

Distance to Frontier, Selection, and Economic Growth*

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Abstract

We analyze an economy where firms undertake both innovation and adoption of technologies from the world technology frontier. The selection of high-skill managers and firms is more important for innovation than for adoption. As the economy approaches the frontier, selection becomes more important. Countries at early stages of development pursue an investment-based strategy, which relies on existing firms and managers to maximize investment, but in return, sacrifices selection. Closer to the world technology frontier, economies switch to an innovation-based strategy with short-term relationships, younger firms, less investment and better selection of firms and managers. We show that relatively backward economies may switch out of the investment-based strategy too soon, so certain policies, such as limits on product market competition or investment subsidies, that encourage the investment-based strategy may be beneficial. However, societies that cannot switch out of the investment-based strategy fail to converge to the world technology frontier. Non-convergence traps are more likely when beneficiaries of existing policies can bribe politicians to prevent policy reform.

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“... in a number of important historical instances industrialization processes, when launched at length in a backward country, showed considerable differences with more advanced countries, not only with regard to the speed of development (the rate of industrial growth) but also with regards to the productive and organizational structures of industry... these differences in the speed and character of industrial development were to a considerable extent the result of application of institutional instruments for which there was little or no counterpart in an established industrial country.”

Gerschenkron (*Economic Backwardness in Historical Perspective*, p. 7)

1 INTRODUCTION

In his famous essay, *Economic Backwardness in Historical Perspective*, Gerschenkron argued that relatively backward economies, such as Germany, France and Russia during the nineteenth century, could rapidly catch up to more advanced economies by investing a lot and rapidly adopting frontier technologies. He emphasized that certain “non-competitive” arrangements, including long-term relationships between firms and banks, large firms and state intervention, facilitate such convergence. If this assessment is correct, the institutions/policies that are appropriate to relatively backward nations should encourage investment and technology adoption, even if this comes at the expense of various market rigidities and a relatively less competitive environment. Implicit in this argument is also the notion that such arrangements are not beneficial for more advanced economies.

In this paper, we construct a simple endogenous growth model where certain relatively rigid arrangements emerge in equilibrium at early stages of development and disappear as the economy approaches the world technology frontier. We also use this framework to investigate how certain policies that might initially increase growth and the speed of convergence could then lead to lower growth, and how the political influence of the beneficiaries of existing policies may prevent policy reform.

To understand the main mechanism in our model, imagine the following stylized economy with three key features: (i) firms (managers) are either high skill or low skill (or high and low type); (ii) there are credit constraints potentially restricting the amount of investment; and (iii) firms engage both in innovation and adoption of existing technologies from the world technology frontier. If a firm is successful and revealed to be high skill, it will continue to operate. If it is revealed to be low skill, it can be terminated and replaced by a new draw, which will on average have higher skills. However, existing firms have retained earnings, and because of the credit market imperfections,

these retained earnings enable them to undertake greater investments, so terminating unsuccessful firms reduces investment. Hence, there is a trade-off between investment and *selection*.

It is also plausible that skills (or match quality between firms and their activities) and the selection of the “right” firms¹ are more important for innovation than for adoption of existing technologies: adoption and imitation are relatively more straightforward activities compared to innovation. This leads to a key implication of our model: retaining unsuccessful firms and managers is more costly, and less likely to arise in equilibrium, when innovation is more important. A corollary is that as an economy approaches the world technology frontier, and there remains less room for adoption and imitation, retention of unsuccessful firms becomes less likely.

A likely equilibrium sequence is for an economy to start with *an investment-based strategy*, relying on existing firms (long-term relationships) in order to maximize investment. Intuitively, this strategy corresponds to an equilibrium where selection is less important, insiders are protected, and savings are channeled through existing firms in an attempt to achieve rapid investment growth and technology adoption. As the economy approaches the world technology frontier, lack of selection becomes more costly, and there is typically a switch to *an innovation-based strategy*, where less successful firms and managers are terminated.

The equilibrium sequence in this economy therefore takes a form reminiscent to Gerschenkron’s discussion of growth in relatively backward economies in the nineteenth century. Furthermore, as suggested by Gerschenkron, government intervention to encourage the investment-based strategy might also be useful, because the investment-based strategy may fail to emerge even when it is good for growth or welfare. This is due to the standard *appropriability effect* in models with monopolistic competition (as in most endogenous technical change models): greater investment leads to greater productivity and output, but monopolists appropriate only part of these gains, while bearing the investment costs. This creates a bias against large investments, and hence against the investment-based strategy. Investment subsidies or limiting the extent of competition, which increases the amount of the gains that monopolists can appropriate, encourage the investment-based strategy and may increase the equilibrium growth rate.

Nevertheless, our analysis also reveals that the investment-based strategy potentially has very high costs. Countering the appropriability effect, there is the *rent-shield effect*:

¹Our argument applies both to the selection of firms and selection of managers to run existing firms. In the model, for simplicity we focus on the selection of managers.

the cash (rents) in the hands of insiders creates a shield protecting them from more efficient newcomers. This effect can outweigh the appropriability effect and imply that an economy may stay in the investment-based strategy too long. Delayed switch to the innovation-based strategy clearly reduces growth, because the economy is not making best use of innovation opportunities. But more important, there exists a level of development (distance to frontier) such that, if an economy does not switch out of the investment-based strategy before this threshold, it will be stuck in a *non-convergence trap*, where convergence to the frontier stops.

An immediate implication of this discussion is a new theory of “leapfrogging”. Economies pursuing policies encouraging the investment-based strategy may initially grow faster than others, but then get stuck in a non-convergence trap and be leapfrogged by the initial laggards. This is a very different view of leapfrogging from the standard approach (e.g., Brezis, Krugman and Tsiddon, 1994), which is based on comparative advantage and learning-by-doing, and focuses on whether the world technological leadership is taken over by a newcomer.²

But this analysis poses another important question: why do governments not choose institutions/policies that favor the investment-based strategy when the country is at early stages of development and then switch to policies supporting innovation and selection as the country approaches the frontier? The answer lies in the political economy of government intervention. Policies that favor the investment-based strategy create and enrich their own supporters. When economic power buys political power, it becomes difficult to reverse policies that have an economically and politically powerful constituency.³ An interesting implication is that under certain circumstances societies

²The type of leapfrogging implied by our model may help explain why some of the Latin American countries, most notably, Brazil, Mexico and Peru, which grew relatively rapidly with import substitution and protectionist policies until the mid-1970s, stagnated and were taken over by other economies with relatively more competitive policies, such as Hong Kong or Singapore.

The experiences of Korea and Japan are also consistent with this story. Though in many ways more market friendly than the Latin American countries, for much of the post-war period both countries achieved rapid growth and convergence relying on high investment, large conglomerates, government subsidies and relatively protected internal markets. Convergence and growth came to an end in the mid-1980s in Japan and during the Asian crisis in Korea (but in the case of Korea, there appears to be some success in reforming the old system after the Asian crisis, and signs of renewed growth).

³Both the Korean and the Japanese cases illustrate the dangers of the investment-based strategy, and the political economy problems created by such a strategy. The close links between government officials and the chaebol in the Korean case, and the bureaucrats and the keiretsu in the Japanese case appear to have turned into major obstacles to progress. On the influence of Korean chaebol on policy, Kong (2002, p. 3) writes “...political—not economic—considerations dominated policymaking... [in Korea].... and ...corruption was far greater than the conventional wisdom allows”. In fact, the patriarchs of Samsung, Daewoo and Jinro, the three major chaebol, were convicted in the late 1990s

may get trapped with “inappropriate institutions” and relatively backward technologies, precisely because earlier they adopted appropriate institutions for their circumstances at the time, but in the process also created a powerful constituency against change.

The key empirical implication of our analysis is that certain non-competitive policies may have limited costs, or even benefits, when countries are far from the world technology frontier, but become much more costly near the frontier. Although this implication appears to be consistent with the experiences of many Latin American countries as well as with those of Korea and Japan discussed in footnote 2, we are not aware of any systematic empirical investigation. While a detailed empirical analysis is beyond the scope of the current paper, a brief look at the data reveals some notable patterns consistent with this implication.

Figures 1a and 1b look at the relationship between growth and initial distance to frontier (GDP per capita relative to the U.S.) in the sample of non-OECD, non-socialist countries separately for those with high and low degree of “non-competitive” policies/barriers to entry (here we do this using the measure of number of procedures necessary for opening a new business, from Djankov, La Porta, Lopez-de-Silanes, and Shleifer, 2002). The figures show growth in per capita income between 1965 and 1995 plotted against distance to frontier in 1965, where we also control for a dummy for sub-Saharan African countries which have much lower growth rates. While there is a strong negative relationship between growth and distance to frontier for countries with high barriers, the relationship is much weaker for countries with low barriers. In other words, high-barrier countries do relatively well when they are far from the frontier, but much worse near the frontier, while low-barrier countries grow almost equally successfully near or far from the frontier.⁴ This is consistent with the notion that barriers to entry are

of major bribing of two former presidents. Significantly, their jail sentences were pardoned in 1997 (see Asiaweek, October 10, 1997).

⁴In the regression of country growth rates between 1965 and 1995 on the sub-Saharan Africa dummy and distance to frontier in 1965 in the sample of low-barrier countries, the coefficient on distance to frontier is -0.031 (s.e.=0.031), which is insignificant at the 5 percent level (shown in Figure 1b). The same coefficient is -0.067 (s.e.=0.023) in the sample of high-barrier countries, which is significant at the 1 percent (shown in Figure 1a). The vertical axes and the figures show country growth rates after the effect of the sub-Saharan Africa dummy, estimated in the corresponding multivariate regression, is taken out.

With country fixed effects and time effects, the coefficient on the distance to frontier in the low-barrier sample is -0.060 (s.e.= 0.040), while in the high-barrier sample it is -0.119 (s.e.= 0.054). We also obtain similar results in fixed effect regressions when distance to frontier is instrumented by its past values in order to avoid biases resulting from the fact that distance to frontier is correlated with lags of the dependent variable. Details on the estimates shown in these figures, information on samples and robustness checks are provided in Appendix A.

more harmful to growth closer to the frontier. Figures 1d and 1e show the same pattern when we look at growth in ten-year intervals and control for country fixed effects and time effects. These estimates are useful since they show that a country with high barriers suffers more as it approaches the frontier relative to its “usual” growth rate.

Figures 2a-2d show that the same results hold when we look at the differential growth experiences of countries that are more and less open to international trade. Here we split the sample according to the predicted openness measure constructed by Frankel and Romer (1999), which exploits “exogenous” differences in openness from a standard “gravity equation” due to differences in population, land area, proximity and common borders to other countries, and whether a country is landlocked.⁵ Finally, Figures 3a-d perform the same exercise by splitting the sample according to low and high human capital (using total years of schooling in 1965). If, as maintained by our approach, skills matter more nearer the frontier, we should see a more negative relationship between growth and distance to frontier for low-human capital than for high-human capital countries. This is the pattern we find in the data, though now the contrast is somewhat weaker in the cross-sectional regressions, and stronger in the fixed effect regressions.⁶ The evidence presented in Figures 1, 2 and 3 therefore suggests that cross-country growth patterns are broadly consistent with the basic implications of our approach, though this is only a first pass, and more detailed empirical analysis of these patterns is necessary in future work.

FIGURES 1, 2 AND 3

Our paper relates to a number of different literatures. First, the notion that managerial skill is more important for innovation than adoption is reminiscent to the emphasis in Galor and Tsiddon (1997) and Hassler and Rodriguez (2000) on skill in times of economic change and turbulence. Second, our model is related to work on finance and growth, including Greenwood and Jovanovic (1990), King and Levine (1993), and Acemoglu and Zilibotti (1997). Third, our focus is related to work on technological convergence, including Barro and Sala-i-Martin (1997), Aghion and Howitt (1998), Howitt (2000)

⁵In the cross-sectional regressions, the coefficient on the distance to frontier for the “closed” economies is -0.049 (s.e.= 0.016), while for the “open” economies, it is -0.020 (s.e.= 0.034). In the fixed effect regressions, the coefficient for closed economies is -0.170 (s.e.= 0.043), while for open economies, it is -0.87 (s.e.= 0.040). See Appendix A for details.

⁶In the cross-sectional regressions, the coefficient on the distance to frontier for low-education countries is -0.076 (s.e.= 0.047), while for high-education countries, it is -0.057 (s.e.= 0.025). In the fixed effect regressions, the coefficient for the low-education countries is -0.262 (s.e.= 0.056) and for the high-education countries, it is -0.088 (s.e.= 0.037).

and especially to Howitt and Mayer (2002), who investigate how some countries may stagnate while others converge to an income level below the world technology frontier, but still grow at the same rate as the frontier. Perhaps more closely related, Tong and Xu (2000) extend the model by Dewatripont and Maskin (1995) and compare “multi-financier” and “single-financier” credit relationships, emphasizing that multi-financier relationships become more beneficial at later stages of development when selecting good R&D projects becomes more important. None of these papers, however, investigate how certain arrangements that are at first growth enhancing later reduce growth or even cause non-convergence traps.

Another link is to the debate on the optimal degree of government intervention in less developed countries. Consistent with the Gerschenkron view, some economists, e.g., Stiglitz (1995) and Hausmann and Rodrik (2002), call for greater government intervention in less developed countries where market failures tend to be more severe than in more advanced economies. Countering this, several economists and political scientists emphasize the greater danger of government failures in less developed nations, where checks on governments are weaker (e.g., Shleifer and Vishny, 1999). Our model combines these two insights. We derive a reason for possible government intervention at the early stages of development, while also highlighting why such intervention can be counterproductive because of political economy considerations.

The rest of the paper is organized as follows. Section 2 outlines the basic model. Section 3 characterizes the equilibrium. Section 4 discusses government policy and the possibility of political economy traps. Section 5 concludes. The Appendix contains details on the empirical evidence discussed above and theoretical extensions.

2 THE MODEL

2.1 AGENTS AND PRODUCTION

The model economy is populated by overlapping generations of two-period lived risk-neutral agents, discounting the future at the rate r . The population is constant. Each generation consists of a mass $1/2$ of “capitalists” with property rights on “production sites”, but no skills or other wealth, and a mass $(N + 1)/2$ of workers who are born with no wealth, but are endowed with skills. Property rights are transmitted within dynasties. All workers supply their labor inelastically and are equally productive in production tasks, but they have heterogeneous productivity in management. In particular, we assume that each worker has high skill (ability) in management with probability λ and

low skill with probability $1 - \lambda$.

There is a unique final good in the economy, also used as an input to produce intermediate inputs. We take this good as the numeraire. The final good is produced competitively from labor and a continuum 1 of intermediate goods as inputs with the aggregate production function:

$$y_t = \frac{1}{\alpha} L_t^{1-\alpha} \left[\int_0^1 (A_t(\nu))^{1-\alpha} x_t(\nu)^\alpha d\nu \right], \quad (1)$$

where $A_t(\nu)$ is productivity in sector ν at time t , $x_t(\nu)$ is the flow of intermediate good ν used in final good production again at time t , L_t is the number of production workers at time t and $\alpha \in (0, 1)$.

In each intermediate sector ν , one production site has access to the most productive technology, $A_t(\nu)$, so this “leading firm” will enjoy monopoly power. Each leading firm employs a manager and needs to undertake some investment as described in detail below. It then has access to a technology to transform one unit of the final good into one unit of intermediate good of productivity $A_t(\nu)$. A fringe of additional firms can “steal” this technology, and produce the same intermediate good, with the same productivity $A_t(\nu)$, without using the production site or a manager. But this fringe faces higher costs of production, and needs χ units of the final good to produce one unit of the intermediate, where $1/\alpha \geq \chi > 1$ (naturally, these firms will not be active in equilibrium). The parameter χ captures both technological factors and government regulation affecting entry. A higher χ corresponds to a less competitive market. The fact that $\chi > 1$ implies that the fringe is less productive than the incumbent producer, while $\chi \leq 1/\alpha$ implies that this productivity gap is sufficiently small for the incumbent to be forced to charge a limit price to prevent entry by the fringe. This limit price is equal to the marginal cost of the fringe:

$$p_t(\nu) = \chi. \quad (2)$$

The final good sector is competitive, so each intermediate good producer ν at date t faces the inverse demand schedule: $p_t(\nu) = (A_t(\nu) L_t / x_t(\nu))^{1-\alpha}$. This equation together with (2) gives equilibrium demands: $x_t(\nu) = \chi^{-\frac{1}{1-\alpha}} A_t(\nu) L_t$, with monopoly profits equal to:

$$\pi_t(\nu) = (p_t(\nu) - 1) x_t = \delta A_t(\nu) L_t, \quad (3)$$

where $\delta \equiv (\chi - 1) \chi^{-\frac{1}{1-\alpha}}$ is monotonically increasing in χ (since $\chi \leq 1/\alpha$). Thus, a higher δ corresponds to a less competitive market, and implies higher profits for the leading firms.

Equation (1) gives aggregate output as $y_t = \alpha^{-1} \chi^{-\frac{\alpha}{1-\alpha}} A_t L_t$, where

$$A_t \equiv \int_0^1 A_t(\nu) d\nu. \quad (4)$$

is the average level of technology in the economy at time t . The market clearing wage level is equal to the marginal product of labor in production:

$$w_t = (1 - \alpha) \alpha^{-1} \chi^{-\frac{\alpha}{1-\alpha}} A_t. \quad (5)$$

Finally, let net output, y_t^{net} , be final output minus the cost of intermediate production. Then,

$$y_t^{net} = y_t - \int_0^1 x_t(\nu) d\nu = \zeta A_t L_t, \quad (6)$$

where $\zeta \equiv (\chi - \alpha) \chi^{-\frac{1}{1-\alpha}} / \alpha$ is monotonically decreasing in χ . Thus for given average technology A_t , both total output and net output are decreasing in the extent of monopoly power, i.e., in χ , because of standard monopoly distortions. Note also that net output, (6), and profits, (3), have identical forms except that net output has the term ζ instead of $\delta < \zeta$. This reflects an *appropriability effect*: monopolists only capture a fraction of the greater productivity in the final goods sector (or of the consumer surplus) created by their production.

2.2 TECHNOLOGICAL PROGRESS AND PRODUCTIVITY GROWTH

Each leading firm (capitalist) requires one manager, so a total 1 of workers will be employed as managers, and there will be $L_t = N$ production workers (recall that the total size of worker population is $N + 1$).

Each firm, in addition, chooses between two levels of investment (two project sizes): large and small. The investment costs can be financed either through retained earnings, or by borrowing from a set of competitive intermediaries that transfer funds from savers to managers/firms at the beginning of the period, and collect payments at the end. Intermediation is without any costs and there is free entry into this activity. Moreover, since intermediation takes place within a period, there are no interest costs to be covered.

Managerial skills are potentially important for productivity growth (technological progress). These are initially unknown, and are revealed after an agent works as a manager for the first time. Managers perform two important tasks:

1. They engage in *innovation*, and managerial skills are important for success in this activity.

2. They also *adopt* technologies from the frontier, and here skills play a less important role than in innovation. This assumption captures the notion that relatively backward economies can grow by adopting already well-established technologies, and the adoption of these technologies is often relatively straightforward.

Let us denote the growth rate of the world technology frontier, $\bar{A}_t$, by g , i.e.,

$$\bar{A}_t = (1 + g)^t \bar{A}_0. \quad (7)$$

We return to the determination of this growth rate below. All countries have a state of technology, A_t , defined by (4), less than the frontier technology. In particular, for the representative country, we have $A_t \leq \bar{A}_t$.

The productivity of intermediate good ν at time t is expressed as:

$$A_t(\nu) = s_t(\nu) \left(\eta \bar{A}_{t-1} + \gamma_t(\nu) A_{t-1} \right), \quad (8)$$

where $s_t(\nu) \in \{\sigma, 1\}$ denotes the size of the project, with $s_t(\nu) = \sigma < 1$ corresponding to a small project and $s_t(\nu) = 1$ corresponding to a large project. $\gamma_t(\nu)$ denotes the skill of the manager running this firm. Equation (8) captures the two dimensions of productivity growth: adoption and innovation. By adopting existing technologies, firms benefit from the state of world technology in the previous period, $\bar{A}_{t-1}$, irrespective of the skill of the manager. In addition, there is productivity growth due to innovation building on the existing body of local knowledge, A_{t-1} , and success in innovation depends on managerial skills as captured by the term $\gamma_t(\nu)$. Put differently, this type of innovation requires managerial skills, thus *managerial selection*.⁷ Finally, equation (8) also implies that greater investment (or the large project) leads to greater productivity improvements.

Rearranging (8) and using the definition in (4), we have the growth rate of aggregate technology as:

$$\frac{A_t}{A_{t-1}} \equiv \frac{\int_0^1 A_t(\nu) d\nu}{A_{t-1}} = \int_0^1 s_t(\nu) \left(\eta \frac{\bar{A}_{t-1}}{A_{t-1}} + \gamma_t(\nu) \right) d\nu. \quad (9)$$

Equation (9) shows the importance of *distance to frontier*, as captured by the term $\bar{A}_{t-1}/A_{t-1}$. When this term is large, the country is far from the world technology frontier, and the major source of growth is the adoption of already well-established technologies as captured by the $\eta \bar{A}_{t-1}/A_{t-1}$ term. When $\bar{A}_{t-1}/A_{t-1}$ becomes close to 1, so that the

⁷In practice, in addition to the selection of which managers should run existing firms, managerial selection in our model also corresponds to the selection of firms, i.e., which firms should continue to exist and which should be replaced by new entrants.

country is close to the frontier, innovation matters relatively more, and growth is driven by the $\gamma_t(\nu)$ term. Consequently, as the country develops and approaches the world technology frontier, innovation and managerial selection become more important.

For simplicity, we assume that $\gamma_t(\nu) = 0$ for a low-skill manager, and denote the productivity of a high-skill manager by $\gamma_t(\nu) = \gamma > 0$. Recall that a manager is high skill with probability λ and low skill with probability $1 - \lambda$. To guarantee a decreasing speed of convergence to the world technology frontier, we also assume that $\lambda\gamma < 1$.

Investment costs are given by:

$$k_t(\nu | s) = \begin{cases} \phi\kappa\bar{A}_{t-1} & \text{if } s_t(\nu) = \sigma \\ \kappa\bar{A}_{t-1} & \text{if } s_t(\nu) = 1 \end{cases}, \quad (10)$$

where $\phi < 1$. In other words, small projects require less investment than large projects. The assumption that investment costs are proportional to $\bar{A}_{t-1}$ ensures balanced growth.⁸ Intuitively, an important component of managerial activity is to undertake imitation and adaptation of already-existing technologies from the world frontier. As this frontier advances, managers need to incur greater costs to keep up with, and make use of, these technologies, hence investment costs increase with $\bar{A}_{t-1}$. We also assume that

$$\phi > \sigma; \sigma\delta N\eta > \phi\kappa \text{ and } (1 - \sigma)\delta N\eta > (1 - \phi)\kappa. \quad (11)$$

The first part of this assumption implies that there are decreasing returns to investment (project size); the second part ensures that even when $A_{t-1}/\bar{A}_{t-1}$ is small, innovation is profitable (to see this, combine (3) with (8) and evaluate as $A_{t-1}/\bar{A}_{t-1} \rightarrow 0$); and the third part states that even when $A_{t-1}/\bar{A}_{t-1}$ is small, the large project is more profitable than the small one.

2.3 CONTRACTS, INCENTIVE PROBLEMS AND CREDIT CONSTRAINTS

Capitalists make contractual offers to a subset of workers to become managers and to intermediaries, specifying the loan amount from intermediaries, and payments to managers and to intermediaries, as well as the level of investment. Investment costs are financed either through the retained earnings of managers or through borrowing from

⁸Alternatively, investment costs of the form $k_t(\nu) = \kappa\bar{A}_{t-1}^\rho A_{t-1}^{1-\rho}$ for any $\rho \in [0, 1]$ would ensure balanced growth. We choose the formulation in the text with $\rho = 1$ because it simplifies some of the expressions, without affecting any of our major results. See the NBER working paper version for the expressions when $\rho < 1$.

Note also that for all cases where $\rho > 0$, an improvement in the world technology frontier, $\bar{A}_{t-1}$, increases both the returns and the costs of innovation, but Assumption (11) is sufficient to ensure that the benefits always outweigh the costs.

intermediaries (recall that young capitalists and managers have no wealth to finance projects).⁹ To simplify some of the expressions below, we assume that old managers can only work in old firms (e.g., because old cohorts' skills are not adaptable to the new vintage of technologies), thus a new firm (young capitalist) cannot make an offer to an old manager.

Free entry implies that intermediaries make zero (expected) profits. Thus, intermediaries must receive expected payments equal to the loan they make. The loan made to each firm is equal to the cost of investments, $k_t(\nu)$, minus the manager's possible contribution to the investment paid out of retained earnings, $RE_t(\nu)$.

Managers engaged in innovative activities, or even simply entrusted with managing firms, are difficult to monitor. This creates a standard moral hazard problem, which we formulate in the simplest possible way: we assume that a manager can divert a fraction μ of the returns for his own use, and will never be prosecuted. The parameter μ measures the extent of the incentive problems, or equivalently, the severity of the credit market imperfections resulting from these incentive problems. Moral hazard plays two important roles in our model: first, it creates credit market constraints, restricting investment, especially for young managers who do not have any retained earnings; second, via this channel, it enables the retained earnings of old managers (or equivalently the cash in the hands of existing firms) to shield them against the threat of entry by new managers (firms).

To specify the incentive compatibility constraints more formally, define $\pi_t(\nu \mid s, e, z)$ as the ex post cash-flow generated by firm ν at date t as a function of the size of the project, $s \in \{\sigma, 1\}$, and of the manager's age, $e \in \{Y, O\}$ and skill level $z \in \{L, H\}$, where Y denotes, O denotes old, L stands for low skill and H for high skill. $\pi_t(\nu \mid s, e, z)$ is simply given by the expression in (3) with $A_t(\nu)$ substituted from (8) as a function of s , e and z . For the manager not to divert revenues, the following incentive compatibility constraint must be satisfied:¹⁰

$$W_t(\nu \mid s, e, z) - \mu \pi_t(\nu \mid s, e, z) \geq 0, \quad (12)$$

where $W_t(\nu \mid s, e, z)$ is the salary of a manager of age e and skill z , running a project of size s .

⁹Whether old capitalists inject their own funds or still borrow from intermediaries is immaterial, since there is no cost of intermediation, and the incentive problems are on the side of managers.

¹⁰This specification rules out long-term contracts where the payment to an old manager is conditioned on whether he has diverted funds in the first period or not. Such long-term contracts would require a commitment technology on the part of capitalists, which we assume is not present in this economy. Including long-term contracts does not change the main results.

Capitalists have to satisfy not only the incentive compatibility but also the participation constraints of managers, so that agents prefer becoming managers to working at the market wage, w_t , i.e.,

$$W_t(\nu \mid s, e, z) - RE_t(\nu \mid s, e, z) - w_t \geq 0, \quad (13)$$

where recall that $RE_t(\nu \mid s, e, z)$ is retained earnings injected by the manager to finance part of the costs of investments, thus $RE_t(\nu \mid s, e, z) \leq k_t(\nu \mid s)$, and $RE_t(\nu \mid s, e = Y, \cdot) = 0$, since young agents have no funds.¹¹ To simplify the exposition, we restrict attention to economies where the participation constraints of managers are slack as long as their incentive compatibility constraints are satisfied. This amounts to assuming that μ is sufficiently large, and a sufficient condition is given in Assumption (26) below.

Finally, let us next define

$$V_t(\nu \mid s, e, z) = \pi_t(\nu \mid s, e, z) - W_t(\nu \mid s, e, z) - (k_t(\nu \mid s) - RE_t(\nu \mid s, e, z)) \quad (14)$$

as the value of capitalists with a project of size s , manager of age e and skill z , and

$$s^*(e, z) \in \arg \max_s E_t V_t(\nu \mid s, e, z) \quad (15)$$

as the profit-maximizing project size choice for capitalists when the manager has age e and skill z , where E_t is the expectations operator at time t which applies in the case of young managers whose skills are yet unknown. Also let us denote the maximized value of the capitalists by

$$E_t V_t^*(e, z) = E_t V_t(\nu \mid s^*(e, z), e, z). \quad (16)$$

As long as the participation constraint, (13), is satisfied, there will be an excess supply of young agents willing to become managers. Thus young managers will be paid the lowest salary consistent with incentive compatibility, (12). The same also applies to old low-skill managers (since these managers cannot work in young firms, old capitalists will make take-it-or-leave-it offers to them, forcing them down to their incentive compatibility constraint). But there will typically be an excess demand for old managers who are revealed to be high skill. Competition between old capitalists then implies that:

$$V_t^*(e = O, z = H) \leq \max \langle V_t^*(e = O, z = L); E_t V_t^*(e = Y, \cdot) \rangle. \quad (17)$$

¹¹We assume that managers cannot pay capitalists over and beyond the cost of investments, for example, because capitalists would take these payments, and then switch to hiring another manager if this is profitable.

Suppose this condition did not hold. Then an old capitalist currently hiring either an old low-skill manager or a young manager could deviate, offer a higher salary to attract an old high-skill manager, and increase his profits. To rule out such deviations, (17) must hold.

3 EQUILIBRIUM

3.1 DEFINITION OF EQUILIBRIUM

To define an equilibrium, let us first introduce the notation

$$a_t \equiv \frac{A_t}{\bar{A}_t} \quad (18)$$

as an inverse measure of the country's distance to frontier. This variable will summarize the state of the economy.

The key decisions in this economy are the level of investment (project size) with various types of managers and whether to terminate a manager and replace him with a new one. It is clear that high-skill managers will always be retained, so the crucial choice is whether the low-skill manager will be retained or not. We denote the retention decision by $R_t(\nu) \in \{0, 1\}$, with $R_t = 0$ corresponding to termination and $R_t = 1$ corresponding to retention.

We can then define an equilibrium given the state of the economy, a_t , as:

Definition 1: (Static Equilibrium) Given a_t , an equilibrium is a set of intermediate good prices, $p_t(\nu)$, that satisfy (2), profit levels given by (3), a wage rate, w_t , given by (5), project size choices, $s^*(e, z)$, given by (15), managerial payments, $W_t(\cdot \mid s, e, z)$ and retained earnings contributions by older managers, $RE_t(\cdot \mid s, e = O, z)$, that satisfy (12), (13), and (17), and a continuation decision with low-skill managers, R_t , such that $R_t = 1$ when $E_t V_t^*(e = Y, \cdot) \geq \max \langle 0; V_t^*(e = O, z = L) \rangle$ and $R_t = 0$ when $E_t V_t^*(e = Y, \cdot) < V_t^*(e = O, z = L)$.

This definition requires prices to clear markets and firms to make profit-maximizing decisions, including in the choice of size of investment and termination decision of managers. A dynamic equilibrium is obtained by piecing together static equilibria as defined in Definition 1 through the law of motion of aggregate productivity as given by (9). Rearranging this equation and combining it with (15) and (18), we have:

Definition 2: (Dynamic Equilibrium) A dynamic equilibrium is a sequence of static equilibria such that the law of motion of the state of the economy is given by (9) with $s^*(e, z)$ and R_t given by the static equilibrium.

We will give the equilibrium law of motion in greater detail below.

3.2 EQUILIBRIUM INVESTMENTS

We now characterize equilibrium investments (project size), under the assumption that the moral hazard problem specified above is severe enough that the incentive compatibility constraints in (12) bind and the participation constraints in (13) are slack. To simplify the analysis and focus on the case of interest, we will also make a number of assumptions on the parameters (see Appendix B for the analysis when some of these assumptions are relaxed). The interesting case for us is the one where, because of moral hazard, young managers are credit constrained and are forced to run small projects, while the retained earnings of old managers relax the credit constraint and allow them to run large projects.

For this reason, we start with the following assumption:

$$(1 - \mu) \delta N (\eta + \lambda \gamma) - \kappa < (1 - \mu) \sigma \delta N (\eta + \lambda \gamma) - \phi \kappa, \quad (19)$$

which guarantees that young managers are always constrained in their investments and choose the small project. To see this, recall that $L_t = N$, that (12) is assumed to bind so that young managers obtain a fraction μ of ex post profits, and that young managers are high skill with probability λ . Then, using (3), (8), (10) and (18), we have:

$$E_t V_t (\nu \mid s = \sigma, e = Y, \cdot) = [(1 - \mu) \delta N \sigma ((\eta + \lambda \gamma a_{t-1})) - \phi \kappa] \bar{A}_{t-1}, \quad (20)$$

and

$$E_t V_t (\nu \mid s = 1, e = Y, \cdot) = [(1 - \mu) \delta N ((\eta + \lambda \gamma a_{t-1})) - \kappa] \bar{A}_{t-1}. \quad (21)$$

Assumption (19) guarantees that (20) is larger than (21) for all values of a_{t-1} . Intuitively, young managers receive the minimum salary consistent with incentive compatibility, (12), that is, a fraction μ of the ex post profits. Since these managers have no funds, the cost of greater investment (larger project) is borne by the capitalists, who, in return, only receive a fraction $1 - \mu$ of the returns, and thus have a tendency to underinvest. Assumption (19) therefore builds in the notion that credit constraints induced by moral hazard are binding on young managers.

Are they also binding for old managers? Not necessarily. These managers can use their retained earnings to finance part of the costs of the larger project. More formally, let us look at the values to capitalists with an old low-skill manager, bearing in mind that capitalists make the contract offers, and they can force old low-skill managers down to

their incentive compatibility constraint, paying them a fraction μ of the ex post profits, and also force these old managers to pay their retained earnings towards investment costs. Since we have assumed that the participation constraint (13) is slack (see below for a sufficient condition), old low-skill managers prefer to accept these contract offers rather than work for the market wage. We therefore have:

$$V_t(\nu \mid s = \sigma, e = O, z = L) = [(1 - \mu) \delta \sigma N \eta \bar{A}_{t-1} - \max \langle \phi \kappa \bar{A}_{t-1} - RE_t, 0 \rangle], \quad (22)$$

and

$$V_t(\nu \mid s = 1, e = O, z = L) = [(1 - \mu) \delta N \eta \bar{A}_{t-1} - \max \langle \kappa \bar{A}_{t-1} - RE_t, 0 \rangle], \quad (23)$$

where RE_t is the maximum amount of retained earnings that the old low-skill manager is willing and able to inject, and the max operator takes care of the fact that the manager can only do this up to the point where he or she pays for the entire cost of investment. We have also used the fact that for a low-skill manager $\gamma_t(\nu) = 0$. Next, RE_t has to be less than the maximum retained earnings of the manager. Then we have that

$$RE_t \leq \frac{1+r}{1+g} \sigma \mu \delta N \eta \bar{A}_{t-1}. \quad (24)$$

The right-hand side of (24) is the total retained earnings that the manager has, which is obtained by noting that the manager is low skill and given Assumption (19), in his youth, he ran a small project thus receiving a wage of $\mu \delta \sigma N \eta \bar{A}_{t-2} = \mu \delta \sigma N \eta \bar{A}_{t-1} / (1+g)$. Using (7) and taking into account the interest payments at the rate r gives us the first term in (24). The requirement that the old low-skill manager should run a large project simply boils down to a comparison of (22) and (23) with RE_t given by (24). The following assumption is sufficient to ensure that (23) is greater, so that old low-skill managers run large projects and undertake larger investments than young managers:¹²

$$\kappa > \frac{1+r}{1+g} \sigma \mu \delta N \eta > \min \langle \phi \kappa; \kappa - (1 - \sigma) (1 - \mu) \delta N \eta \rangle. \quad (25)$$

This condition, a fortiori, implies that old high-skill managers will also run large projects.

¹²The first inequality in Assumption (25) is adopted to simplify the expressions in the text (see Appendix B for the case where this assumption is relaxed). The first part of the second inequality, that $(1+r) \mu \sigma \delta N \eta / (1+g) > \phi \kappa$, implies that retained earnings exceed the investment cost associated with small projects. If this were not the case, retained earnings would cancel out from the comparison of (22) and (23), and (19) would imply that low-skill old managers would also run small projects (see Appendix B). Finally, the second part of the second inequality, that $(1+r) \mu \sigma \delta N \eta / (1+g) > \kappa - (1 - \sigma) (1 - \mu) \delta N \eta$, ensures that retained earnings are sufficiently large for low-skill old managers to finance a large share of investment costs, making it worthwhile for capitalists to prefer large projects. To see this, simply use $\kappa \bar{A}_{t-1} > RE_t > \phi \kappa \bar{A}_{t-1}$ and compare (22) and (23).

Finally, we impose:

$$\left(1 - \frac{1+r}{1+g}\sigma\right) \mu\delta N\eta > (1+g)(1-\alpha)\alpha^{-1}\chi^{-\frac{\alpha}{1-\alpha}}, \quad (26)$$

which ensures that the participation constraint, (13), is always slack even when old low-skill managers inject all their retained earnings to finance part of the costs of the large investment project. To see why this condition is sufficient, note that $\mu\delta N\eta\bar{A}_{t-1}$ is the revenue that the old low-skill manager will receive when he runs the large project, and $(1+r)\sigma\mu\delta N\eta\bar{A}_{t-1}/(1+g)$ is the amount of retained earnings he is injecting. The difference between these two gives the left-hand side of (26). If the manager turns down the capitalist's offer, he will work for the market wage, $w_t = (1-\alpha)\alpha^{-1}\chi^{-\frac{\alpha}{1-\alpha}}A_t$ from (5). Assumption (26) therefore ensures that the additional income he receives by accepting the offer exceeds this amount, even when $A_t = \bar{A}_t = (1+g)\bar{A}_{t-1}$.

This discussion can be summarized in the following Lemma.

Lemma 1 Suppose that Assumptions (11), (19), (25) and (26) hold. Then for all $a \in (0, 1)$, we have $s^*(e = Y, \cdot) = \sigma$ and $s^*(e = O, z) = 1$, that is, young managers run small projects and old managers run large projects.

Lemma 1 implies that because of the credit constraints imposed by moral hazard, old managers, who can use their retained earnings, will undertake larger investments than young managers. This introduces the key trade-off in our paper, that between investment and selection. Retaining old low-skill managers achieve greater investments, but at the expense of selection and innovation.

To further elaborate this point, let us write the equilibrium law of motion of a_t . To do this, note that half of the firms are young and use (4) to write $A_t \equiv \int_0^1 A_t(\nu) d\nu = (A_t^Y + A_t^O)/2$, where A_t^Y is average productivity among young firms and A_t^O is average productivity among old firms. In addition, since all young firms hire young managers who, from Lemma 1, choose $s = \sigma$ and a fraction λ of those are high skill, we have $A_t^Y = \sigma(\eta\bar{A}_{t-1} + \lambda\gamma A_{t-1})$.

Average productivity among old firms depends whether we have $R = 1$ or $R = 0$. With $R = 1$, all managers are retained, so a fraction λ are high ability, and from Lemma 1, all old managers choose $s = 1$, so $A_t^O[R = 1] = \eta\bar{A}_{t-1} + \lambda\gamma A_{t-1}$. If, on the other hand, $R = 0$, only a fraction λ of the managers, those revealed to be high skill, are retained, and the remaining $1 - \lambda$ are replaced by young managers. Thus, in this case $A_t^O[R = 0] = \lambda(\eta\bar{A}_{t-1} + \gamma A_{t-1}) + (1 - \lambda)\sigma(\eta\bar{A}_{t-1} + \lambda\gamma A_{t-1})$. Using the definition of a_t

in (18), we have:

$$a_t = \begin{cases} \frac{1+\sigma}{2(1+g)} [\eta + \lambda\gamma a_{t-1}] & \text{if } R_t = 1 \\ \frac{1}{2(1+g)} [(\lambda + \sigma + (1 - \lambda)\sigma)\eta + (1 + \sigma + (1 - \lambda)\sigma)\lambda\gamma a_{t-1}] & \text{if } R_t = 0 \end{cases}. \quad (27)$$

This expression, which is also depicted in Figure 4, shows that the economy with $R_t = 1$ achieves greater growth (higher level of a_t for given a_{t-1}) through the imitation/adoption channel, as captured by the fact that $(1 + \sigma)\eta > (\lambda + \sigma + (1 - \lambda)\sigma)\eta$. However, it also achieves lower growth through the innovation channel, since $(1 + \sigma)\lambda\gamma a_{t-1} < (1 + \sigma + (1 - \lambda)\sigma)\lambda\gamma a_{t-1}$. In light of this observation, we can think of an equilibrium with $R_t = 1$ as corresponding to *an investment-based strategy*, where firms undertake greater investments, even if this comes at the expense of sacrificing managerial selection, and they achieve this with longer-term relationships (managers are never fired) and by shielding older managers from the competition of younger ones. In contrast, with $R_t = 0$, we can think of the economy as pursuing *an innovation-based strategy* where there is greater selection of managers (and more generally of firms) and where the emphasis is on maximizing innovation at the expense of investment. Consequently, the innovation-based strategy results in a more “competitive” environment where unsuccessful managers are terminated and only successful managers are retained.

FIGURE 4 HERE

3.3 EQUILIBRIUM RETENTION AND TERMINATION DECISIONS

Given Lemma 1, the payoff to capitalists from pursuing the innovation-based strategy, i.e., from terminating an unsuccessful manager and hiring a new one, is given by $E_t V_t^*(e = Y, \cdot) = E_t V_t(\nu \mid s = \sigma, e = Y, \cdot)$ as in (20), whereas the payoff from the investment-based strategy is given by $V_t^*(e = O, z = L) = V_t(s = 1, e = O, z = L)$ in (23) with RE_t given by (24) as an equality. Inspection of these two expressions shows that $E_t V_t^*(e = Y, \cdot)$ increases faster in a_{t-1} than does $V_t^*(e = O, z = L)$. This is an immediate implication of the fact that closer to the world technology frontier (with a higher value of a_{t-1}), innovation is more valuable, and replacing old unsuccessful managers with new draws from the distribution makes innovation more likely. It also formalizes the idea discussed in the Introduction, that certain rigid arrangements corresponding to the investment-based strategy here may become more costly (less attractive) when an economy is technologically more developed and/or closer to the world technology frontier.

However, the investment-based strategy also has benefits. At $a_{t-1} = 0$, we have $V_t^*(e = O, z = L) > E_t V_t^*(e = Y, \cdot)$, because so far from the frontier, innovation has little value, and it is more profitable to maximize investment and technology adoption by retaining old managers and making use of their retained earnings.

These observations immediately imply that there will exist a threshold level of the distance to frontier, $a_r(\mu, \delta)$, such that below this threshold, the investment-based strategy is preferred, and above this threshold, capitalists opt for the innovation-based strategy. Equating the expressions in (20) and (23) gives this threshold as:

$$a_r(\mu, \delta) \equiv \frac{\left((1 - \mu)(1 - \sigma) + \frac{1+r}{1+g} \mu \sigma \right) \eta - \frac{\kappa(1-\phi)}{\delta N}}{(1 - \mu) \sigma \lambda \gamma}. \quad (28)$$

This threshold $a_r(\mu, \delta)$ is increasing in δ : when product markets are less competitive (higher δ), the switch to an innovation-based strategy occurs later. This comparative static reflects two effects. The first is the appropriability effect, which, as pointed out above, implies that firms do not capture the entire surplus created by their innovation. Capitalists bear the costs of investment, but because of the appropriability effect, they obtain only a fraction of the returns, consequently they have a bias against the investment-based strategy which involves greater investments.¹³ A higher δ weakens the extent of this appropriability effect and enables the firms, and hence the capitalists, to capture more of the surplus, encouraging the investment-based strategy. Second, as shown by (24), a higher δ implies greater profits and greater retained earnings for old unsuccessful managers, which they can use to “shield” themselves against competition from young managers, making their retention and the investment-based strategy more likely.

The effect of incentive problems/credit market imperfections, μ , on $a_r(\mu, \delta)$ is ambiguous, however. On the one hand, a higher μ increases the earnings retained by managers and raises these insiders’ shield against competition from newcomers, encouraging $R = 1$. On the other hand, a higher μ reduces the profit differential between hiring a young and an old low-skill manager. If

$$\delta > \frac{(1 - \phi) \kappa}{\sigma \eta L} \frac{1 + g}{1 + r}, \quad (29)$$

then, the former effect dominates and a_r is increasing in μ , and more severe moral

¹³Capitalists do not pay the full investment costs, since managers also contribute their retained earnings. Nevertheless, Assumption (25) ensures that capitalists pay a sufficiently large fraction of the costs and that there is a tendency for underinvestment.

hazard/credit market problems encourage the investment-based strategy. In contrast, when (29) does not hold, these problems encourage the termination of low-skill managers.

So far, we have implicitly assumed that young firms were always viable, i.e., that $E_t V_t^*(e = Y, \cdot) \geq 0$. However, despite Assumption (11), which guarantees that innovation is always beneficial, the moral hazard problem between capitalists and managers implies that this may not be the case. When competition is very high (i.e δ is very small) or moral hazard problems are severe (i.e μ is very large), then capitalists' share of revenues may be too small for them to cover the costs of investment even for a small project. It is straightforward to verify that this will occur only if

$$a_{t-1} < a_{ng}(\mu, \delta) \equiv \frac{1}{\lambda\gamma} \left(\frac{\phi}{\sigma(1-\mu)} \frac{\kappa}{\delta N} - \eta \right). \quad (30)$$

In a country with $a_0 < a_{ng}(\mu, \delta)$, there will be no innovation or adoption of new technologies, and production will be carried out by the fringe at the technology A_{t-1} without any further technological progress. We say that such an economy is in a *stagnation trap*.

We now summarize the analysis of the static equilibrium as follows:

Proposition 1 Suppose that Assumptions (11), (19), (25) and (26) hold. Then, given a_{t-1} , there exists a unique equilibrium such that if $a_{t-1} < a_{ng}(\mu, \delta)$ where $a_{ng}(\mu, \delta)$ is given by (30), the economy will be in a stagnation trap with no innovation and no growth. If $a_{t-1} \geq a_{ng}(\mu, \delta)$, then the equilibrium has $R_t = 1$ and an investment-based strategy for all $a_{t-1} < a_r(\mu, \delta)$, and $R_t = 0$ and an innovation-based strategy for all $a_{t-1} > a_r(\mu, \delta)$ where $a_r(\mu, \delta)$ is given by (28). $a_r(\mu, \delta)$ is increasing in δ , so the switch to an innovation-based strategy occurs later when the economy is less competitive.

3.4 DYNAMIC EQUILIBRIUM

Proposition 1 characterizes the static equilibrium given the state of the economy a_{t-1} . The full equilibrium is then given by combining this with the equilibrium law of motion, (27), which, using Proposition 1, simplifies to

$$a_t = \begin{cases} \frac{a_{t-1}}{1+g} & \text{if } a_{t-1} < a_{ng}(\mu, \delta), \\ \frac{1+\sigma}{2(1+g)} (\eta + \lambda\gamma a_{t-1}) & \text{if } a_{ng}(\mu, \delta) < a_{t-1} \leq a_r(\mu, \delta) \\ \frac{1}{2(1+g)} \left(\begin{array}{l} (\lambda + \sigma + (1-\lambda)\sigma)\eta \\ + (1 + \sigma + (1-\lambda)\sigma)\lambda\gamma a_{t-1} \end{array} \right) & \text{if } a_{t-1} > a_r(\mu, \delta) \end{cases}. \quad (31)$$

FIGURE 5 HERE

Figure 5 depicts the equilibrium dynamics. As (31) shows, equilibrium dynamics are always given by a piecewise linear first-order difference equation. When $a_{t-1} < a_{ng}(\mu, \delta)$, there is no innovation, so A_t remains constant, which implies that a_t will decline at the rate of growth of the world technology frontier, asymptotically approaching $a = 0$. Therefore, the equilibrium equation corresponds to $a_{t-1}/(1+g)$, and the economy falls further and further below the world technology frontier. When $a_{ng}(\mu, \delta) < a_{t-1} \leq a_r(\mu, \delta)$, the economy pursues the investment-based strategy, and then finally, when a_{t-1} exceeds $a_r(\mu, \delta)$, the economy switches to the steeper line. In the discussion, we generally focus on economies where $a_{t-1} \geq a_{ng}(\mu, \delta)$, which do not feature stagnation traps. Nevertheless, a *non-convergence* trap is possible even when $a \geq a_{ng}(\mu, \delta)$.

To analyze the possibility of non-convergence traps, let us first characterize the world growth rate, which we assume is determined endogenously by the most advanced economy in the world pursuing the innovation-based strategy. Equation (31) evaluated at $a = 1$ gives this growth rate as:

$$g = \frac{(\lambda + \sigma + (1 - \lambda)\sigma)\eta + (1 + \sigma + (1 - \lambda)\sigma)\lambda\gamma}{2} - 1, \quad (32)$$

which we assume to be strictly positive. Moreover, we assume that at $a = 1$, the innovation-based strategy yields higher growth than the investment-based strategy, i.e.,

$$(1 - \sigma)\eta < \lambda\gamma. \quad (33)$$

These two observations imply that at $a = 1$, the $R = 0$ line intersects the 45 degree line and is above the $R = 1$ line. But then, as drawn in Figure 1, the $R = 1$ line must intersect the 45 degree line at some $a_{trap} < 1$. From (27), this threshold value can be calculated as:

$$a_{trap} = \frac{(1 + \sigma)\eta}{2(1 + g) - \lambda\gamma(1 + \sigma)}. \quad (34)$$

If the economy is pursuing the investment-based strategy when it reaches $a = a_{trap}$, then it will stay there forever. In other words, it will have fallen into a non-convergence trap.

However, in practice, the economy may switch out of the investment-based strategy before a_{trap} is reached. Therefore, the necessary and sufficient condition for an equilibrium non-convergence trap is

$$a_{trap} < a_r(\mu, \delta),$$

which corresponds to the case depicted in Figure 5.

When is this condition likely to be satisfied? From (34), a_{trap} is an increasing function of $\lambda\gamma$, and is independent of $\kappa/\delta N$ and μ . Also, recall that $a_r(\mu, \delta)$ is a decreasing function of $\kappa/\delta N$ and of $\lambda\gamma$, and, if condition (29) holds, it is an increasing function of μ . These observations imply that smaller values of $\kappa/\delta N$ and $\lambda\gamma$ make it more likely that $a_{trap} < a_r(\mu, \delta)$. Furthermore, if condition (29) holds, then traps are more likely in economies with severe incentive problems/credit market imperfections. These comparative statics are intuitive. First, smaller values of κ and greater values of δN make the retention of low-skill managers more likely. Since a trap can only arise due to excess retention, a greater $\kappa/\delta N$ reduces the likelihood of traps. Second, large values of $\lambda\gamma$ increase the opportunity cost of employing low-skill managers, and make it less likely that a trap can emerge due to lack of selection. Finally, when condition (29) holds, more severe credit market imperfections (incentive problems) favor insiders by raising retained earnings and increase the likelihood of a non-convergence trap.

The next proposition summarizes the equilibrium dynamics:

Proposition 2 Suppose that Assumptions (11), (19), (25), (26) and (33) hold and the economy starts with distance to frontier a_0 . Then the unique dynamic equilibrium is as follows:

1. If $a_0 < a_{ng}(\mu, \delta)$, then the economy stagnates, and a_t falls steadily towards $a = 0$.
2. If $a_{ng}(\mu, \delta) < a_0 < a_r(\mu, \delta)$ and $a_{trap} \geq a_r(\mu, \delta)$, then the economy starts with the investment-based strategy, switches to the innovation-based strategy at $a = a_r(\mu, \delta)$, and converges to the world technology frontier, $a = 1$, with a_t monotonically increasing throughout.
3. If $a_{ng}(\mu, \delta) < a_0 < a_r(\mu, \delta)$ and $a_{trap} < a_r(\mu, \delta)$, then the economy starts with the investment-based strategy and converges towards the world technology frontier until it reaches $a = a_{trap} < 1$, where convergence and the growth of a_t stop.
4. If $a_r(\mu, \delta) \leq a_0$, then the economy starts with the innovation-based strategy and converges to the world technology frontier, $a = 1$, with a_t monotonically increasing throughout.

This proposition therefore shows the possibility of two different types of traps: stagnation traps where the economy progressively falls further and further behind the world technology frontier; and non-convergence traps where the economy grows at the same

rate as the frontier, but fails to converge to this frontier. A stagnation trap arises when an economy starts too far from the frontier, and a non-convergence trap results when it fails to switch out of the investment-based strategy.

3.5 GROWTH-MAXIMIZING STRATEGIES AND A THEORY OF LEAPFROGGING

Imagine a social planner interested in maximizing the growth rate of the economy, and she has to take the equilibrium prices and project size choices of Lemma 1 as given. Will she choose an innovation-based strategy ($R = 0$) or an investment-based strategy ($R = 1$)?

Inspection of (27) or of Figure 1 immediately shows that growth will be maximized when the economy reaches the highest level of a_t for a given a_{t-1} , or in other words, she should pursue a strategy of $R = 1$ whenever $a_{t-1} < \hat{a}$, and the innovation-based strategy, $R = 0$, whenever $a_{t-1} > \hat{a}$, where $\hat{a}$ is given by the intersection of the $R = 0$ and $R = 1$ lines in Figure 1 or by:¹⁴

$$\hat{a} \equiv \frac{\eta(1 - \sigma)}{\lambda\gamma\sigma}. \quad (35)$$

Assumption (33) ensures $\hat{a} < 1$. Therefore, similar to equilibrium behavior, the growth-maximizing sequence also starts with the investment-based strategy and then switches to an innovation-based strategy. But the switch from the investment- to the innovation-based strategy does not necessarily occur at the same point as the equilibrium.

How does $\hat{a}$ compare to the equilibrium threshold $a_r(\mu, \delta)$? Generally, the ranking of these two thresholds is ambiguous, and depends, among other things, on the degree of competition as measured by δ . The appropriability effect discussed above means that equilibrium behavior is biased against the investment-based strategy, creating a force towards $a_r(\mu, \delta) < \hat{a}$. However, countering this there is what we might call the “rent-shield” effect: the retained earnings that old low-skill managers use to finance part of the investment costs create a transfer to the capitalists, shielding them from the competition from young managers. In other words, while the appropriability effect creates a bias against insiders to invest more, the retained earnings (rents) of the insiders protect them from competition and create a bias in favor of the investment-based strategy.

Which effect dominates is ambiguous. A greater δ increases $a_r(\mu, \delta)$ relative to $\hat{a}$ (which does not depend on δ), but this might increase or reduce the gap between the

¹⁴We characterize the growth-maximizing strategy not for a discussion of welfare issues, but to derive the implications of equilibrium behavior for aggregate growth rates. In Appendix C, we characterize the welfare-maximizing strategies and show that the comparison of those to the equilibrium is very similar to the comparison of the growth-maximizing strategy to the equilibrium.

equilibrium and the growth-maximizing allocations, depending on whether we start from a situation where $\hat{a} > a_r(\mu, \delta)$ or $\hat{a} < a_r(\mu, \delta)$. Given μ , there exists a unique level of competition δ , denoted by $\hat{\delta}(\mu)$, such that $\hat{a} = a_r(\mu, \hat{\delta}(\mu))$, where

$$\hat{\delta}(\mu) = \frac{(1 - \phi) \kappa}{\mu \sigma \eta L} \frac{1 + g}{1 + r}.$$

If the product market is less competitive than implied by this threshold, namely, if $\delta > \hat{\delta}(\mu)$, then we have $\hat{a} < a_r(\mu, \delta)$, and the economy generates excess retention of low-skill managers relative to the growth-maximizing allocation.¹⁵ In this case, which is the one shown in Figure 5, limiting competition (larger δ) would further increase the growth gap between the equilibrium and the growth-maximizing strategy. Conversely, if product market competition is high, namely if $\delta < \hat{\delta}(\mu)$, then $\hat{a} > a_r(\mu, \delta)$ and the economy switches out of the investment-based strategy too quickly, and limiting competition would reduce the gap between the equilibrium and the growth-maximizing allocations.

An implication of this discussion is that less competitive environments may foster growth at early stages of development (far from the technology frontier). For example, starting with an economy featuring $\hat{a} > a_r(\mu, \delta)$ and $a_{t-1} \in (a_r(\mu, \delta), \hat{a})$, an increase in δ (a reduction in competition) may induce the investment-based strategy in this range and secure more rapid growth. However, the discussion of non-convergence traps in the previous subsection also highlights that limited competition may later become harmful to growth, and prevent convergence to the frontier. In particular, there exists a threshold competition level, $\delta^*(\mu)$, such that

$$a_r(\mu, \delta^*(\mu)) = a_{trap}, \quad (36)$$

where a_{trap} is given by (34). An economy with a sufficiently high level of competition, $\delta < \delta^*(\mu)$, will never fall into a non-convergence trap. Therefore, excessively high competition may cause a slowdown in the process of technological convergence at the earlier stages of development, but does not affect the long-run equilibrium.¹⁶ Low competition, on the other hand, may have detrimental effects in the long-run.

An important implication of this discussion is a new theory of “leapfrogging”. Imagine two economies that start with the same distance to frontier, a_{t-1} , but differ in terms

¹⁵That there is a non-empty set of parameter values where $\hat{a} < a_r$ can be seen by considering large values of μ and δN , and comparing (28) and (35).

¹⁶The exception is that because high competition increases a_{ng} , it makes stagnation traps more likely. Thus the statement in the text applies to economies with $a \gg a_{ng}$.

of their competitive policies, in particular with, $a_r(\mu, \delta_1) < a_{t-1} < \hat{a} < a_r(\mu, \delta_2)$, where δ_1 and δ_2 refer to the levels of competition in the two economies. Given this configuration, economy 1 will pursue the innovation-based strategy, while economy 2 starts with the investment-based strategy and initially grows faster than economy 1. However, once these economies pass beyond $\hat{a}$, economy 1 starts growing more rapidly, since economy 2 still pursues the investment-based strategy despite the fact that growth is now maximized with the innovation-based strategy. Furthermore, if $a_{trap} < a_r(\mu, \delta_2)$, economy 2 will get stuck in a non-convergence trap before it can switch to the innovation-based strategy, and will be leapfrogged by economy 1, which avoids the non-convergence trap and converges to the frontier. This result further illustrates the claim made in the Introduction that certain rigid institutions, for example associated with the less competitive structure supporting the investment-based strategy here, become more costly (perhaps much more costly) as an economy approaches the world technology frontier. It may also shed some light on why some economies, such as Brazil, Mexico or Peru, that initially grew relatively rapidly with highly protectionist policies, were then overtaken by economies with more competitive policies such as Hong Kong or Singapore.¹⁷

4 POLICY AND POLITICAL ECONOMY TRAPS

The analysis so far has established that:

1. the dynamic equilibrium typically starts with the investment-based regime, which features high investment and long-term relationships. As the economy approaches the world technology frontier, this is followed by a switch to an innovation-based regime, with lower investment, shorter relationships between firms and managers, younger firms and more selection.
2. if there is no switch to the innovation-based regime, the economy will get stuck in a non-convergence trap, and fail to converge to the frontier.
3. for some parameter values, far from the world technology frontier, the growth rate can be increased if the economy can be induced to stay longer in the investment-based regime.

The last observation raises the possibility of useful policy interventions along the lines suggested by Gerschenkron: governments in relatively backward economies can intervene

¹⁷Interestingly, before 1967 the growth of GDP per worker was indeed slower in Singapore (2.6% per year) than in both Mexico (3.9%) and Peru (5.3%). This ranking was reverted in the 1970s and 1980s.

to increase investment and to induce faster adoption of existing technologies. However, the second observation points out that this type of intervention may have long-run costs if not reversed later. In this section, we start with a brief discussion of possible policies to foster growth, which can be interpreted as corresponding to “appropriate institutions” for countries at different stages of development, since they are useful at the early stages of development, but harmful later. The bulk of the section is devoted to an analysis of how political economy considerations, in particular lobbying by groups benefiting from existing policies, might make it harder for the society to abandon these policies, thus turning appropriate institutions into “inappropriate institutions,” and potentially generating non-convergence traps.

4.1 POLICY AND APPROPRIATE INSTITUTIONS

Consider an equilibrium allocation with $a_r(\mu, \delta) < \hat{a}$ where the economy switches out of the investment-based strategy before the growth-maximizing threshold. A policy intervention that encourages greater investment will increase growth over the range $a \in (a_r(\mu, \delta), \hat{a})$.¹⁸ A number of different policies can be used for this purpose. Probably the most straightforward is an investment subsidy, which might take the form of direct subsidies or preferential loans at low interest rates etc. Imagine the government subsidizes a fraction τ of the cost of investment. An analogous analysis to before gives the threshold for switching from the investment- to the innovation-based strategy as:

$$\tilde{a}_r(\mu, \delta, \tau) \equiv \frac{\left((1 - \mu)(1 - \sigma) + \frac{1+r}{1+g}\mu\sigma \right) \eta - \frac{\kappa(1-\tau)(1-\phi)}{\delta N}}{(1 - \mu)\sigma\lambda\gamma}.$$

If τ is chosen appropriately, in particular if $\tau = \tilde{\tau}$ such that $\tilde{a}_r(\mu, \delta, \tilde{\tau}) = \hat{a}$, the economy can be induced to switch out of the investment-based strategy exactly at $\hat{a}$ (or at some other desired threshold, if the government is pursuing a different objective). An additional role of investment subsidies is that they would reduce $a_{ng}(\mu, \delta)$, the stagnation threshold, thus making stagnation less likely.

Investment subsidies are difficult to implement, however, especially in relatively backward economies where tax revenues are scarce. Furthermore, it may be difficult for the government to observe exactly the level of investment made by firms. For this reason, we focus on another potential policy instrument that affects the equilibrium threshold

¹⁸The analysis in Appendix V also shows that with μ or δ sufficiently small, we can also have $a_r(\mu, \delta)$ less than the threshold at which a welfare-maximizing social planner would choose to switch from the investment- to the innovation-based strategy, so this discussion could be carried out in terms of policies to encourage welfare maximization rather than growth maximization.

$a_r(\mu, \delta)$, the extent of anti-competitive policies, such as entry barriers, merger policies etc.. Naturally, this discussion also applies to investment subsidies.

Anti-competitive policies are captured by the parameter χ in our model, and recall that δ is monotonically increasing in χ . Thus high values of χ or δ correspond to a less competitive environment. Starting from a situation where $a_r(\mu, \delta) < \hat{a}$, policies that restrict competition will close the gap between the equilibrium threshold and the growth-maximizing threshold. Although restricting competition creates static losses (recall equation (6)), in the absence of feasible tax/subsidy policies this may be the best option available for encouraging faster growth and technological convergence. Similar to investment subsidies, a higher δ (or a higher χ) also reduces $a_{ng}(\mu, \delta)$ and the range of stagnation.

The situation where the government chooses a less competitive environment in a relatively backward economy in order to encourage long-term relationships, greater investment and faster technological convergence is reminiscent to Gerschenkron's analysis.¹⁹ But our analysis also reveals that such institutions/policies limiting competition (and similarly investment subsidies) become harmful for economies closer to the world technology frontier. Appropriate institutions for early stages of development therefore become *inappropriate* for an economy close to the frontier. Thus an economy that adopts such institutions must later abandon them; otherwise, it will end up in a non-convergence trap.

A sequence of policies whereby certain interventions are first adopted and then abandoned raises important political economy considerations, however. Groups that benefit from anti-competitive policies will become richer while these policies are implemented, and will oppose a change in policy. To the extent that economic power buys political power, for example, via lobbying, these groups can be quite influential in opposing such changes. Therefore, the introduction of "appropriate institutions" to foster growth also raises the possibility of "political economy traps", where groups enriched by these institutions successfully block reform, and the economy ends up in a non-convergence trap because, at earlier stages of development, it adopted appropriate institutions.

We now build a simple political economy model where special interest groups may capture politicians. Our basic political economy model is a simplified version of the special-interest-group model of Grossman and Helpman (1994, 2001), extended to include a link between economic power and political influence (see also Do, 2002, on this)

¹⁹It is also reminiscent to the well-known "infant-industry" arguments calling for protection and government support for certain industries at the early stages of development.

and combined with our growth setup.

4.2 POLITICAL ENVIRONMENT

Suppose that competition policy, χ , is determined in each period by a politician (or government) that cares about the current consumption, but is also sensitive to bribes—or campaign contributions. For tractability, we adopt a very simple setup: politicians at time t can be bribed to affect policies at time $t + 1$. The politician’s pay-off is equal to HA_{t-1} , where $H > 0$, if she behaves honestly and chooses the policy that maximizes current consumption (similar to the “myopic planner” discussed in Appendix C), and to B_t otherwise, where B denotes a monetary bribe the politician might receive in order to pursue a different strategy. The utility of pursuing the right policy is assumed to be linearly increasing in A_{t-1} in order to ensure stationary policies in equilibrium, since bribes will be increasing in A .

In this formulation the “honesty parameter” H can be interpreted as a measure of the aggregate welfare concerns of politicians, or more interestingly, as the quality of the system of check-and-balances that limit the ability of special interest groups to capture politicians. This formulation is similar to that in Grossman and Helpman (1994, 2001), but simpler since in their formulation, the utility that the politician gets from adopting various policies is a continuous function of the distance from the ideal policy. As in their setup, the politician is assumed to have perfect commitment to deliver the competition policy promised to an interest group in return for bribes.

Young agents have no wealth, so they cannot bribe politicians. We also assume that only capitalists can organize as interest groups, so the only group with the capability to bribe politicians are old capitalists.²⁰

To simplify the analysis further, we assume that the institutional choice facing the politician is between two policies, low and high competition, or between “competitive” and “anti-competitive” policies, i.e., $\chi_t \in \{\underline{\chi}, \bar{\chi}\}$ where $\underline{\chi} < \bar{\chi} \leq 1/\alpha$. We set, by analogy, $\delta_t \equiv (\chi_t - 1)\chi_t^{-\frac{1}{1-\alpha}} \in \{\underline{\delta}, \bar{\delta}\}$, which, recall, is the parameter in the profit function, (3). We will use χ and δ interchangeably to refer to the degree of competition. Finally, we also set $\zeta_t \equiv (\chi_t - \alpha)\chi_t^{-\frac{1}{1-\alpha}}/\alpha \in \{\underline{\zeta}, \bar{\zeta}\}$, which is the parameter in net output, (6), above. The assumption that χ is a discrete rather than a continuous choice variable is reasonable, since the ability of the politicians to fine-tune institutions is often limited

²⁰The qualitative results would not change if we allowed older managers to contribute to the anti-competitive lobby.

(i.e., they can either impose entry barriers or not, etc.), and it approximates a situation where the main choice is whether or not to undertake some major reform.

4.3 POLITICAL EQUILIBRIUM

As a benchmark, let us start with the policy choice with the case without bribes or an “honest” politician, i.e., $H \rightarrow \infty$. Such a politician will maximize total current consumption

$$C_t = \zeta N A_t - \int_0^1 k_t(\nu) d\nu,$$

that is, net output minus investment, at date t . Throughout the analysis, we maintain Assumptions (11), (19), (25) and (26), so Lemma 1 holds and Proposition 1 describes the static equilibrium.

Will an honest politician ever choose anti-competitive policies ($\chi = \bar{\chi}$ and $\delta = \bar{\delta}$)? It is straightforward to show that he will only do so for $a \in (a_r(\mu, \underline{\delta}), a_{WM})$, where:²¹

$$a_{WM} \equiv \frac{(\bar{\zeta}(1 + \sigma) - \underline{\zeta}(\lambda + \sigma(2 - \lambda)))\eta - (1 - \phi)(1 - \lambda)\kappa/\delta N}{\lambda\gamma(\underline{\zeta}(1 + \sigma(2 - \lambda)) - \bar{\zeta}(1 + \sigma))}. \quad (37)$$

Below $a_r(\mu, \underline{\delta})$, reducing competition does not affect retention decisions, since $R = 1$ anyway, and creates only static monopoly distortions. Above a_{WM} , inducing the investment-based strategy is not sufficiently beneficial. In the range $(a_r(\mu, \underline{\delta}), a_{WM})$, the benefits from inducing the investment-based strategy outweigh the static losses.

Next consider the competition policy set by a politician who responds to bribes (i.e., H finite). Clearly, capitalists always prefer low to high competition, as this increases their profits. Let $B_t^W \equiv B^W(a_{t-1})\bar{A}_{t-1}$ denote the maximum bribe that capitalists are *willing* to pay in order to induce anti-competitive policies, $\delta = \bar{\delta}$, rather than competitive policies, $\delta = \underline{\delta} < \bar{\delta}$. We also assume that agents cannot borrow to pay bribes, so the amount of bribes that they can pay will also be limited by their current income. This assumption introduces the link between economic power and political power (and through this channel, the possibility of history dependence): *richer agents can pay greater bribes and have a greater influence on policy*. Let $B_t^C \equiv B^C(\delta_{t-1}, a_{t-1})\bar{A}_{t-1}$ denote the maximum bribe that they *can* pay, where $\delta_{t-1} \in \{\underline{\delta}, \bar{\delta}\}$ is the level of competition at date $t - 1$. It is equal to the profits generated by young firms in period $t - 1$ that accrues to

²¹ a_{WM} is derived by equating consumption under (i) $R = 1$ and low competition, $\bar{\zeta}$, and (ii) $R = 0$ and high competition, $\underline{\zeta}$. See the working paper version for details. Note also that the set $(a_r(\mu, \underline{\delta}), a_{WM})$ could be empty.

capitalists:

$$B^C(\delta_{t-1}, a_{t-1}) = \delta_{t-1} (1 - \mu) \sigma (N\eta + \lambda\gamma a_{t-1}) - \phi\kappa. \quad (38)$$

δ_{t-1} features in this equation, since the extent of competition in the previous period determines profits and the maximum bribe that capitalists can pay the politician.

Equilibrium bribes are therefore: $B(\delta_{t-1}, a_{t-1}) = \min \langle B^W(a_{t-1}), B^C(\delta_{t-1}, a_{t-1}) \rangle$. We focus on economies where capitalists are credit constrained in the range of interest. Thus, from now on, we have:²²

$$B(\delta_{t-1}, a_{t-1}) = B^C(\delta_{t-1}, a_{t-1}). \quad (39)$$

This is in the spirit of capturing the notion that economic and political power are related. If capitalists were not credit constrained, this link would be absent.

As long as $a_{t-1} \notin [a_r(\mu, \underline{\delta}), a_{WM}]$, i.e., as long as the politician does not want to choose the anti-competitive policy, $\bar{\delta}$, for welfare-maximizing reasons, she will be induced to change the policy to $\bar{\delta}$ if and only if bribes are sufficient to cover the honesty cost, Ha_{t-1} , or if and only if: $B^C(\delta_{t-1}, a_{t-1}) \geq Ha_{t-1}$. Using (38), we can rewrite this inequality as

$$\delta_{t-1} (1 - \mu) \sigma N (\eta + \lambda\gamma a_{t-1}) - \phi\kappa \geq Ha_{t-1}. \quad (40)$$

Greater δ_{t-1} makes it more likely that (40) holds, since it corresponds to greater profits for capitalists, which they can use for bribing politicians. We define a_L and a_H as the unique values of a_{t-1} such that (40) holds with equality for $\delta_{t-1} = \bar{\delta}$ and $\delta_{t-1} = \underline{\delta}$, respectively. Thus:

$$a_L \equiv \frac{\bar{\delta} (1 - \mu) \sigma N \eta - \phi\kappa}{H - \lambda\gamma \bar{\delta} (1 - \mu) \sigma N} > a_H \equiv \frac{\underline{\delta} (1 - \mu) \sigma N \eta - \phi\kappa}{H - \lambda\gamma \underline{\delta} (1 - \mu) \sigma N}. \quad (41)$$

Politicians will be bribed to maintain the anti-competitive policy, $\bar{\delta}$, as long as $a_{t-1} \leq a_L$. Similarly, they will be bribed to switch from competitive to the anti-competitive policies when $a_{t-1} \leq a_H$. That $a_L > a_H$ follows because capitalists make greater profits with low competition and have greater funds to bribe politicians. This formalizes the idea that once capitalists become economically more powerful, they also become politically more influential and consequently more likely to secure the policy that they prefer. Note that both cutoffs, a_L and a_H , are decreasing functions of H , because more honest politicians will be harder to convince to pursue the policy preferred by the capitalist lobby.

FIGURE 6 HERE

²²See the working paper version for the expression for B_t^W and more details on this point.

Figure 6 summarizes this pattern diagrammatically. When $a \in (a_r(\mu, \underline{\delta}), a_{WM})$, politicians choose anti-competitive policies without bribes, since this is the consumption-maximizing policy. Outside this range, anti-competitive policies will only be chosen when the lobby pays sufficient bribes to politicians. When $a \leq a_H$, irrespective of current policy the capitalist lobby can pay enough bribes, and the politician chooses the anti-competitive policies. In contrast, $a \geq a_L$, the politician cannot be bribed and the political equilibrium will involve high competition. Finally and perhaps most interestingly, if $a \in (a_H, a_L)$, the outcome is *history dependent*. If competition is initially low, capitalists enjoy greater monopoly profits and are sufficiently wealthy to successfully lobby to maintain the anti-competitive policies $(\bar{\chi}, \bar{\delta})$. If competition is initially high, capitalists make lower profits and do not have enough funds to buy politicians, so there is no effective lobbying activity, and equilibrium policies are competitive.

To discuss the possibility of political economy traps, now assume that

$$\underline{\delta} < \delta^*(\mu) < \bar{\delta}, \quad (42)$$

where recall that $\delta^*(\mu)$ is the threshold competition level such that $a_r(\mu, \delta^*(\mu)) = a_{trap}$ defined in (36). This assumption implies that $a_r(\mu, \underline{\delta}) < a_{trap} < a_r(\mu, \bar{\delta})$. So a non-convergence trap will arise when anti-competitive policies, $\delta = \bar{\delta}$, are being pursued, while with $\delta = \underline{\delta}$, the economy will switch out of the investment-based strategy before it reaches a_{trap} , and it will continue to converge to the world technology frontier. Whether the economy will get stuck in a non-convergence trap therefore depends on whether the political process leads to a switch from anti-competitive policies, $\bar{\delta}$, to more competitive policies, $\underline{\delta}$ before a_{trap} is reached. Also to simplify the discussion, in the rest of this section we assume that $(a_r(\mu, \underline{\delta}), a_{WM}) = \emptyset$, which removes the case where the politician chooses low competition without receiving bribes.

Next consider the evolution of an economy starting with initial level of technology $a_0 < a_L$, and with a low initial level of competition $\delta = \bar{\delta}$. Then, the politician will be bribed into maintaining low competition as long as a remains below a_L . If we also have

$$a_{trap} \leq a_L, \quad (43)$$

then the economy will reach a_{trap} with anti-competitive policies, $\delta = \bar{\delta}$. Assumption (42) implies that at this point it will be pursuing the investment-based strategy, and get stuck in a non-convergence trap. We refer to this non-convergence trap as a “political economy trap”, since the reason why the economy fails to switch from the investment-based to the innovation-based strategy is successful lobbying by the capitalists in favor of anti-competitive policies.

In contrast, if (43) does not hold, then eventually, a will exceed a_L , and the capitalist lobby will no longer be able to capture the politician, and the economy will revert to the high competition policy, $\delta = \underline{\delta}$, switch to the innovation-based strategy, and converge to the frontier. Inspection of (43) shows that it is more likely to be satisfied when H is low, that is, when the political system is more corruptible. Therefore, in societies with weak political institutions, political economy traps are more likely and government intervention is more “risky” (potentially much more costly, especially for long-run growth).

FIGURE 7 HERE

Figure 7 describes how the trap arises diagrammatically. Lobbying activity implies low competition for all $a \leq a_L$. If the economy ever reached distance to frontier $a = a_L$, it would switch to high competition and to an innovation-based strategy, and would eventually converge to the frontier. But this stage is never reached since convergence stops at $a = a_{trap} < a_L$.

Notice also that whether a political economy trap arises or not depends on initial conditions. For example, suppose that the economy starts with initial distance to frontier $a_0 > a_H$, but differently from before, with competitive policies, $\delta = \underline{\delta}$. Then, as Figure 6 shows, the capitalist lobby will not have enough funds to bribe the politician, because with $\delta = \underline{\delta}$ profits are low, and the economy will remain competitive, i.e., with $\delta = \underline{\delta}$. Assumption (42) then ensures that the economy switches to the innovation-based strategy before a_{trap} and converges to the frontier.

This discussion establishes:

Proposition 3 Suppose that Assumptions (11), (19), (25), (26), (33) and (42) hold. Suppose also that competition policy, $\delta \in \{\underline{\delta}, \bar{\delta}\}$, is decided by a sequence of politicians with honesty cost H , potentially receiving bribes from the capitalist lobby according to equation (39).

Then, there exists a threshold level a_L such that as long as $a < a_L$, starting with $\delta = \bar{\delta}$ the politician will be bribed into maintaining a low level of competition, $\delta_0 = \bar{\delta}$, and a threshold level $a_H < a_L$ such that as long as $a < a_H$ the politician will always be bribed into maintaining or switching to a low level of competition, $\delta = \bar{\delta}$. Both a_H and a_L are decreasing in H .

The dynamic equilibrium takes the following form:

1. If (43) holds, and the economy starts with $a_0 < a_L$ and $\delta_0 = \bar{\delta}$ or with $a_0 < a_H$, then the equilibrium will feature bribes and the investment-based strategy throughout. It will grow until it reaches a_{trap} , and then it will be stuck in a non-convergence trap.
2. If (43) does not hold, and the economy starts with $a_0 < a_L$ and $\delta_0 = \bar{\delta}$ or with $a_0 < a_H$, then the equilibrium will start with bribes and the investment-based strategy. Bribes will stop and there will be a switch to the innovation-based strategy before a_{trap} is reached, and the economy will converge to the frontier.
3. If the economy starts with $a_0 > a_H$ and $\delta = \underline{\delta}$, then there will be no bribes in equilibrium, the economy will switch out of the investment-based strategy and converge to the frontier.

This proposition therefore demonstrates the existence of multiple steady state equilibria, one with the political economy trap and no convergence to the frontier, and the other without the trap and convergence to the frontier. Which of these two long-run equilibria emerges depends on whether the economy starts with low or high competition and on its initial level of development. Since a_H and a_L are decreasing in H , the proposition also shows that political economy traps are more likely when there are few checks and balances on politicians.

5 CONCLUSION

There are marked differences in the economic organization of technological leaders and technological followers. While technological leaders often feature younger firms, greater churning and greater selection, technological followers emphasize investment and long-term relationships. In other words, while technological leaders follow an innovation-based strategy, technological followers adopt an investment-based strategy of growth.

In this paper, we proposed a model which accounts for this pattern, and also evaluates the pros and cons of investment-based and innovation-based strategies. In our economy, firms engage both in copying and adoption technologies from the world frontier and in innovation activities. The selection of high-skill managers and firms is more important for innovation than for adoption. Consequently, as the economy approaches the frontier, selection becomes more important. As a result, countries that are far from the technology frontier pursue an investment-based strategy, with long-term relationships, high average size and age of firms, large investments, but little selection. Closer to the technology

frontier, there is less room for copying and adoption of well-established technologies, and consequently, there is an equilibrium switch to an innovation-based strategy with short-term relationships, younger firms, less investment and better selection of managers.

We show that economies may switch out of the investment-based strategy too soon or too late. A standard appropriability effect, resulting from the fact that firms do not internalize the greater consumer surplus they create by investing more, implies that the switch may occur too soon. In contrast, the presence of retained earnings that incumbent managers can use to shield themselves from competition makes the investment-based strategy persist for too long. When the switch is too soon, government intervention in the form of policies limiting product market competition or providing subsidies to investment may be useful by encouraging the investment-based strategy.

Equally interesting, we find that retained earnings may shield insiders so much that some societies may never switch out of the investment-based strategy, and these societies never converge to the world technology frontier. The reason is that they fail to take advantage of the innovation opportunities that require selection. This means that policies encouraging investment-based strategies might also lead to non-convergence traps.

The growth-maximizing (or welfare-maximizing) policy sequence is therefore a set of policies encouraging investment and protecting insiders, such as anti-competitive policies at the early stages of development, followed by more competitive policies. Such a sequence of policies creates obvious political economy problems. Beneficiaries of existing policies can bribe politicians to prevent policy reform. Moreover, these groups, in our model the capitalists, will be politically powerful precisely because they have economically benefited from the less competitive policies in place. Therefore, the model illustrates how a well-meaning attempt to speed up convergence may lead to a political economy trap. Interestingly, such traps are more likely when the underlying political institutions are weak, making politicians easier to capture. In this context, the model also sheds some light on the debate about whether government intervention should be more prevalent in less developed countries. The answer suggested by the model is that, abstracting from political economy considerations, there may be greater need for government intervention when the economy is relatively backward. But unless political institutions are sufficiently developed (or become developed in the process of economic growth) and impose effective constraints on politicians and elites, such government intervention may result in the capture of politicians by groups that benefit from the intervention, paving the way for political economy traps.

Even though much of the emphasis in this paper is on cross-country comparisons, the

same reasoning also extends to cross-industry comparisons. In particular, our analysis suggests that the organization of firms and of production should be different in industries that are closer to the world technology frontier. More generally, cross-industry differences in the internal organization of the firm and the type of equilibrium financial and employment relationships, and the political economy implications of these differences, constitute a very interesting, and relatively underexplored, area for future research.

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6 APPENDIX A: DETAILS ON EMPIRICAL WORK AND DATA

In this appendix, we provide details on the empirical results briefly presented in the Introduction. The sample of countries includes all non-OECD (including those that joined the OECD in the 1990s, such as Korea and Mexico) and all non-socialist countries for which we have data. The sample is chosen so as to approximate “follower” countries, which are significantly behind the world technology frontier and therefore provide us an opportunities to investigate convergence patterns.

We split the sample into low-barrier and high-barrier countries according to the “number of procedures to open a new business” variable from Djankov, La Porta, Lopez-de-Silanes, and Shleifer (2002) (the results are similar using the two other measures of barriers to entry from Djankov et al.). The low-barrier sample includes: Chile, Egypt, Ghana, Hong Kong, Indonesia, Israel, Jamaica, Kenya, Malaysia, Nigeria, Pakistan, Peru, South Africa, Singapore, Sri Lanka, Taiwan, Thailand, Tunisia, Uganda, Zambia, and Zimbabwe, while the high-barrier sample includes Argentina, Bolivia, Burkina Faso, Brazil, Columbia, Dominican Republic, Ecuador, Jordan, Madagascar, Malawi, Mali, Mexico, Morocco, Mozambique, the Philippines, Tanzania, and Venezuela. Distance to frontier is defined as the ratio of the country’s GDP to the U.S. GDP at the beginning of the sample. For the cross-sectional regressions, per capita GDP growth rates are for 1965-95, and the initial data are for 1965. The output data are from the Summers-Heston data set, obtained from the National Bureau of Economic Research.

Appendix Table 1 reports a number of regressions using this sample. The first column is for all countries that are in our sample and have barriers to entry data. We also control for a dummy for sub-Saharan Africa, since sub-Saharan African countries have experienced much slower growth than the rest of the world during this time period, and we do not think that this is related to the mechanisms emphasized here (see Acemoglu, Johnson and Robinson, 2001, on the role of “institutions” and Easterly and Levine, 1997, on the role of ethno-linguistic fragmentation in explaining low growth in Africa). Thus the estimating equation is:

$$g_{i,65-95} = \alpha_0 + \alpha_1 \left(\frac{y_{i,65}}{y_{US,65}} \right) + \alpha_2 SA_i + \varepsilon_i,$$

where $g_{i,65-95}$ is growth in GDP per capita in country i between 1965 and 1995, $y_{i,65}$ is GDP per capita in country i in 1965, $y_{US,65}$ is GDP per capita in the U.S. in 1965, and SA_i is a dummy for sub-Saharan Africa. The coefficient of interest is α_1 . We are particularly interested in the contrast of this coefficient between the low-barrier and

the high-barrier samples. A more negative estimate for α_1 implies that countries do relatively well far from the frontier, but worse closer to the frontier.

The second and third columns report the regressions shown in Figure 1a and 1b. We can see that there is a much stronger (negative) relationship between distance to frontier and subsequent growth (a more negative estimate of α_1) for the high-barrier countries. The estimate of α_1 is twice the magnitude in the high-barrier sample as in the low-barrier sample, and strongly statistically significant (at the 1 percent level). The table also reports the F-test for the equality of the coefficient on distance to frontier in the low-barrier and the high-barrier samples, which shows that...

The next two columns repeat this regression also controlling for the standard human capital variables (years of schooling and life expectancy in 1965) typically included in cross-country growth regressions. The results are similar to those in columns 4 and 5.

However, even when we control for human capital variables, there are significant differences in the 30-year growth rates across countries. It is informative to investigate whether the same pattern holds when we look at deviations from the country’s “usual growth rate”. This is particularly useful to establish that the differential effects of distance to frontier on subsequent growth in the two samples do not capture permanent growth differences between the high-barrier and the low-barrier countries caused by other factors. To do this, we run a similar regression for ten-year intervals, but also include country fixed effects and time effects. Thus the estimating equation becomes:

$$g_{i,t} = \alpha_0 + \alpha_1 \left(\frac{y_{i,t-1}}{y_{US,t-1}} \right) + d_i + f_t + \varepsilon_{it},$$

where $g_{i,t}$ is the growth rate in country i between $t - 1$ and t , $y_{i,t-1}$ is GDP per capita in country i at date $t - 1$, $y_{US,t-1}$ is GDP per capita in the United States i at date $t - 1$, the d_i ’s denote a full set of country effects, and the f_t ’s denote a full set of time effects, and we take the time intervals to be ten years.

The results shown in columns 6 and 7 are similar, and in some sense, stronger, than those shown in previous columns. Again, the coefficient of interest is about twice in the high-barrier sample as in the low-barrier sample.

Distance to frontier is correlated with the lags of the dependent variable, since $g_{i,t} \approx (y_{i,t} - y_{i,t-1}) / y_{i,t}$. As is well-known, this creates a bias in the estimation of the fixed effects, and therefore in the estimates of α_1 (see, for example, Arellano and Bond, 1991). To deal with this problem, in columns 8 and 9, we report regressions where distance to frontier is instrumented by its one-period lags. The results are similar to those reported in columns 6 and 7.

In the bottom panel of Appendix Table 1 report regressions that do not split the sample, but interact the barrier variable with distance to frontier. The results are consistent with those reported in the top panel.

Appendix Table 2 has an identical form to Appendix Table 1, but splits the sample according to the degree of openness to international trade. Rather than using the ratio of actual trade to GDP, which is a highly endogenous variable, we use the degree of openness predicted by a standard “gravity” equation as in Frankel and Romer (1999). The gravity equation estimates degree of openness as a function of differences in population, land area, proximity and common borders to other countries, and whether a country is landlocked. As in the previous case, we split the sample into two parts, “open” and “closed” countries. The open economies are Barbados, Botswana, Burkina Faso, Cyprus, Cape Verde, Cameroon, Congo, Costa Rica, Dominican Republic, El Salvador, Guinea, Guyana, Honduras, Hong Kong, Israel, Ivory Coast, Jamaica, Jordan, Korea, Lesotho, Malaysia, Mauritius, Namibia, Nicaragua, Panama, Senegal, Seychelles, Singapore, Syria, Taiwan, Trinidad, and Togo, while the close economies are Argentina, Bolivia, Brazil, Central African Republic, Chile, Colombia, Dominican Republic, Ecuador, Egypt, Ethiopia, Fiji, Iran, India, Indonesia, Kenya, Madagascar, Malawi, Mexico, Morocco, Mozambique, Nigeria, Pakistan, Papua New Guinea, Paraguay, Peru, South Africa, Tanzania, Thailand, Uganda, Uruguay, Venezuela, Zambia and Zimbabwe. The results of interest in Appendix Table 2 are similar: both in the cross-sectional and the fixed effect regressions, the estimates of α_1 are substantially larger (more negative) for the closed sample, indicating that closed economies do relatively well far from the frontier, but worse near the frontier.

Finally, Appendix Table 3 reports results with the sample split according to years of schooling in 1965. Our mechanism suggests that skills, and thus human capital, should be more useful near the frontier, so we should find more negative estimate of α_1 in the low-education sample. The point estimates in the cross-sectional regressions are consistent with this, but have large standard errors, so the picture here is not clear. But in the fixed effect regressions, we find considerable support for the hypothesis.

7 APPENDIX B: EQUILIBRIUM WHEN ASSUMPTIONS (19) AND (25) ARE RELAXED

7.1 RELAXING ASSUMPTION (25)

First, suppose that, contrary to (25), we have $RE \equiv \frac{1+x}{1+g}\sigma\mu\delta N\eta \geq \kappa$. In this case, in equation (23) we have $\kappa\bar{A}_{t-1} \leq RE_t$, so we have $V_t(\nu \mid s=1, e=O, z=L) =$

$(1 - \mu) \delta N \eta \bar{A}_{t-1}$, and old low-skill managers are retained whenever

$$a_{t-1} \leq \bar{a}_r(\mu, \delta) \equiv \frac{(1 - \mu)(1 - \sigma)\eta + \phi\kappa/\delta N}{(1 - \mu)\sigma\lambda\gamma}.$$

The rest of the analysis is similar to that in the text, except that the comparative statics of $\bar{a}_r(\mu, \delta)$ with respect to δ are the opposite of those for $a_r(\mu, \delta)$: more anti-competitive policies now favor selection. The reason is that all investment costs are now incurred by old low-skill managers, and an increase in δ decreases the importance of the investment costs borne by capitalists run by young managers relative to profits.

The growth-maximizing threshold $\hat{a}$, it is still given by equation (35), so in this case we always have:

$$\hat{a} < \bar{a}_r(\mu, \delta),$$

in other words, refinancing continues for too long as the economy approaches the frontier, which in turn follows from the fact that old managers now have sufficient retained earnings to shield themselves from the competition of young managers.

Next, suppose that $RE < \min\langle\phi\kappa; \kappa - (1 - \sigma)(1 - \mu)\delta N\eta\rangle$. In this case, old low-skill managers also run small projects, and are retained when:

$$RE - \phi\kappa + (1 - \mu)\delta N\sigma\eta > -\phi\kappa + (1 - \mu)\delta N\sigma(\eta + \lambda\gamma a_{t-1}),$$

or equivalently, when:

$$a_{t-1} < \tilde{a}_r(\mu) \equiv \frac{1 + r}{1 + g} \frac{\mu}{1 - \mu} \frac{\eta}{\lambda\gamma}. \quad (44)$$

Since in this case both young and old managers run small projects, there is no growth advantage to retaining old low-skilled managers, and growth is always maximized by $R = 0$, or in other words, we have $\hat{a} = 0$. Thus in this case the investment-based strategy is inefficient, but it arises as an equilibrium when $a_{t-1} < \tilde{a}_r(\mu)$ because of the shield provided by old low-skill managers' retained earnings, which applies even when they do not invest more than young managers.

7.2 RELAXING ASSUMPTION (19)

When Assumption (19) does not apply, young managers will also undertake large projects for some values of a_t . In particular, a comparison of (20) and (21) shows that $s(e = Y, \cdot) = 1$ whenever

$$a_{t-1} \geq a_s(\mu, \delta) \equiv \frac{(1 - \phi)\kappa/\delta N - (1 - \mu)(1 - \sigma)\eta}{(1 - \mu)(1 - \sigma)\lambda\gamma}.$$

(Note that Assumption (19) guaranteed that $a_s(\mu, \delta) > 1$, so this case never arose in the text).

Now suppose that $s(e = Y, \cdot) = 1$, then it is straightforward to see that low-skill old managers will be retained when:

$$(1 - \mu)\delta N\eta + \frac{1 + r}{1 + g}\mu\delta N > (1 - \mu)\delta N(\eta + \lambda\gamma a_{t-1}),$$

or when $a_{t-1} < \tilde{a}_r(\mu)$ with $\tilde{a}_r(\mu)$ defined by (44) in the previous subsection. We can also see that whenever $a_s(\mu, \delta) > 0$, we have

$$a_r(\mu, \delta) > \tilde{a}_r(\mu),$$

where $a_r(\mu, \delta)$ is the retention threshold given by (28) in the text, which applies when old managers run large projects and young managers run small projects.

Then we can see that the analysis in the text applies whenever $a_s(\mu, \delta) > a_r(\mu, \delta)$, but now after a_t reaches $a_s(\mu, \delta)$, young managers also run large projects. In contrast, when $a_s(\mu, \delta) < a_r(\mu, \delta)$, the retention threshold is $\tilde{a}_r(\mu)$. This is because in this case, we must also have $a_s(\mu, \delta) < \tilde{a}_r(\mu) < a_r(\mu, \delta)$, so by the time $\tilde{a}_r(\mu)$ arrives young managers are already running large projects.²³ Therefore, the equilibrium sequence is as follows:

- If $a_s(\mu, \delta) > a_r(\mu, \delta)$, then we have: $s(e = Y, \cdot) = \sigma$ and $R = 1$ when $a_{t-} \leq a_r(\mu, \delta)$, $s(e = Y, \cdot) = \sigma$ and $R = 0$ when $a_r(\mu, \delta) < a_{t-} \leq a_s(\mu, \delta)$, and $s(e = Y, \cdot) = 1$ and $R = 0$ when $a_s(\mu, \delta) < a_{t-}$.
- If $a_s(\mu, \delta) < a_r(\mu, \delta)$, then we have: $s(e = Y, \cdot) = \sigma$ and $R = 1$ when $a_{t-} \leq a_s(\mu, \delta)$, $s(e = Y, \cdot) = 1$ and $R = 1$ when $a_s(\mu, \delta) < a_{t-} \leq \tilde{a}_r(\mu)$, and $s(e = Y, \cdot) = 1$ and $R = 0$ when $\tilde{a}_r(\mu) < a_{t-}$.

Turning to the growth-maximizing threshold, it is clear that terminating low-skill old managers is always beneficial whenever both young and old managers are running large projects. This implies that the growth-maximizing refinancing threshold becomes:

$$\hat{a}_1 = \min \langle \hat{a}, a_s(\mu, \delta) \rangle,$$

where $\hat{a}$ given by (35) is the growth-maximizing threshold given in the text when young managers run small projects and old managers run large projects.

²³To see this notice that $\tilde{a}_r(\mu) = (1 - \sigma)a_s(\mu, \delta) + \sigma a_r(\mu, \delta)$, i.e., since $\sigma \in (0, 1)$, it is a convex combination of $a_s(\mu, \delta)$ and $a_r(\mu, \delta)$. Then $a_s(\mu, \delta) < a_r(\mu, \delta)$ immediately ensures that $a_s(\mu, \delta) < \tilde{a}_r(\mu) < a_r(\mu, \delta)$.

8 APPENDIX C: WELFARE ANALYSIS

In this Appendix, we compare the equilibrium with the retention policy that maximizes social welfare. More formally, consider a planner who maximizes the present discounted value of the consumption stream, with a discount factor $\beta \equiv 1/(1+r)$, i.e., she maximizes $C_t + \sum_{j=1}^{\infty} \beta^j C_{t+j}$, where $C_t = \zeta N A_t - \int_0^1 k_t(\nu) d\nu$ is equal to net output minus investment at date t with

$$\int_0^1 k_t(\nu) d\nu = \begin{cases} \left(\frac{1+\phi}{2}\right) \kappa \bar{A}_{t-1} & \text{if } R_t = 1 \\ \frac{\lambda+\phi(2-\lambda)}{2} \kappa \bar{A}_{t-1} & \text{if } R_t = 0. \end{cases}$$

As before, we start with an allocation where prices $p_t(\nu)$ satisfy (2), and the wage rate, w_t , is given by (5), and assume that Lemma 1 holds. The planner takes all decentralized decisions, including those regarding project size, as given as in Section 3, and only chooses R .

A useful benchmark, it is useful to start by characterizing the choice of a “myopic planner” who puts no weight on future generations, i.e., $\beta = 0$. The myopic planner chooses the retention policy at t so as to maximize total consumption at t , and will retain old low-skill managers if and only if $a_{t-1} < a_{mfb}$, where the threshold a_{mfb} is such that $R_t = 0$ and $R_t = 1$ yield the same consumption, i.e.,

$$a_{mfb} \equiv \frac{\eta(1-\sigma) - (1-\phi)\kappa/\zeta N}{\sigma\lambda\gamma}. \quad (45)$$

This can be compared with the growth-maximizing policy. Since the planner takes into account the cost of innovation, which is ignored by the growth-maximizing strategy, the myopic planner sets $a_{mfb} < \hat{a}$.

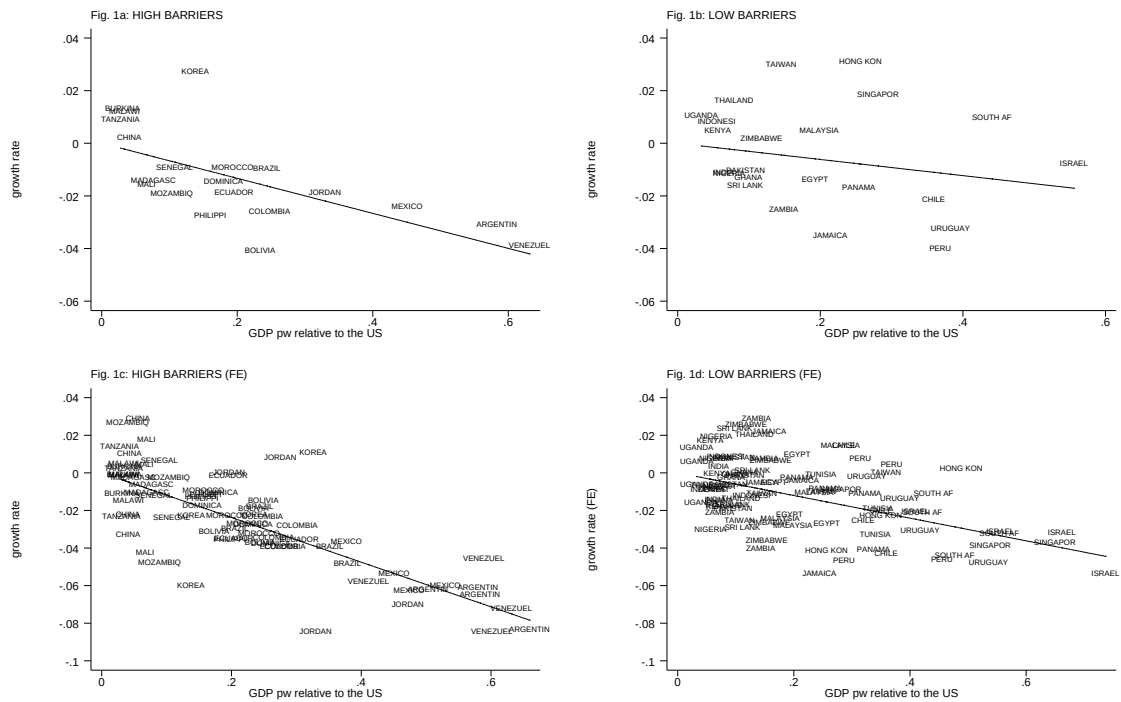
Now, consider a non-myopic planner who also cares about future consumption, i.e., she has $\beta > 0$. She will realize that by increasing the retention threshold on a_{mfb} , she can increase future consumption at the expense of current consumption. For any positive β , and in particular for $\beta = 1/(1+r)$, a small increase of the threshold starting at a_{mfb} involves no first-order loss in current consumption, while generating first-order gains in productivity, A_t , and in the present discounted value of future consumption. Thus, the non-myopic planner will choose a threshold, $a_{fb} > a_{mfb}$. Moreover, we can see that a_{fb} cannot exceed the growth-maximizing threshold, $\hat{a}$. Any candidate threshold larger than $\hat{a}$, say $\tilde{a} > \hat{a}$, can be improved upon, since any threshold in the range $(\tilde{a}, \hat{a}]$ increases both current and future consumption relative to $\tilde{a}$. Thus, the optimal threshold cannot be to the right of $\hat{a}$. In summary, we have

$$a_{mfb} < a_{fb} < \hat{a}.$$

In particular an economy with sufficiently high μ and δN switches to an innovation-based strategy too late, since $a_r(\mu, \delta) > \hat{a}$ in such an economy, as shown in Section 3.5 above. On the other hand, we can also verify that an economy with sufficiently small μ switches to an innovation-based strategy ($R_t = 0$) too soon relative to the welfare-maximizing allocation, i.e., $a_r(\mu, \delta) < a_{fb}$. To see this, note first that the expression of a_{mfb} is identical to the expression of $a_r(\mu, \delta)$ (see equation (28)) for $\mu \rightarrow 0$, except that here ζ replaces δ in (28).²⁴ Recall that because of the appropriability effect, $\zeta > \delta$. By continuity, this implies that for μ sufficiently small, $a_{mfb} > a_r(\mu, \delta)$, and thus a fortiori $a_{fb} > a_r(\mu, \delta)$, i.e., the planner puts more weight on the benefits of innovation than the equilibrium allocation.

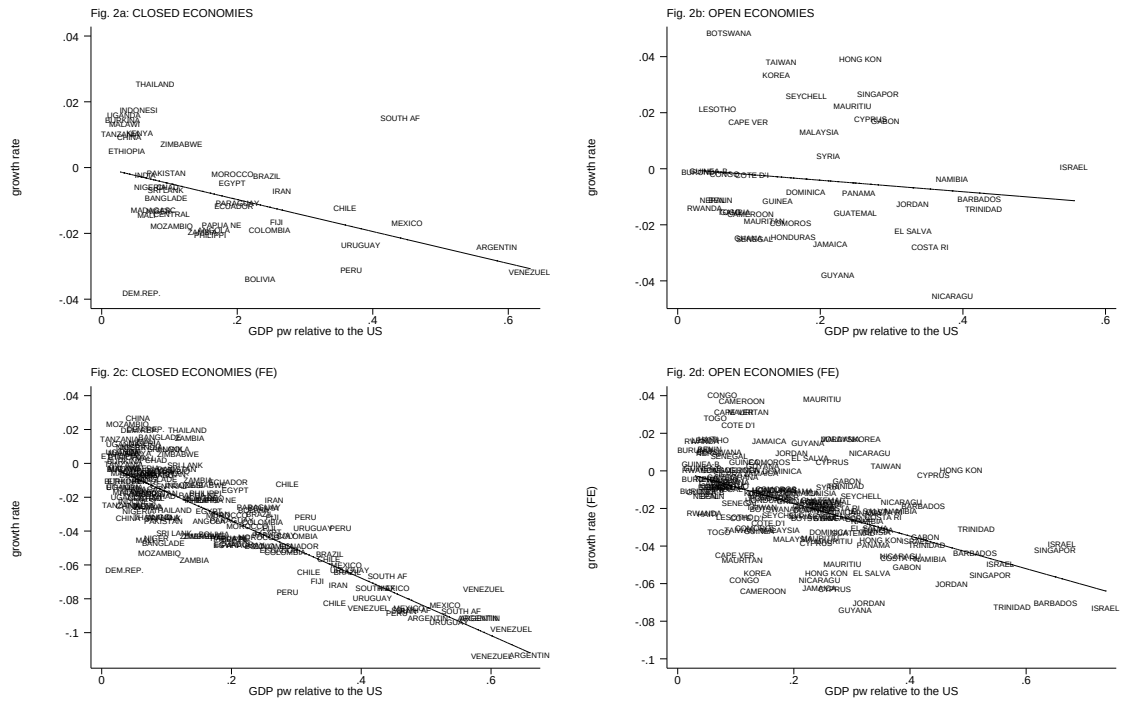
²⁴Recall, however, that as $\mu \rightarrow 0$, we need to change other parameters so that Assumption (26) continues to hold.

FIGURE 1.



STATA

FIGURE 2.



STATA

FIGURE 3.

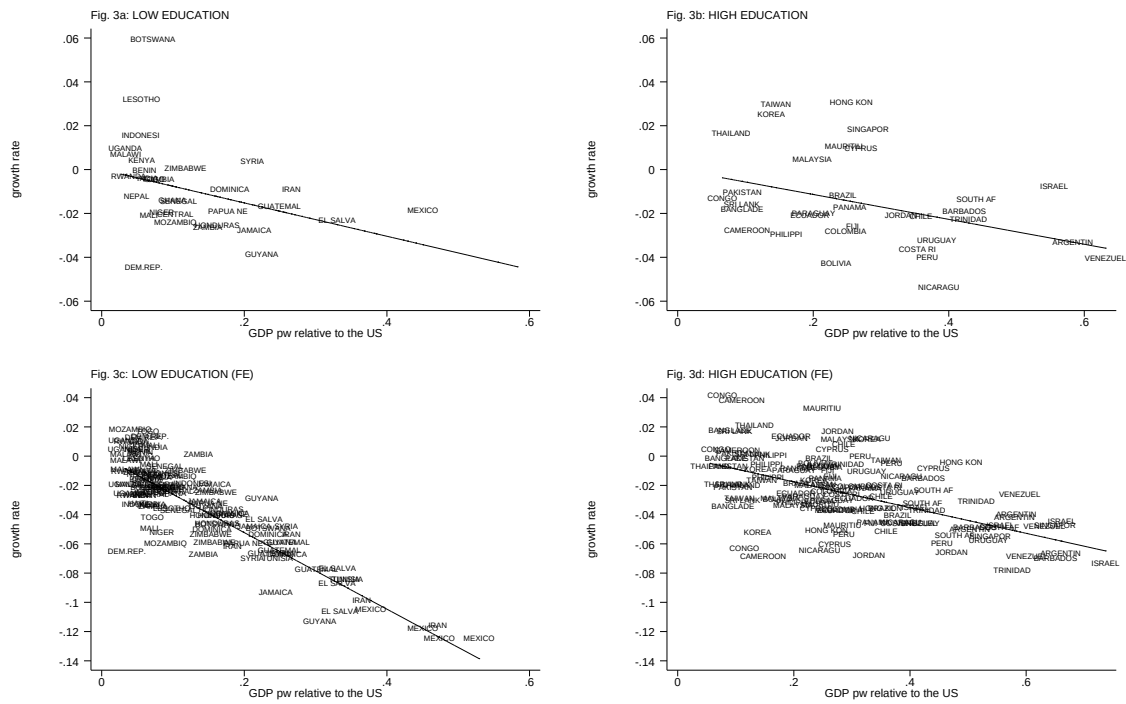


FIGURE 4

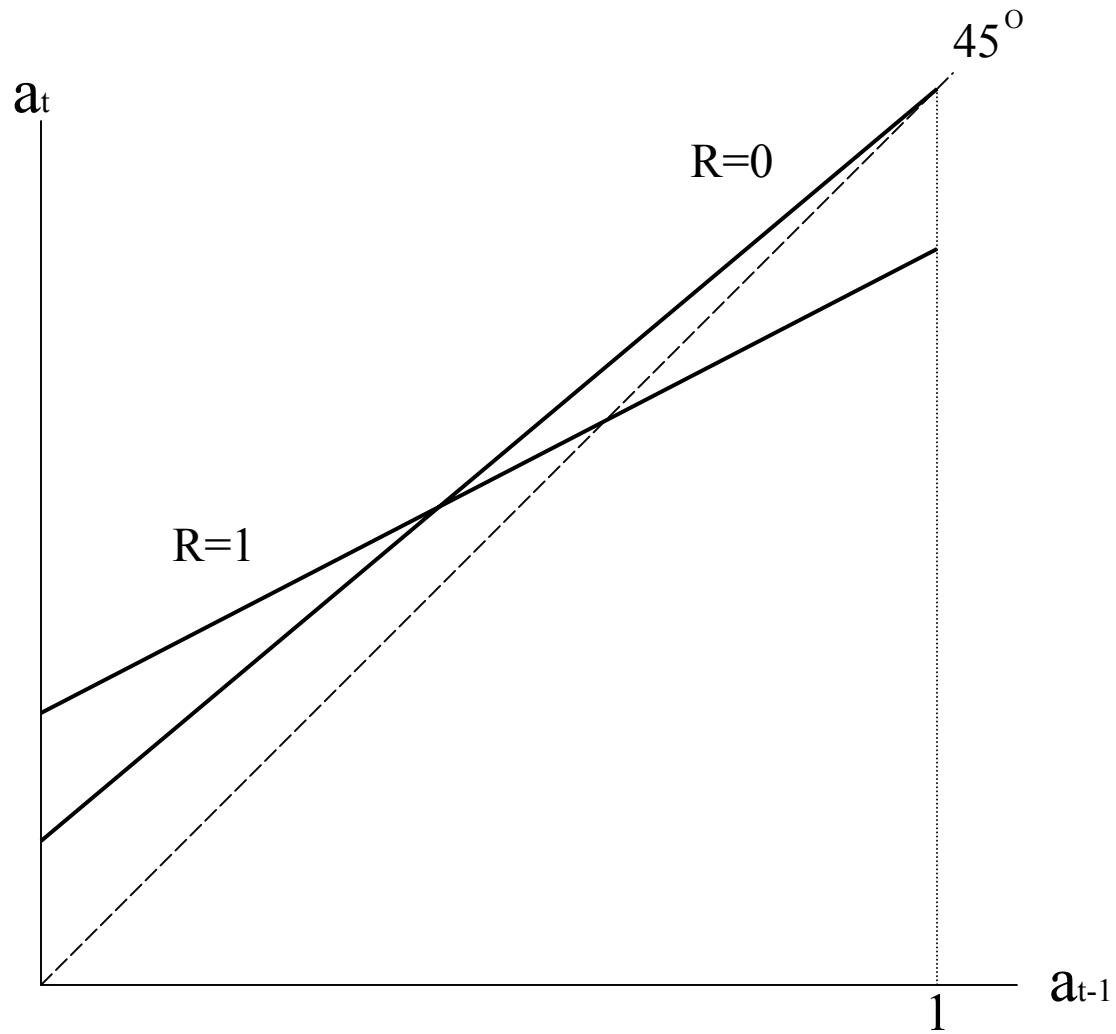


FIGURE 5

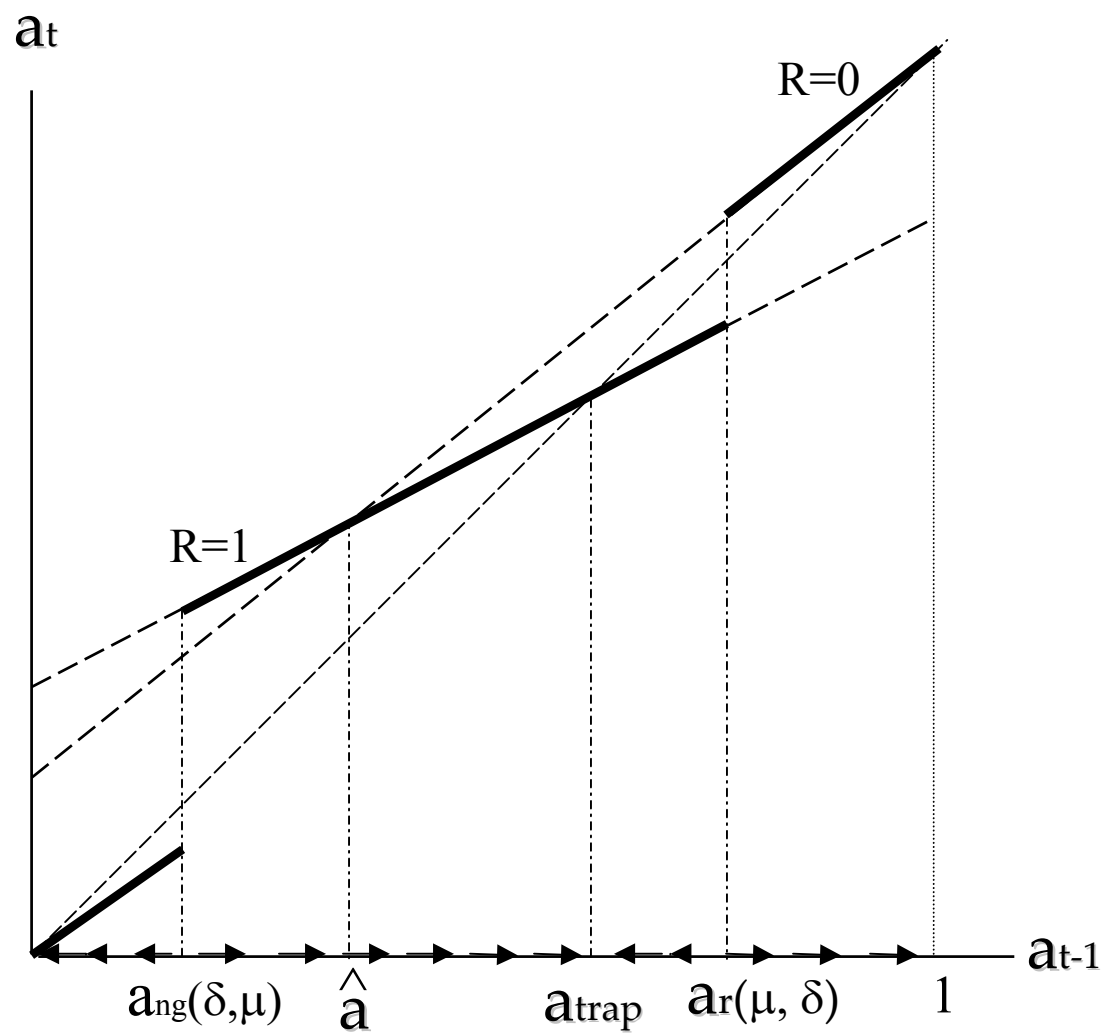


FIGURE 6

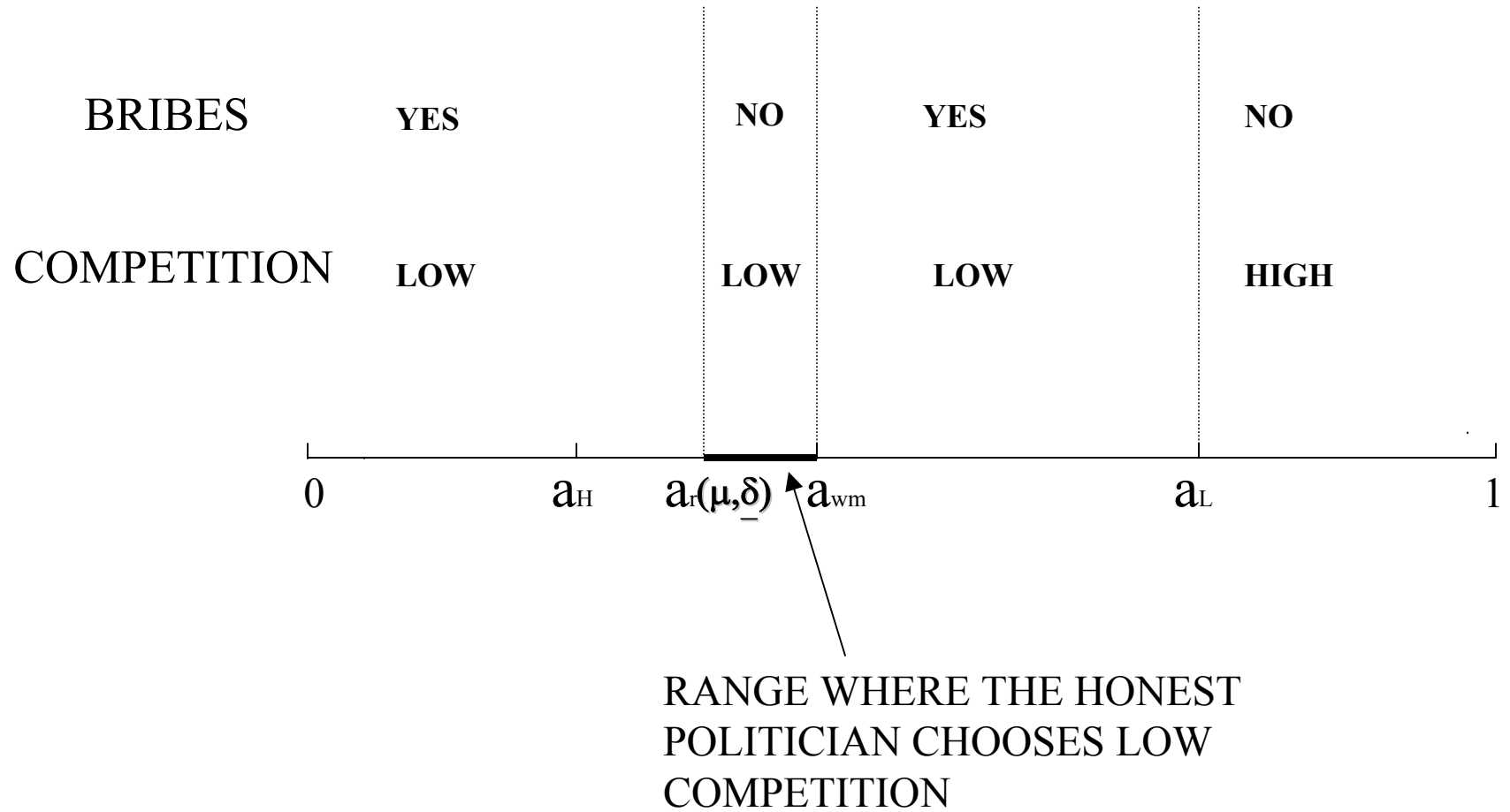


FIGURE 7

