Stabilization vs. Growth

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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 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 subsidies, debt restructuring, or evergreening of loans all reduce GDP volatility, but they also feature lower economic growth. Welfare is higher in an economy without such interventions, calling into question the tendency to stabilize business cycles at all costs.

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1 Introduction

A number of policy interventions and lending practices in credit markets imply a fundamental trade-off: they can stabilize business cycle fluctuations but may reduce 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 had the goal 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 preventing other firms from entry and reducing economic growth in the medium to long-term. Thus, how should such firm credit programs be optimally 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-vs.-growth trade-off can 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.

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, easing credit conditions, or by directly issuing grants to firms. We show that a lender's decision to save a firm in distress is the optimal result of a decision problem that aims to maximize lender profits. Intuitively, a lender rather offers a distressed firm more favorable loan terms and therefore receives at least part of the outstanding debt, as opposed to letting the firm default and recover only the collateral that backs the loan. Second, aggregate total factor productivity (TFP) is endogenous and shaped by firms' innovation decisions to invest in research and development (R&D). We posit that firms learn from each other and that the R&D costs depend

negatively on the average productivity of incumbent firms. As a result, if low-productive 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 lead 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 distressed firms receive grants ("transfer 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 each period, thereby raising output and employment all else equal, and reducing output volatility overall as well as in response to adverse aggregate shocks. However, by keeping less-productive firms alive, the average productivity of incumbents falls, raising the R&D costs for subsequent firms all else equal. This effect is due to the innovation externality that we closely match to the data based on our regression estimates. As a result, the hard credit economy features around 0.14%-0.23% higher GDP growth per year compared with the counterfactual economies. That is because more firms exit in this economy each period, leading to lower R&D costs and higher innovation choices of new firm vintages. 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 3-4.5 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. We find that welfare in the hard credit economy is largest due to higher economic growth. Relative to this benchmark, the restructuring and the transfer economies show around 2% lower welfare, while the evergreening economy features an additional 2.8% reduced 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 higher labor demand and increased wages. In turn, firm profits are lower, and firms invest less in R&D, further reducing economic growth.

In summary, our results show the striking welfare benefits of creative destruction (Aghion and Howitt, 1992). At a minimum, they also speak against excessive and poorly targeted firm subsidy programs, bankruptcy systems that are designed to save even less-productive firms, and bank regulation that does not penalize the practice of evergreening loans. But beyond this minimum, our findings call into question a short-run focused tendency to stabilize business cycles at all costs, as such efforts may come with reduced economic growth and, on net, a welfare loss to the economy as a whole.

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.

Our model baseline is called *hard credit economy*, and is characterized by the absence of ex-post interventions and arrangements that may support firms in distress. We compare this benchmark to three soft-credit economies that each feature a different type of ex-post intervention: (i) the *evergreening economy*, where lenders may condition current loan terms on outstanding debts, (ii) the *restructuring economy*, where lenders may undertake ex-post restructuring of legacy debts, and (iii) the *transfer economy*, where firms in distress may

receive transfers from a fiscal authority.

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 $\phi \equiv \tilde{\phi} Z^{\frac{1-\eta}{1-\alpha}}$ denoting the level costs of R&D which follow a time trend where Z is the aggregate fundamental productivity.[1] The parameter κ governs the curvature of R&D costs, and x^* is the average x of operating firms, that is, the average product of the fundamental and idiosyncratic component for firms that produced this 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 (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

[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 2.7.

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 when $\rho = 0$, while it depends only on average 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.

Timing. The model setup is such that, in equilibrium, all firms choose the same state variables across periods: capital, interperiod debt, and fundamental productivity. However, at the beginning of each period, firms are hit with a purely idiosyncratic productivity shock ϵ. Additionally, they need to take on an intraperiod loan to finance the hiring of labor. 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, they produce, repay their debts, and choose the state variables for the next period. The exact timing within the period is as follows:

1. Firms enter the period with endogenous states $s \equiv (z, k, b, \zeta)$ and a realization of the capital-quality shock.

2. Idiosyncratic productivity shocks $\varepsilon \sim F$ are realized.

3. Based on the realization of the idiosyncratic shocks, lenders and policymakers can intervene to save distressed firms from default. We consider three types of interven-

tions. In the *evergreening economy*, lenders offer interest rates on intraperiod debt i, which can be relatively favorable for distressed firms. In the *restructuring economy*, lenders can write off a fraction ξ of a firm's legacy debt. In the *transfer economy*, the fiscal authority can choose a lump-sum transfer τ to save distressed firms.

4. Given idiosyncratic shocks and ex-post interventions, firms choose to default or to repay any outstanding interperiod debt, and produce. Firms hire labor n at a wage rate w to produce subject to the working capital constraint (3).

5. Exiting firms are replaced by entrants with zero capital. Entering firms do not produce in their period of entry.

6. Surviving firms and entrants choose (z', k', b') subject to the collateral constraint (4).

This timing—summarized in Figure 1—generates 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).

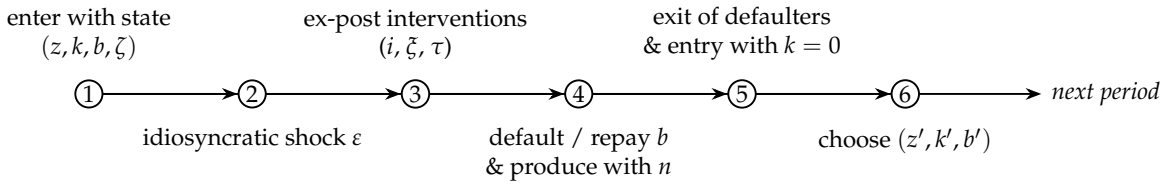


Figure 1: Intra-period timing of firm decisions and shocks.

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 $M(S', S)$,
- 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. 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

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

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 is discounted using the household's stochastic discount factor, M, and continuation depends on next period's state (s', ε').

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 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

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

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

2.2 Lenders

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

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

$$W_1(s) = \max_{q,d'} \mathbb{E}_{\zeta',\varepsilon'}\{\, M[\, W_0(s',\varepsilon') - d'\,]\,\}$$

$$\text{s.t.} \qquad qb' \leq Q^d d'.$$

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 cannot commit to i when offering q.

Intraperiod problem. Lenders offer the intraperiod interest rate i and the debt write-off ξ after 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 offer take-it-or-leave-it offers, which can generate heterogeneity across firms depending on ε. The problem for a lender at the intraperiod lending stage is

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

where 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 define economies in light of those limits and the possible transfers by policymakers. We term an economy without transfers and ex-post interventions of lenders the hard credit economy, that is, $i^{reg} = \omega$, $\xi^{reg} = 0$, 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 transfer economy features $\tau^{reg} > 0$. The minimum possible i^{reg} and the maximum possible ξ^{reg} or τ^{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.

Given any transfers and ex-post lender interventions, if the borrower survives and repays the legacy debt, the firm takes on a working capital loan and the relationship continues. We assume that the firm is free to look for and match with a new intraperiod lender, which in equilibrium constrains the set of feasible i for the incumbent bank. In contrast, if the borrower defaults, the lender recovers a fraction of the firm's capital.

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, so that $d' = qb'/Q^d$. Free entry of banks at the interperiod lending stage implies that expected lender profits

[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.

must be zero:

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

This condition simplifies the intraperiod lending problem, which becomes static once we impose $W_1(s) = 0$. We use this structure to characterize the intraperiod equilibrium in each of the economies considered below.

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 are not allowed to restructure debts, i.e. $\xi^{reg} = 0$. As a consequence, the intraperiod equilibrium is such that all firms are offered loans at the lender's marginal cost of funds, $i = \omega$. 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, as we will see next, it also 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 $i \leq \omega$: if a lender were to offer an intraperiod rate above ω, the firm could switch to a new lender and borrow at a lower rate, which places an upper bound on 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

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

The lender internalizes that the distress threshold $\bar{\varepsilon}(s,i)$ depends on i. To solve the problem, 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

$$\begin{aligned} 0 &= z\varepsilon\, \pi(k, \zeta, i^{\max}) - b + (1-\delta)\zeta k - \nu + V_1(s) \\ \Rightarrow \qquad 1 + i^{\max} &= \frac{\eta}{w} (z\varepsilon)^{\frac{1-\eta}{\eta}} (\zeta k)^{\frac{\alpha}{\eta}} \left(\frac{1-\eta}{b - (1-\delta)\zeta k + \nu - V_1(s)} \right)^{\frac{1-\eta}{\eta}}. \end{aligned}$$

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 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

$$\underline{\varepsilon}_z(s) = \left[\frac{w(1+\omega)}{b-(1-\lambda)\zeta k + \frac{\eta}{1-\eta}\left[b+\nu-(1-\delta)\zeta k - V_1(s)\right]}\right]^{\frac{\eta}{1-\eta}} \times \left[\frac{b+\nu-(1-\delta)\zeta k - V_1(s)}{(1-\eta)(\zeta k)^{\alpha}}\right]^{\frac{1}{1-\eta}} \frac{1}{z}. \tag{10}$$

The following proposition characterizes the intraperiod equilibrium:

Proposition 1. *The intraperiod equilibrium is given by:*

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 $b > (1-\lambda)\zeta k$.

Figure 2 provides a graphical representation of the intraperiod equilibrium at the stochastic steady state of the model (see Section 3 for details on the calibration). Idiosyncratic productivity is on the horizontal axis. The blue dashed line represents ω, the competitive funding rate. The green dot-dashed line is $i^{\min}$, the minimum interest rate at which the bank is willing to lend, and the solid red 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. 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 solid black 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 influences the amount of labor hired by the firm. 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.

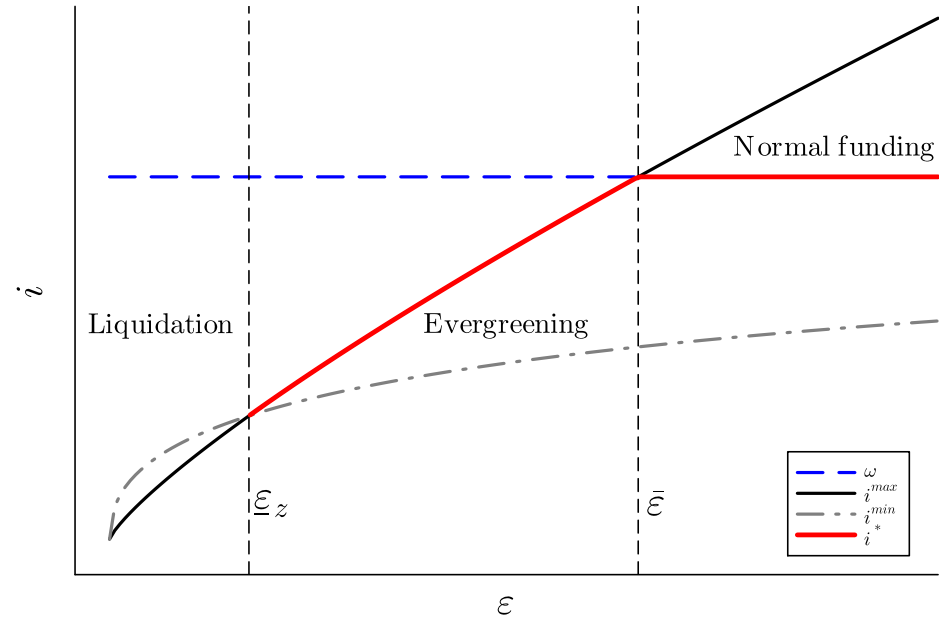


Figure 2: Intraperiod equilibrium for the evergreening economy as a function of idiosyncratic productivity ε. i^* denotes the equilibrium interest rate offered by the lender.

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.

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:

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

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.

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.

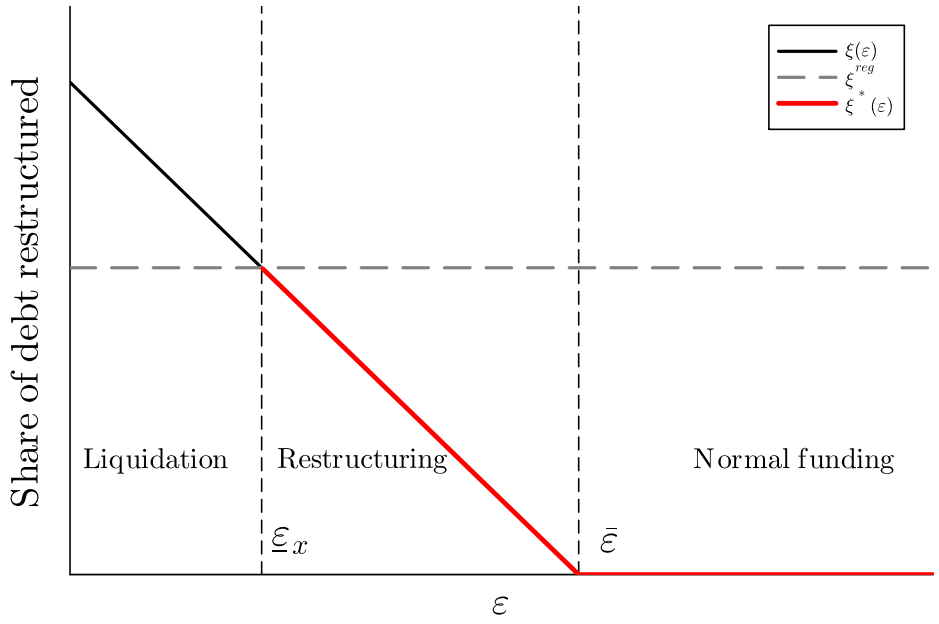


Figure 3: Intraperiod equilibrium for the restructuring economy as a function of idiosyncratic productivity ε.

2.3.4 Transfer Economy

In the fourth economy, a fiscal authority issues transfers to support businesses in distress. 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, some important differences are that we consider an intervention that is directly targeted at firms in financial distress, with an amount that is just large enough to save a firm from default, and which 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 $\bar{\tau}$ per firm. Thus, this economy nests the hard credit economy when $\bar{\tau} = 0$.

As in the previous economies, firms that are not distressed with $\varepsilon > \bar{\varepsilon}(s)$ are never eligible for transfers. 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 $\bar{\tau}$. This threshold is given by

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

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).

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.

2.3.5 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 where it is distressed $\varepsilon' < \bar{\varepsilon}(s';S')$, 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 (21) with the firm's first-order condition for debt in (19). Since the firm and the lender have the same SDF, the expected repayment cancels out and leaves a strictly positive expected recovery term that implies that the Lagrange multiplier must be positive.

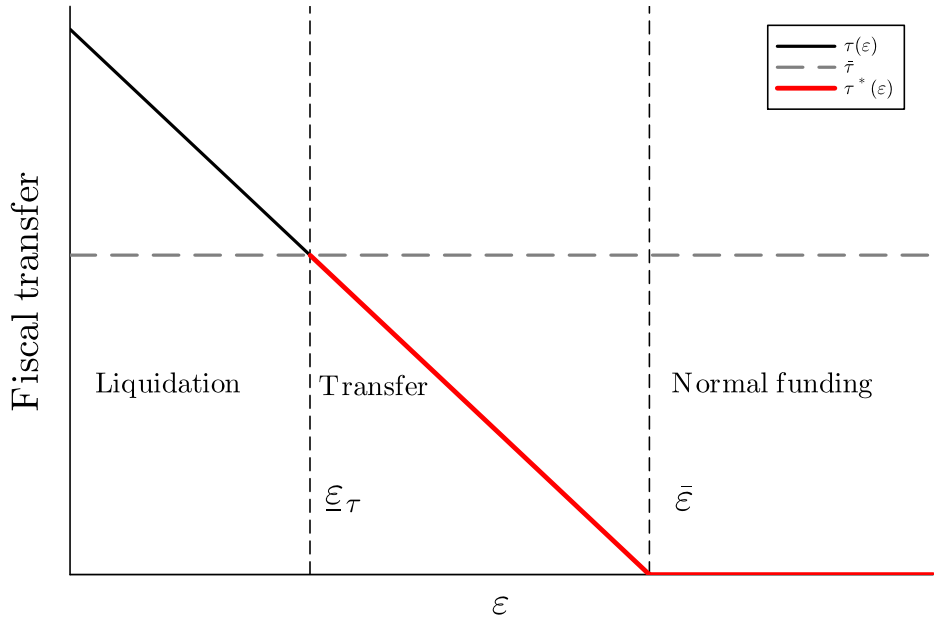


Figure 4: Intraperiod equilibrium for the fiscal transfer economy as a function of idiosyncratic productivity ε.

2.4 Households

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

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

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.

[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 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

$$C + Q^d D' = wN + D + \Psi,$$

where Ψ are net transfers from firms and financial intermediaries. The problem yields two optimality conditions: a labor supply condition and an Euler equation, given by

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

2.5 Aggregate Resource Constraint

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

$$\begin{aligned}&(z\varepsilon)^{1-\eta}(\zeta k)^{\alpha}n^{\eta} - (1+i)wn + (1-\delta)\zeta k - b(1-\xi) - \nu + b(1-\xi) + (i-\omega)wn + \tau,\\ =&(z\varepsilon)^{1-\eta}(\zeta k)^{\alpha}n^{\eta} - (1+\omega)wn + (1-\delta)\zeta k - \nu + \tau.\end{aligned}$$

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

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

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, 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.

2.6 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. In equilibrium, all firms make identical dynamic decisions, so $s_t = S_t$.

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.

2.7 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.3.

An expression for the gross rate of productivity growth G_z can be obtained by rewriting the firms' dynamic decision (20), shown in Appendix A.2, in its detrended form as:

$$\frac{z'}{z} = (\varepsilon^*)^{\frac{\rho\kappa}{\kappa-\frac{1-\eta}{1-\alpha}}} \times \left\{ \frac{\mathbb{E}[M \int_{\bar{\varepsilon}(s')}^{\infty} \varepsilon'(\zeta'\tilde{k}')^{\frac{\alpha}{1-\eta}} \left[\frac{\eta}{\tilde{w}'(1+\omega)}\right]^{\frac{\eta}{1-\eta}} (1-\eta) \mathrm{d}F(\varepsilon')]}{\kappa\tilde{\phi}} \right\}^{\frac{1}{\kappa-\frac{1-\eta}{1-\alpha}}} \equiv G_z \quad (13)$$

This expression determines the growth rate of the common productivity component z and shows 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 played by the innovation externality, which is governed by the parameter ρ: the more productive are firms that survive, the faster the common component of productivity grows. The second term reflects the private benefits of innovation relative to its costs. 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 (13) 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.

3 Calibration and Solution

In this section, we describe our strategy that calibrates 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 that govern the innovation cost function (2), κ and ρ, by combining theoretical relations produced by 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

$$R\&D_{i,s,t} = \phi_t \left(\frac{z_{i,s,t+1}}{z_{i,s,t}^{1-\rho}(x_{s,t}^*)^{\rho}} \right)^{\kappa}, \tag{14}$$

where we associate the productivity and R&D costs to firms denoted by subscript i, and assume for now that the scale ϕ_t has the same time trend for all firms, whereas firms learn from the average productivity x^* that is specific to their industry s. Taking logs and rearranging yields the equation

$$logz_{i,s,t+1} - logz_{i,s,t} = \frac{1}{\kappa} \cdot (logR\&D_{i,s,t} - log\phi_t) + \rho \cdot log\frac{x_{s,t}^*}{z_{i,s,t}}. \tag{15}$$

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

$$logz_{i,s,t+1} - logz_{i,s,t-1} = \chi_t + \beta_1 \cdot logR\&D_{i,s,t} + \beta_2 \cdot log\frac{x_{s,t-1}^*}{z_{i,s,t-1}} + u_{i,s,t}, \tag{16}$$

where β_1 corresponds to $(1/\kappa)$ and β_2 to ρ. When estimating this regression on firm micro data, we would be concerned about the possible endogeneity of the regressors. For example, young firms may conduct less R&D since they have fewer skilled labor for such purposes at the beginning of their lifetime. At the same time, younger firms have higher productivity growth, leading to biased estimates for β_1 when omitting firm age from the regression.

To address the possible endogeneity of $logR\&D_{i,s,t}$, 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).[6] 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.

[6] We use the updated data provided by Glaeser and Yoo (2025), available for the years 1982-2023.

Data and TFP Estimation. We use annual firm data from S&P's Compustat database for publicly-traded corporations for the years 1982-2023.[7] 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

$$log(\text{value added}_{i,t}) = \alpha + \beta_{1,s} \cdot log(\text{capital}_{i,t-1}) + \beta_{1,s} \cdot log(\text{employees}_{i,t}) + u_{i,t}, \quad (17)$$

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

$$log(TFP_{i,t}) = (\hat{\alpha} + \hat{u}_{i,t})/(1-\eta). \quad (18)$$

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

Results. Equipped with the firm micro data and the TFP estimates, we estimate (16) using the outlined instrumental variable approach. The results are shown in Table 1. Column (1) portrays our baseline estimates of 0.33 for β_1 and 0.3 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. Our estimate for κ is close to the parameter values estimated or assumed in other models that rely on similar functional forms for the cost of innovation (see, e.g., Acemoglu et al., 2018; Greenwood, Han and Sánchez, 2022).

The remaining columns show the estimations results from various robustness checks. Column (2) uses industry-time fixed effects to allow for the possibility that ϕ_t in equation (14) also varies by industry, which gets absorbed into these fixed effects. Column (3) 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 (4) assumes that firms learn not only from their industry peers but more broadly from all firms in the economy, such that x^*_{t-1} does not vary by industry in (16). And finally, column (5) uses net property, plant, and

[7] We restrict the sample to firms headquarted 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 Investment Cost Function.

	(i) Baseline	(ii) Fixed Effects	(iii) TFP-Def.	(iv) Learning	(v) Capital
β_1 $(= 1/\kappa)$	0.33***	0.49***	0.39***	0.49***	0.47***
	(0.09)	(0.13)	(0.11)	(0.14)	(0.12)
β_2 $(= \rho)$	0.30***	0.40***	0.40***	0.39***	0.41***
	(0.02)	(0.04)	(0.06)	(0.04)	(0.03)
Time FE	✓		✓	✓	✓
Industry-Time FE		✓			
First-Stage F-Stat	18	17	15	15	17
R-squared	0.12	0.17	0.11	0.14	0.16
Observations	35,795	35,463	35,795	35,795	36,833
Number of Firms	4,945	4,921	4,945	4,945	5,506
Number of Industries	46	41	46	46	47

equipment as a measure of the firm's capital stock. Across the various robustness checks, we find estimates for β_1 and β_2 that are close to our baseline numbers, ranging between 0.33-0.49 and 0.3-0.41, respectively. If anything, our baseline estimates are conservative in the sense that they imply a higher curvature of the cost function via κ and a lower learning externality via ρ.

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, $\varphi = 1$, and an inverse EIS equal to $\sigma = 1.5$. 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 data.[8] Note that λ coincides with the LGD in equilibrium given our choice of $\theta = 1$.[9] We set the intraperiod lending cost to be 2% annually, similar to the average value of the external bond premium measured 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.[10]

Parameter	Description	Value	Target/Reason
		Households	
σ	Inverse EIS	1.5	-
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, Gilchrist and Zakrajsek (2012)

Table 2: Externally Calibrated Parameters.

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), 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.

[8] 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 taken from Schedule H.1, which is a quarterly loan-level dataset that contains detailed information on all credit facilities over $ 1 million. For details, see https://www.federalreserve.gov/publications/fr-y-14-qas/y-14-qas.htm.

[9] 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.

[10] 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.

Given the direct estimation and the external calibration, we jointly choose the eight remaining parameters such that simulated model averages are close to eight empirical target moments: the productivity of firms that exit relative to continuing firms, the typical historical firm exit rate, an average credit spread, the real interest rate, 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 $\sigma_\varepsilon = 0.192$, 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 firms that exit is about 65% that of continuing firms. The fixed cost ν is set to 0.012, 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 -5.1% 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 ratio of EBITDA to value added among Compustat firms, which is 42.2%.[11] 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.

Parameter	Description	Value	Moment	Source	Data	Model
σ_ε	Variance of prod.	0.192	Relative TFP firms	LM(2015)	0.65	0.65
ν	Fixed cost	0.012	Exit/default rate	See text	5.0%	4.99%
i^{reg}	Lower bound int. rate	-0.051	Credit spread	Y14 data	2.0%	1.97%
β	Discount factor	0.995	Real interest rate	U.S. data	3.0%	2.99%
ψ	Returns to scale	0.864	EBITDA/Value Added	Compustat	42.2%	41.6%
$\tilde{\phi}$	Level cost of R&D	0.171	GDP pc growth	U.S. data	2%	2%
ρ_ζ	Capital quality persistence	0.685	GDP growth rate	U.S. data	0.044	0.041
σ_ζ	Capital quality volatility	0.020	GDP growth rate	U.S. data	0.023	0.024

Table 3: Internally calibrated parameters. LM(2015) refers to Lee and Mukoyama (2015).

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

3.4 Solution Method

We obtain a global nonlinear solution of the model using time iteration over a set of policy functions that depend on the state variables of the model. 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 then guess functional forms for the model's policy functions as a function of the (aggregate) endogenous and exogenous state variables: (k, ζ).[12] 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.

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.

4.1 Aggregate Moments

To begin, we simulate the various economies and compute aggregate moments that are reported in Table 4. To make the soft credit economies comparable, we calibrate ξ^{reg} and τ^{reg} for the restructuring and transfer economies, such that the share of firms that are saved is equalized to the one in the evergreening economy at around 6%. Of course, that share is zero in the hard credit economy where ex-post interventions are not permitted. This economy therefore features almost twice as much firm exit compared with the various soft credit 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 0.14-0.23 p.p. higher in the hard credit economy compared with the counterfactual economies. The evergreening economy lacks behind on GDP growth, which is around 0.09 p.p. lower relative to the restructuring and the transfer economy.

However, higher growth in the hard credit economy comes at the cost of higher volatility. For example, relative to the evergreening economy, the standard deviation of GDP-growth in the hard credit economy is around 0.7 p.p. higher. These patterns also carry

[12] 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.

Moment	Hard Credit	Evergreening	Restructuring	Transfer
Saved firms	0.00	5.95	5.96	5.96
Exit rate	9.77	4.99	4.92	4.94
ε^*	1.03	1.02	1.02	1.02
GDP growth	2.23	2.00	2.08	2.09
$\sigma(G_Y)$	3.12	2.44	2.54	2.54
$\sigma(G_C)$	2.42	2.37	2.40	2.39
$\sigma(\log N)$	1.92	1.59	1.69	1.60
Spread, %	3.75	1.97	1.96	1.96
i, %	2.00	1.79	2.00	2.00
K/Y ratio	2.04	2.36	2.36	2.36
Wage	0.76	0.82	0.82	0.82
Welfare	0.00	4.81	2.02	2.05

Table 4: Simulated moments for hard credit, evergreening, restructuring, and transfer economies. Welfare is computed as the CEV gain of moving to the hard credit economy.

over to consumption and hours worked, which show similar differences across hard and soft credit economies, though these effects are less pronounced quantitatively.

The possibility to save distressed firms ex-post also affects the pricing of intertemporal credit. Across the 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 taken away in the hard credit economy, spreads almost double to 3.75%. As credit becomes less flexible, lenders more often face a steeper loss when firms are in the default region, which is reflected in the pricing of credit ex-ante.

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 invest more in physical capital in the soft credit economies. In turn, this increases the capital-to-output ratio in these economies relative to the hard credit economy. Thus, while the hard credit 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 soft credit economies. Appendix Figure 8 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 produce, 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 the soft credit economies, it does impact the liquidation and distress thresholds as shown in Appendix Figure 9. Relative to the hard credit economy, the distress threshold in the soft credit economies is slightly higher in terms of the idiosyncratic shock ϵ due to the wage effect that depresses firm profits.

To assess the stabilization-vs.-growth trade-off quantitatively, we report welfare differences in the final line of Table 4, measured as the consumption-equivalent variation (CEV) of moving to the hard credit economy. To obtain the CEV, we compare each soft credit economy (sc) to a version of the hard credit (hc) economy with the same initial z, and then compute the additional percent consumption that the representative agent would require to be compensated at the BGP to move to the hard credit economy, that is,[13]

$$\text{Welfare} = \exp[(1-\beta)(\mathcal{U}^{\text{hc}} - \mathcal{U}^{\text{sc}})] - 1.$$

This difference is around 2% for the restructuring and the transfer economies, and around 4.8% for the evergreening economy. Thus, despite higher volatility, the hard credit economy outperforms the rest in overall welfare due to higher economic growth. The evergreening economy performs worst since it distorts firm labor decisions as intraperiod loan terms are eased, leading to slightly higher wages in that economy versus the other two soft credit economies.

4.2 Responses to Aggregate Shocks

To illustrate the stabilization-vs.-growth differences across economies, we study the response of each of the economies to an aggregate shock, a disturbance to the capital quality level ζ. 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 one where the capital quality level is perturbed with a one-standard-deviation 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 5% shock to capital quality in the hard credit, the evergreening, and the restructuring economies. We omit the

[13] See more details on how to obtain a recursive formulation of welfare in appendix A.4.

transfer economy as the results turn out to be very similar to the restructuring economy. Since the economies have different balanced growth paths, we start them with the same z, 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 ζ, which is assumed to follow an AR(1) process and reverts to its mean over time.

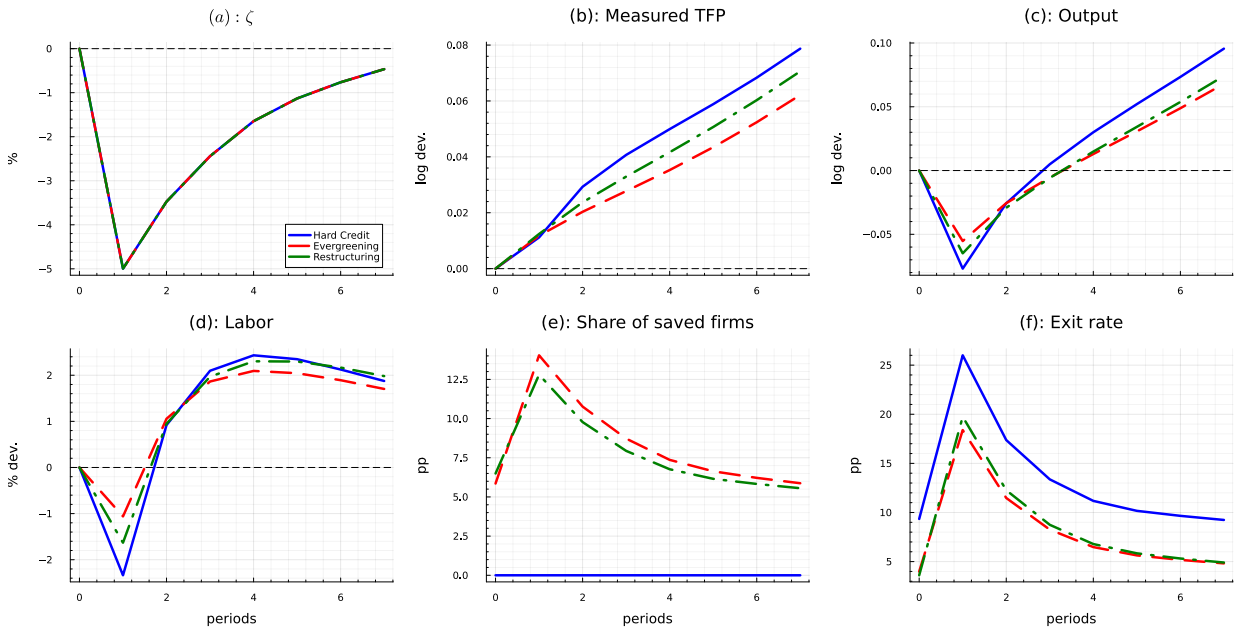


Figure 5: Generalized impulse response functions with respect to a one standard deviation shock to capital quality for hard credit, evergreening, and restructuring economies.

Panel (b) plots the path of aggregate 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 hard credit economy continues to grow at a similar rate, the soft credit economies experience a more pronounced slowdown. Panels (c) and (d) plot the paths of GDP and labor. At the time when the shock realizes, both fall by more in the hard credit economy compared with the soft credit economies. However, over time, the hard credit economy catches up and its level of output surpasses the one in the other economies as it grows faster, illustrating the initial stabilization and subsequent growth differences to such an adverse shock.

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 than in the soft credit 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.

4.3 Comparative Statics

To gain further intuition on our key results and to test their robustness, we compute comparative statics with respect to important parameters in this section and document how stochastic steady states of the different economies change.

First, we vary the exogenous limits i^{reg}, ξ^{reg}, and τ^{reg} that determine the strength of the ex-post interventions in the various soft credit economies. The results for selected variables are shown in Figure 6. To make the economies comparable, we report the share of subsidized firms on the horizontal axis. The vertical dashed lines mark our calibration benchmark that normalizes this share to around 6% in the soft credit 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.

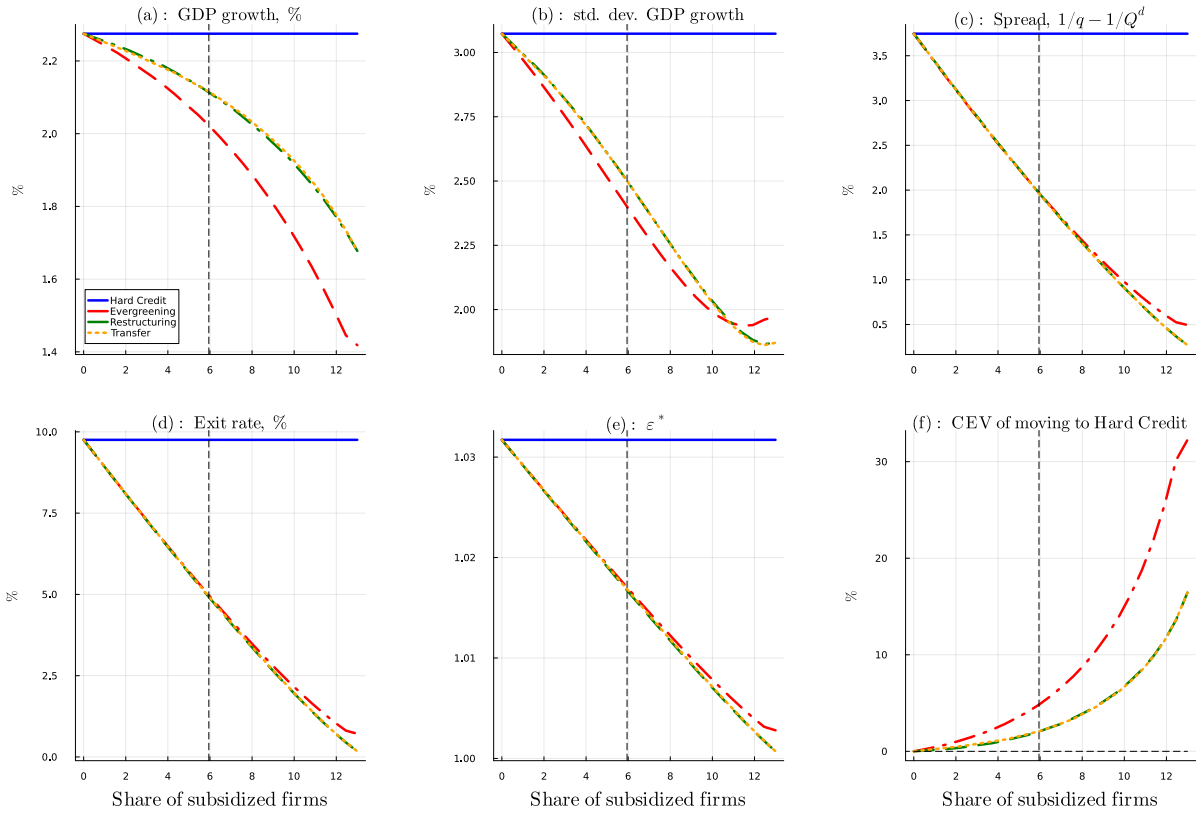


Figure 6: Comparative statics with respect to i^{reg}, ξ^{reg}, and τ^{reg}.

Starting with the top left panel, GDP growth falls as ex-post interventions become

stronger and more distressed firms are saved. This decline is more pronounced for the evergreening economy as lenders in this economy have an additional effect on firm labor decisions when easing credit terms to save distressed firms. As shown in panel (b), the standard deviation of GDP growth similarly falls as the ex-post interventions stabilize economies, but the relative decline of the evergreening economy is less pronounced. Panel (c) shows the decline in lending spreads, which reflects the reduced exit reported in panel (d). Both of these patterns are similar across economies, illustrating the inherent relation between the two variables.

Panel (e) shows the average idiosyncratic productivity ϵ^* of incumbents. As more distressed firms are saved, ϵ^* falls, leading to the GDP growth differences in panel (a). Finally, panel (f) shows how growth and stabilization effects are ultimately valued by the representative household. As more firms are saved, all of the soft credit economies perform worse, as the welfare gains of moving to the hard economy rise. The slope of this increase is sharpest for the evergreening economy due to its distortive effects on firm hiring decisions.

The innovation externality via the R&D cost function (2) is an important mechanism in our model that shapes productivity differences and determines the cleansing effect of recessions. The strength of this mechanism is determined by the parameter ρ, and we therefore vary this parameter in the next exercise to understand how it affects model outcomes.

Our benchmark calibration uses $\rho = 0.3$, and we recompute stochastic steady states for values of ρ from zero to 0.5. The results are reported in Figure 7. Panel (a) shows that higher values ρ imply faster GDP growth for all economies: as firms learn more past vintages of surviving firms, their costs of innovation are reduced, leading to higher innovation choices and, hence, more growth. Comparing hard and soft credit economies, the growth differences become larger the higher is ρ. That is because the hard credit economy features more exit and higher ϵ^*, intensifying the learning effect the higher ρ is.

Panel (b) shows that the volatility of GDP growth declines when ρ increases. To gain intuition on this relation, consider an adverse shock that decreases output and raises firm exit. As a result of more exit, the average productivity of surviving firms increases. Thus, the higher ρ is, the more easily an economy can recover from such an adverse shock, lowering overall volatility.

While GDP growth and its volatility are therefore strongly affected by the parametrization of ρ, panels (c)-(e) show that it is less important for the exit decision of firms, the ex-post interventions, and the pricing of intertemporal credit. What matters more for these margins are the exogenous limits we analyze in Figure 6.

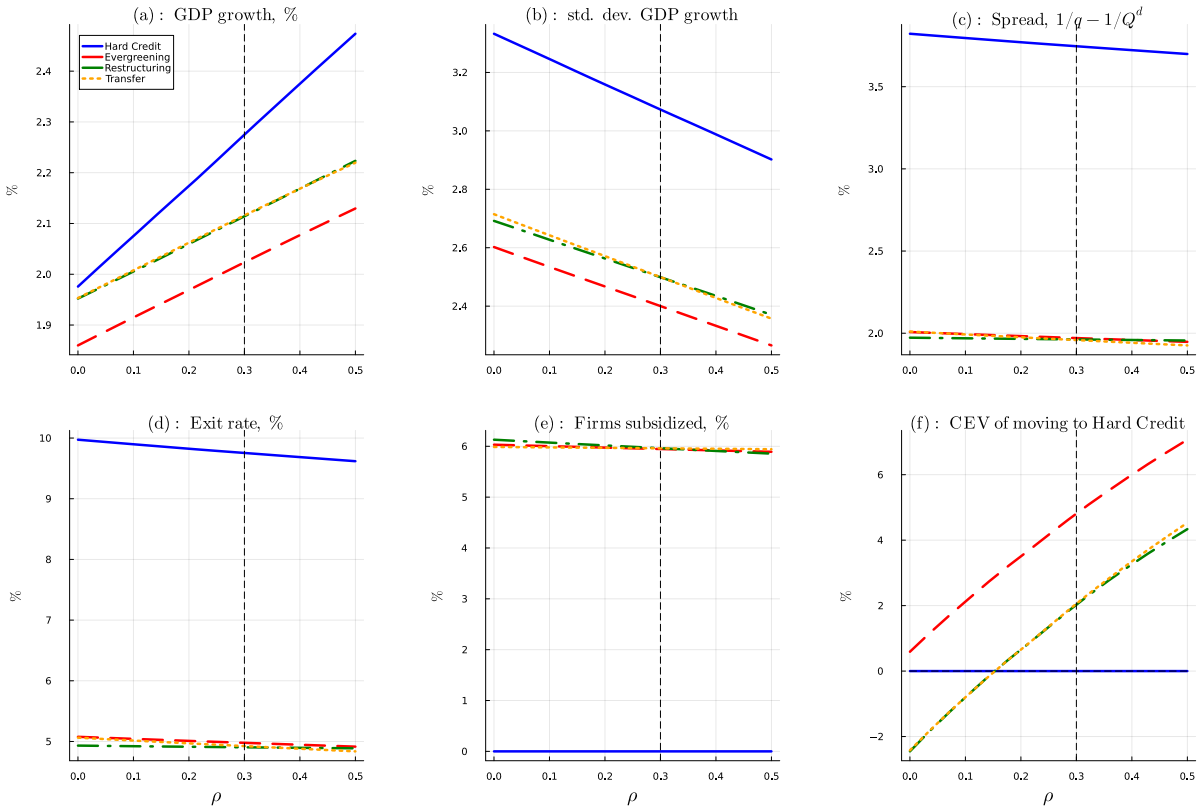


Figure 7: Comparative statics with respect to ρ.

Finally, panel (f) shows the effect of ρ on welfare. Specifically, we report again the CEV of moving to the hard credit economy. As documented in Table 4, the hard credit economy obtains the highest welfare for our benchmark calibration with $\rho = 0.3$, outperforming the restructuring and the transfer economies by around 2%, and the evergreening economy by around 4.8%. Higher values of ρ only intensify these differences. It is only at about half of its benchmark value, so around $\rho = 0.15$, that welfare in the hard credit, the restructuring, and the transfer economies equalize. For lower values of ρ, the stabilization benefits start to outweigh growth differences, such that the restructuring and the transfer economies begin to outperform the hard credit economy. In contrast, due to its distortionary effects on the labor market, the evergreening economy always performs worse than the hard credit economy.

References

Acemoglu, Daron, Ufuk Akcigit, Harun Alp, Nicholas Bloom and William Kerr. 2018. "Innovation, Reallocation, and Growth." *American Economic Review* 108(11):3450–91.

Aghion, Philippe and Peter Howitt. 1992. "A Model of Growth through Creative Destruction." *Econometrica* 60(2):323–351.

Bloom, Nicholas, Mark Schankerman and John Van Reenen. 2013. "Identifying Technology Spillovers and Product Market Rivalry." *Econometrica* 81(4):1347–1393.

Boppart, Timo and Per Krusell. 2020. "Labor Supply in the Past, Present, and Future: A Balanced-Growth Perspective." *Journal of Political Economy* 128(1):118–157.

Brunnermeier, Markus K. and Yuliy Sannikov. 2014. "A Macroeconomic Model with a Financial Sector." *American Economic Review* 104(2):379–421.

Caballero, Ricardo, Takeo Hoshi and Anil Kashyap. 2008. "Zombie Lending and Depressed Restructuring in Japan." *American Economic Review* 98(5):1943–1977.

Christiano, Lawrence J., Martin Eichenbaum and Charles L. Evans. 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." *Journal of Political Economy* 113(1):1–45.

Crane, Leland D., Ryan A. Decker, Aaron Flaaen, Adrian Hamins-Puertolas and Christopher Kurz. 2022. "Business exit during the COVID-19 pandemic: Non-traditional measures in historical context." *Journal of Macroeconomics* 72(C):None.

Faria-e-Castro, Miguel. 2024. "Fiscal Multipliers and Financial Crises." *The Review of Economics and Statistics* 106(3):728–747.

Faria-e-Castro, Miguel, Pascal Paul and Juan M. Sánchez. 2024. "Evergreening." *Journal of Financial Economics* 153(C).

Gilchrist, Simon and Egon Zakrajsek. 2012. "Credit Spreads and Business Cycle Fluctuations." *American Economic Review* 102(4):1692–1720.

Glaeser, Stephen and Jaeho Yoo. 2025. "Is Innovating Risky? The Effects of R&D on Idiosyncratic and Systematic Firm Risk." *SSRN Working Paper* .

Gomes, Joao, Urban Jermann and Lukas Schmid. 2016. "Sticky Leverage." *American Economic Review* 106(12):3800–3828.

Greenwood, Jeremy, Pengfei Han and Juan M. Sánchez. 2022. "Financing Ventures." *International Economic Review* 63(3):1021–1053.

Kermani, Amir and Yueran Ma. 2020. Asset Specificity of Non-Financial Firms. Working Paper 27642 National Bureau of Economic Research.

King, Robert G., Charles I. Plosser and Sergio T. Rebelo. 1988. "Production, growth and business cycles : I. The basic neoclassical model." *Journal of Monetary Economics* 21(2-3):195–232.

Kornai, Janos, Eric Maskin and Geard Roland. 2003. "Understanding the Soft Budget Constraint." *Journal of Economic Literature* 41(4):1095–1136.

Lagos, Ricardo and Randall Wright. 2005. "A Unified Framework for Monetary Theory and Policy Analysis." *Journal of Political Economy* 113(3):463–484.

Lee, Yoonsoo and Toshihiko Mukoyama. 2015. "Entry and exit of manufacturing plants over the business cycle." *European Economic Review* 77(C):20–27.

Lucas, Robert E. 2009. "Ideas and Growth." *Economica* 76(301):1–19.

Lucas, Robert E. and Benjamin Moll. 2014. "Knowledge growth and the allocation of time." *Journal of Political Economy* 122(1):1–51.

Ottonello, Pablo and Thomas Winberry. 2020. "Financial Heterogeneity and the Investment Channel of Monetary Policy." *Econometrica* 88(6):2473–2502.

Peek, Joe and Eric S. Rosengren. 2005. "Unnatural Selection: Perverse Incentives and the Misallocation of Credit in Japan." *American Economic Review* 95(4):1144–1166.

Perla, Jesse and Christopher Tonetti. 2014. "Equilibrium Imitation and Growth." *Journal of Political Economy* 122(1):52–76.

Philippon, Thomas. 2015. "Has the US Finance Industry Become Less Efficient? On the Theory and Measurement of Financial Intermediation." *American Economic Review* 105(4):1408–38.

Richter, Alexander, Nathaniel Throckmorton and Todd Walker. 2014. "Accuracy, Speed and Robustness of Policy Function Iteration." *Computational Economics* 44(4):445–476.

Schumpeter, Joseph A. 1939. *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process*. New York: McGraw-Hill.

Vereshchagina, Galina. 2023. "Financial constraints and economic development: the role of firm productivity investment." *Review of Economic Dynamics* 51(None):322–342.

Wilson, Daniel J. 2009. "Beggar Thy Neighbor? The In-State, Out-of-State, and Aggregate Effects of R&D Tax Credits." *The Review of Economics and Statistics* 91(2):431–436.

A Model Appendix

A.1 Intraperiod equilibrium conditions

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

A.1.1 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.1.2 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.1.3 Restructuring

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

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

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.1.4 Fiscal transfers

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 is in the transfer region:

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

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.2 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:

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

$$[b']: \quad q - \mathbb{E}_{\zeta'|\zeta} \left\{ M(s',s) \int_{\bar{\varepsilon}(s')}^{\infty} \mathrm{d}F(\varepsilon') \right\} - \lambda = 0 \tag{19}$$

$$[z']: \quad -\phi \left[\frac{z'}{z(\varepsilon^*)^\rho} \right]^\kappa \frac{\kappa}{z'} + \mathbb{E}_{\zeta'|\zeta} \left\{ M(s',s) \int_{\bar{\varepsilon}(s')}^{\infty} \varepsilon' \left[\frac{\eta}{w(1+\omega)} \right]^{\frac{\eta}{1-\eta}} (1-\eta)(\zeta' k')^{\frac{\alpha}{1-\eta}} \mathrm{d}F(\varepsilon') \right\} = 0 \tag{20}$$

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.1. 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:

$$\begin{aligned} q = {} & \mathbb{E}_{\zeta'|\zeta} M(s',s) \left\{ \int_{\bar{\varepsilon}(s')}^{\infty} \mathrm{d}F(\varepsilon') + \int_{\underline{\varepsilon}(s')}^{\bar{\varepsilon}(s')} \frac{b' + \eta[\nu - (1-\delta)(\zeta' k') - V']}{b'(1-\eta)} \mathrm{d}F(\varepsilon') \right\} \\ & - \mathbb{E}_{\zeta'|\zeta} M(s',s) \left\{ \int_{\underline{\varepsilon}(s')}^{\bar{\varepsilon}(s')} \frac{w'(1+\omega)}{b'} \left(\frac{b' + \nu - (1-\delta)(\zeta' k') - V'}{(1-\eta)(z'\varepsilon')^{1-\eta}(\zeta' k')^{\alpha}} \right)^{\frac{1}{\eta}} \mathrm{d}F(\varepsilon') \right\} \\ & + \mathbb{E}_{\zeta'|\zeta} M(s',s) \left\{ \int_{0}^{\underline{\varepsilon}(s')} \min\left[1, \frac{(1-\lambda)\zeta' k'}{b'}\right] \mathrm{d}F(\varepsilon') \right\} \end{aligned} \tag{21}$$

A.3 Full list of equilibrium conditions for the evergreening economy

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

A.4 Welfare

In this appendix, we explain how to obtain a recursive formulation for welfare that allows comparisons between economies.

Time-0 welfare comparisons. Comparing economies with different growth rates is not trivial since they will presumably have different detrending factors Z. Our welfare comparisons are based on assumptions that both economies start out with identical levels of Z_0, similar to the assumptions in Acemoglu et al. (2018).

EIS different than 1, $\sigma \neq 1$. When the EIS is different than 1, a recursive formulation for welfare is trivial and given by

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

where $\tilde{C}$ is detrended consumption, and $\tilde{\mathcal{U}}$ is equal to $\mathcal{U} \times Z^{(1-\sigma)\frac{1-\eta}{1-\alpha}}$. Thus welfare comparisons across economies are valid as long as the comparison starts at a point where both economies have the same Z, which we assume throughout the paper. Note that the above formulation is not valid for the case $\sigma = 1$, when King, Plosser and Rebelo (1988) preferences become separable. We treat this case separately next.

EIS equal to 1, $\sigma = 1$. To derive a recursive formulation for welfare under separable preferences, it is convenient to start from the sequential formulation of welfare:

$$W_t = \sum_{i=0}^{\infty} \beta^i \left[\log(C_{t+i}) - \chi \frac{N_{t+i}^{1+\varphi}}{1+\varphi} \right]$$

Detrend consumption to obtain

$$W_t = \sum_{i=0}^{\infty} \beta^i \left[\log(\tilde{C}_{t+i}) - \chi \frac{N_{t+i}^{1+\varphi}}{1+\varphi} + \frac{1-\eta}{1-\alpha} \log Z_{t+i} \right]$$

Now subtract $\frac{1-\eta}{1-\alpha}\log Z_t \frac{1}{1-\beta}$ from both sides to write

$$W_t - \frac{1}{1-\beta}\frac{1-\eta}{1-\alpha}\log Z_t = \sum_{i=0}^{\infty}\beta^i\left[\log(\tilde{C}_{t+i}) - \chi\frac{N_{t+i}^{1+\varphi}}{1+\varphi} + \frac{1-\eta}{1-\alpha}\log(Z_{t+i}/Z_t)\right]$$
$$= \underbrace{\sum_{i=0}^{\infty}\beta^i\left[\log(\tilde{C}_{t+i}) - \chi\frac{N_{t+i}^{1+\varphi}}{1+\varphi}\right]}_{\nu_{1,t}} + \underbrace{\sum_{i=0}^{\infty}\beta^i\left[\frac{1-\eta}{1-\alpha}\log(Z_{t+i}/Z_t)\right]}_{\nu_{2,t}}$$

The $\nu_{1,t}$ term is simple and can be written recursively as

$$\nu_{1,t} = \log(\tilde{C}_t) - \chi\frac{N_t^{1+\varphi}}{1+\varphi} + \beta\nu_{1,t+1}$$

The $\nu_{2,t}$ term requires some extra work. Expand the summation to write:

$$\begin{aligned}\nu_{2,t} &= \frac{1-\eta}{1-\alpha}\left[0 + \beta\log G_t + \beta^2[\log G_t + \log G_{t+1}] + \beta^3[\log G_t + \log G_{t+1} + \log G_{t+2}] + \ldots\right]\\ &= \frac{1-\eta}{1-\alpha}\left[\beta\log G_t\sum_{i=0}^{\infty}\beta^i + \beta^2\log G_{t+1}\sum_{i=0}^{\infty}\beta^i + \beta^3\log G_{t+2}\sum_{i=0}^{\infty}\beta^i + \ldots\right]\\ &= \frac{1-\eta}{1-\alpha}\frac{1}{1-\beta}\sum_{i=1}^{\infty}\beta^i\log G_{t-1+i}\end{aligned}$$

Thus we can write this term recursively as

$$\nu_{2,t} = \frac{1-\eta}{1-\alpha}\frac{\beta}{1-\beta}\log G_t + \beta\nu_{2,t+1}$$

We can therefore write welfare recursively as

$$\nu_t = \log(\tilde{C}_t) - \chi\frac{N_t^{1+\varphi}}{1+\varphi} + \frac{1-\eta}{1-\alpha}\frac{\beta}{1-\beta}\log G_t + \beta\mathbb{E}\nu_{t+1}$$

where ν_t is detrended welfare, equal to

$$\nu_t = W_t - \frac{1}{1-\beta}\frac{1-\eta}{1-\alpha}\log Z_t.$$

As with the previous case, time-0 welfare comparisons are valid for economies with the same Z_0.

B Firm Policies and Default Thresholds

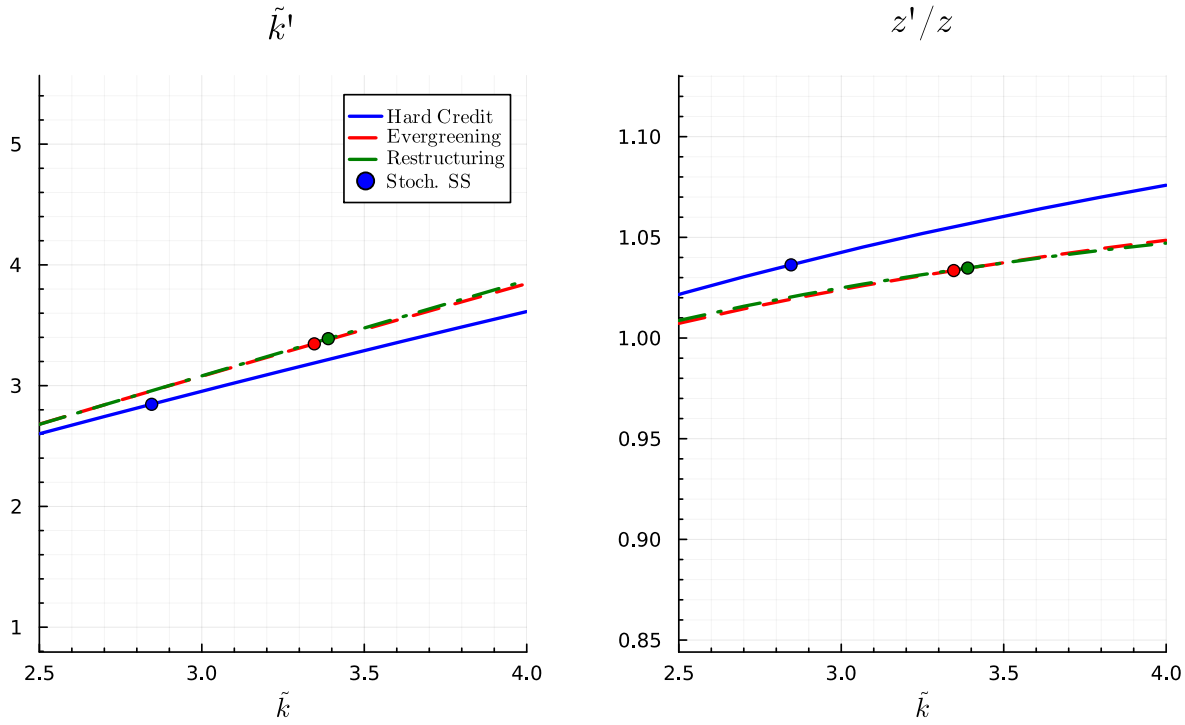


Figure 8: Firm policy functions for detrended physical capital $\tilde{k}'$ and R&D z' for evergreening, restructuring, and hard credit economies. The dots indicate the stochastic steady state of each respective economy.

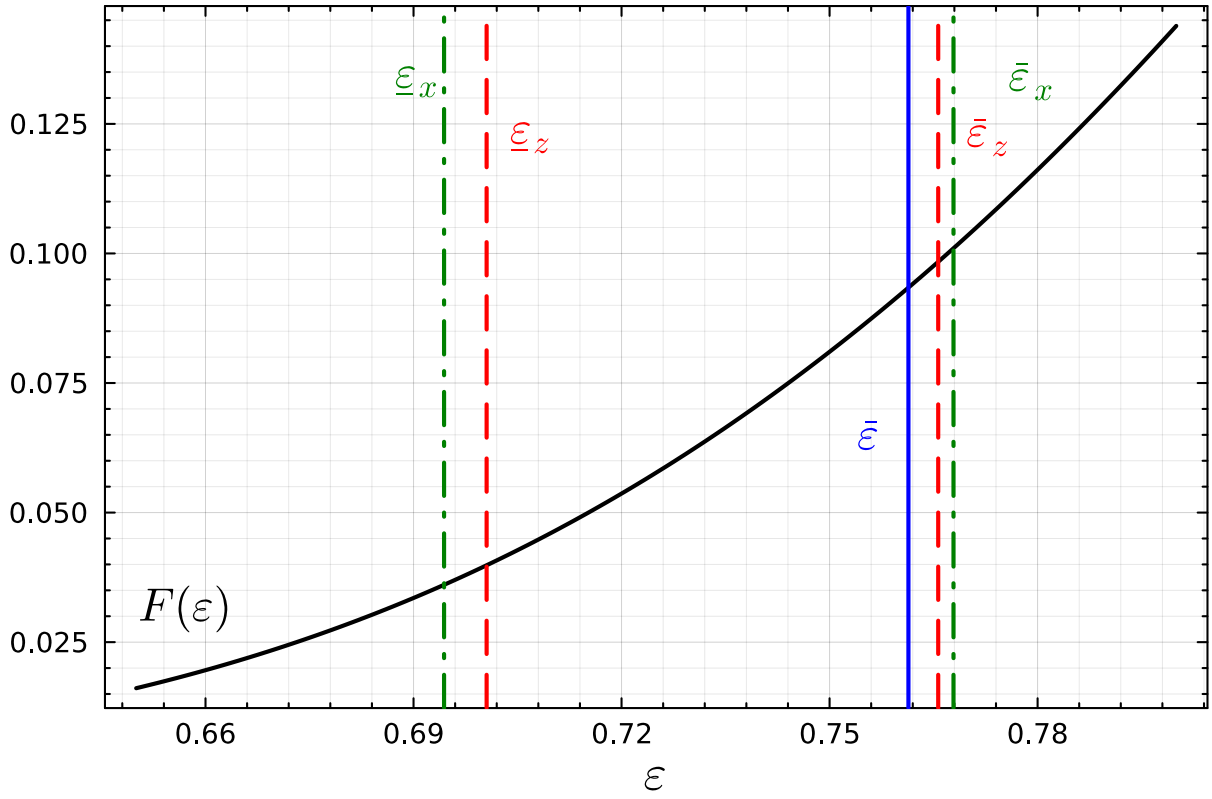


Figure 9: Probability distribution function of idiosyncratic productivity, liquidation and distress thresholds in the evergreening economy (red), the restructuring economy (green), and liquidation threshold in the hard credit economy (blue).