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Organizational Modes within Firms and Productivity Growth

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Abstract

This paper develops a simple growth model with moral hazard contracting to examine the interactions between the organizational mode of firms and economic productivity growth. The organizational mode of firms differs in terms of the degree to which decisions of R&D investment are delegated to a manager. We show that the market size restricts the extent of delegation with respect to R&D, which in turn determines the productivity growth rate of the economy. We then show that there exist multiple equilibria: "partial decentralization equilibrium" with a low growth rate and "full decentralization equilibrium" with a high growth rate. Finally, we study the effects of social capital and competition on equilibrium organizational modes and show that, under some parametric conditions, these factors induce more decentralized organization and higher productivity growth while lowering the risk of the economy converging to a poverty trap.

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1 Introduction

Adam Smith's *The Wealth of Nations* (1776) has long been a touchstone for studies of economics.[1] It is well-known that Smith (1776) pointed out the importance of the division of labor to the improvement of worker productivity, and this improved productivity contributes to the economic growth of nations. Since the industrial revolution, the market economy has been sophisticated, and the relationships among markets and firms have been recognized as a main determinant of economic growth. Since Smith's time, the question of how to coordinate labor within firms, or more generally, the question of how to organize firms themselves in the context of the market economy has become one of the most crucial issues for driving economic growth. Addressing himself to this task, Coase (1937) provided us with a novel view of the firm in a market economy. The crux of his view is the transaction cost, and he asserts that a firm should exist in a market in order to deal with this cost more efficiently. Following this argument, Williamson's studies (1975, 1985) have elaborated the theory of transaction cost, and his theory has led the development of research on organizational economics. In particular, the approach of incomplete-contracting models has continued to offer insightful views of organizational modes within firms. In this way, since the very origin of economics, economists have continued to be interested in the organization of firms and have fruitfully investigated the topics of organizational efficiency, the interaction between markets and firms, and the greater question of how these relationships influence the economic growth of nations.

Economists have developed a range of theories to address these issues but have produced comparatively less in the way of empirical evidence.[2] Recently, however, some empirical studies on organizational economics have discussed choices of organization-specifically, the delegation of decisions within firms and the impact of the same on firm performance-as they relate to the productivity growth of the economy. For example, Bloom et al. (2009) find that, while conditional on size and industry, countries with high social capital, such as trust or rule of law, are generally associated with more decentralized decision-making within firms and that such conditions contribute to enhanced productivity and to

[1] Formally, the title of this book was *An Inquiry Into The Nature and Causes of the Wealth of Nations.*

[2] We review the theoretical research that discusses organizational modes and the relationship of organization to economic productivity in the next chapter.

growth in scale of firms.[3] These results are consistent with the argument made by Penrose (1959) and Chandler (1962) who asserted that decentralization was essential for the creation of large firms. This is because decentralization could mitigate the burden of the top managers who need to make ever more decisions as their firms grow larger. Bloom et al. (2009) find that larger firms are indeed significantly more decentralized. The authors emphasize that the importance of this result has to do with the effective reallocation of resources (i.e., capital and labor) within the economy. Productive firms need to grow large and take market share from unproductive firms.[4]

Motivated by these empirical facts, we develop a simplified Shumpeterian growth model à la Aghion and Howitt (2009), incorporating a moral hazard problem in order to examine the interaction between organizational modes and productivity growth. In our economy, there are two types of one-period-lived and risk-neutral individuals, a mass M of capitalists and a mass $N + 1$ workers. The economy consists of the following two sectors: a final good sector and a series of intermediate good sectors. The final good sector is perfectly competitive and produces the homogeneous numéraire good using labor and a variety of intermediate inputs. Each intermediate good sector is monopolistic. The monopolistic firm owned by a capitalist has access to the most productive technology transforming one unit of final good into one unit of intermediate good. The capitalist, however, cannot exploit these technologies by herself. She must hire one worker as a manager for each intermediate good sector. Because the number of intermediate good sectors is smaller than that of workers, there is some positive probability that each worker fails to match with a capitalist. The worker who succeeds in matching with a capitalist and accepts the contract offered by the capitalist will become a manager of the intermediate good sector. However, a worker who fails to match a capitalist or rejects the work as a manager will work as a production worker in the final good sector. After successfully matching, the capitalist chooses an organizational mode for each intermediate good sector that she owns. If the capitalist adopts a *centralized organization* (hereafter, C-mode), she handles the R&D decision

[3] Bloom et al. (2010) suggest that this result is able to explain the divergent moves towards decentralization over time in the developed countries and towards centralization in less developed countries.

[4] Bloom et al. (2009) introduce some studies that support the importance of reallocation for growth. For example, Foster, Haltiwanger, and Krizon (2000, 2006) show that about 50% of productivity growth in US manufacturing and 90% in US retail comes from reallocation. Further, Hsieh and Klenow (2009) show that China and India would experience a 30% to 60% total factor productivity (TFP) increase if they were to achieve the same efficiency in allocating inputs across production units as the US.

herself. On the other hand, if the capitalist adopts a *decentralized organization* (hereafter, D-mode), the R&D decision is delegated to the manager. Each capitalist decides how many sectors should be delegated to the manager (i.e., D-mode) and how many to handle herself (i.e., C-mode) among the sectors she owns.

To make an R&D decision, either the capitalist under C-mode or the manager under D-mode must choose an unobservable action that stochastically affects the outcome of the R&D (i.e., success or failure). We suppose each manager is guaranteed by the limited liability; thus, there exists a moral hazard problem even though both capitalists and managers are risk-neutral. The fact that the capitalists suffer from the moral hazard problem represents the negative aspect of D-mode for the capitalists. We also suppose that the managers have superior information on the R&D decision to the capitalists so that they can make R&D decisions more efficiently than the capitalists. This represents the positive aspect of D-mode for the capitalist.[5]

We use this model to show the characteristics of the equilibrium organizational mode, which depends on market size, the possibility of multiple equilibria and the selection of the same, and the effects of social capital and competition on the optimal organizational mode. First, this paper shows that the larger market size promotes the delegation of the R&D decision, which in turn enhances the productivity growth of the economy. Second, we show that multiple equilibria are likely to occur when the principal should care about the moral hazard problem.[6] These multiple equilibria include a "partial decentralization equilibrium" with a low growth rate and a "full decentralization equilibrium" with a high growth rate. Multiple equilibria occur due to the positive feedback mechanism between decentralization in intermediate good sectors and labor productivity in the final good sector.[7] That is, the higher the share of D-mode sectors is, the higher the labor productivity is, the higher the reservation wage of the manager is, the higher the capitalist's benefit of choosing D-mode is, and the

[5]This tradeoff of decentralized decision-making between the loss of control and the advantageous information is usually supposed in literature on decentralization or delegation. See, for example, Aghion and Tirole (1997) or Dessein (2002).

[6]Specifically, this is the case where the incentive compatibility constraint rather than the individual rationality constraint is binding.

[7]As we will introduce in the next section, Grossman and Helpman (2002) and Ishiguro (2010) also derived multiple equilibria in their contexts. Our multiple equilibria result, however, relies on the feedback mechanism between decentralization and labor productivity, which substantially differs from theirs.

higher the share of D-mode sectors becomes, and so forth.[8] Whether the economy converges to "full decentralization equilibrium" or "partial decentralization equilibrium" depends upon the expectation the capitalist has in equilibrium. The capitalist's expectation influences the above feedback mechanisms and leads either equilibrium to be a self-fulfilling equilibrium.[9] Finally, we examine how social capital and competition influence the properties of equilibrium organizational mode. We show that, under some parametric conditions, improvements in social capital and enhancement in competition policy promote greater decentralized organization and higher productivity growth and lower the risk of the economy converging to a poverty trap. These theoretical results are consistent with the empirical findings by Bloom et al. (2009, 2010). Moreover, they could offer a proof that the arguments by Smith (1776), Penrose (1959), and Chandler (1962) have generally provided accurate views of the relationship between organizational modes and economic growth.

The rest of the paper is organized as follows: Section 2 gives an overview of the related literature, Section 3 sets up the basic model with incentive contracting, Section 4 describes the capitalist's choice of organizational mode, Section 5 characterizes equilibrium and shows that multiple equilibria occur under some plausible parameter conditions, Section 6 discusses the government policies for improving social capital and enhancing competition and finally, Section 7 concludes the paper.

2 Related Literature

Following of the pioneering studies of the transaction cost theory by Coase and Williamson, economic theory for understanding the determinants of organizational modes within firms has made great progress in the last three decades.

After the early formulation of the incomplete contracting approach developed by Grossman and Hart (1986) and Hart and Moore (1990) to study the incentive effects of different organizational

[8]We should recall the following points to understand this feedback mechanism: first, the higher share of D-mode sectors increases the labor productivity because the manager has better information on R&D decision, and second, the enhanced labor productivity is associated with a higher reservation value of the manager (i.e., the wage obtained in the final good sector). This implies that the cost of adopting C-mode increases, and then, the capitalist is more likely to adopt D-mode.

[9]If the capitalist expects full decentralization to occur, then the positive feedback mechanism, which we mentioned above, would be realized. On the other hand, if each capitalist expects partial decentralization to occur, the negative feedback mechanism will be realized. The negative feedback mechanism means that the lower the share of D-mode sector is, the lower the labor productivity is, the lower the reservation wage is, the lower the share of D-mode sector becomes, and so forth.

modes, Aghion and Tirole (1997) developed a theory of allocation of formal authority (the right to decide) and real authority (the effective control over decisions) within organizations. They showed some conditions where the delegation of formal authority is preferable. The main tradeoff in delegating formal authority is that it enhances the agent's ex ante incentives to acquire information but results in some loss of control. The authors show that the delegation of decision making enhances the agent's incentives to acquire information but weakens the principal's incentives to be informed and to control decisions.[10] More recently, Dessein (2002) applies the cheap talk model à la Crawford and Sobel (1982) and explains why the uninformed principal delegates the decision to the informed agent, although their preferences are different. Unlike Aghion and Tirole (1997), Dessein (2002) supposes that the agent is better informed in advance, but he focuses on the tradeoff in delegating decisions between control loss and avoiding miscommunication. He shows that the principal would rather delegate control to the agent with better information than communicate with this agent so long as the divergence in preferences is not too large relative to the principal's uncertainty about the environment. In both Aghion and Tirole (1997) and Dessein (2002), a high congruence of preferences between the principal and the agent is associated with a higher degree of decentralization within firms. Our model does not explicitly include the parameter that represents such congruency, but one can interpret it such that the congruence is less under the situation with moral hazard than that without moral hazard. As in Dessein (2002), we take the information structure as given, in that the agent is assumed to be better informed in advance. However, our central tradeoff under decentralization is one between availability of better information from the agent and a loss of control due to moral hazard. Thus, the main tradeoff in our model differs from that of these studies.

Our model also has an even more important difference from previous investigations. Earlier studies employ a decision theory approach and treat the environment surrounding the firm as given, thus neglecting the interdependence among the choices that various firms make in the economy. For example, the attractiveness of decentralization to a certain firm may well depend on whether other

[10] Also, they find that without the incentive view, delegating decision making is more likely to occur both when the decision is less important for the principal due to either little cash flow or high congruence with the agent's preference and when the decision is more important for the agent due to either high private benefit or low congruence with the principal's preference.

firms have chosen to be decentralized or not. Moreover, under this decision theory approach, we cannot explicitly examine how the organizational choice of each firm affects the aggregate productivity of the economy, which in turn could influence each firm's choice of organizational mode through changes in macroeconomic variables. Recently, in order to tackle these issues, Grossman and Helpman (2002), Acemoglu et al. (2003), Ishiguro (2007, 2010) and others offer a framework in which the organizational mode of the firm is treated as an equilibrium phenomenon using a general equilibrium model.[11]

Grossman and Helpman (2002) propose a static, incomplete contracting model in which final good manufacturers decide whether to outsource production of intermediate goods or produce them in-house. They show that different organizational modes (outsourcing and vertical integration) can coexist as multiple equilibria only when there are increasing returns to scale in matching among intermediate input producers. The key factor to deriving multiple equilibria in their models is the externality effect yielding the thickness of the market for inputs.[12] Acemoglu et al. (2003) also develop an endogenous growth model with incomplete contracting. They show that in economies behind the world technology frontier, imitation of existing technologies is more important, and vertical integration is preferred. However, as an economy approaches the world frontier, the value of innovation increases, and firms are induced to outsource in order to be able to focus on innovation activities.[13] The key factor to deriving organizational change in their model is the property of technological progress.

Ishiguro (2007, 2010) propose an alternative general equilibrium model of a firm's decentralization decision using a moral hazard contracting approach. Ishiguro (2010) develops a search theoretic model with moral hazard contracting to explain how and why diversity of organizational modes arises endogenously. The organizational mode within firms differs in terms of the degree to which decisions are delegated to a manager. He shows that different organizational modes (decentralization and central-

[11] In addition to the works mentioned hereafter, this paper is closely related to the recent literature on growth and contracts. For example, Francois and Roberts (2003) and Martimont and Vardier (2004) show how a high rate of creative destruction may discourage long-term relationships within firms. This paper also relates to recent work on vertical integration decisions in international trade like Antras (2003) and Grossman and Helpman (2005). Moreover, Thesmar and Theonig (2000) study the endogenous choice of firms' organizational structures in a Schumpeterian growth model. However, they abstain from an explicit discussion of agency costs and rather emphasize how different internal structures affect wage differences between skilled and unskilled workers.

[12] The more frequently other final good manufacturers choose to outsource productions of intermediate goods, the more attractive it becomes for a given manufacture to do so as well.

[13] In vertically integrated firms, owners have to spend time on both production and innovation activities, and this creates managerial overload and discourages innovation. Outsourcing of some production activities mitigates the managerial overload but creates a hold up problem.

ization) can coexist as multiple equilibria for the same parameter value of the model. The key factor to deriving multiple equilibria in his model is the dynamic search market mechanism.[14] Ishiguro (2007) also develops a two-period overlapping generations model with moral hazard contracting to explain how organizations change organizational modes to govern transactions and how such organizational change leads to an endogenous process of economic development. He argues that the equilibrium organizational mode depends upon the financing cost underlying the economy. He also shows that there exist multiple equilibrium paths, some of which converge to the steady-state with decentralized organization while others converge to the steady-state with centralized organization.

Although our model shares a number of interests with these studies, our focus is different still. We focus on the effects of the moral hazard problem on organizational modes within firms and productivity growth rather than the results of the incompleteness of contracts, which have been derived by Grossman and Helpman (2002) and Acemoglu et al. (2003). As it applies the moral hazard contract approach, our model could be interpreted as an extension of Ishiguro (2007, 2010). However, our model incorporates moral hazard into a simplified Shumpeterian growth model à la Aghion and Howitt (2009). Such a simple model brings at least two benefits. First, we can provide a theoretical model that explicitly addresses empirical findings concerning the relationship between organizational modes within firms and productivity growth. Second, we can additionally and relatively straightforwardly find some policy implications regarding organizational modes within firms and economic growth.

3 The Model

3.1 Production and Profit

We consider an economy of an infinite sequence of discrete time periods indexed by $t = 0, 1, 2, \cdots$. In each period, there are two types of individuals, a mass $N + 1$ of workers and a mass M of capitalists. All of them live for one period and are risk-neutral. Each worker is endowed with a unit of labor-skill but no wealth, while each capitalist owns a continuum $\frac{1}{M}$ of intermediate good production sites but

[14]The intertemporal linkage between the current and future contract choices plays a crucial role in deriving the endogenous diversity of organizations. The optimal contract choices by the current period owners depend on the reservation value of the managers, which, in turn, depends on what contracts will be offered by owners in the future periods. By deriving the steady-state points of such a recursive structure of search market equilibrium, the diversity of production organizations arise as multiple steady-state equilibria.

no labor-skills. Because each capitalist owns a continuum $\frac{1}{M}$ of intermediate good production sites, there exists a continuum 1 of intermediate goods in this economy (i.e., $M\frac{1}{M}=1$).

A unique final good, which also serves as the numéraire, is produced competitively by using labor inputs and a continuum 1 of intermediate good inputs. The final good production function is

$$Y_t = N_t^{1-\alpha} \int_0^1 A_t(i)^{1-\alpha} x_t(i)^{\alpha} di, \tag{1}$$

where N_t is the number of production workers in period t,[15] $A_t(i)$ is the productivity parameter that reflects the quality of an intermediate good i in period t, $x_t(i)$ is the flow of intermediate good i used in final good production in period t, and $\alpha \in (0,1)$. The final output is used not only for consumption, but also for an input to produce the intermediate goods.

The profit function of the final good producer is

$$Y_t - w_t N_t - \int_0^1 p_t(i) T x_t(i) di,$$

where $p_t(i)$ is the price of the intermediate good i, w_t is the wage for production workers, and T is the parameter that expresses the efficiency of contract enforcement. Trading between a final good producer and an intermediate good producer incurs transaction costs in the form of iceberg costs. Suppose that a final good producer wants to use one unit of the intermediate good for her own production. Then a final good producer needs to purchase $T \geq 1$ units of intermediate goods. This difference between T and 1 captures the degree of trading costs in this transaction. The final good producer needs to invest $T-1$ units of intermediate good in the verification technology by which she can commit herself to pay for one unit of good in the intermediate good market.[16] As such, T increases when it becomes more difficult for the final good producer to make a credible payment commitment. We could thus interpret T as the parameter value measuring the efficiency of contract enforcement. The strength of legal institutions affects the efficiency of contract enforcement. When the intermediate good producer (or final good producer) can successfully sue for breach of contract including overdue and

[15] As we will discuss later in detail, in equilibrium, workers with size 1 become the managers of intermediate good sectors, and the remaining workers with size N become the production workers in the final good sector.

[16] Although we only consider the case where the verification cost is paid by the final good producer, the main implication of this paper does not change even if we consider the case where the verification cost is paid by the intermediate good producer.

non-payment, this will make contracts easier to enforce and will lower the transaction cost. However, the parlous legal system makes formal prosecution of such behavior extremely difficult, which raises the transaction cost. Besides formal legal institutions, there exists a variety of social arrangements that facilitate corporation and improve the efficiency of contract enforcement. These social arrangements are often labeled as "social capital". Social capital takes a variety of forms including formal legal and political institutions, informal norms, trust, culture, and the like. Therefore, we could interpret T more broadly as the parameter value measuring the quality of social capital in this economy.

Because of the perfect competition, the final good producer can get zero profit. Then, from first order conditions, the inverse demand schedules for each intermediate good i and for production workers are

$$p_t(i) = T^{-1}\alpha(N_t A_t(i))^{1-\alpha} x_t(i)^{\alpha-1}, \tag{2}$$

$$w_t = (1-\alpha)N_t^{-\alpha} \int_0^1 A_t(i)^{1-\alpha} x_t(i)^{\alpha} di. \tag{3}$$

A continuum $\frac{1}{M}$ of intermediate good production sites are owned by one capitalist. In each intermediate good sector, there is one production site owned by the capitalist who has access to the most productive technology $A_t(i)$ capable of transforming one unit of the final good into one unit of the intermediate good with productivity $A_t(i)$. So this leading firm can enjoy monopoly power in each intermediate good market. However, in order to exploit each intermediate good production technology, the capitalist has to hire one worker as a manager. That is, we assume that the capitalist cannot exploit these intermediate good production technologies by herself.[17]

Here, for clarity of explanation, we will continue our discussion under the assumption that the capitalist has already succeeded in employing one manager for each intermediate good production site. Under this assumption, the site owned by the capitalist can be seen as a monopolistic firm in each intermediate good sector. Thus, the gross profit of monopolist firm i is

$$\pi_t(i) = \{p_t(i) - 1\} T x_t(i). \tag{4}$$

The cost of production is therefore equal to the quantity produced $Tx_t(i)$. Here, following Acemoglu, et al. (2006), we implicitly assume that there is a competitive fringe of firms who can steal this

[17] We will later explain our specification with respect to this point in detail.

technology and produce the same intermediate good without the production site. However, this fringe faces higher costs of production and needs $\hat{\chi}$ (> 1) units of the final good to produce one unit of the intermediate good, where $1 < \hat{\chi} \leq 1/\alpha$. The parameter $\hat{\chi}$ captures the technological factors as well as government regulations affecting entry. A higher $\hat{\chi}$ corresponds to a less competitive market. Thus, the monopolist firm should care about this limit price constraint, $p_t(i) \leq \hat{\chi}$, because otherwise the competitive fringe could profitably undercut its price. Therefore, the monopolist firm decides its price so as to maximize $\pi_t(i)$ in (4) subject to (2) and $p_t(i) \leq \hat{\chi}$. Then, we obtain an equilibrium price as follows.

$$p_t(i) = \min\{\hat{\chi}, \frac{1}{\alpha}\} \equiv \chi, \tag{5}$$

which implies an equilibrium quantity:

$$x_t(i) = (\alpha/T\chi)^{\frac{1}{1-\alpha}} N_t A_t(i), \tag{6}$$

and an equilibrium profit:

$$\pi_t(i) = \delta N_t A_t(i), \tag{7}$$

where $\delta \equiv (\chi - 1)(\alpha/\chi)^{\frac{1}{1-\alpha}} T^{\frac{-\alpha}{1-\alpha}}$. Here we can confirm that $\frac{\partial \delta}{\partial T} < 0$ and $\frac{\partial \delta}{\partial \chi} > 0$ hold. Thus, improvements in contract enforcement and a less competitive market lead to a higher profit. Moreover, substituting (6) into (1) and (3), we obtain an equilibrium final good output and its wage rate as follows.

$$Y_t = (\alpha/\chi)^{\frac{\alpha}{1-\alpha}} T^{\frac{-\alpha}{1-\alpha}} N_t A_t, \tag{8}$$

$$w_t = \mu A_t, \tag{9}$$

where $A_t \equiv \int_0^1 A_t(i) di$ and $\mu \equiv (1-\alpha)(\alpha/\chi)^{\frac{\alpha}{1-\alpha}} T^{\frac{-\alpha}{1-\alpha}}$. Both Y_t and w_t are proportional to the aggregate productivity parameter A_t, which is just the unweighted numerical average of all the individual productivity parameters of the intermediate good. In addition, we can confirm that $\frac{\partial \mu}{\partial T} < 0$ and $\frac{\partial \mu}{\partial \chi} < 0$ hold. Thus, improvements in contract enforcement and a more competitive market lead to a higher market wage.

3.2 Matching

Each capitalist owns a continuum $\frac{1}{M}$ of intermediate good production sites but cannot exploit these production technologies by herself. In order to exploit these technologies, each capitalist has to hire one worker as a manager for each intermediate good production site. Here, we assume that each worker has the necessary skills to exploit these technologies.

As in Ishiguro (2010), we consider the following simple matching process between workers and capitalists. At the beginning of each period, each capitalist with a continuum $\frac{1}{M}$ of projects (i.e., the management of intermediate good production sites) enters the matching market to find one worker as a manager for each intermediate good production site. Each worker also enters the matching market in order to find an opportunity to work as a manager. However, the total number of projects (i.e., $M\frac{1}{M} = 1$) is always smaller than the number of workers (i.e., $1 < 1+N$). Thus, projects are always on the short side of the matching market. For simplicity, we suppose that each match between a project and a worker occurs in favor of the short side of the market. That is, a player on the short side of the market can certainly find a trading partner. Applying this short-side principle in the current model, we can ensure that each project surely meets a worker, while each worker fails to match with a project with some positive probability. Here, workers are assumed to be rationed randomly.

On the one hand, the worker who succeeds in matching a project can be a potential manager of an intermediate good production site. Alternatively, he can always decline to work as a manager even when he matches a project if he wants to do so. In that case, such worker will be a production worker in the final good sector to earn the competitive labor market wage w_t. On the other hand, the worker who fails to match a project has nothing but to be a production worker in the final good sector. Therefore, in order to exploit intermediate good production technologies, the capitalist has to offer an acceptable wage contract to the matching worker.

3.3 Innovation and Organizational Modes

In each intermediate good production sector, the monopolistic firm has an opportunity to attempt an innovation. The firm can realize innovation through R&D. The probability of success in R&D

depends on the organizational mode of the firm and the level of R&D effort by either the capitalist or the manager. As we will explain later, the subject who exerts this effort is determined by the organizational mode, which is chosen by the capitalist.

The productivity of the monopolistic firm i at period t $A_t(i)$ is

$$A_t(i) = \begin{cases} \gamma_s A_{t-1} & \text{if R\&D succeeds,} \\ \gamma_f A_{t-1} & \text{if R\&D fails,} \end{cases} \tag{10}$$

where

$$\Delta_\gamma \equiv \gamma_s - \gamma_f > 0, \quad \gamma_f \geq 1.$$

Following the specifications of Aghion and Howitt (2009), we assume that the firm can innovate by building upon the previous technology. That is, innovations build on the knowledge stock of the country; therefore, they multiply A_{t-1}.[18] This specification implies the existence of intersectoral spillover effects among the intermediate good production sites. If the R&D succeeds, the innovation occurs and creates a new version of the intermediate product with the productivity parameter of $\gamma_s A_{t-1}$, which is larger than that of $\gamma_f A_{t-1}$ created when R&D fails. Thus, the gross profit of intermediate good production site i in period t is given by the following:

$$\pi_t(i) = \begin{cases} \delta N_t \gamma_s A_{t-1} \equiv \pi_t^s(i) & \text{if R\&D succeeds,} \\ \delta N_t \gamma_f A_{t-1} \equiv \pi_t^f(i) & \text{if R\&D fails.} \end{cases} \tag{11}$$

We consider two different organizational modes of the firm. We call the organizational mode in which the R&D decision is made by the capitalist *centralized organization* or simply, C-mode. On the other hand, we call the organizational mode in which the R&D decision is delegated to the manager as *decentralized organization* or simply, D-mode. After matching one worker, each capitalist decides on an organizational mode for each intermediate good production site. Precisely, she decides how many projects (e.g., R&D decisions) she carries out by herself (i.e., she adopts C-mode) and how many projects she delegates to the manager (i.e., she adopts D-mode). Let $k_t \in [0, 1]$ (resp. $1 - k_t \in [0, 1]$)

[18] In chapter 11 of Aghihon and Howitt (2009), intermediate firms have two ways to generate productivity growth: (1) they can imitate existing world frontier technologies $\bar{A}_{t-1}$; and (2) they can innovate upon the previous local technology A_{t-1}. Specifically, the productivity of the intermediate good production site i at period t is given by $A_t(i) = \eta \bar{A}_{t-1} + \gamma A_{t-1}$, where the terms $\eta \bar{A}_{t-1}$ and γA_{t-1} refer to the imitation and the innovation components of productivity growth, respectively. In this paper, we ignore the imitation components and only consider the innovation components explicitly. Daido and Tabata (work in progress) consider both imitation and innovation and study the relationship between organizational modes and the technology frontier.

to be the share of sites where the capitalist employs C-mode (resp. D-mode) among $\frac{1}{M}$ sites she owns. Note that k_t is a choice variable by the capitalist. Under C-mode (resp. D-mode), the outcome of R&D, either success or failure, depends upon the effort for R&D taken by the capitalist (resp. the manager). The effort choice is assumed to be binary. We denote the capitalist's (resp. the manager's) effort exerted for R&D under C-mode (resp. D-mode) as $a_C \in \{0,1\}$ (resp. $a_D \in \{0,1\}$), where $a_i = 0$ represents a low effort and $a_i = 1$ is a high effort, for $i = C, D$. Then, we assume that R&D will succeed with probability $p^C(a_C) \in (0,1)$ (resp. $p^D(a_D) \in (0,1)$) but fails with $1 - p^C(a_C)$ (resp. $1 - p^D(a_D)$) under C-mode (resp. D-mode). We also assume that $p^C(1) = p^C$, $p^D(1) = p^D$, $p^C(0) = p^D(0) = p_0$, $\Delta_C \equiv p^C - p_0 > 0$, and $\Delta_D \equiv p^D - p_0 > 0$. Define $\Delta_p \equiv p^D - p^C$. Throughout this paper, then, we make the following assumption:

Assumption 1.

$$\Delta_p \equiv p^D - p^C > 0.$$

The probability of success in R&D depends upon the organizational mode. Specifically, the probability of success in R&D under D-mode will be higher than that under C-mode when a high effort is exerted for R&D. This assumption implies that the manager is more productive than the capitalist when carrying out the task of R&D investment. This assumption is justified by the following two arguments. First, in general, the fact that the manager can proceed to the task more efficiently due to his informational advantage is often assumed as a positive effect of delegation.[19] Secondly, and a more specific reason in our model, the capitalist has more tasks (e.g., the choices of organizational modes, the designing of wage contracts, R&D decisions on other sites, etc.) than the manager. Therefore, on average, the productivity of the manager with respect to R&D decisions for a particular site would be higher than that of the capitalist because the manager can concentrate solely on his R&D decision.[20]

The capitalist's effort cost of R&D depends upon the number of projects $\hat{z}_t$ for which she chooses $a_C = 1$ among $\frac{k_t}{M}$ projects under C-mode (i.e., $\hat{z}_t \leq \frac{k_t}{M}$). Thus, the capitalist incurs the action cost

[19] See, for example, Aghion and Tirole (1997) or Dessein (2002).

[20] An empirical study by Acemoglu et al. (2007) shows that firms closer to the technological frontier are more likely to choose decentralization because they are dealing with new technologies about which there is only limited historical information publicly available. This empirical result is partly consistent with our specification that the probability of success in R&D under D-mode will be higher than that under C-mode.

$\tilde{c}_t(\hat{z}_t)$ when she chooses $a_C = 1$ for $\hat{z}_t$ projects and $a_C = 0$ for the remaining $\frac{k_t}{M} - \hat{z}_t$ projects. Here, $\tilde{c}_t(\hat{z}_t)$ is specified as

$$\tilde{c}_t(\hat{z}_t) = c(\hat{z}_t)A_{t-1}, \tag{12}$$

where $c'(\hat{z}_t) > 0$, $c''(\hat{z}_t) > 0$ and $c'''(\hat{z}_t) > 0$. $c'(\hat{z}_t) > 0$ implies that the capitalist must incur a higher cost as she carries out more projects and exerts $a_C = 1$ for them. $c''(\hat{z}_t) > 0$ implies that the capitalist's marginal cost of action becomes larger when she exerts a high effort for more projects. $c'''(\hat{z}_t) > 0$ implies the convexity of the marginal cost function.[21] Moreover, we specify that the capitalist's action cost is proportional to A_{t-1} to ensure balanced growth. Here, for notational simplicity in the following discussion, let $z_t \in [0, 1]$ be the share of sectors where the capitalist chooses $a_C = 1$ among $\frac{k_t}{M}$ projects under C-mode. Then, we can represent $\hat{z}_t$ as $\frac{z_t k_t}{M}$ (i.e., $\hat{z}_t = \frac{z_t k_t}{M}$).

On the other hand, the manager's effort cost of R&D does not depend upon the number of projects because each manager deals with only one matched project. Thus, the manager's cost of R&D $\tilde{d}_t(a_D)$ simply depends upon the action he chooses and is specified as

$$\tilde{d}_t(a_D) = \begin{cases} dA_{t-1} \equiv \tilde{d}_t & \text{if } a_D = 1, \\ 0 & \text{if } a_D = 0. \end{cases} \tag{13}$$

The manager's action cost is also assumed to be proportional to A_{t-1} to ensure balanced growth.

3.4 Contracts and Organizational Modes

After matching one worker to each intermediate good production site, the capitalist decides on an organizational mode for each site. If the capitalist adopts C-mode, the R&D decision is made by the capitalist herself. On the other hand, if the capitalist adopts D-mode, the R&D decision is delegated to the manager. We assume that the capitalist cannot observe the manager's effort choice for the R&D decision. The verifiable signals are the only realized outcomes of each R&D projects - success or failure. This means that the capitalist suffers from a moral hazard problem under D-mode. Thus, under D-mode, a contract offered to the manager should specify the payment to him contingent on the verifiable outcome. Let $W_t = \{w_t^s, w_t^f\}$ be a contract offered to the manager under D-mode in period t where w_t^s (resp. w_t^f) represents the payment when R&D succeeds (resp. fails) in R&D.

[21] $c'''(\hat{z}_t) > 0$ is assumed for simplicity of the following discussion. The main conclusion of this paper does not change without this specification.

Unlike D-mode, the capitalist does not suffer from a moral hazard problem under C-mode because she makes the R&D decision herself. Thus, under C-mode, the capitalist specifies a fixed payment w_t to the manager because he does not choose unobservable action and hence is not subject to incentive problem. Recall here that the manager is still necessary for the production of the intermediate good even when he is not delegated the R&D decision. Therefore, the capitalist offers a contract with a fixed wage just to compensate the manager's reservation value, w_t (i.e., the wage for the production worker in the final good sector).

Now, we summarize the timing of events in the following way.

(i) The intermediate good production sites owned by the capitalists are matched with workers at the beginning of period t. According to the short-side principle, each site surely meets a worker, while there is some positive probability that each worker fails to match a site.

(ii) The capitalist chooses an organizational mode for each intermediate good production site. More specifically, the capitalist decides the share of intermediate good production sites ($k_t \in [0,1]$) where she adopts C-mode and also ($1 - k_t \in [0,1]$) where she adopts D-mode among $\frac{1}{M}$ sites

(iii) The capitalist offers contracts to the matched workers according to the organizational modes she has chosen.

(iv) Each matched worker chooses whether to accept or reject the contract. If he rejects it, then he works as a production worker in the final good sector. If he accepts it, then he works as a manager in an intermediate good production site.[22]

(v) Given the contracts, the capitalists and the managers choose their actions simultaneously.

(vi) Outcomes are realized and payments are made according to the contracts.

[22]The worker can be a potential manager only for the initial matching project in the intermediate good sector. If he rejects the contract offered by a matched project, he has nothing but to be a production worker in the final good sector. Thus, whether the worker receives a wage contract of a D-mode project or that of a C-mode project depends upon the initial matching.

4 Optimal Contracts and Organizational modes

4.1 The Capitalists' Effort Choices Under C-mode

In this subsection, we characterize the optimal contract under each organizational mode. In each period t, the capitalist chooses an optimal organizational mode, either C-mode or D-mode, as well as the associated optimal contracts offered to the manager. In that stage, the capitalist takes the market wage rate w_t as given because she regards her effect on the market wage to be negligible.

Now, we examine the capitalists' effort choices under C-mode given k_t. The capitalist has $\frac{k_t}{M}$ sites where she could make the R&D decision by herself. Then, she has to choose the share of projects z_t where she exerts a high effort $a_C = 1$ among $\frac{k_t}{M}$ sites. Under C-mode, the manager will be paid the fixed wage w_t because he is necessary for production even when he is not given the R&D decision, and hence, he is compensated just for his reservation value. Given this, the capitalist's expected payoff from the sites under C-mode is given by

$$\frac{k_t}{M}\Big[z_t\{p^C\pi_t^s(i) + (1-p^C)\pi_t^f(i) - w_t\} + (1-z_t)\{p_0\pi_t^s(i) + (1-p_0)\pi_t^f(i) - w_t\}\Big] - \tilde{c}_t(\frac{k_t z_t}{M}). \quad (14)$$

Here, the first (resp. second) term in the bracket means the expected net revenue from a certain sector i by choosing $a_C = 1$ (resp. $a_C = 0$). The last term in (14) indicates the capitalist's effort cost of R&D. Then, the capitalist chooses $z_t \in [0,1]$, the share of sites with $a_C = 1$ among $\frac{k_t}{M}$ sites, so as to maximize equation (14). Throughout this paper, we assume that choosing $a_C = 0$ for any sites under C-mode is not optimal for the capitalists. The following conditions support this assumption:

Assumption 2.

$$\Delta_C\Delta_{\pi_t(i)} \geq \tilde{c}_t'(\frac{1}{M}),$$

where $\Delta_{\pi_t(i)} \equiv \pi_t^s(i) - \pi_t^f(i) = \delta N_t \Delta_\gamma A_{t-1}$.[23] By differentiating (14) with respect to z_t, we obtain $\Delta_C\Delta_{\pi_t(i)} - \tilde{c}_t'(\frac{k_t z_t}{M}) > 0$ under Assumption 2. Thus, Assumption 2 ensures that it is optimal for the capitalist to choose $a_C = 1$ for all sites under C-mode (i.e., $z_t = 1$). Hence, the capitalist's expected payoff under C-mode is given by

$$\frac{k_t}{M}\{p^C\pi_t^s(i) + (1-p^C)\pi_t^f(i) - w_t\} - \tilde{c}_t(\frac{k_t}{M}). \quad (15)$$

[23]Parameter conditions for which this assumption holds are discussed in Appendix A. Appendix A shows that this assumption holds under a large set of parameter values.

4.2 The Optimal Contracts under D-mode

We consider the optimal contract under D-mode. As mentioned in the previous section, we assume that all the managers are risk neutral but protected by limited liability. Thus, the capitalists face the standard moral hazard problem. By delegating the R&D decision to the manager, the capitalist can save her effort cost and have access to the better R&D success probability, but she may have to incur the agency cost due to the unobservability of the manager's actions and the limited liability constraints.

First, we will solve the following standard contracting problem when the capitalist wants to implement $a_D = 1$ from the manager:

- Problem (D1)

$$\max_{(w_t^s, w_t^f)} p^D(\pi_t^s(i) - w_t^s) + (1 - p^D)(\pi_t^f(i) - w_t^f)$$

  subject to

$$p^D w_t^s + (1 - p^D) w_t^f - \tilde{d}_t \geq w_t \tag{IR}$$

$$p^D w_t^s + (1 - p^D) w_t^f - \tilde{d}_t \geq p_0 w_t^s + (1 - p_0) w_t^f \tag{IC}$$

$$w_t^s \geq 0 \text{ and } w_t^f \geq 0. \tag{LL}$$

Recall that w_t^s (resp. w_t^f) denotes the rewards to the manager when R&D succeeds (resp. fails) in each site. The first constraint indicates the individual rationality constraint (IR) for the manager. Note that the reservation value for the manager is the marker wage w_t. The second constraint is the incentive compatibility constraint (IC), which induces the manager to choose $a_D = 1$ instead of $a_D = 0$ under the contract $W_t = (w_t^s, w_t^f)$. Finally, (LL) is the limited liability constraint ensuring that the manager receives non-negative rewards whether R&D succeeds or not.

The optimal solution to the above problem is given as follows.[24] (a) When $(\frac{p^D}{\Delta_D})\tilde{d}_t - \tilde{d}_t > w_t$, the optimal contract is $(w_t^s, w_t^f) = (\tilde{d}_t/\Delta_D, 0)$. In this case, (IC) binds. (b) When $(\frac{p^D}{\Delta_D})\tilde{d}_t - \tilde{d}_t \leq w_t$, the

[24] We briefly give a proof in Appendix B.

optimal contract is (w_t^s, w_t^f), which satisfies (IR) with equality and (LL). One of these is $(w_t^s, w_t^f) = ((w_t + \tilde{d}_t)/p^D, 0)$.

In the former case (a), (IC) is binding, while (IR) becomes slack. In this case, the capitalist must give the manager positive information rent over his reservation value w_t in order to induce $a_D = 1$ from him. Therefore, the expected payoff of the manager $(\frac{p^D}{\Delta_D})\tilde{d}_t - \tilde{d}_t$ becomes higher than his reservation value w_t, and thus, the capitalist suffers from the agency cost. One implication derived from this result is that the delegation of R&D decision gives the manager more power to extract higher rewards $\tilde{d}_t/\Delta_D$, which reflects his informational advantage over the capitalist in the organization. In other words, the reward for the D-mode (delegated) manager is determined by the internal logic of the organization and is not necessarily equal to the outside market value (the reservation wage). Hence, in the case (a), the reward of the delegated manager is not sensitive to the change in outside market value. This is in contrast to the case of C-mode in which R&D decision is not delegated to the manager, and hence his reward falls to his reservation wage.

However, in the latter case (b), (IR) is binding, while (IC) becomes slack. In this case, the capitalist does not have to give the manager positive information rent over his reservation value w_t in order to induce $a_D = 1$ from him. This is simply because the reservation market wage w_t is so high that the constraint (IC) becomes negligible relative to the constraint (IR). The informational advantage over the capitalist gives the manager power to extract higher rewards only when constraint (IC) is binding. Therefore, the expected payoff to the manager equals his reservation value w_t; thus, the capitalist does not suffer from the agency cost. In this sense, the unobservability of the manager's action does not matter for the capitalist in case (b).

Summarizing these arguments, when $a_D = 1$ is implemented, the payoff of the capitalist from D-mode at site i is given by

$$V_1^D(i) = p^D \pi_t^s(i) + (1 - p^D)\pi_t^f(i) - \max\{\frac{p^D}{\Delta_D}\tilde{d}_t, w_t + \tilde{d}_t\}. \tag{16}$$

Next, we consider the case where the capitalist wants to implement $a_D = 0$ from the manager. In this case, unobservability of actions is not subject to incentive problem. Thus, as in the case of

C-mode, the principal offers the fixed payment w_t just to compensate the manager's reservation value. Therefore, when $a_D = 0$ is implemented, the principal's expected payoff from D-mode at site i is given by $V_0^D(i) = p_0\pi_t^s(i) + (1-p_0)\pi_t^f(i) - w_t$. Here, from (14), $V_0^D(i)$ equals the value of expected net revenue that is achieved when $a_c = 0$ is exerted at a certain sector i under C-mode.

Now, the capitalist has to determine whether she should implement $a_D = 1$ or $a_D = 0$ from the manager. However, under Assumption 2, implementing $a_D = 0$ from the manager is never optimal for the capitalist. Assumption 2 indicates that the relation $p^C\pi_t^s(i)+(1-p^C)\pi_t^f(i)-w_t-\tilde{c}_t'(\frac{1}{M}) \geq V_0^D(i)$ holds. Thus, suppose the capitalist implements $a_D = 0$ from the manager at a certain site i under D-mode. She can raise her expected payoff by changing this site i to C-mode and exerting high action $a_C = 1$. Hence, under Assumption 2, implementing $a_D = 1$ from the manager can be a unique candidate for equilibrium solution. Thus, the capitalist's expected payoff from site i under D-mode is given by

$$V^D(i) = V_1^D(i) = p^D\pi_t^s(i) + (1-p^D)\pi_t^f(i) - \max\{\frac{p^D}{\Delta_D}\tilde{d}_t, w_t + \tilde{d}_t\}. \tag{17}$$

Finally, for simplicity, we focus our analysis on the case where the capitalist's net expected payoff becomes non-negative. The sufficient condition for which this assumption holds is given by [25]

Assumption 3.

$$V^D(i) \geq 0.$$

Under Assumption 3, the capitalist always enters the intermediate good production market and offers acceptable contracts to all matched managers.

4.3 Organizational Modes

In this subsection, we characterize the optimal organizational mode (i.e., the capitalist's choice of k_t). In each period t, given the market wage rate w_t, the capitalist chooses organizational modes. Under parametric conditions for which Assumptions 2 and 3 hold simultaneously, the expected payoff for the

[25] Parameter conditions for which this assumption holds are discussed in Appendix A. Appendix A also shows some parametric conditions for which Assumptions 2 and 3 hold simultaneously and confirms that these assumptions hold under a large set of parameter values.

capitalist with k_t share of C-mode sites and $(1-k_t)$ share of D-mode sites among $\frac{1}{M}$ sites is given by

$$\frac{k_t}{M}\{p^C\pi_t^s(i)+(1-p^C)\pi_t^f(i)-w_t\}-\tilde{c}_t(\frac{k_t}{M})+(\frac{1-k_t}{M})\big[p^D\pi_t^s(i)+(1-p^D)\pi_t^f(i)-\max\{\frac{p^D}{\Delta_D}\tilde{d}_t, w_t+\tilde{d}_t\}\big]. \tag{18}$$

Then, the capitalist chooses $k_t \in [0,1]$ so as to maximize her expected payoff (18). By differentiating (18) with respect to k_t, we obtain the optimal k_t as follows:

$$k_t^* = \begin{cases} 0 & \text{if } \tilde{c}_t'(\frac{k_t}{M}) + \Delta_p\Delta_{\pi_t(i)} > \max\{\frac{p^D}{\Delta_D}\tilde{d}_t - w_t, \tilde{d}_t\}, \\ k_t \in (0,1) & \text{if } \tilde{c}_t'(\frac{k_t}{M}) + \Delta_p\Delta_{\pi_t(i)} = \max\{\frac{p^D}{\Delta_D}\tilde{d}_t - w_t, \tilde{d}_t\}, \\ 1 & \text{if } \tilde{c}_t'(\frac{k_t}{M}) + \Delta_p\Delta_{\pi_t(i)} < \max\{\frac{p^D}{\Delta_D}\tilde{d}_t - w_t, \tilde{d}_t\}. \end{cases} \tag{19}$$

L.H.S. of the condition in (19) (i.e., $\tilde{c}_t'(\frac{k_t}{M}) + \Delta_p\Delta_{\pi_t(i)}$) represents the marginal cost of choosing C-mode (or the marginal benefit of choosing D-mode). By increasing the number of C-mode projects, the capitalist incurs more effort cost $\tilde{c}_t'(\frac{k_t}{M})$ and obtains smaller profits due to the lower R&D success probability $\Delta_p\Delta_{\pi_t(i)}$. On the other hand, R.H.S of the condition in (19) (i.e., $\max\{\frac{p^D}{\Delta_D}\tilde{d}_t - w_t, \tilde{d}_t\}$) represents the marginal benefit of choosing C-mode (or the marginal cost of choosing D-mode). The term $\frac{p^D}{\Delta_D}\tilde{d}_t - w_t$ represents the case where (IC) is binding under D-mode, while the term $\tilde{d}_t$ represents the case where (IR) is binding. By increasing the number of C-mode projects, the capitalist can marginally save the information rent by $\frac{p^D}{\Delta_D}\tilde{d}_t - w_t$ when (IC) is binding, while she can save the payment to the manager by $\tilde{d}_t$ when (IR) is binding.

From (19), when (IC) is binding under D-mode, the increase in the market wage w_t reduces the capitalist's marginal benefit of choosing C-mode and thus increases the share of sectors where the capitalist employs D-mode. The intuitive mechanism behind this result is explained as follows: under D-mode where (IC) binds, the payment to the manager is independent of his reservation market wage w_t because his reward is determined by the internal logic of the organization (i.e., the manager's informational advantage over the capitalist). However, under C-mode, the payment to the manager equals his reservation market wage w_t. Thus, his reward increases with market wage w_t. Therefore, the rise in market wage w_t increases the capitalist's benefit of choosing D-mode and thus, increases the share of sectors where the capitalist employs D-mode.

5 Equilibrium

5.1 Equilibrium Organizational Modes

This section characterizes the general equilibrium of our model. Under Assumption 3, the capitalist always offers acceptable contracts to all managers. Thus, after matching process, the workers with size 1 become the managers of intermediate good production sites, and the remaining workers with size N become the production workers in the final good sector (i.e. $N_t = N$). From (9), the market wage w_t in this economy is proportional to the aggregate productivity parameter A_t. Then, the definition of A_t implies

$$A_t = \{\int_0^1 \gamma_t(i)di\}A_{t-1} = \{k_t\gamma^C + (1-k_t)\gamma^D\}A_{t-1}, \tag{20}$$

where $\gamma^C \equiv p^C\gamma_s + (1-p^C)\gamma_f$, $\gamma^D \equiv p^D\gamma_s + (1-p^D)\gamma_f$, and $\gamma^D - \gamma^C = \Delta_p\Delta_\gamma > 0$. Therefore, the productivity growth rate of the economy g_t is given by

$$g_t \equiv \frac{A_t}{A_{t-1}} - 1 = k_t\gamma^C + (1-k_t)\gamma^D - 1.$$

Here, note that the level of A_t and the productivity growth rate g_t depend upon the share of D-mode sectors (i.e., $1-k_t$). Because the probability of success in R&D is relatively higher under D-mode (i.e., $\gamma^D > \gamma^C$), the level of A_t and g_t become higher, as the share of D-mode sectors increases. This implies that both A_t and g_t are decreasing in k_t in equilibrium. Then, by substituting (9), (11), (12), (13), (20), and $N_t = N$ into (19), we obtain the following condition, which determines the organizational mode in general equilibrium.

$$k_t^* = \begin{cases} 0 & \text{if } c'(\frac{k_t}{M}) > R(k_t), \\ k_t \in (0,1) & \text{if } c'(\frac{k_t}{M}) = R(k_t), \\ 1 & \text{if } c'(\frac{k_t}{M}) < R(k_t), \end{cases} \tag{21}$$

where

$$\begin{aligned} R(k_t) &\equiv \max\{R_{IC}(k_t), R_{IR}\}, \\ R_{IC}(k_t) &\equiv \frac{p^D}{\Delta_D}d - \mu\{k_t\gamma^C + (1-k_t)\gamma^D\} - \Delta_p\Delta_\gamma\delta N, \\ R_{IR} &\equiv d - \Delta_p\Delta_\gamma\delta N. \end{aligned}$$

As described in the previous section, $R(k_t) = R_{IC}(k_t)$ when (IC) is binding under D-mode, while $R(k_t) = R_{IR}$ when (IR) is binding. Here, we can confirm that the relation $R'_{IC}(k_t) = \mu\Delta_p\Delta_\gamma > 0$

holds, while R_{IR} is constant with respect to k_t. As shown in Appendix C, the relation $R_{IC}(k_t) > R_{IR}$ (resp. $R_{IC}(k_t) \leq R_{IR}$) holds for all $k_t \in [0,1]$ when $\mu\gamma^D < \frac{p^D}{\Delta_D}d - d$ (resp. $\frac{p^D}{\Delta_D}d - d \leq \mu\gamma^C$). Thus, the inequality $\mu\gamma^D < \frac{p^D}{\Delta_D}d - d$ implies the sufficient parametric conditions for which (IC) is binding, while $\frac{p^D}{\Delta_D}d - d \leq \mu\gamma^C$ gives the sufficient parametric conditions for which (IR) is binding. In addition, suppose $\mu\gamma^C < \frac{p^D}{\Delta_D}d - d \leq \mu\gamma^D$, $R_{IC}(k_t)$ has one intersection with R_{IR} at $\hat{k_t} \in [0,1]$, as shown in Figure 7. Thus, when $\mu\gamma^C < \frac{p^D}{\Delta_D}d - d \leq \mu\gamma^D$, (IC) is binding when $\hat{k_t} < k_t$, while (IR) is binding when $k_t \leq \hat{k_t}$. In the following subsections, we focus our analysis on the case where parametric conditions $\mu\gamma^D < \frac{p^D}{\Delta_D}d - d$ or $\frac{p^D}{\Delta_D}d - d \leq \mu\gamma^C$ hold. Then, we briefly discuss the case $\mu\gamma^C < \frac{p^D}{\Delta_D}d - d \leq \mu\gamma^D$.

5.2 The Case Where (IR) is Binding

This subsection considers the case where (IR) is binding under D-mode (i.e., $\frac{p^D}{\Delta_D}d - d \leq \mu\gamma^C$). In this case, the unobservability of the delegated manager's action does not matter for the capitalist. Equation (21) is represented as

$$k_t^* = \begin{cases} 0 & \text{if } c'(\frac{k_t}{M}) > R_{IR}, \\ k_t \in (0,1) & \text{if } c'(\frac{k_t}{M}) = R_{IR}, \\ 1 & \text{if } c'(\frac{k_t}{M}) < R_{IR}, \end{cases} \tag{22}$$

where

$$R_{IR} \equiv d - \Delta_p \Delta_\gamma \delta N.$$

Figure 1 shows all possible patterns of the relationship between $c'(\frac{k_t}{M})$ and R_{IR} in (22). From (22), we can confirm that $c'(0) > R_{IR}$ (resp. $c'(\frac{1}{M}) < R_{IR}$) holds when $N_0^{IR} < N$ (resp. $N < N_1^{IR}$), where $N_1^{IR} \equiv \frac{d - c'(\frac{1}{M})}{\Delta_p \Delta_\gamma \delta} < \frac{d - c'(0)}{\Delta_p \Delta_\gamma \delta} \equiv N_0^{IR}$. This illustrates the kind of equilibrium that occurs according to the population size of workers (i.e., N). First, when the population size of workers is sufficiently small to satisfy $N < N_1^{IR}$, $c'(\frac{k_t}{M}) < R_{IR}$ holds for all $k_t \in [0,1]$, and the unique full centralization equilibrium (i.e., $k_t^* = 1$) is realized (see E_1 in Figure 1). Second, when that size is intermediate and in $N \in [N_1^{IR}, N_0^{IR}]$, neither full decentralization (i.e., $k_t = 0$) nor full centralization (i.e., $k_t = 1$) ever occur, and then, the unique partial decentralization equilibrium (i.e., $k_t^* \in (0,1)$) is realized (see E_2 in Figure 1). Third, when the size is sufficiently large to satisfy $N_0^{IR} < N$, the relation $c'(\frac{k_t}{M}) > R_{IR}$ holds for all $k_t \in [0,1]$, and the unique full decentralization equilibrium (i.e., $k_t^* = 0$) is realized (see

E_3 in Figure 1). All of these results imply that the higher the value of N is, the higher the share of D-mode sectors becomes among the intermediate-goods production sectors.

We could interpret the value of N as reflecting the quality adjusted value of labor size. Accordingly, this value is likely to be larger in developed countries than developing ones because, in general, people in developed countries have more fruitful opportunities of education or job training. Notice that, from (6), the value of N reflects the size of each intermediate good market. Then, we can learn from Figure 1 that the larger the size of each intermediate good market is, the higher the extent to which R&D decisions are delegated in the intermediate good sectors. Recall that the higher share of D-mode leads to higher productivity growth in the economy. These results show, on the contrary, that the market size would restrict the extent of specialization with respect to R&D, which in turn determines the productivity growth rate of the economy.

As we noted at the beginning of this paper, Smith (1776) argued that specialization (division of labor) is one of the most important engines for enhancing labor productivity but that the extent of specialization is limited by the market size. In this regard, our theoretical result would be consistent with Adam Smith's view. Also, our model would be consistent with the arguments proposed by Penrose (1959) and Chandler (1962). They argued that decentralization was essential for the creation of large firms because CEOs are constrained in the number of decisions they can make. As firms grow, CEOs need to increasingly decentralize the process of decision-making and delegate it to their managers. As mentioned in the first section of this paper, Bloom et al. (2009) confirm these arguments, and find that decentralized firms tend to have a higher productivity and that larger firms are significantly more decentralized. In our model, the larger market implies the larger workload of each intermediate good production site. Therefore, our theoretical result would be consistent with the findings of Bloom et al. (2009) and thus the views of both Penrose (1959) and Chandler (1962) as well.

5.3 The Case Where (IC) is Binding

This subsection considers the case where (IC) is binding under D-mode (i.e., $\mu\gamma^D < \frac{p^D}{\Delta_D}d - d$). In contrast to the (IR)-binding case, the capitalist suffers from inefficiency due to moral hazard. (21) is represented as

$$k_t^* = \begin{cases} 0 & \text{if } c'(\frac{k_t}{M}) > R_{IC}(k_t), \\ k_t \in (0,1) & \text{if } c'(\frac{k_t}{M}) = R_{IC}(k_t), \\ 1 & \text{if } c'(\frac{k_t}{M}) < R_{IC}(k_t), \end{cases} \tag{23}$$

where

$$R_{IC}(k_t) \equiv \frac{p^D}{\Delta_D} d - \mu\{k_t\gamma^C + (1-k_t)\gamma^D\} - \Delta_p\Delta_\gamma \delta N.$$

From (23), we can confirm that $c'(0) > R_{IC}(0)$ (resp. $c'(\frac{1}{M}) < R_{IC}(1)$) holds when $N_0^{IC} < N$ (resp. $N < N_1^{IC}$), where $N_0^{IC} \equiv \frac{\frac{p^D}{\Delta_D}d - \mu\gamma^D - c'(0)}{\Delta_p\Delta_\gamma\delta}$ and $N_1^{IC} \equiv \frac{\frac{p^D}{\Delta_D}d - \mu\gamma^C - c'(\frac{1}{M})}{\Delta_p\Delta_\gamma\delta}$. As in the (IR)-binding case, the kind of equilibrium realized depends on the population size of workers (i.e., N). When the population size of workers is sufficiently large (resp. small) to satisfy $N_0^{IC} < N$ (resp. $N < N_1^{IC}$), full decentralization (i.e., $k_t = 0$) (resp. full centralization (i.e., $k_t = 1$)) could be a candidate for the rational expectation equilibrium.

For clarity of discussion, we add the following parametric assumptions:

Assumption 4.

$$\mu\Delta_p\Delta_\gamma + c'(0) < c'(\frac{1}{M}).$$

This assumption is likely to be satisfied when the capitalist's marginal cost of effort is sufficiently large in the case where she chooses full centralization (i.e., $k_t = 1$). For example, this assumption holds when $\lim_{k_t\to 1} c'(\frac{k_t}{M}) = \infty$. Under Assumption 4, $N_1^{IC} < N_0^{IC}$ holds. Thus, we can ignore the parametric regions where both full decentralization (i.e., $k_t = 0$) and full centralization (i.e., $k_t = 1$) coexist.[26]

Figures 2 to 5 show the possible patterns of the relationship between $c'(\frac{k_t}{M})$ and $R_{IC}(k_t)$ in (23) under Assumption 4. Figure 2 shows the case where the population size of workers is sufficiently small to satisfy $N < N_1^{IC}$. In this case, $c'(\frac{k_t}{M}) < R_{IC}(k_t)$ holds for all $k_t \in [0,1]$. Then, the unique full centralization equilibrium (i.e., $k_t^* = 1$) is realized (see E in Figure 2). Figure 3 shows the case where the population size of workers satisfies the condition of $N_1^{IC} \le N \le N_0^{IC}$. In this case, neither the full decentralization (i.e., $k_t = 0$) nor the full centralization (i.e., $k_t = 1$) occur. Then, the unique partial decentralization equilibrium (i.e., $k_t^* \in (0,1)$) is realized (see E in Figure 3). Figures 4 and 5 show the

[26]Even if we consider the case $N_0^{IC} \le N \le N_1^{IC}$, our results are still almost maintained. In order to avoid an unnecessarily complicated discussion, we introduce Assumption 4.

case where the population size of workers is sufficiently large to satisfy $N_0^{IC} < N$. In this case, because $c'(0) > R_{IC}(0)$, full decentralization (i.e., $k_t = 0$) could be a possible outcome. However, there are two other possible patterns in this parameter region. The first case is shown in Figure 4. In Figure 4, $c'(\frac{k_t}{M}) > R_{IC}(k_t)$ holds for all $k_t \in [0, 1]$.[27] Thus, the unique full decentralization equilibrium (i.e., $k_t^* = 0$) is realized (see E in Figure 4). The second case is shown in Figure 5. In Figure 5, $c'(\frac{k_t}{M})$ and $R_{IC}(k_t)$ have two intersections k_2^* and k_3^* at $k_t \in (0, 1)$.[28] Thus, there are the following three rational expectation equilibria: (1) the full decentralization equilibrium (see E_1 in Figure 5), (2) the partial decentralization equilibrium with a relatively lower share of D-mode (see E_2 in Figure 5), and (3) the partial decentralization equilibrium with a relatively higher share of D-mode (see E_3 in Figure 5). However, it seems that E_3 is unstable, while the other two (i.e., E_1 and E_2) are stable. We can explain this instability as follows. Suppose that the economy lies in E_3, and consider the following experiment. Due to some parametric changes, k_t is increased slightly from k_3^*. In this case, as shown in Figure 5, the relation $c'(\frac{k_t}{M}) < R_{IC}(k_t)$ holds. The capitalist has an incentive to increase k_t until it reaches k_2^*, and thus the economy eventually converges to E_2. Next, we consider another experiment. Due to some parametric changes, k_t is decreased slightly from k_3^*. In this case, as shown in Figure 5, the relation $c'(\frac{k_t}{M}) > R_{IC}(k_t)$ holds. The capitalist has an incentive to decrease k_t until it reaches 0, and thus the economy eventually converges to E_1. These experiments imply that E_3 is not sustainable when exogenous parametric changes are explicitly considered. In this sense, E_3 is unstable. Therefore, there exist two stable equilibria E_1 and E_2 in Figure 5.

Notice that the feedback mechanism between decentralization and the aggregate productivity parameter A_t results in multiple equilibria. Due to the advantage in R&D success probability under D-mode, the rise in the share of D-mode increases the level of aggregate productivity parameter A_t. This rise in A_t leads to the high reservation value of the manager (i.e., w_t) because w_t is proportional to A_t. Recall that the payment to the manager is independent of w_t under D-mode where (IC)

[27] The sufficient condition for Figure 4 is given by $\frac{1}{M}c''(0) > R'_{IC}(0) = \mu\Delta_p\Delta_\gamma$. Under this condition, $c'(\frac{k_t}{M})$ and $R_{IC}(k_t)$ have no intersection at all $k_t \geq 0$.

[28] The sufficient condition for Figure 5 is that $R_{IC}(\bar{k}) > c'(\frac{\bar{k}}{M})$ holds for $\bar{k}$ such that $\frac{1}{M}c''(\frac{\bar{k}}{M}) = R'_{IC}(\bar{k})$. Suppose we specify $c(\frac{k_t}{M})$ as $b\ln(a) - b\ln(a - \frac{k_t}{M})$, where $a > 1$ and $b > 0$. In this case, $\bar{k}$ is given by $M[a - (\frac{b}{M\mu\Delta_p\Delta_\gamma})^{1/2}]$. Therefore, the condition $R_{IC}(\bar{k}) > c'(\frac{\bar{k}}{M})$ is expressed as $\frac{(\frac{p^D}{\Delta_D})d - \mu(\gamma^D - \mu\Delta_p\Delta_\gamma Ma) - \Delta_p\Delta_\gamma\delta N}{2(M\mu\Delta_p\Delta_\gamma)^{1/2}} > b^{1/2}$.

binds but that payment under C-mode is increasing in w_t. These results imply that the rise in w_t increases the capitalist's cost of choosing C-mode. Thus, the capitalist is more likely to choose D-mode. Therefore, the higher the share of D-mode is, the higher the values of A_t is, the higher the value of reservation wage w_t is, the higher the share of D-mode is, and so forth. This feedback mechanism between decentralization and the aggregate productivity parameter works only when (IC) is binding, and thus, multiple equilibria occur only when (IC) is binding.

Whether the economy converges to E_1 or E_2 in Figure 5 depends upon the expectation that each capitalist has in equilibrium. On the one hand, suppose each capitalist expects that the full decentralization occurs (i.e., each capitalist expects that other capitalists choose D-mode for all of their own projects). Then, the expected reservation value of the manager (i.e., w_t) becomes sufficiently high, which in turn makes choosing D-mode more attractive for each capitalist. Therefore, the positive feedback mechanism between decentralization and the aggregate productivity parameter works. Thus, the result of full decentralization (i.e., $k_t^* = 0$) and the higher productivity growth (i.e., $g_t^* = \gamma^D - 1$) is realized as a self-fulfilling equilibrium at E_1. On the other hand, suppose each capitalist expects that the partial decentralization occurs (i.e., each capitalist expects that other capitalists do not choose D-mode for all of their own projects). Then, the expected reservation value of the manager becomes sufficiently low, which in turn makes choosing D-mode less attractive for each capitalist. Therefore, the negative feedback mechanism between the centralization and the aggregate productivity parameter works. Thus, the result of partial decentralization (i.e., $k_t^* \in (0, 1)$) and the lower productivity growth (i.e., $g_t^* = k_t^* \gamma^C + (1 - k_t^*)\gamma^D - 1$) is realized as a self-fulfilling equilibrium at E_2. Therefore, the equilibrium organizational mode depends upon how each capitalist forms her own expectation about the intentions for others. An empirical study by Bloom et al. (2009) finds that cultural factors such as religion and regional trust play crucial roles in accounting for cross-regional differences in the organizational mode within firms.[29] It has also been argued often that these cultural factors play substantial roles for coordinating people's expectation. These results suggest that our multiple equilibria result could provide some possible explanations for Bloom et al. (2009) empirical findings.

[29] Barro and McCleary (2006) argue that religious practices and beliefs have important consequences for economic growth.

Figure 6 shows some numerical examples for which multiple equilibria emerge. The dotted line shows $c'(\frac{k_t}{M})$; the solid line shows $R_{IC}(k_t)$ when $N = 21.8$; the dashed line shows $R_{IC}(k_t)$ when $N = 22.8$; and the dash-dot line shows $R_{IC}(k_t)$ when $N = 23.8$, respectively. In this numerical example, we specify the capitalist's R&D cost function $c(\frac{k_t}{M})$ as $b\ln(a) - b\ln(a - \frac{k_t}{M})$, where $a > 1$ and $b > 0$. The parameter values for the base-line simulation are summarized in Appendix D. These numerical examples confirm that multiple equilibria occur under some plausible range of parameter values.

Finally, the results obtained from Figure 2 to Figure 6 show that the higher the value of N is, the higher the share of D-mode in the intermediate good sectors is. Thus, analogous to the case where (IR) is binding, the market size restricts the extent of specialization with respect to R&D, which in turn determines the productivity growth rate of the economy. Moreover, the decentralized organization is more likely to emerge as the workload of each intermediate good production site becomes large. Therefore, even in the case where (IC) is binding, our results could be related to the view of Smith (1776) as well as to those of both Penrose (1959) and Chandler (1962).

5.4 Mixed Case

In this subsection, we consider the parameter region where (IC) is binding and that where (IR) is binding coexist (i.e., $\mu\gamma^C < \frac{p^D}{\Delta_D}d - d \leq \mu\gamma^D$). In this case, however, it is difficult to provide rigorous illustrations of all possible patterns of the relationships among $c'(\frac{k_t}{M})$, $R_{IC}(k_t)$, and R_{IR} in (21). Thus, we only present one intuitive example shown in Figure 7. Figure 7 shows that (IR) is binding when $k_t \leq \hat{k}_t$ (i.e., $R_{IR} \geq R_{IC}(k_t)$) and (IC) is binding when $k_t > \hat{k}_t$ (i.e., $R_{IR} < R_{IC}(k_t)$).

As in the cases of the previous subsections, the realized equilibrium depends on the population size of workers (i.e., N). First, when the population size of workers is sufficiently small to satisfy $N < N_1^{IC}$, $c'(\frac{k_t}{M}) < R_{IC}(k_t)$ holds for all $k_t \in [0, 1]$. Thus, the unique full centralization equilibrium (i.e., $k_t^* = 1$) is realized (see E_1 in Figure 7). Second, when the size satisfies the condition of $N_1^{IC} \leq N \leq N_0^{IR}$, the unique partial decentralization equilibrium (i.e., $k_t^* \in (0, 1)$) is realized (see E_2 in Figure 7). Third, when the size is sufficiently large to satisfy $N_0^{IR} < N$, $c'(\frac{k_t}{M}) > R_{IR}$ holds for all $k_t \in [0, 1]$. Then, the unique full decentralization equilibrium (i.e., $k_t^* = 0$) is realized (see E_3 in Figure 7). Therefore, as in the previous cases, we can also confirm that the higher the value of N is, the higher the share of D-mode sectors becomes in the intermediate good sectors.[30]

6 Policy Analysis

6.1 The Efficiency of Contract Enforcement

This subsection examines how the policy that improves efficiency of contract enforcement between the final good producer and the intermediate good producer influences the equilibrium organizational mode within firms. Here, recall that the parameter T captures the efficiency of contract enforcement between the final good producer and the intermediate good producer. Smaller T leads to the smaller transaction cost between them, while larger T leads to the higher transaction cost. Thus smaller T corresponds to the case where the government or local community improves the quality of the social capital that facilitates contract enforcement (e.g., strong legal recourse), while larger T corresponds to the case where the quality of social capital is deteriorated (e.g., weak legal recourse).

In order to avoid lexicographic explanations and to shed light on intuitive policy implications, we focus our analysis on the case where (IC) is binding under D-mode (i.e., $\mu\gamma^D < \frac{p^D}{\Delta_D}d - d$).[31] Then, we first consider the case where the unique partial decentralization equilibrium is realized as shown at E in Figure 3. By totally differentiating the condition $c'(\frac{k_t}{M}) = R_{IC}(k_t)$ in (23) with respect to k_t and T, we obtain

$$\frac{dk^*}{dT} > 0. \tag{24}$$

The derivation of (24) is explained in Appendix E. This result is summarized in Figure 8. Improvements in contract enforcement by decreasing T shift the $R_{IC}(k_t)$ line downwards. The equilibrium E shifts leftward, and thus, the equilibrium organizational mode becomes more decentralized. The intuitive mechanism behind this result is explained as follows. Improvement in contract enforcement

[30] Moreover, we can show some examples where multiple equilibria occur in this case. However, key factors to derive multiple equilibria are the same as those discussed in the previous subsection. Therefore, in order to avoid repetitive explanation, we do not discuss it explicitly here.

[31] When (IR) is binding under D-mode (i.e., $\frac{p^D}{\Delta_D}d - d \leq \mu\gamma^C$), from (22) and Figure 1, improvements in contract enforcement by decreasing T shift the R_{IR} line downwards, and thus, equilibrium E_2 shifts leftward. Therefore, the equilibrium organizational mode becomes more decentralized. The intuitive mechanism behind this result is simple. Improvements in contract enforcement increase the capitalist's profits from superior R&D skills which increases the capitalist's benefit from choosing D-mode.

increases the capitalist's profits from superior R&D skills, which increases the capitalist's benefit of choosing D-mode. Moreover, improvement in contract enforcement increases the reservation value of the manager (i.e., the market wage), which again increases the capitalist's benefit of choosing D-mode. These two factors promote the more decentralized organizational mode.

This policy implication becomes more profound in the case where multiple equilibria emerge as shown in Figure 5. Again, by totally differentiating the condition $c'(\frac{k_t}{M}) = R_{IC}(k_t)$ in (23) with respect to k_t and T, we obtain

$$\frac{dk_2^*}{dT} > 0 \tag{25}$$

$$\frac{dk_3^*}{dT} < 0 \tag{26}$$

The derivation of (25) and (26) are explained in Appendix E. These results are summarized in Figure 9. Improvements in contract enforcement by decreasing T shift the $R_{IC}(k_t)$ line downwards. Thus, equilibrium E_2 shifts leftward (i.e., $\frac{dk_2^*}{d\chi} > 0$), and E_3 shifts rightward (i.e., $\frac{dk_3^*}{d\chi} < 0$), respectively. Moreover, suppose the shift of $R_{IC}(k_t)$ is sufficiently large, and $c'(\frac{k_t}{M}) > R_{IC}(k_t)$ holds for all $k_t \in [0, 1]$. In this case, the partial decentralized equilibrium is eliminated, and thus, the unique full decentralization equilibrium is realized, as shown in Figure 4. This indicates that the economy can escape from the partial decentralized equilibrium characterized as a low growth rate. Therefore, improvements in contract enforcement promote the more decentralized organizational mode and lower the risk of the economy converging to a poverty trap.[32]

An empirical study by Bloom et al. (2009) finds that social capital as proxied by regional trust and "Rule of Law" is strongly associated with more decentralized firms. The trust measure is developed using the World Values Survey, which aims at measuring generalized trust (i.e., the overall level of trustworthiness in a society). The Rule of Law measure is developed by the World bank and measures "the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, the police, and the court, as well as the likelihood of crime and violence" (Kaufmann et al., (2007)). Bloom et al. (2009) also argue that social capital can improve

[32]The intuitive mechanism behind these results is analogous to the case in Figure 8.

aggregate productivity through facilitating greater firm decentralization. Both regional trust and Rule of Law are strongly related to the efficiency of contract enforcement. Therefore, our theoretical results complement these empirical findings and arguments of Bloom et al. (2009).

6.2 Competition Policy

This subsection examines how the policy that enhances competition in the intermediate good market influences the equilibrium organizational mode within firm. Here, recall that the parameter $\hat{\chi}$ captures the technological factors as well as the government regulations affecting entry into the intermediate good market. Therefore, from (5), a lower χ corresponds to the case where the government enhances competition policies (e.g., encouragements to entry), while a higher χ corresponds to the case where the government enhances anti-competition policies (e.g., promotion of patent protections).

In order to avoid lexicographic explanations and to shed light on intuitive policy implications, we focus on the case where (IC) is binding under D-mode (i.e., $\mu\gamma^D < \frac{p^D}{\Delta_D}d - d$).[33] We first consider the case where the unique partial decentralization equilibrium is realized as shown at E in Figure 3. By totally differentiating the condition $c'(\frac{k_t}{M}) = R_{IC}(k_t)$ in (23) with respect to k_t and χ, we obtain

$$\frac{dk^*}{d\chi} \begin{cases} < 0 & \text{if } 1 \leq \chi \leq \bar{\chi}, \\ > 0 & \text{if } \bar{\chi} \leq \chi \leq \frac{1}{\alpha}. \end{cases} \tag{27}$$

where $\bar{\chi} \equiv \frac{1}{\alpha + (1-\alpha)\frac{k^*\gamma^C + (1-k^*)\gamma^D}{\Delta_p \Delta_\gamma N}}$. Derivation of (27) is explained in Appendix F. This result is summarized in Figure 10. Suppose the monopoly power of the capitalist's firm is already sufficiently large (i.e., $\bar{\chi} \leq \chi \leq \frac{1}{\alpha}$), the enhancement of a competition policy by decreasing χ shifts the $R_{IC}(k_t)$ line downwards, and thus, the equilibrium E shifts leftward. Therefore, the equilibrium organizational mode becomes more decentralized. However, suppose the monopoly power of the capitalist's firm is sufficiently small (i.e., $1 \leq \chi \leq \bar{\chi}$), the enhancement of a competition policy by decreasing χ shifts the $R_{IC}(k_t)$ line upwards, and thus, the equilibrium E shifts rightward. Therefore, the equilibrium organizational mode becomes more centralized. Figure 10 shows the effects of a competition policy on

[33]When (IR) is binding under D-mode (i.e., $\frac{p^D}{\Delta_D}d - d \leq \mu\gamma^C$), from (22) and Figure 1, the enhancement of a competition policy by decreasing χ shifts the R_{IR} line upwards, and thus, equilibrium E_2 shifts rightward. Therefore, the equilibrium organizational mode becomes more centralized. The intuitive mechanism behind this result is simple. The enhancement of a competition policy decreases the capitalist's profits from superior R&D skills, which in turn lowers capitalist's benefit of choosing D-mode.

the equilibrium organizational modes. Note that the downward shift of $R_{IC}(k_t)$ occurs either when χ decreases for $\chi \in [\bar{\chi}, \frac{1}{\alpha}]$ or when χ increases for $\chi \in [1, \bar{\chi}]$. These results imply that whether the competition policy induces decentralization or centralization of intermediate good sites depends upon the monopoly power that the capitalist already exercises in the intermediate good market. Suppose the monopoly power of the capitalist is already sufficiently large (i.e., $\chi \in [\bar{\chi}, \frac{1}{\alpha}]$), the enhancement of a competition policy would induce the decentralization of intermediate good sectors. On the contrary, suppose the monopoly power is sufficiently low (i.e., $\chi \in [1, \bar{\chi}]$), the enhancement of a competition policy would induce the centralization of intermediate good sectors.

The intuitive mechanism behind these results is explained as follows. On the one hand, the enhancement of a competition policy decreases the capitalist's profits from superior R&D skills, which lowers the capitalist's benefit of choosing D-mode. On the other hand, the enhancement of a competition policy increases the reservation value of the manager (i.e., the market wage), which increases the capitalist's benefit of choosing D-mode. Then, suppose the monopoly power of the capitalist is already sufficiently large, the former anti-decentralization effect is dominated by the latter pro-decentralization effect, and vice versa. Therefore, when the monopoly power of the capitalist is sufficiently large (resp. small), the enhancement of a competition policy induces decentralization (resp. centralization) of intermediate good sites, and thus the equilibrium organizational mode becomes more decentralized (resp. centralized).

Moreover, the role of competition policy becomes more profound in the case where multiple equilibria emerge, as shown in Figure 5. Again by totally differentiating the condition $c'(\frac{k_t}{M}) = R_{IC}(k_t)$ in (23) with respect to k_t and χ, we obtain

$$\frac{dk_2^*}{d\chi} \begin{cases} < 0 & \text{if } 1 \leq \chi \leq \acute{\chi}, \\ > 0 & \text{if } \acute{\chi} \leq \chi \leq \frac{1}{\alpha}, \end{cases} \tag{28}$$

$$\frac{dk_3^*}{d\chi} \begin{cases} > 0 & \text{if } 1 \leq \chi \leq \tilde{\chi}, \\ < 0 & \text{if } \tilde{\chi} \leq \chi \leq \frac{1}{\alpha}, \end{cases} \tag{29}$$

where $\acute{\chi} \equiv \frac{1}{\alpha + (1-\alpha)\frac{k_2^* \gamma^C + (1-k_2^*)\gamma^D}{\Delta_p \Delta_\gamma N}}$, and $\tilde{\chi} \equiv \frac{1}{\alpha + (1-\alpha)\frac{k_3^* \gamma^C + (1-k_3^*)\gamma^D}{\Delta_p \Delta_\gamma N}}$. Derivation of (28) and (29) are explained in Appendix F. These results are summarized in Figure 11. Supposing the monopoly power of the capitalist's firm is already sufficiently large (i.e., $\acute{\chi} \leq \chi \leq \frac{1}{\alpha}$), the enhancement of a competition policy by decreasing χ shifts the $R_{IC}(k_t)$ line downwards. Thus, equilibrium E_2 shifts leftward (i.e., $\frac{dk_2^*}{d\chi} > 0$), and E_3 shifts rightward (i.e., $\frac{dk_3^*}{d\chi} < 0$), respectively. Moreover, supposing the shift of $R_{IC}(k_t)$ is sufficiently large, $c'(\frac{k_t}{M}) > R_{IC}(k_t)$ holds for all $k_t \in [0, 1]$. In this case, the partial decentralized equilibrium is eliminated, and thus, the unique full decentralization equilibrium is realized, as shown in Figure 4. Therefore, the economy may escape from the partial decentralized equilibrium characterized by a low growth rate. However, suppose the monopoly power of the capitalist's firm is sufficiently small (i.e., $1 \leq \chi \leq \hat{\chi}$). The policy implication then becomes the opposite. In this case, the enhancement of anti-competition policy by increasing χ shifts the $R_{IC}(k_t)$ line downwards and thus eliminates the risk of the economy converging to the partial decentralization equilibrium. Therefore, whether the competition policy may lower or raise the risk of the economy converging to a poverty trap (i.e., the partial decentralization equilibrium) depends upon the monopoly power that the capitalist already exercises in the intermediate good market. Suppose the monopoly power of the capitalist is already sufficiently large. The enhancement of a competition policy would then lower the risk of the economy converging to a poverty trap. However, supposing the opposite, the enhancement of anti-competition policy would lower the risk of the economy converging to a poverty trap.[34]

An empirical study by Bloom et al.(2009) finds a significant positive association between competition and decentralization. In our model, this positive relation holds when (IC) is binding and the monopoly power of the capitalist's firm is sufficiently large. In this sense, our theoretical result could provide some possible explanations for the empirical findings of Bloom et al.(2009). However, out model indicates that the effect of competition on organizational mode may not be straightforward. The competition policy may induce more centralized organization under some parametric conditions.[35] Therefore, further theoretical and empirical investigation is necessary on this issue.

[34] The intuitive mechanism behind these results is analogous to the case in Figure 10.

[35] Competition is likely to affect firm decentralization for several reasons. First, more competitive environments put a greater emphasis on rapid reaction to events. In these circumstances, delegating decisions to managers with local information will be particularly beneficial. Second, if competition is associated with an increased number of firms, it makes yardstick competition easier to implement and therefore enables the CEO to combine decentralization with increased managerial effort. Finally, if competition increases the threat of bankruptcy, then the manager is more likely to make the firm's value maximizing decision if the CEO delegates. Because this paper employs a very simple framework for our main argument, we do not consider these elements explicitly. This may be one of the reasons why our model predicts a positive relationship between competition and decentralization in a limited range of parameter values. However, we believe that the policy intuition obtained in this paper is crucial for a rigorous understanding of the effect of competition on organizational form.

7 Concluding Remarks

In this paper, we have developed a simple growth model with moral hazard contracting to examine the interactions between organizational modes within firms and economic productivity growth. Through this model, we show that greater prevalence of decentralization leads to higher productivity growth in the economy. This result implies that the market size restricts the extent of delegation with respect to R&D, which in turn determines the productivity growth rate of the economy. We could argue that these results are consistent not only with recent empirical findings by Bloom et al (2009, 2010), but also with the traditional view of Smith (1776). We also show that there exist multiple equilibria that represent a "partial decentralization equilibrium" with a low growth rate and the "full decentralization equilibrium" with a high growth rate, respectively. Finally, we examine the effects of social capital and competition on the organizational modes and find that, under some parametric conditions, these factors induce more decentralized organization, higher productivity growth and lower risks of seeing the economy converge to a poverty trap.

Recent empirical research on the relationship between organizational modes within firms and economic growth has provided the opportunity to revisit the reasons for the existence of the firm and its role in the market economy. Moreover, through this lens, we need to elaborate the theoretical models that interact with these empirical findings. We believe that such interactions between empirical and theoretical investigations enhance our understanding of the theme of this paper.

Appendix A

This section shows some parametric conditions for which Assumptions 2 and 3 hold simultaneously. First, we consider Assumption 2. By substituting (11), (12), and $N_t = N$ into Assumption 2 and rearranging it, we obtain the parametric condition for Assumption 2 as [36]

$$N \geq \frac{c'(\frac{1}{M})}{\Delta_C \delta \Delta_\gamma}. \tag{A1}$$

Second, we consider Assumption 3. By substituting (9), (11), (13) and $N_t = N$ into Assumption

[36] Note that the relation $N_t \geq N$ holds in this model. The minimum value of N_t (i.e., N) is achieved when the capitalist employs all matched managers. Here, in order to obtain sufficient parametric conditions for Assumptions 2 to 4, we consider the case where $N_t = N$ holds.

3, we obtain the following inequalities :

$$\gamma^D \delta N A_{t-1} \geq \max\{\frac{p^D}{\Delta_D} dA_{t-1}, \mu A_t + dA_{t-1}\}$$

From the definition of A_t (i.e., $A_t \equiv \int_0^1 A_t(i)di$), the maximum value of A_t that is potentially achieved in this model is expressed as $\gamma^D A_{t-1}$ where $\gamma^D \equiv p^D \gamma_s + (1-p^D)\gamma_f$ (i.e., $A_t \leq \gamma^D A_{t-1}$). Thus, the sufficient conditions for the above inequalities are expressed as

$$\gamma^D \delta N A_{t-1} \geq \max\{\frac{p^D}{\Delta_D} dA_{t-1}, \mu \gamma^D A_{t-1} + dA_{t-1}\}.$$

By rearranging the above inequalities, we obtain the sufficient parametric conditions for Assumption 3 as

$$N \geq \max\{\frac{\frac{p^D}{\Delta_D} d}{\gamma^D \delta}, \frac{\mu \gamma^D + d}{\gamma^D \delta}\}. \tag{A2}$$

Therefore, Assumptions 2 and 3 hold simultaneously when the population size of workers is sufficiently large to satisfy (28) and (29).

Appendix B

Given implementing $a_D = 1$, the capitalist minimizes her expected payment, $w_t^f + p^D(w_t^s - w_t^f)$ under (IR), (IC), and (LL). By substituting (IR) with equality into (IC), we have

$$\frac{\tilde{d}_t + w_t - w_t^f}{p^D} \geq \frac{\tilde{d}_t}{\Delta_D} \tag{IC'}$$

On the one hand, if (IC') satisfies at $w_t^f = 0$, then the optimal contract is determined by holding (IR) with equality. Note that this condition can be represented by $(\frac{p^D}{\Delta_D})\tilde{d}_t - \tilde{d}_t \leq w_t$. One such contract is $(w_t^s, w_t^f) = ((w_t + \tilde{d}_t)/p^D, 0)$.

On the other hand, if (IC') does not satisfy at $w_t^f = 0$, then the optimal contract is determined by holding (IC) with equality. Note that this condition can be represented by $(\frac{p^D}{\Delta_D})\tilde{d}_t - \tilde{d}_t > w_t$. Thus, the optimal contract is $(w_t^s, w_t^f) = (\tilde{d}_t/\Delta_D, 0)$.

Obviously, these contracts satisfy (LL).

Appendix C

This section shows some parametric conditions for which (IC) is binding (i.e., $R_{IC}(k_t) > R_{IR}$) and some for which (IR) is binding (i.e., $R_{IC}(k_t) \leq R_{IR}$), respectively. The relation $R_{IC}(k_t) > R_{IR}$ ($R_{IC}(k_t) \leq R_{IR}$) is rewritten as

$$(\frac{p^D}{\Delta_D})d - d > (\leq)\mu[k_t\gamma^C + (1-k_t)\gamma^D].$$

Thus, suppose $(\frac{p^D}{\Delta_D})d - d > \mu\gamma^D$. We can easily confirm that the relation $R_{IC}(k_t) > R_{IR}$ holds for all $k_t \in [0,1]$. Analogously suppose $(\frac{p^D}{\Delta_D})d - d \leq \mu\gamma^C$. The relation $R_{IC}(k_t) \leq R_{IR}$ holds for all $k_t \in [0,1]$. Moreover, suppose $\mu\gamma^C < (\frac{p^D}{\Delta_D})d - d \leq \mu\gamma^D$. $R_{IC}(k_t)$ has one intersection with R_{IR} at $\hat{k_t} \in [0,1]$. Therefore, suppose $k_t \leq \hat{k_t}$ (i.e., $R_{IC}(k_t) \leq R_{IR}$). Here, (IR) is binding, while (IC) is binding when $\hat{k_t} < k_t$ (i.e., $R_{IR} < R_{IC}(k_t)$).

Appendix D

In this section, we briefly explain the parameter values of our numerical examples. We set the value of p^D as 0.9, p^C as 0.5, p_0 as 0.3, α as 0.3, $\hat{\chi}$ as $1/\alpha$, γ_s as 6.44, γ_f as 1, M as 2, a as $1/M + 0.1$, b as 0.1, d as 3.5, and N as 24.8. The one period in this model is assumed to be about 60 years. Thus, we set the values of γ_s and γ_f to achieve a roughly 3 % balanced growth rate in the full decentralization equilibrium (i.e., $\gamma_s = \frac{(1.03)^{60} - (1-p^D)\gamma_f}{p^D}$. Given the specification of $c(\frac{k_t}{M})$, Assumption 4 holds if $(aM-1)a\mu\Delta_p\Delta_\gamma < b$. Thus, the values of a and b are adjusted to satisfy the above inequalities. The value of d is designed so as to satisfy $(\frac{p^D}{\Delta_D})d - d > \mu\gamma^D$. Here, the inequality $(\frac{p^D}{\Delta_D})d - d > \mu\gamma^D$ holds if $d \geq \mu\gamma^D \frac{\Delta_D}{p_0}$. The value of N is also designed so as to satisfy Assumptions 2 and 3 simultaneously.

Appendix E

By totally differentiating the condition $c'(\frac{k_t}{M}) = R_{IC}(k_t)$ in (23) with respect to k_t and T, we find

$$\frac{dk_t}{dT} = -\frac{\{k_t\gamma^C + (1-k_t)\gamma^D\}\frac{\partial\mu}{\partial T} + \Delta_p\Delta_\gamma N\frac{\partial\delta}{\partial T}}{\frac{1}{M}c''(\frac{k_t}{M}) - \mu\Delta_p\Delta_\gamma}$$

where $\frac{\partial\mu}{\partial T} = -(\alpha/\chi)^{\frac{1}{1-\alpha}}T^{\frac{-1}{1-\alpha}} < 0$ and $\frac{\partial\delta}{\partial T} = -\frac{\alpha}{1-\alpha}(\chi-1)(\alpha/\chi)^{\frac{1}{1-\alpha}}T^{\frac{-1}{1-\alpha}} < 0$. Here, note that the relation $\frac{1}{M}c''(\frac{k_t}{M}) > \mu\Delta_p\Delta_\gamma = R'_{IC}(k_t)$ holds at E in Figure 3 and E_2 in Figure 5, while $\frac{1}{M}c''(\frac{k_t}{M}) <$

$\mu\Delta_p\Delta_\gamma = R'_{IC}(k_t)$ holds at E_3 in Figure 5 . Therefore, we can easily confirm that inequalities in (24), (25), and (26) hold, respectively.

Appendix F

By totally differentiating the condition $c'(\frac{k_t}{M}) = R_{IC}(k_t)$ in (23) with respect to k_t and χ, we find

$$\{\frac{1}{M}c''(\frac{k_t}{M}) - \mu\Delta_p\Delta_\gamma\}dk_t = -\big[\{k_t\gamma^C + (1-k_t)\gamma^D\}\frac{\partial\mu}{\partial\chi} + \Delta_p\Delta_\gamma N\frac{\partial\delta}{\partial\chi}\big]d\chi$$

where $\frac{\partial\mu}{\partial\chi} = -(\alpha/\chi)^{\frac{1}{1-\alpha}}T^{\frac{-\alpha}{1-\alpha}} < 0$ and $\frac{\partial\delta}{\partial\chi} = \frac{(\frac{1}{\chi}-\alpha)}{1-\alpha}(\alpha/\chi)^{\frac{1}{1-\alpha}}T^{\frac{-\alpha}{1-\alpha}} > 0$. Rearranging the above equation, we obtain

$$\frac{dk_t}{d\chi} = \frac{(\alpha/\chi)^{\frac{1}{1-\alpha}}}{\frac{1}{M}c''(\frac{k_t}{M}) - \mu\Delta_p\Delta_\gamma}\frac{\Delta_p\Delta_\gamma NT^{\frac{-\alpha}{1-\alpha}}}{1-\alpha}\big[\frac{(1-\alpha)\{k_t\gamma^C + (1-k_t)\gamma^D\}}{\Delta_p\Delta_\gamma N} + \alpha - \frac{1}{\chi}\big]$$

Here, note that the relation $\frac{1}{M}c''(\frac{k_t}{M}) > \mu\Delta_p\Delta_\gamma = R'_{IC}(k_t)$ holds at E in Figure 3 and E_2 in Figure 5, while $\frac{1}{M}c''(\frac{k_t}{M}) < \mu\Delta_p\Delta_\gamma = R'_{IC}(k_t)$ holds at E_3 in Figure 5 . Therefore, we can easily confirm that the inequalities in (27), (28), and (29) hold respectively.

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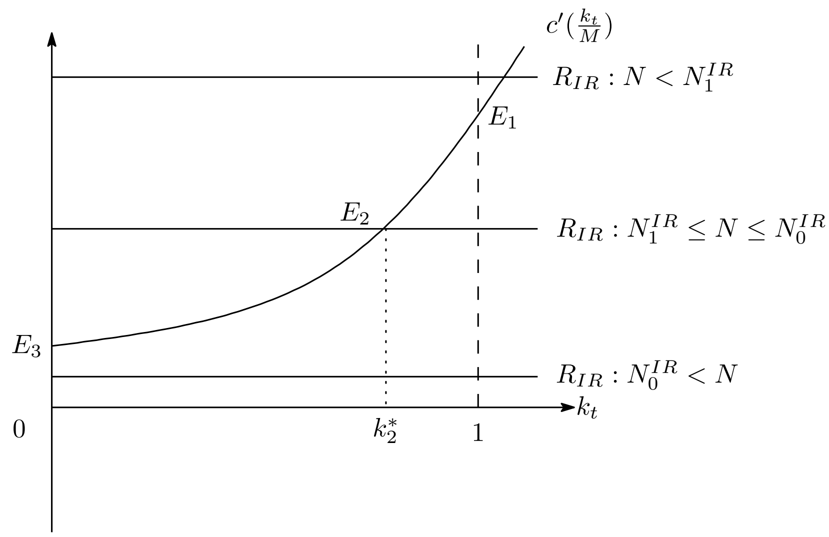

Figure 1: IR-bind

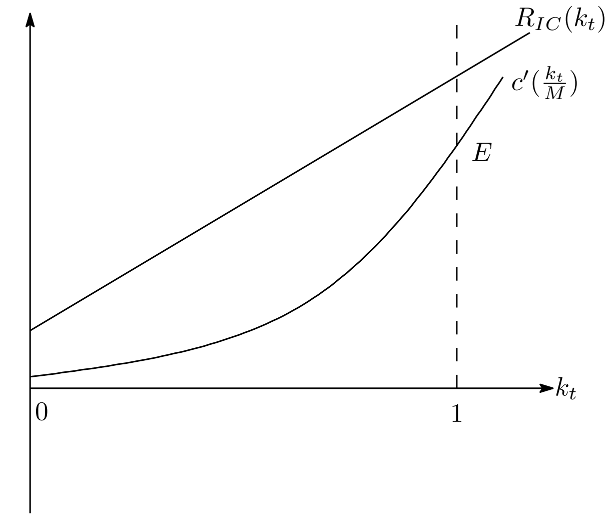

Figure 2: Unique Full Centralization(IC-bind)

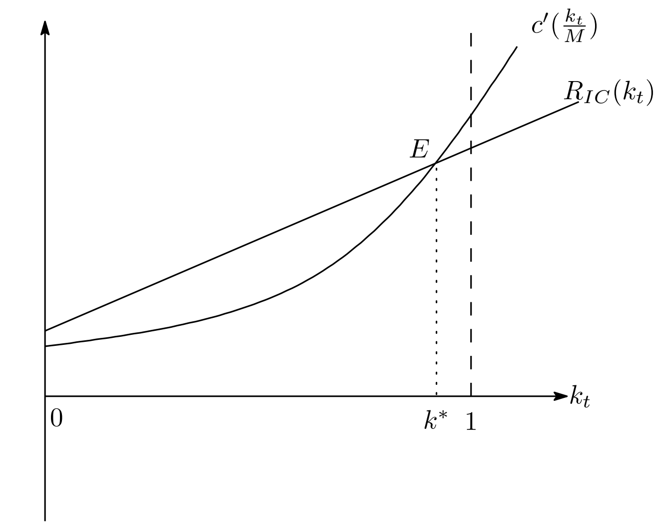

Figure 3: Unique Partial Decentralization (IC-bind)

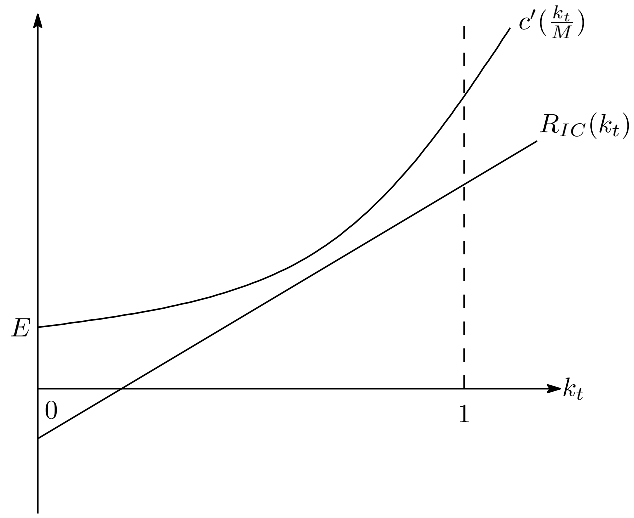

Figure 4: Unique Full Decentralization (IC-bind)

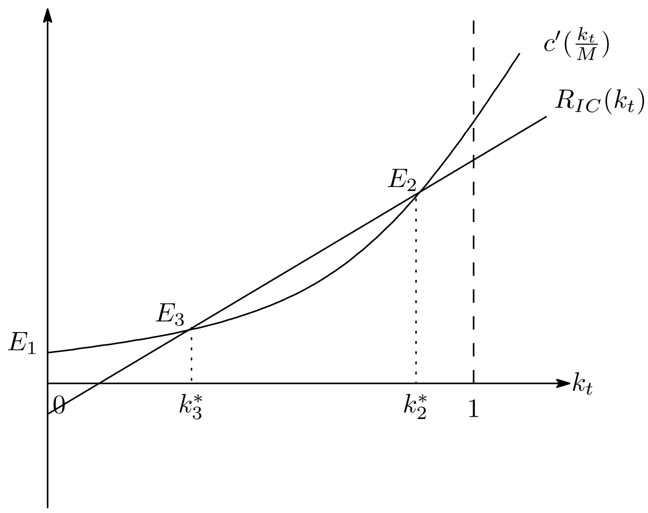

Figure 5: Multiple Equilibria (IC-bind)

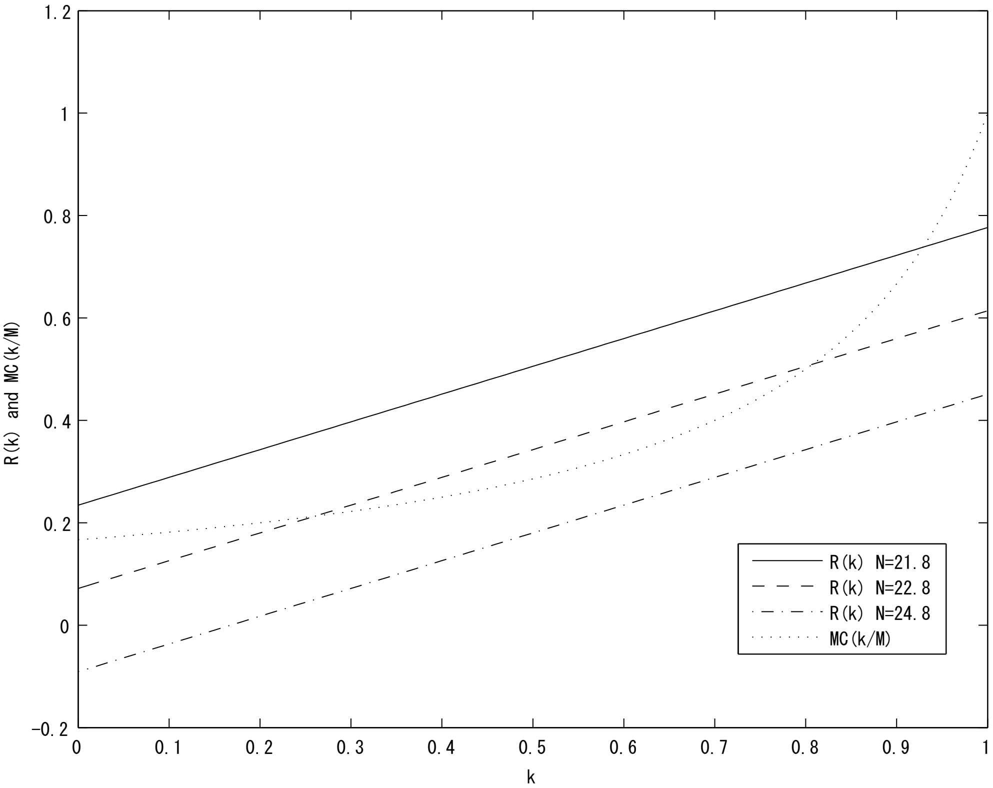

Figure 6: Numeral example of Multiple equilibria (N=21.8, 22.8, 24.8)

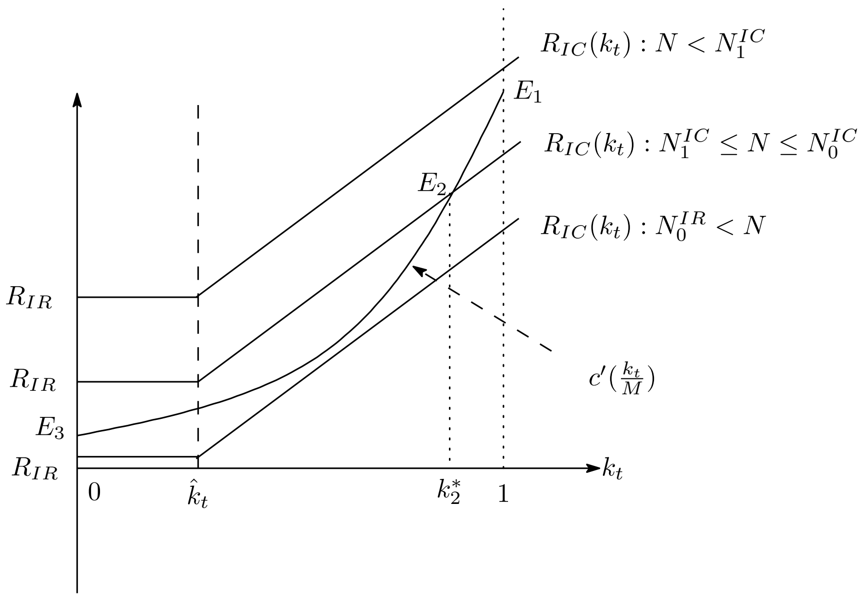

Figure 7: Mixed Case

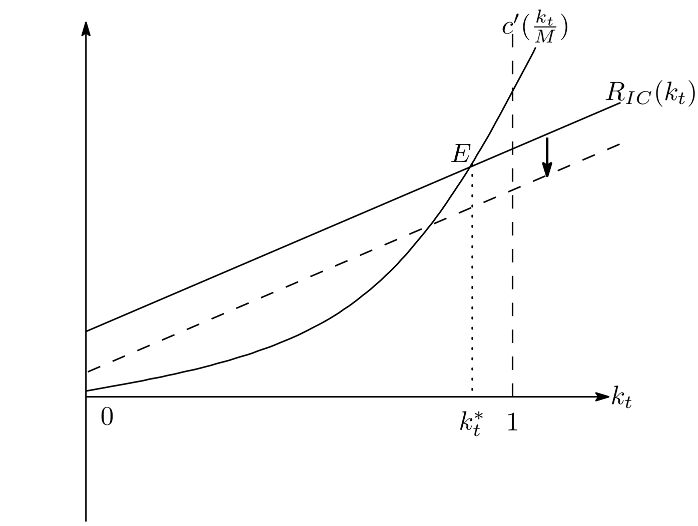

Figure 8: Improvements in Contract Enforcement(IC-bind)

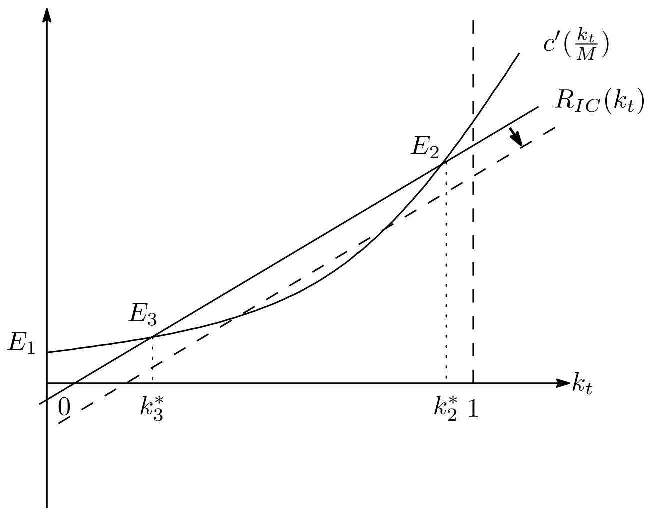

Figure 9: Improvements in Contract Enforcement(Multiple Equilibria)

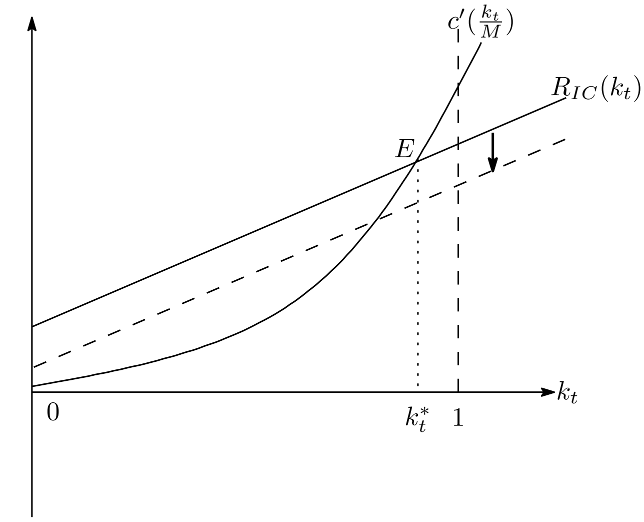

Figure 10: Competiton policy (IC-bind)

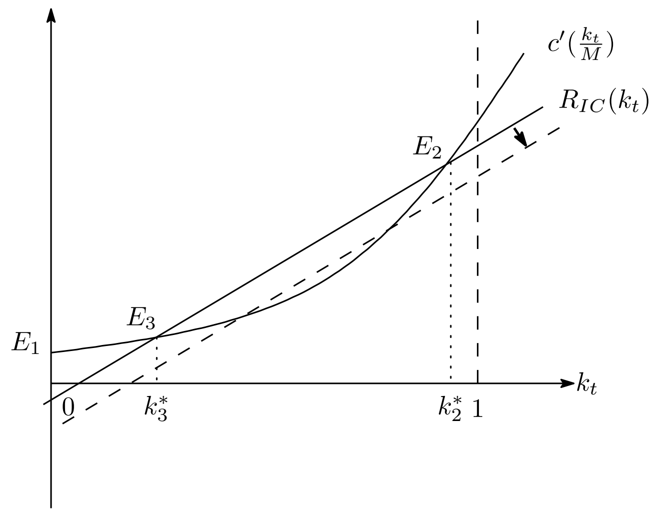

Figure 11: Competition Policy (Multiple Equilibria)