Online Appendix

The Rise and Evolution of the Innovative Firm: A Tale of Technology, Market Structure, and Managerial Incentives

Domenico Ferraro Maurizio Iacopetta Pietro F. Peretto

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A. Additional Theoretical Analysis

A.1. The contract and global optimality

The compensation and employment conditions have the same right-hand side. Dividing them yields $\xi/[1-\xi+h/(1-h)] = 1$, hence $h^* = 1 - 1/(2\xi)$. For the maintained decreasing-returns specification, $1/2 < \xi < 1$ gives an interior effort choice. The incentive condition then gives $a = 2\varepsilon {h^*}^{1-\xi}/\pi$. Substituting this expression into the employment condition yields the delegation threshold $\pi_D = 2\varepsilon\mu/{h^*}^{2\xi-1}$ and the closed-form rules in Proposition 1.

For a fixed h, define $x = h^{\xi}/a$. The owner's retained productivity is a concave quadratic in m. When $x > \mu$, its maximum is $(x+\mu)^2/(4x)$; otherwise the owner operates alone. Since the former increases in x, the global choice reduces to maximizing $x = (\pi\xi/\varepsilon)h^{2\xi-1}(1-h)$. Its unique maximum is h^*. This establishes global optimality within the symmetric contract class when participation is slack. For $\xi = 1$, the same derivation gives $h^* = 1/2$ and $\pi_D = 4\varepsilon\mu$.

A.2. Steady-state branches and local stability

Let $\ell = \Lambda/N = K\pi^{1/\gamma} + m(\pi)$ denote employment per firm, where

$$K = [(1-\theta)\theta^{(1+\theta)/(1-\theta)}\Omega^{1-\gamma}]^{-1/\gamma}.$$

On the active-R&D branch,

$$z_{NA} = \frac{\beta\alpha - 1 + ma}{\beta - 1} M\pi - \phi, \qquad z_{GE} = \alpha M\pi - \phi - \rho.$$

At zero R&D the entry return is $r = (1 - ma)M\pi/\beta - \phi/\beta$, and a stationary corner requires $r = \rho$ and $\alpha M\pi - \phi \leq \rho$. The household budget gives

$$n = r - z + \frac{M\pi}{\beta\theta} + \frac{maM\pi}{\beta} - \frac{c\ell}{\beta},$$
$$\dot{\pi} = \frac{\ell}{\ell'}(\lambda - n), \qquad \dot{c} = c(r - z - \rho).$$

These equations include managerial income within the household. At a positive-R&D steady state, with $\mathcal{R} = r - z - \rho$, the Jacobian in (π, c) order is

$$J = \begin{pmatrix} -(\ell/\ell')n_\pi & \ell^2/(\beta\ell') \\ c\mathcal{R}' & 0 \end{pmatrix}, \qquad \det J = -\frac{c\ell^2}{\beta\ell'}\mathcal{R}'.$$

Thus $\mathcal{R}' > 0$ implies a saddle. When $\mathcal{R}' < 0$, stability depends additionally on the trace; stable nodes or foci are possible and imply local indeterminacy with one state and one jumping variable. The sign cannot be inferred solely from root multiplicity.

Proposition 1 (Number of admissible steady states) *Suppose $\beta > 1$ and managerial participation is slack. Across the owner-managed, delegation, zero-R&D, and positive-R&D branches, the model has at most two admissible steady states.*

Proof. With positive R&D, a steady state satisfies

$$\frac{1 - \alpha - m(\pi)a(\pi)}{\beta - 1} M(\pi)\pi = \rho.$$

Without delegation, the left-hand side is linear and increasing in π. On the delegation branch it is

$$\frac{\mu}{4(\beta - 1)\pi_D}\left[(1 - 2\alpha)\pi^2 + 2(1 - \alpha)\pi_D\pi + \pi_D^2\right].$$

For $\alpha \leq 1/2$ this expression is increasing, so there is at most one positive-R&D steady state. For $\alpha > 1/2$ it is concave and can have two roots. At π_D it equals

$$\frac{1 - \alpha}{\beta - 1}\mu\pi_D.$$

An owner-managed positive-R&D root requires ρ to be no larger than this value. Two delegation roots require the delegation expression to start below ρ and subsequently rise above it before declining, which requires the opposite strict inequality. Hence an owner-managed root and two delegation roots cannot coexist. If the delegation expression is already decreasing at π_D, it can have at most one admissible delegation root.

It remains to consider the zero-R&D corner. A stationary zero-R&D equilibrium satisfies

$$\frac{[1 - m(\pi)a(\pi)]M(\pi)\pi - \phi}{\beta} = \rho, \qquad \alpha M(\pi)\pi - \phi \leq \rho.$$

The entry return is increasing on each applicable contract branch and continuous at π_D, so there is at most one such corner. Let π_Z denote the unique R&D activation threshold. If a zero-R&D steady state is admissible, it lies weakly below π_Z. At π_Z, the entry and innovation returns coincide and the entry return is therefore weakly above ρ. Since $z = 0$ at the activation threshold, the positive-R&D steady-state expression is also weakly above ρ at π_Z. If the positive-R&D condition has two algebraic roots, concavity then places π_Z weakly between them. The smaller root is therefore below the R&D activation threshold and is inadmissible; at most the larger positive-R&D root remains. Thus the zero-R&D corner can coexist with at most one admissible positive-R&D steady state. ■

A.3. A sufficient condition excluding binding participation at steady states

Let $F = \pi(1 - ma)M$. Free entry and the Euler equation require $F = \phi + \beta\rho + (\beta - 1)z$. For $\beta > 1$ and $z \geq 0$, this is bounded below by $F_0 = \phi + \beta\rho$. Let F_u be the unconstrained optimum: $F_u = \mu\pi$ below π_D, and $\mu(\pi + \pi_D)^2/(4\pi_D)$ above it. Because constrained profit cannot exceed F_u, every steady state satisfies $\pi \geq \underline{\pi}$, where $F_u(\underline{\pi}) = F_0$.

Suppose $\underline{\pi} > \pi_D$. An optimal delegating firm can always choose founder-only operation, so $F \geq \mu\pi$. Consequently $M \leq h^{\xi}/a \leq \mu\pi/\pi_D$. The same bound covers no delegation in this region. General-equilibrium wages therefore satisfy

$$w/Z = \frac{\gamma\pi M}{\theta K \pi^{1/\gamma}} \leq \frac{\gamma\mu}{\theta K \pi_D}\pi^{2-1/\gamma}.$$

The unconstrained manager's net payoff is

$$U_u = \frac{h^{*\xi}}{2}(\pi + \pi_D) + \varepsilon \log(1 - h^*).$$

Proposition 2 (Global participation condition) *If* $\underline{\pi} > \pi_D$ *and*

$$\inf_{\pi \geq \underline{\pi}} \frac{h^{*\xi}(\pi + \pi_D)/2 + \varepsilon \log(1 - h^*)}{[\gamma\mu/(\theta K \pi_D)]\pi^{2-1/\gamma}} > 1,$$

participation is strictly slack at every symmetric steady state with $z \geq 0$*. Hence binding participation cannot create additional steady states.*

Proof. The wage bound applies to any optimal candidate contract. The stated inequality makes the unconstrained global optimum feasible at that wage. The owner therefore selects it. ■ If $h^{*\xi}\pi_D/2 + \varepsilon \log(1 - h^*) > 0$ and $1/2 < \gamma < 1$, the ratio has its minimum on the admissible region at

$$\max\left\{\underline{\pi}, \frac{2\gamma - 1}{1 - \gamma}\left[\pi_D + \frac{2\varepsilon \log(1 - h^*)}{h^{*\xi}}\right]\right\}.$$

This is a sufficient parameter restriction, not an unconditional claim about all calibrations or transition paths.

A.4. The shape of the $\dot{\pi} = 0$ locus

For the derivations in this subsection, define $K \equiv [(1 - \theta)\theta^{(1+\theta)/(1-\theta)}\Omega^{1-\gamma}]^{-1/\gamma}$, so that $\ell \equiv \Lambda/N = K\pi^{1/\gamma} + m(\pi)$. Equation (35) then implies that the $\dot{\pi} = 0$ locus satisfies

$$c(\pi) = \frac{\beta}{\ell}\left[r(\pi) - z(\pi) + \frac{M(\pi)\pi}{\beta\theta} + \frac{m(\pi)a(\pi)M(\pi)\pi}{\beta} - \lambda\right]. \tag{A.1}$$

Because $\ell' > 0$, differentiation gives

$$\begin{aligned}\operatorname{sign} c'(\pi) = \operatorname{sign}\Bigg\{ & \ell \frac{d}{d\pi}\left[r - z + \frac{M\pi}{\beta\theta} + \frac{maM\pi}{\beta}\right] \\ & - \ell'\left[r - z + \frac{M\pi}{\beta\theta} + \frac{maM\pi}{\beta} - \lambda\right]\Bigg\}.\end{aligned} \tag{A.2}$$

Thus the slope depends on the growth of the resources available for entry relative to the growth of labor per firm. It is not signed globally by the primitives of the model.

On the owner-managed positive-R&D branch, $m = 0$, $M = \mu$, and

$$r - z = \frac{1 - \alpha}{\beta - 1}\mu\pi.$$

Hence

$$c(\pi) = \frac{\beta}{K\pi^{1/\gamma}} \left\{ \mu \left[\frac{1-\alpha}{\beta-1} + \frac{1}{\beta\theta} \right] \pi - \lambda \right\}. \tag{A.3}$$

For $0 < \gamma < 1$, an extension of this branch eventually slopes downward. In equilibrium, however, the owner-managed branch terminates at π_D whenever delegation occurs before that turning point.

On the delegation branch with positive R&D,

$$m(\pi) = \frac{\mu}{2h^{*\xi}} \left(\frac{\pi}{\pi_D} - 1 \right), \qquad \ell = K\pi^{1/\gamma} + m(\pi).$$

Direct substitution into (A.1) shows that the expression in square brackets is quadratic in π. Its leading coefficient is

$$\frac{\mu[-2\alpha\beta\theta + 2\beta\theta + 2\beta - \theta - 2]}{4\beta(\beta-1)\pi_D\theta}.$$

When this coefficient is positive, the large-π behavior of the locus is

$$c(\pi) \sim \frac{\mu[-2\alpha\beta\theta + 2\beta\theta + 2\beta - \theta - 2]}{4(\beta-1)\pi_D\theta K} \pi^{2-1/\gamma}. \tag{A.4}$$

It follows that the delegation branch is eventually decreasing for $\gamma < 1/2$ and eventually increasing for $\gamma > 1/2$; at $\gamma = 1/2$ it approaches a constant to first order. These are asymptotic statements. In particular, $\gamma > 1/2$ does not imply global monotonicity. The exact condition is (A.2). The model therefore permits both a hump-shaped $\dot{\pi} = 0$ locus and a locus that is increasing over the economically relevant domain.

The slope of this locus also determines the trace of the Jacobian. From the system in Appendix A.2,

$$\frac{\partial \dot{\pi}}{\partial c} = \frac{\ell^2}{\beta \ell'} > 0.$$

Implicit differentiation of $\dot{\pi} = 0$ therefore yields

$$c'(\pi) = -\frac{\partial \dot{\pi}/\partial \pi}{\partial \dot{\pi}/\partial c},$$

so that

$$\operatorname{sign}(\operatorname{tr} J) = -\operatorname{sign} c'(\pi^*). \tag{A.5}$$

At the smaller root of a two-root positive-R&D configuration, $\mathcal{R}' > 0$, so $\det J < 0$ and

the steady state is a saddle. At the larger root, $\mathcal{R}' < 0$, so $\det J > 0$. Equation (A.5) then gives

$$c'(\pi^*) > 0 \implies \text{stable node or stable focus,}$$
$$c'(\pi^*) < 0 \implies \text{unstable node or unstable focus.}$$

The distinction between node and focus depends on the discriminant of the Jacobian and cannot be inferred from the nullclines alone. Thus the shape of the $\dot{\pi} = 0$ locus does not change the maximum number of steady states established above, but it changes the local dynamics of the larger steady state.

B. Calibration Details

This appendix reports the equilibrium restrictions used to construct the baseline calibration summarized in Table 1. The calculations proceed sequentially so that the empirical role of each moment is transparent.

B.1. Baseline calibration

We calibrate the model to long-run features of the U.S. economy. The main case sets $\lambda = 0.011$ and $\theta = 0.45$, using the intermediate-input share described in Section 8.1 of the paper. We set the firm-specific knowledge elasticity $\alpha = 0.33$, following Iacopetta and Peretto (2021). At the main parameterization, the selected positive-R&D steady state is a local saddle.

Growth, returns, and innovation. Along the balanced growth path, the Euler equation gives

$$r = \rho + z. \tag{B.1}$$

We set the growth rate of firm-level knowledge and real income per capita to $z = 0.02$, consistent with the long-run U.S. growth evidence in Jones (2016), and the real interest rate to $r = 0.055$, the midpoint between the after-tax return to business capital and the return to the S&P 500 calculated by Gomme et al. (2011). Hence,

$$\rho = r - z = 0.035. \tag{B.2}$$

Let $v = A/GDP$ denote the wealth-to-GDP ratio and s_R incumbent R&D expenditure as a share of GDP. Steady-state accounting gives

$$s_R = \frac{vz}{\beta}, \qquad \beta = \frac{vz}{s_R}. \tag{B.3}$$

Using $v = 4$ and $s_R = 0.0148$ yields

$$\beta = 5.4054. \tag{B.4}$$

Thus, the wealth embodied in firms, the rate at which their knowledge grows, and the resources devoted to incumbent R&D jointly discipline the cost of creating a new firm.

The wealth-to-GDP ratio satisfies

$$v = \frac{\beta\theta}{M\pi\left[1+\theta\left(1-\phi/(M\pi)\right)\right]}, \tag{B.5}$$

while the return to incumbent innovation is

$$r = \alpha M\pi - \phi. \tag{B.6}$$

Combining the two equations gives

$$M\pi = \frac{\beta/v - r}{(1+\theta)/\theta - \alpha}, \qquad \phi = \alpha M\pi - r. \tag{B.7}$$

At the baseline values,

$$M\pi = 0.4482, \qquad \phi = 0.0929. \tag{B.8}$$

The positive-R&D steady-state condition then determines the total fraction of firm cash flow paid to managers:

$$\rho(\beta - 1) = M\pi(1 - \alpha - ma), \tag{B.9}$$

and therefore

$$ma = 1 - \alpha - \frac{\rho(\beta-1)}{M\pi} = 0.3260. \tag{B.10}$$

Managerial compensation is consequently disciplined by the innovation and entry block before we use any evidence on managerial compensation itself.

Management. The contract implies

$$h = 1 - \frac{1}{2\xi}. \tag{B.11}$$

Managers work approximately 45 hours per week in our IPUMS-USA data. As a measurable counterpart of managerial effort, we use the fraction of available weekday time spent working,

$$h = \frac{45}{5\times 24} = 0.375. \tag{B.12}$$

Hours do not exhaust the concept of effort, which also captures the intensity and quality of managerial input, but they provide a direct empirical measure with which to discipline

it. The effort observation implies

$$\xi = \frac{1}{2(1-h)} = 0.8. \tag{B.13}$$

Our calculations using the Decennial Census and American Community Survey from IPUMS-USA and firm counts from the Business Dynamics Statistics yield $m = 2.12$ managers per firm. Since ma has already been determined by the innovation and entry restrictions,

$$a = \frac{ma}{m} = 0.1538. \tag{B.14}$$

The contract condition

$$(1 - ma)h^{\xi} = a(mh^{\xi} + \mu) \tag{B.15}$$

then identifies the owner's managerial input:

$$\mu = mh^{\xi}\left(\frac{1}{ma} - 2\right) = 1.0326. \tag{B.16}$$

Managerial services per firm are

$$M = \mu + mh^{\xi} = 1.9999, \tag{B.17}$$

so the identified product $M\pi$ implies

$$\pi = 0.2241. \tag{B.18}$$

Finally, the manager's effort condition,

$$\frac{h^{1-\xi}}{1-h} = \frac{\xi}{\varepsilon}a\pi, \tag{B.19}$$

identifies

$$\varepsilon = a\pi\xi(1-h)h^{\xi-1} = 0.0210. \tag{B.20}$$

Labor income and firm scale. The model implies

$$\frac{\text{Labor Income}}{GDP} = \frac{\theta ma + \gamma}{1 + \theta(1 - \phi/(M\pi))}. \tag{B.21}$$

Let s_L denote the labor share of GDP. Solving for γ gives

$$\gamma = s_L \left[1 + \theta \left(1 - \frac{\phi}{M\pi}\right)\right] - \theta ma. \tag{B.22}$$

We set $s_L = 0.65$, consistent with Koh et al. (2020), which yields

$$\gamma = 0.7352. \tag{B.23}$$

The managerial employment share supplies the remaining information about firm scale. Let $f = mN/\Lambda$ denote managers as a fraction of total employment. Our IPUMS-USA calculations give $f = 0.075$. Hence,

$$\frac{\Lambda}{N} - m = \frac{m(1-f)}{f} = 26.15. \tag{B.24}$$

The symmetric production relation then identifies the fixed factor endowment:

$$\Omega = \left[\frac{\pi}{(1-\theta)\theta^{(1+\theta)/(1-\theta)}\left[m(1-f)/f\right]^{\gamma}}\right]^{1/(1-\gamma)}. \tag{B.25}$$

At the baseline calibration, $\Omega = 0.0111$. This endowment is identified by the managerial employment share through the equilibrium production relation.

The calibration has a nearly recursive structure. External evidence disciplines λ, θ, and α. Long-run growth and returns identify ρ. Wealth, growth, and incumbent R&D identify β. The wealth and no-arbitrage restrictions then determine $M\pi$, ϕ, and the total managerial compensation fraction ma. Managerial effort identifies ξ; managers per firm then identify individual managerial compensation and the owner's managerial input, and the effort condition determines ε. The aggregate labor share identifies γ, while the managerial employment share identifies Ω.

The procedure leaves additional managerial evidence unused in identifying the parameters. In particular, we do not target managers' share of aggregate labor compensation or managers' compensation relative to production workers. The calibrated model predicts both. The main calibration predicts a managerial share of labor compensation of 0.166 and managerial compensation per worker equal to 2.46 times the non-manager wage. These untargeted moments provide additional evidence on the contract and the model's allocation of labor income.

The analytical structure makes the sources of identification transparent. Observed

quantities enter specific equilibrium restrictions, those restrictions identify structural parameters, and parameters identified at one stage become inputs into the next. Untargeted moments then provide an independent assessment of dimensions of managerial organization that the model was not calibrated to reproduce.

The same logic applies to the model's dynamic implications. The empirical content of a dynamic growth model is not exhausted by its steady-state restrictions. Once the parameters are disciplined by the long-run restrictions above, the equilibrium laws of motion determine transition paths without additional parameters chosen to fit those paths. We therefore use impulse responses as quantitative implications of the calibrated theory rather than as additional calibration targets.

Accounting relationships. The GDP measure used in the calibration is

$$G = Y - NX - \phi NZ = \frac{NZM\pi D}{\theta}.$$

It follows that

$$\frac{A}{G} = \frac{\beta\theta}{M\pi D'}, \qquad \frac{W_{\text{labor}}}{G} = \frac{\gamma + \theta ma}{D}, \qquad \frac{R_\Omega}{G} = \frac{1-\gamma}{D}, \qquad \frac{S_I}{G} = \frac{\theta(1 - ma - \phi/(M\pi))}{D},$$

where $D = 1 + \theta(1 - \phi/(M\pi))$. At a steady state,

$$\frac{S_I}{G} = v\rho + \frac{vz}{\beta}.$$

Aggregate nonlabor income adds no independent restriction once the labor share is targeted, while incumbent R&D expenditure relative to GDP identifies β given v and z. If f denotes the managerial employment share and s_M the managerial share of labor compensation, relative compensation per manager is

$$R = \frac{s_M}{1 - s_M}\frac{1-f}{f}.$$

Hourly relative wages require the corresponding hours adjustment.

B.2. Calibration for the three-economy comparison

For the three-economy comparison, set $\theta = 0.45$ and $\lambda = 0.011$. The common targets are $z = 0.02$, $r = 0.055$, and $s_L = 0.65$. For the endogenous-manager economy, the remaining

targets and the recursive restrictions above give the input-share column of Table 1. The resulting total managerial compensation fraction is $ma = 0.3260$.

With $m = 1$, the target for managers per firm is replaced by the organizational restriction. The aggregate entry and innovation restrictions continue to determine $M\pi$, ϕ, and the total compensation fraction, now $a = 0.3260$. Retaining $\xi = 0.8$ and targeting $h = 0.375$, the one-manager contract determines

$$\mu = h^{\xi}\frac{\xi(1-h)-a}{a(1-\xi+\xi h)}, \qquad \pi = \frac{M\pi}{\mu + h^{\xi}}, \qquad \varepsilon = a\pi\xi(1-h)h^{\xi-1}.$$

The first expression follows from the one-manager owner's effort condition, rather than the unrestricted managerial-employment condition. These restrictions give $\mu = 0.4871$ and $\varepsilon = 0.0942$. The labor-share restriction retains $\gamma = 0.7352$. The managerial employment share $f = 0.075$ implies $\Lambda/N = 1/f$, identifying $\Omega = 1.5256$. Thus the changes in managerial technology and firm scale follow from matching the retained managerial targets under $m = 1$.

With $m = 0$, the growth and return restrictions instead imply

$$M\pi = \frac{\rho(\beta-1)}{1-\alpha}, \qquad \phi = \alpha M\pi - r, \qquad \gamma = s_L\left[1+\theta\left(1-\frac{\phi}{M\pi}\right)\right].$$

They give $M\pi = 0.2301$, $\phi = 0.0209$, and $\gamma = 0.9159$. The managerial targets are absent. We retain the full economy's μ and Ω, so employment per firm is determined by the production relation. This restriction preserves a common fixed-factor endowment rather than imposing a new employment-per-firm normalization. The entry-cost parameter β is retained from the full calibration; the owner-managed economy matches the common growth, return, and labor-share targets, but does not separately reproduce the full economy's wealth-to-GDP and incumbent R&D-to-GDP ratios. The innovation and entry restrictions explain why the operating cost must change when managerial compensation is removed.

Holding every full-economy primitive fixed gives a different result. The owner-managed positive-R&D candidate implies $z \simeq -0.052$, and the one-manager candidate implies $h \simeq 0.4697$ and $z \simeq -0.0189$. These candidates are inadmissible under nonnegative investment. The organizational restriction can therefore move the economy outside the positive-R&D regime. The common-primitive imposed owner-managed corner instead has $M\pi = \phi + \beta\rho \simeq 0.2821$, $r = \rho$, and $z = 0$. This regime change is distinct from

the target-preserving path comparison in Section 8.3.

C. The Model with One Manager per Firm

This appendix considers a restricted version of the model in which a delegating firm employs one manager. The exercise serves two purposes. First, it shows which results follow from delegation itself rather than from the firm's choice of the number of managers. Second, the modular structure of the calibration allows the restricted model to be disciplined by essentially the same long-run moments as the baseline economy.

C.1. Delegation with one manager

Set $m = 1$ whenever the owner delegates. Managerial services are then

$$M = \mu + h^{\xi}. \tag{C.1}$$

The manager's incentive condition is

$$a\pi\xi h^{\xi-1} = \frac{\varepsilon}{1-h}, \tag{C.2}$$

or

$$a = \frac{\varepsilon h^{1-\xi}}{\pi\xi(1-h)}. \tag{C.3}$$

The owner chooses the contract taking into account the induced managerial effort. Substituting (C.3) into retained operating cash flow gives

$$(1-a)(\mu + h^{\xi})\pi. \tag{C.4}$$

The first-order condition for an interior effort choice can be written as

$$\pi = \frac{\varepsilon h^{1-2\xi}\left[h^{\xi} + \mu(1-\xi+\xi h)\right]}{\xi^2(1-h)^2}. \tag{C.5}$$

Thus the fixed-manager restriction changes an important property of the contract. In the baseline model, the joint choice of managerial employment and compensation makes effort per manager constant on the delegation branch. With one manager, the employment margin is absent and managerial effort responds to profitability.

Delegation occurs when the value generated by the contract exceeds the value from

owner management. The threshold is therefore determined by

$$\max_{0<h<1} \left\{ [1 - a(h, \pi)](\mu + h^{\xi})\pi \right\} = \mu\pi, \tag{C.6}$$

with $a(h, \pi)$ given by (C.3). This preserves an endogenous extensive margin of delegation even though managerial employment conditional on delegation is fixed.

The innovation block retains the same structure as in the baseline model. By the envelope theorem, the derivative of optimized retained cash flow with respect to profitability is M. Since $d\pi_i/dZ_i = \alpha\pi_i/Z_i$, the return to firm-level innovation on the positive-R&D branch is

$$r = \alpha M\pi - \phi. \tag{C.7}$$

The no-arbitrage condition becomes

$$z_I = \frac{\beta\alpha - 1 + a}{\beta - 1} M\pi - \phi, \tag{C.8}$$

and a positive-R&D steady state satisfies

$$\frac{1 - \alpha - a}{\beta - 1} M\pi = \rho. \tag{C.9}$$

Hence fixing managerial employment changes the contract and the mapping from profitability into managerial services, but it does not change the basic interaction between delegation, innovation, and entry.

C.2. Uniqueness with one manager

The one-manager restriction isolates the intensive margin of managerial organization. Combining (C.2) and (C.5), the compensation share can be written as a function of effort alone:

$$a(h) = \frac{\xi h^{\xi}(1 - h)}{h^{\xi} + \mu(1 - \xi + \xi h)}. \tag{C.10}$$

The owner's first-order condition similarly defines profitability as

$$\pi(h) = \frac{\varepsilon h^{1-2\xi} \left[h^{\xi} + \mu(1 - \xi + \xi h) \right]}{\xi^2 (1 - h)^2}. \tag{C.11}$$

A positive-R&D steady state is therefore a solution of

$$\frac{[1-\alpha-a(h)](\mu+h^{\xi})\pi(h)}{\beta-1}=\rho. \tag{C.12}$$

Equations (C.10)–(C.12) make clear why the restricted model behaves differently from the baseline model. With one manager, profitability affects managerial services only through effort,

$$M(\pi)=\mu+h(\pi)^{\xi}.$$

Effort is costly and subject to diminishing returns. In the baseline model, by contrast, effort per manager is fixed at h^* on the delegation branch and profitability expands managerial services through employment:

$$M(\pi)=\mu+m(\pi)h^{*\xi}=\frac{\mu}{2}\left(1+\frac{\pi}{\pi_D}\right).$$

The extensive margin therefore provides a substantially stronger feedback from profitability to managerial services and, through the innovation return, back to profitability.

For the parameterization reported below, the left-hand side of (C.12) is strictly increasing on the economically relevant delegation branch. Hence it crosses ρ only once. The unique positive-R&D steady state has

$$h^*=0.375, \qquad \pi^*=1.2309.$$

The restricted economy thus retains endogenous delegation, endogenous managerial effort, and the complementarity between management and innovation, but it does not display the multiple-steady-state configuration of the baseline model. The comparison identifies the source of multiplicity: it is the scalability of delegated management through the extensive margin, rather than the intensive response of a single manager's effort.

C.3. Calibration

The restricted model can be calibrated with the same long-run discipline used in the baseline economy. The aggregate targets continue to imply

$$\rho=r-z, \qquad \beta=\frac{vz}{s_R}, \tag{C.13}$$

and the wealth and innovation-return restrictions determine $M\pi$ and ϕ. The positive-R&D steady-state condition then identifies the compensation share,

$$a = 1 - \alpha - \frac{\rho(\beta - 1)}{M\pi}. \tag{C.14}$$

We retain the baseline value of ξ and the same managerial-effort target h. Combining the owner's first-order condition (C.5) with the incentive condition (C.2) identifies the owner's managerial input:

$$\mu = h^{\xi} \frac{\xi(1-h) - a}{a(1 - \xi + \xi h)}. \tag{C.15}$$

Managerial services and profitability then follow from

$$M = \mu + h^{\xi}, \qquad \pi = \frac{\beta/v - r}{M[(1+\theta)/\theta - \alpha]}, \tag{C.16}$$

and the incentive condition identifies

$$\varepsilon = a\pi\xi(1-h)h^{\xi-1}. \tag{C.17}$$

As in the baseline calibration, the aggregate labor share identifies γ. Since each delegating firm now employs exactly one manager, the managerial employment share identifies Ω.

Table C.1 reports the resulting parameterization. The parameters identified by aggregate long-run restrictions are unchanged from the baseline calibration. Restricting managerial employment changes the parameters governing the management technology and the scale required to reproduce the managerial employment share.

At the calibrated steady state, the restricted model has

$$a = 0.3260, \qquad M = 0.9434, \qquad \pi = 0.4751, \qquad h = 0.375. \tag{C.18}$$

The same aggregate restrictions therefore remain compatible with a model in which each delegating firm employs only one manager. What changes is the internal adjustment mechanism. The baseline model uses both managerial employment and the contract to respond to profitability; the restricted model must instead rely on managerial effort and compensation. The large change in the calibrated fixed-factor endowment reflects the scale adjustment required to reproduce the same managerial employment share when managerial employment per firm is fixed.

The comparison illustrates the modularity of the quantitative structure. The restric-

Table C.1: Calibration with one manager per firm

Parameter	Baseline model	One-manager model
λ	0.0110	0.0110
θ	0.4500	0.4500
α	0.3300	0.3300
ρ	0.0350	0.0350
β	5.4054	5.4054
ϕ	0.0929	0.0929
ξ	0.8000	0.8000
μ	1.0326	0.4871
ε	0.0210	0.0942
γ	0.7352	0.7352
Ω	0.0111	1.5256

tions identifying discounting, entry costs, fixed operating costs, and the aggregate production parameters can be carried over directly. Only the block governing the internal organization of the firm must be recalibrated when the managerial-employment margin is removed. This makes the one-manager economy a useful robustness exercise rather than a separate quantitative model.

D. Data Sources and Sample Definitions

This appendix documents the data sources, sample selection, and variable definitions used to construct the U.S. managerial moments for 1950–2017.

D.1. Data Sources and Variables' Construction

Data are from the Decennial Census 1 percent samples for 1950, 1960, and 1970, from the Decennial Census 5 percent samples for 1980, 1990, and 2000, and from the American Community Survey (ACS) for 2001-2017. Data were extracted from the Integrated Public Use Microdata Series (IPUMS) USA, on March 29, 2019.

Sample selection The data sample consists of individuals of 16+ years old. As standard, we exclude individuals who fall in the following categories: (i) Residents of institutional group quarters, prisons and psychiatric institutions (GQ = 3-4); (ii) Self-employed (CLASSWKR = 1); (iii) Armed forces (CLASSWKRD = 26); (iv) Unpaid family workers (CLASSWKRD = 29); (v) Unknown occupations (OCC1990 = 999); (vi) agriculture (OCC1990 $\geq$ 473 & OCC1990 $\leq$ 498).

Income and managerial occupations The income variable is *total pre-tax wage and salary income* (INCWAGE):

> "INCWAGE reports each respondent's total pre-tax wage and salary income - that is, money received as an employee - for the previous year. [...] Sources of income in INCWAGE include wages, salaries, commissions, cash bonuses, tips, and other money income received from an employer. Payments-in-kind or reimbursements for business expenses are not included."

INCWAGE is adjusted for top coding based on the procedure in Autor and Dorn (2013). Hourly wages are defined as yearly wage and salary income divided by the product of weeks worked (WKSWORK1) times usual hours worked per week (UHRSWORK). To determine the employment status, we use the variable EMPSTAT. Averages are calculated using person weight (PERWT). To convert dollar figures to constant 1999 dollars, we use CPI99.

To classify managers, we use the occupation variable OCC1990:

Code	Description
004	Chief executives and public administrators
007	Financial managers
008	Human resources and labor relations managers
013	Managers and specialists in marketing, advertising, etc.
014	Managers in education and related fields
015	Managers of medicine and health occupations
016	Postmasters and mail superintendents
017	Managers of food-serving and lodging establishments
018	Managers of properties and real estate
019	Funeral directors
021	Managers of service organizations, n.e.c.
022	Managers and administrators, n.e.c.

E. Organizational Restrictions with Unchanged Parameters

This exercise imposes $m = 1$ or $m = 0$ on the full economy's main calibration, retaining every structural parameter, including $\theta = 0.45$ and $\beta = 5.4054$. Each economy starts with the same population, mass of firms, and firm-specific knowledge as the full economy's steady state. At time zero, an unanticipated permanent restriction changes managerial organization. The unrestricted economy remains at its steady state and provides the reference path. The one-manager economy retains endogenous effort and compensation under its restricted contract; the owner-managed economy retains the owner's managerial services.

The common initial stocks imply $\ell \equiv \Lambda/N = 28.2667$. Using the production coefficient K defined in Appendix A, profitability satisfies $\ell = K\pi^{1/\gamma} + m$. Consequently, the initial restriction releases labor from management and raises profitability from 0.2241 to 0.2311 with one manager and to 0.2373 without salaried managers. Consumption adjusts on impact; firm value also adjusts when entry is inactive. Equal initial stocks therefore do not imply equal initial profitability across organizational regimes.

Investment and entry constraints. The positive-R&D steady-state candidates under both restrictions imply negative knowledge growth, as shown in Appendix B. We impose nonnegative investment throughout the transition. With positive entry, the innovation and return conditions are

$$z(\pi) = \max\left\{0, \frac{[\beta\alpha - 1 + ma(\pi)]M(\pi)\pi}{\beta - 1} - \phi\right\},$$
$$r(\pi) = \begin{cases} \alpha M(\pi)\pi - \phi, & z(\pi) > 0, \\ \dfrac{[1 - ma(\pi)]M(\pi)\pi - \phi}{\beta}, & z(\pi) = 0. \end{cases} \tag{E.1}$$

The resulting one-manager transition has positive entry and zero R&D throughout. The restricted contract satisfies managerial participation along the path, and retained operating profits remain positive.

For the owner-managed economy, continuing the positive-entry equations from the common initial stocks would imply negative entry. The admissible path instead begins with no entry and no R&D. During this phase N and Z are constant, and firm value

satisfies $V < \beta Z$. The resource constraint, household Euler equation, and firm valuation equation give

$$\begin{aligned} \frac{\dot{\ell}}{\ell} &= \lambda, \qquad c = \frac{(1+1/\theta)M\pi - \phi}{\ell}, \\ r &= \rho + \frac{\dot{c}}{c}, \quad \dot{V} = rV - (M\pi - \phi)Z. \end{aligned} \tag{E.2}$$

Population growth raises employment per incumbent and profitability. We join this phase to the positive-entry saddle path where entry first becomes nonnegative, consumption is continuous, and $V = \beta Z$. The no-entry phase lasts approximately 0.84 years. Initially $V/Z = 5.3837$, below the entry cost 5.4054; it reaches the entry cost when entry resumes. Operating profits remain positive and the return to innovation remains below the interest rate during this phase. Thereafter the economy follows the zero-R&D, positive-entry saddle path. The numerical solutions satisfy the investment and entry constraints, and extending the terminal horizon from 200 to 280 years changes the computed paths by less than 2×10^{-9} in (π, c).

Table E.1: Organizational restrictions with unchanged parameters: impact and long-run values

	Unrestricted	One manager		Owner-managed	
	Steady state	Impact	Long run	Impact	Long run
Profitability π	0.2241	0.2311	0.2211	0.2373	0.2732
Normalized consumption c	0.0450	0.0357	0.0368	0.0247	0.0221
Managerial services M	1.9999	1.6014	1.5916	1.0326	1.0326
Managerial effort h	0.3750	0.4940	0.4833	—	—
Knowledge growth z (%)	2.000	0	0	0	0
Real return r (%)	5.500	3.796	3.500	3.317	3.500
Entry rate n (%)	1.100	1.672	1.100	0	1.100

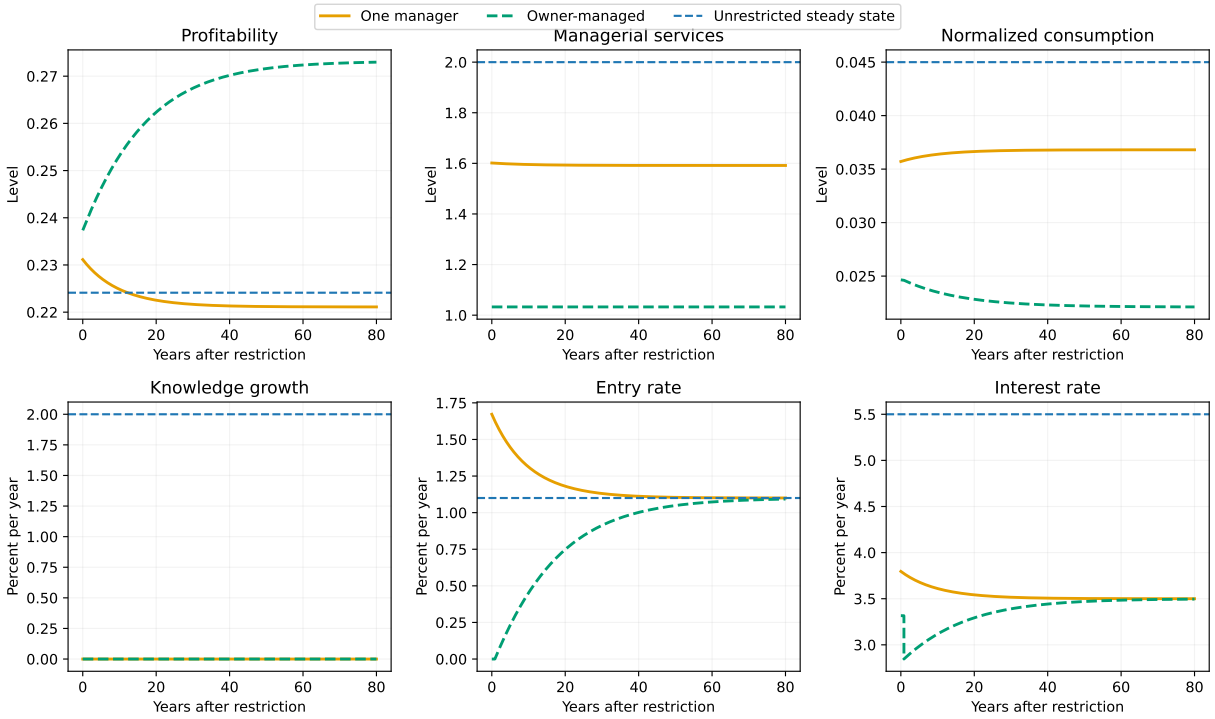


Figure E.1: Transitions after imposing $m = 1$ or $m = 0$ with all structural parameters unchanged and initial stocks common to the full economy's steady state. Panels report levels; rates are percentages per year. The blue reference is the unrestricted steady state. Both restricted knowledge-growth paths coincide at zero. The owner-managed economy begins with a short no-entry phase, followed by positive entry; the interest rate changes when entry resumes.

Both organizational restrictions eliminate steady-state firm-specific innovation under these parameters. Knowledge growth falls from 2% to zero on impact and remains zero, while the interest rate converges to $\rho = 3.5\%$. Entry eventually grows at the population growth rate, $n = \lambda = 1.1\%$. With one manager, profitability decreases after its initial upward adjustment; without salaried managers, it continues to rise as employment per incumbent increases. Normalized consumption remains below the unrestricted path in both economies. Since knowledge is constant in the restricted economies but grows in the unrestricted economy, the consumption-level comparison also reflects the subsequent divergence in knowledge stocks.

The fixed-parameter and target-preserving exercises answer different questions. Here, the organizational restrictions change the growth regime from a common initial allocation and common primitives. Section 8.3 instead compares responses to higher entry costs among three economies calibrated to reproduce common pre-shock growth, return, and labor-share targets. The latter comparison illustrates differences in amplification among

initially growing economies; its response magnitudes reflect both organizational margins and the parameter adjustments required to match those targets.

F. Markup-Based Robustness Results

F.1. IRF exercises

The robustness calibration sets $\theta = 1/1.20$ and retains $\lambda = 0.011$ and the remaining targets used for the main case. Table F.1 reports the full and one-manager parameterizations. Both have $z = 0.02$ and $r = 0.055$. The owner-managed restrictions require $\phi = 0.0209$ and $\gamma = 1.1424$ to match growth, returns, and the labor share. Because the latter violates the maintained technology restriction, no target-matching owner-managed IRF is reported under this calibration.

Table F.1: Markup-based calibration

Parameter	Endogenous managers	One manager
λ	0.0110	0.0110
θ	0.8333	0.8333
α	0.3300	0.3300
ρ	0.0350	0.0350
β	5.4054	5.4054
ϕ	0.1738	0.1738
ξ	0.8000	0.8000
μ	0.2266	0.1069
ε	0.0746	0.3352
γ	0.6829	0.6829
Ω	25.3142	1366.6815

Table F.2: Full-economy steady-state response elasticities under the markup-based calibration

Parameter	Profitability π^*	Innovation z^*
β	0.734	14.936
α	0.901	27.403
μ	-0.199	-3.296
ξ	0.226	-0.916
ε	0.401	-1.631

The five figures below report the same permanent one-percent parameter changes as in Section 8.2 of the paper. Each path starts from the markup-based steady state and holds all other structural parameters fixed. Managerial-technology shocks preserve the predetermined initial employment per firm when determining the impact change in profitability.

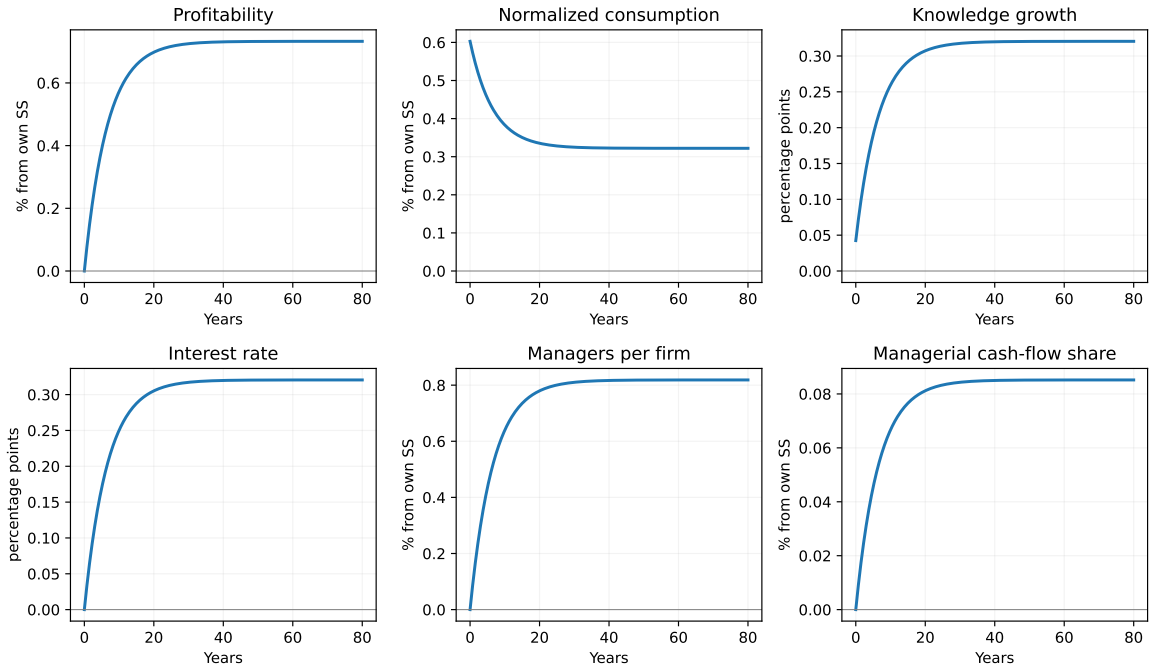


Figure F.1: Markup-based transition after a one-percent increase in entry costs

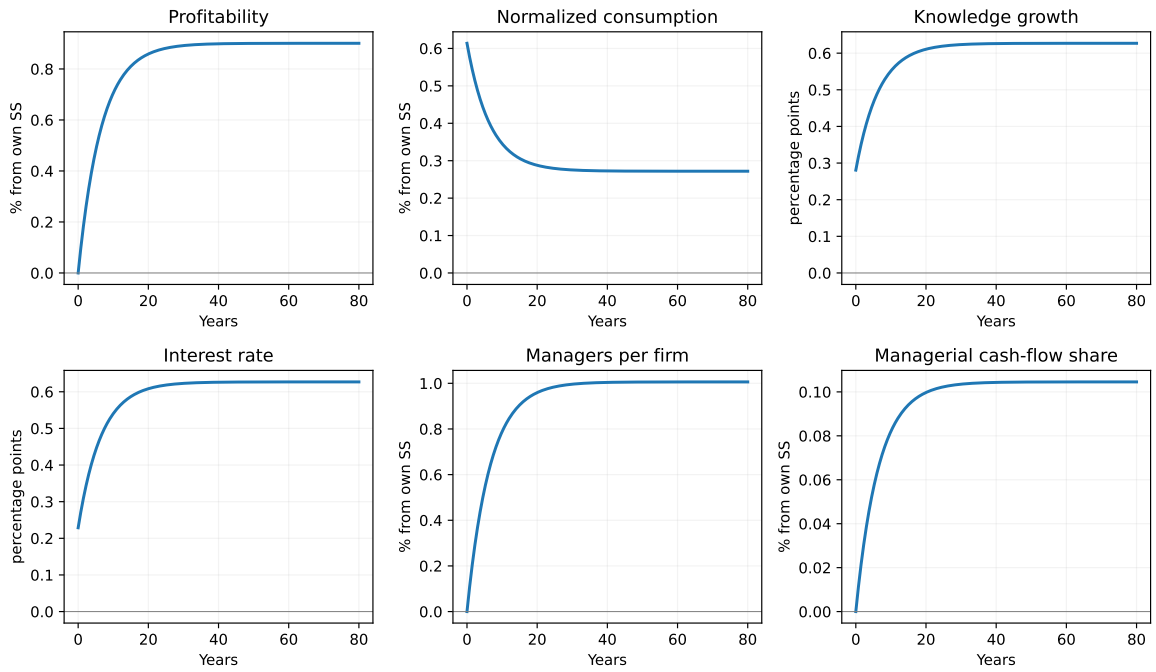


Figure F.2: Markup-based transition after a one-percent increase in the firm-specific knowledge elasticity

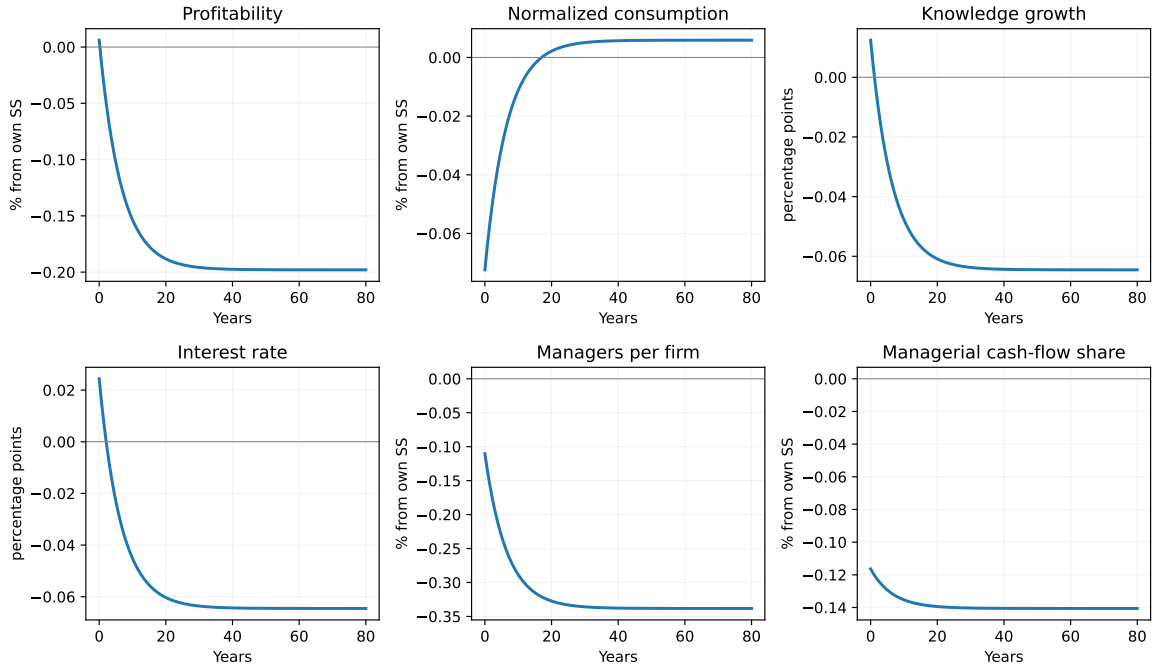


Figure F.3: Markup-based transition after a one-percent increase in the owner's managerial input

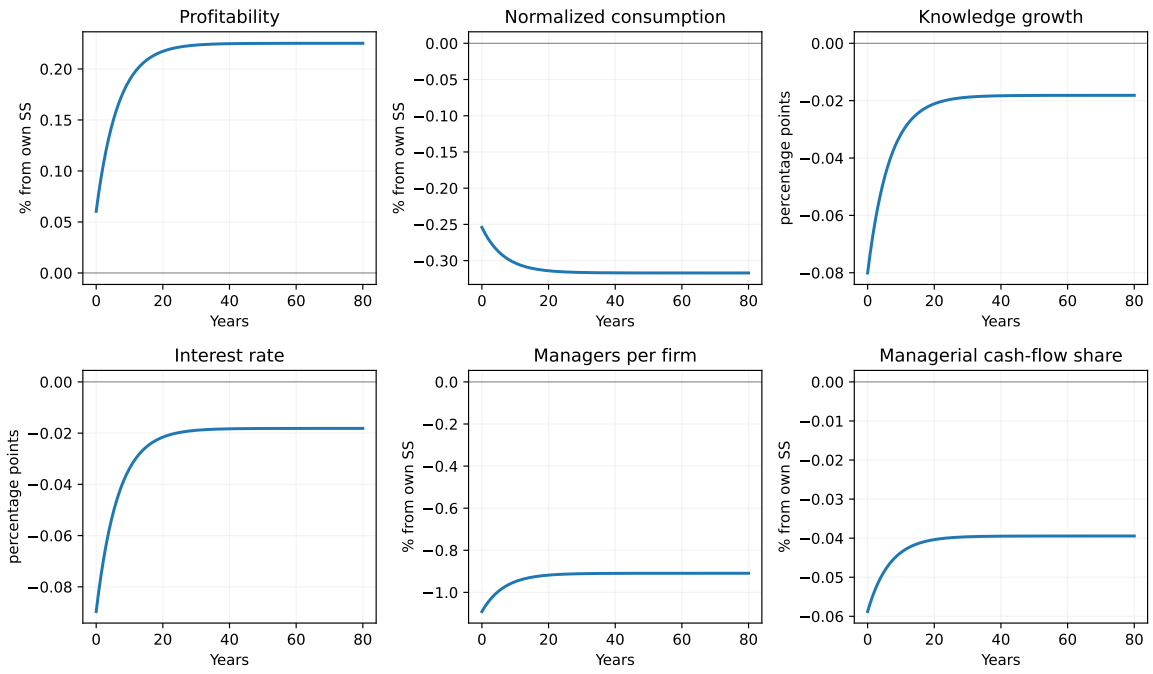


Figure F.4: Markup-based transition after a one-percent increase in managerial-effort curvature

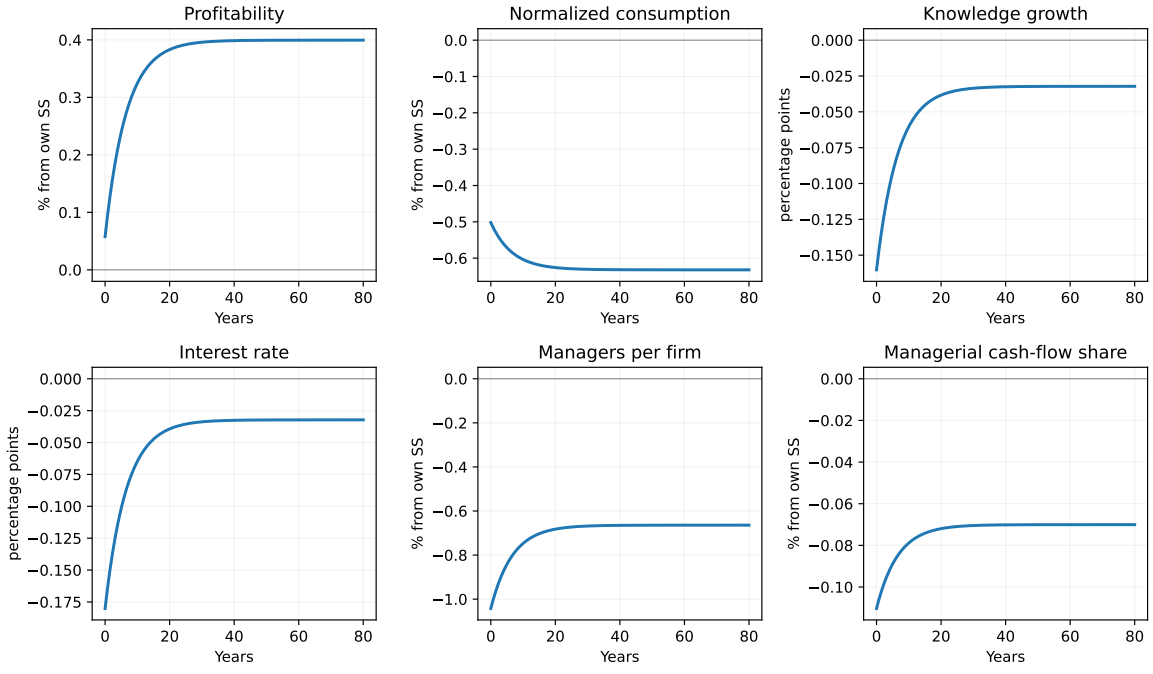


Figure F.5: Markup-based transition after a one-percent increase in managerial effort cost

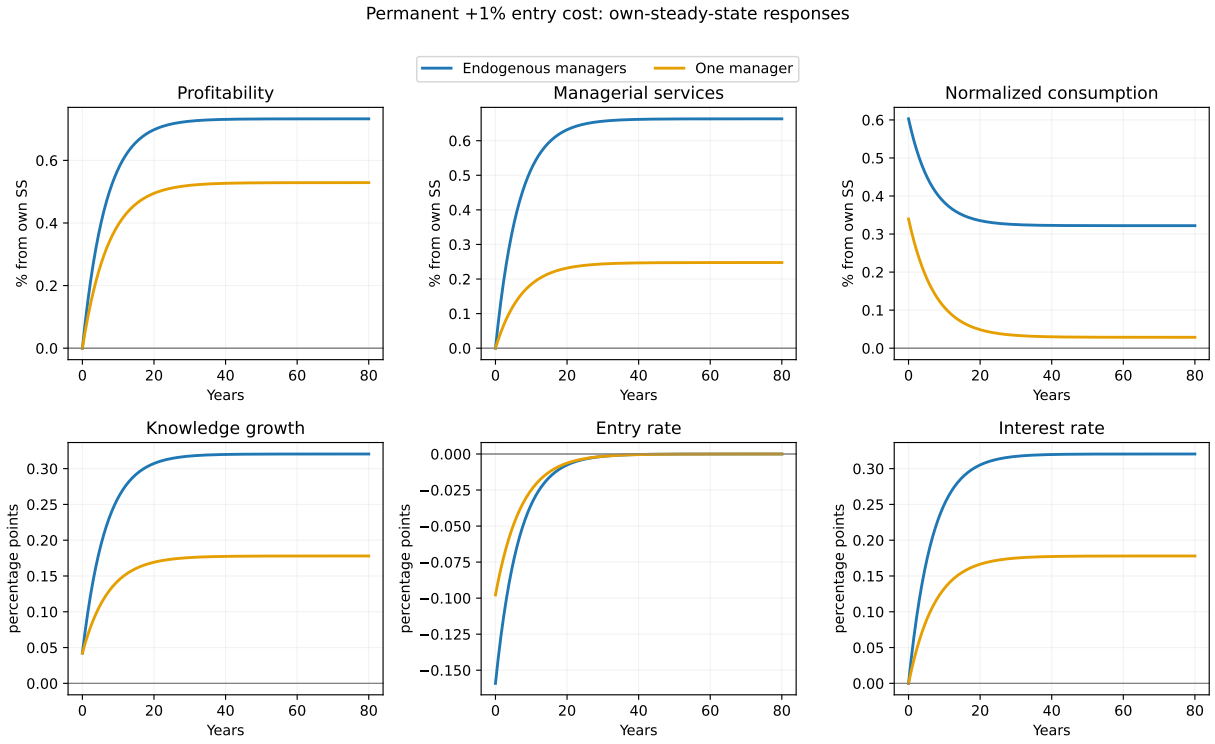


Figure F.6: Markup-based full and one-manager transitions after a one-percent increase in entry costs

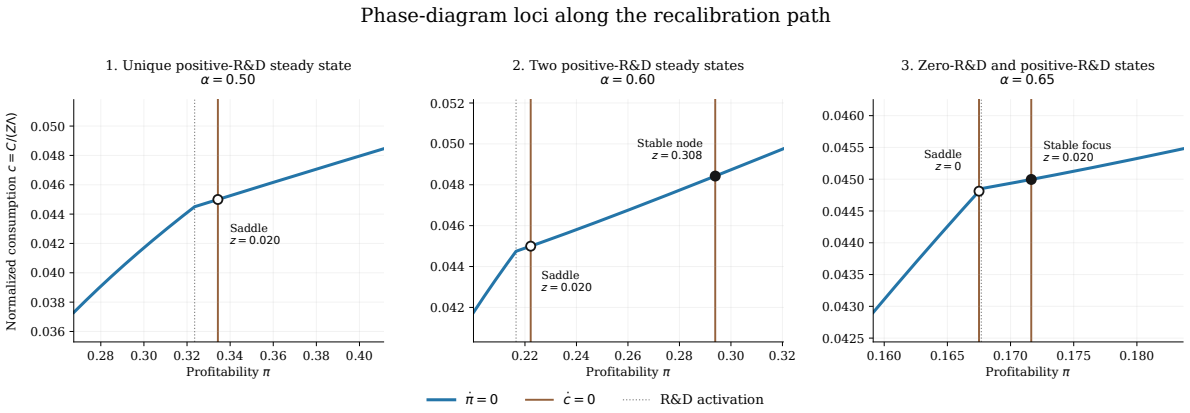
F.2. Structural stability exercises

The following supplementary figures use the markup-based parameterization with $\lambda = 0.01$. Using that parameterization, the impulse responses characterize how changes in α and the other structural parameters propagate around the benchmark steady state, where the equilibrium has the familiar saddle-path structure. We now ask a different question. As α changes more substantially, does the economy simply converge to a different steady state of the same type, or can the qualitative structure of equilibrium itself change? This supplementary exercise examines that change in equilibrium structure.

We use α for this exercise because it plays a particularly important role in the theory. At the firm level, α governs the contribution of firm-specific knowledge to profitability and hence the private return to in-house innovation. At the aggregate level, the resulting innovation decisions determine knowledge accumulation and growth. The parameter therefore links the microeconomic innovation decision to the macroeconomic dynamics of the economy. Moreover, because higher profitability induces firms to expand managerial organization, α is a major determinant of the amplification mechanism studied in the

paper.

We begin with the quantitatively disciplined experiment. At each value of α, we recalibrate the remaining parameters using the same long-run targets and equilibrium restrictions as in the markup-based calibration. Figure F.7 illustrates three representative economies along this path. At $\alpha = 0.50$, the economy has a unique positive-R&D saddle-path steady state. At $\alpha = 0.60$, two positive-R&D steady states coexist: a lower-profitability saddle and a higher-profitability locally stable steady state. At $\alpha = 0.65$, the lower branch has crossed into the zero-R&D region, while the positive-R&D equilibrium lies on the locally stable branch. The three panels thus provide snapshots of the change in equilibrium structure before we trace the underlying branches continuously.



Exact nonlinear loci; no direction arrows. Panel ranges differ to make the intersections visible.
Targets retained: growth 2%, interest 5.5%, wealth/GDP 4, labor share 65%, and incumbent R&D/GDP 1.48%.
An open circle denotes a saddle; a filled circle denotes a stable equilibrium (node or focus). Stability is computed from the Jacobian.

Figure F.7: Representative steady states along the α recalibration path

Figure F.8 then compares this recalibration exercise with the conventional bifurcation experiment. Panel (a) varies α while holding all other structural parameters at their markup-based values. Panel (b) varies α while recalibrating the remaining parameters to preserve the benchmark empirical targets. The distinction is substantive. The first exercise describes the nonlinear equilibrium structure of a fixed parameterization as one structural force changes. The second asks whether that structure survives when the model is required to remain quantitatively consistent with the same evidence.

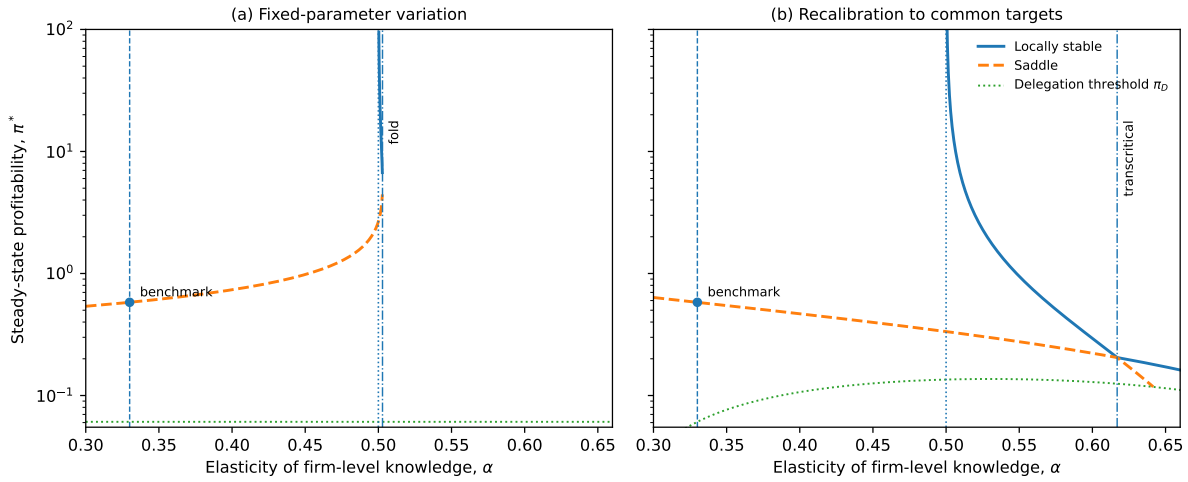


Figure F.8: Structural stability and steady-state bifurcations as α varies

Panel (a) shows the familiar saddle-node geometry. Starting from the benchmark, the unique admissible positive-R&D steady state persists as α rises. Once α exceeds $1/2$, a second admissible steady state appears at high profitability. The two steady states coexist over a narrow interval and collide in a saddle-node bifurcation at approximately $\alpha = 0.503$, beyond which the positive-R&D steady states associated with the benchmark parameterization disappear.

Panel (b) answers a different question. Because the remaining parameters are recalibrated at every value of α, one steady-state branch exists by construction. Once α exceeds $1/2$, a second positive-R&D steady state becomes possible and is realized along the recalibration path. The lower-profitability steady state is initially a saddle and the higher-profitability steady state is locally stable. The two branches meet at approximately $\alpha = 0.617$ in a transcritical bifurcation: the steady states coincide and exchange stability. Beyond the crossing, the lower branch eventually passes below the R&D activation threshold and ceases to be an admissible positive-R&D steady state. The less familiar geometry in panel (b) therefore reflects the quantitative discipline imposed by requiring the economy to continue matching the same long-run targets as α changes.

The two exercises provide complementary quantitative counterparts to the analytical multiplicity result. On the delegation branch, the positive-R&D steady-state condition contains the term

$$(1 - 2\alpha)\pi^2.$$

For $\alpha \leq 1/2$, the relevant steady-state mapping cannot bend backward in the way required for two positive-R&D steady states. Once $\alpha > 1/2$, the sign of this curvature term

changes and multiplicity becomes possible. Panel (a) shows how this change operates in the conventional fixed-parameter experiment; panel (b) shows that multiplicity remains quantitatively relevant when the model is required to continue matching the evidence.

The organizational margin is central to this result. A larger α strengthens the private return to innovation and the resulting profitability response in both the baseline and restricted models. In the baseline economy, however, higher profitability also induces firms to employ more managers, generating a strong extensive-margin increase in managerial services. Appendix C shows that when a delegating firm is restricted to one manager, adjustment occurs only through managerial effort. This intensive margin is substantially weaker and the calibrated one-manager economy retains a unique positive-R&D steady state. The comparison therefore separates the primitive force that strengthens innovation incentives from the organizational mechanism that amplifies it enough to change the qualitative structure of equilibrium.

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