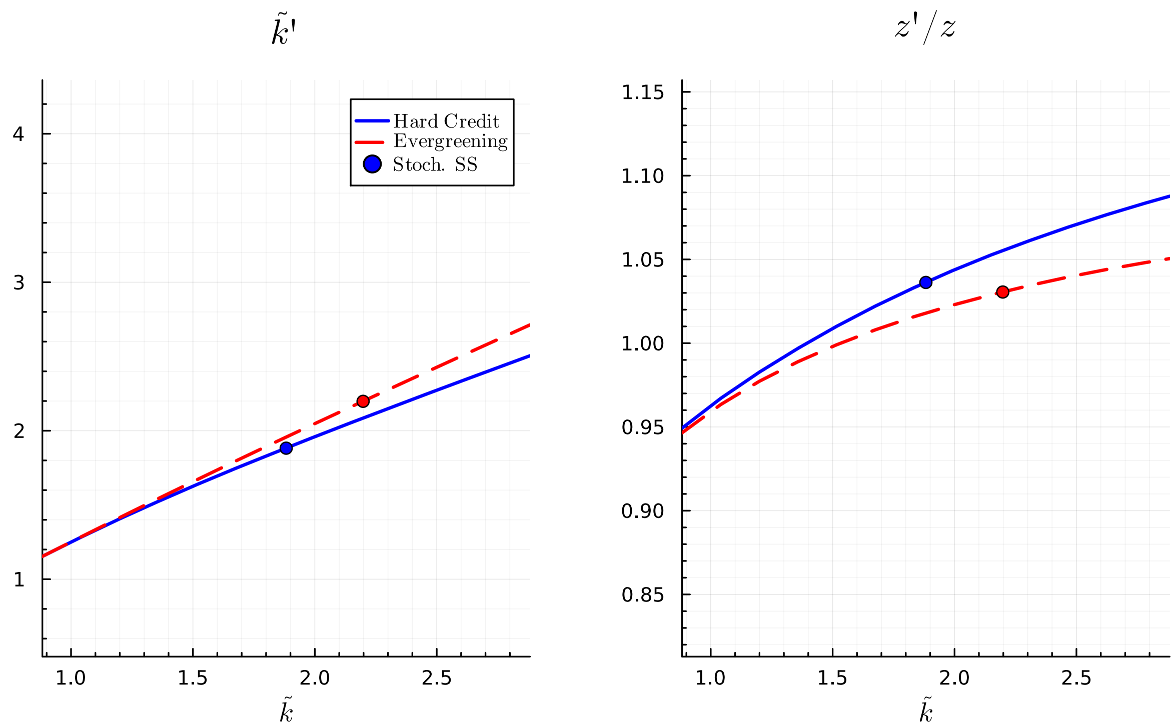

Figure 12: Firm policy functions for detrended physical capital $\tilde{k}'$ and R&D z' for evergreening and hard credit economies. The dots indicate the stochastic steady state of each respective economy.

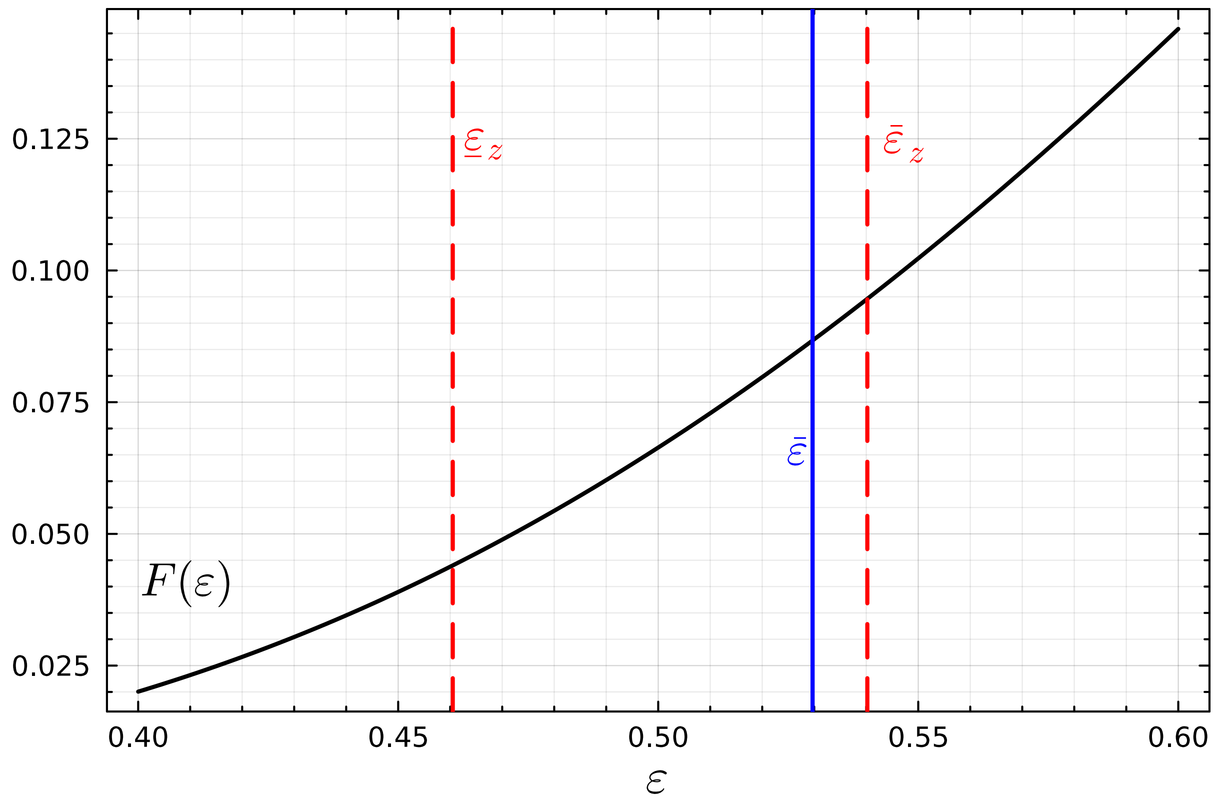

Figure 13: Probability distribution function of idiosyncratic productivity, liquidation and distress thresholds in the evergreening economy (red), and liquidation threshold in the hard credit economy (blue).

D Model Robustness: preference parameters

Tables 11 and 12 compare moments and welfare across the four economies for different preference parameters, $\beta = 0.99$ and $\sigma = 3$, respectively. For each case, we recalibrate the respective parameters so as to match the same targets as in the baseline. The tables show that the key qualitative results remain: hard credit is associated with faster GDP growth and higher GDP and consumption growth volatilities. Exit rates and the degree of selection are rather robust to preferences, with most of the differences emerging in both the level of real interest rates and the lending spread. As expected, CEV calculations are sensitive to preference parameters: an increase in patience magnifies the welfare losses relative to hard credit, as the benefits of this counterfactual economy are backloaded. More risk-aversion, on the other hand, compresses the welfare advantage of hard credit. This is explained not just by lower volatility but also by the level effect on the utility composite, and the fact that higher risk-aversion also corresponds to a lower elasticity of substitution.

Table 11: Model moments, higher discount factor ($\beta = 0.99$).

	Hard Credit	Evergreening	Restructuring	Guarantee
Share of subsidized firms (%)	0.00	5.00	5.00	5.00
Exit rate (%)	8.82	4.97	4.98	5.01
ε^*	1.05	1.03	1.03	1.03
GDP growth	2.37	2.00	2.05	2.06
$\sigma(g_Y)$	2.84	2.03	2.30	2.26
$\sigma(g_C)$	2.61	2.44	2.55	2.52
Real interest rate, $1/Q^d - 1$	5.50	4.87	4.90	4.92
Lending spread, $(1/q - 1/Q^d)$	3.49	2.01	2.05	2.00
Detrended wage, $\tilde{w}$	0.75	0.80	0.80	0.80
K/Y	1.49	1.73	1.74	1.73
$corr(R\&D, Y)$	0.70	0.89	0.83	0.90
CEV of moving from HC		-5.55	-4.51	-4.39

Table 12: Model moments, higher risk-aversion ($\sigma = 3$).

	Hard Credit	Evergreening	Restructuring	Guarantee
Share of subsidized firms (%)	0.00	5.00	4.45	5.78
Exit rate (%)	8.78	4.86	5.29	4.31
ε^*	1.05	1.03	1.03	1.03
GDP growth	2.36	2.00	2.08	2.01
$\sigma(g_Y)$	2.79	2.03	2.34	2.15
$\sigma(g_C)$	3.03	2.77	2.92	2.84
Real interest rate, $1/Q^d - 1$	8.36	7.52	7.63	7.48
Lending spread, $(1/q - 1/Q^d)$	3.70	2.12	2.32	1.86
Detrended wage, $\tilde{w}$	0.72	0.76	0.76	0.77
K/Y	1.28	1.47	1.45	1.50
$corr(R\&D, Y)$	0.68	0.90	0.86	0.89
CEV of moving from HC		-0.69	-0.20	-0.33