Firm-Specificity of Asset, Managerial Capability, and Labor Market Competition

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Abstract

We develop a model that captures the link between specificity of a firm's asset and capability of the firm's top management, two important sources of profitability. It contributes to strands of economics and management literature by proposing a logic through which firm-specificity and heterogeneity are determined endogenously through labor market competition. Higher importance of managerial capability raises labor mobility, which reduces firm-specificity of asset and human capital, and firm size, whereas higher importance of asset specificity yields opposite effects. Our findings yield novel empirical implications and predictions, given that the importance of managerial capability differs across industries, countries and time.Â

1 Introduction

Firms let their employees operate their assets to produce and sell goods and services. Specificity of a firm's asset and capability of its top management are two important sources of the firm's profitability. In this paper, we develop a new theoretical model that captures the link between specificity of a firm's asset and capability of the firm's top management, where the degree of firm-specificity is endogenously determined through firms' competition in the labor market.

In the resource-based view of the firm (Wernerfelt, 1984; Barney, 1991), firm-specificity of the asset, often referred to as heterogeneity of firm resources (physical capital, human capital, and organizational capital resources), has been identified as a critical source of sustained competitive advantage. The point here is that heterogeneity of firm resources enables a firm to conceive and implement a value-creating strategy that is unique and unable to be imitated by other firms, leading the firm to establish a sustained competitive advantage (Barney, 1991). Among the three broad categories of firm resources just mentioned, in this paper we focus on physical capital resources, human capital resources, and the interaction between the two.

In transaction cost economics (Williamson, 1979; 1985), firm-specificity of an asset, referred to as asset specificity, also serves as a key concept in the analysis of governance structure. If a seller tailors the nature of its physical capital specifically to its transactions with a buyer, the seller can increase efficiency of its production for the buyer (Williamson, 1979; Riordan and Williamson, 1985). Furthermore, there is an important link between relation specificity of physical capital and human capital, because, if employees operate firm-specific physical capital, their training and learning-by-doing to operate the physical capital also become firm-specific (Williamson, 1979). In our theoretical model, we incorporate this link, which is a key element for the endogenous determination of firm-specificity of asset and human capital in the presence of labor market competition.

The capability of a firm's top management is a critical determinant of the firm's profitability, because it is the top management that sets the strategy for the firm, determines its organizational structure, and establishes systems and processes for implementing the strategy (Porter and Nohria, 2010). It has been widely recognized that the capabilities

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of top managements differ across firms. Several papers have explored theoretical models in which an individual with higher managerial talent assumes a top position of a larger firm (see Lucas, 1978; Rosen, 1982; Gabaix and Landier, 2008; Terviö, 2008).[1]

In our model, a firm that has realized a high managerial capability hires some workers from a firm that has realized a low managerial capability. The labor mobility generated by ex ante uncertainty of firms' managerial capabilities plays a key role in the endogenous determination of firm-specificity of asset and human capital. It has been widely recognized that capabilities of top managements are mostly innate, uncertain, and ex ante unknown.[2] Given the uncertainty, Pan, Wang and Weisbach (2015) empirically study the process through which the market learns about the CEO's ability, and Denis, Denis and Walker's (2015) empirical study concludes that the need for assessment of the CEO's ability is an important element of the structure of newly formed boards. Closely related to the uncertainty of top managements' capabilities, several papers have studied firm-dynamics models in which the efficiency of firms in an industry is different across firms, and no firm knows its own true efficiency ex ante (Jovanovic, 1982; Lippman and Rumelt, 1982; Hopenhayn, 1992).

The importance of top management's capability (hereafter referred to as managerial capability) differs across an industry's life cycle, countries, and time. For instance, as an industry evolves from infancy stage, firms typically undergo revolutionary technological changes. Thus, a business's success depends on the quality of its strategic decision making because firms during this stage are surrounded by a high level of uncertainty about the needs of customers, the products and services that will prove to be the most desired, and the best configuration of activities and technologies to deliver them. Whereas in the mature phase of an industry, institutional structures become clear and the opportunity for radical innovation is few. These arguments suggest that the importance of managerial capability is higher during the early phase of an industry's life cycle with revolutionary technological changes and higher level of uncertainty, while the importance tends to be lower in the mature phase of an industry with less technological advancement and lower

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[1]See also Oi (1983) for a related analysis.

[2]As Goleman (1998) puts it, "Every business person knows a story about a highly intelligent, highly skilled executive who was promoted into a leadership position only to fail at the job. And they also know a story about someone with solid—but not extraordinary—intellectual abilities and technical skills who was promoted into a similar position and then soared. See also Aaker (2011), who points out that a gifted CEO needs two qualities, executive talent and strategic judgement, which come with birth, and not training in his view.

level of uncertainty.

How do differences in the importance of managerial capability affect firm-specificity of assets, the nature of human capital acquisition within firms, firm size, and labor mobility? Our two-period duopoly model of labor market competition provides an answer to this question. We find that, as the importance of managerial capability increases, firms make their asset less firm-specific, a smaller number of workers are hired (implying smaller average firm size), and labor mobility increases. Also, lower firm-specificity of asset leads to lower firm-specificity of skills acquired by workers.

The logic behind our result is as follows. In period 1, each firm hires a certain number of workers and determines the degree of firm-specificity of its asset (physical capital) without knowing its own managerial capabilities. As the importance of managerial capability increases, each firm anticipates that a larger number of workers switch their employers in period 2. This is because the higher importance of managerial capability makes firms' productivity more sensitive to their managerial capabilities, implying that period 2 productivity between a high-capability and a low-capability firm becomes larger. Anticipation of the higher labor turnover rate decreases a firm's incentive to invest in raising firm-specificity of its asset, because higher firm-specificity of the asset increases its worker's period 2 output only if the worker is already familiarized with firm-specific nature of the firm's asset through period 1 employment in the same firm. Lower asset specificity increases transferability of the firm's employees skills to the other firm and hence reduces firm-specificity of their human capital. The link between asset specificity and firm-specificity of human capital, not emphasized in the existing literature, is a driving force of our key results.

A higher labor turnover rate leads to lower firm-specificity of the asset, which, in turn, reduces each firm's incentive to hire workers in period 1, through two channels. First, lower firm-specificity reduces period-2 output of a retained worker. Second, lower firm-specificity increases the fraction of workers who switch employers in period 2. These two effects together reduce the expected period-2 productivity of each period-1 worker, implying that the number of workers employed by each firm in period 1 decreases as the importance of managerial capability increases.

Our theoretical framework yields empirical implications and predictions from a previously unexplored perspective. First, it enriches a prediction of transaction cost eco-

nomics (TCE) on the relationship between uncertainty and governance structure by indicating that uncertainty has an indirect effect on vertical integration transmitting through asset specificity. In TCE, the three critical dimensions for characterizing transactions are uncertainty, the frequency with which transactions recur, and the degree to which transaction-specific investments are incurred (that is, the degree of asset specificity) (Williamson, 1979; 1985). A standard prediction of TCE is that, in line with asset specificity and frequent transactions, higher uncertainty makes vertical integration more likely. This TCE prediction holds true in our framework only if uncertainty's positive direct effect outweighs its negative indirect effect; while the opposite relationship, not compatible with TCE prediction, is still suited in ours. Existing empirical evidence on this TCE prediction, in fact, are rather mixed, suggesting that channels through which uncertainty affects the likelihood of vertical integration can be richer than the standard one. Our analysis contributes to the TCE literature by pointing out a possible new channel and its implication in estimation. See Section 5.1 for details.

Furthermore, given that the importance of managerial capability can differ as an industry goes through stages of its life cycle, our model predicts that labor mobility is higher, specificity of asset and human capital is lower, and average firm size is smaller in the early or growing phases of an industry's life cycle that features rapid change of markets and disruptive technologies. Also, as the economy makes a transition from industrial capitalism to post-industrial capitalism, modern economies are becoming increasingly knowledge-intensive which renders the disadvantage to the firms that heavily rely on physical assets. This aspect allows us to apply the model results in explaining the observed difference in the labor mobility, specificity of asset and human capital, and firm size across countries and time (see Section 5.2 and 5.3 for more discussions).

2 Relationships with literature

As mentioned in the previous section, our theoretical analysis makes a contribution to TCE by proposing a new prediction on the relationship between uncertainty and governance structure. In this section, we discuss our contributions to the resource-based view (RBV) of the firm and the human capital theory. In the RBV literature, several authors have pointed out the importance of developing a theory in which firm heterogeneity,

the central concept of the RBV, is determined endogenously rather than assumed exogenouly (see Mahoney and Pandian, 1992; Helfat and Peteraf, 2003; Hoopes, Madsen and Walker, 2003). Mahoney and Pandian (1992), for example, point out, "A major advancement in the strategy field is the development of models where firm heterogeneity is an endogenous creation of economic actors."

As mentioned earlier, several papers have previously explored models in which an individual with higher managerial talent assumes a top position of a larger firm (Lucas, 1978; Rosen, 1982; Gabaix and Landier, 2008; Terviö, 2008). These papers can be viewed as contributions to the RBV literature because they analyse the process in which the distribution of managerial capabilities endogenously determines the size distribution of firms, where the difference in firm size is an important element of firm heterogeneity.

Our contribution to the RBV literature is complementary to these earlier contributions. As in these models, the distribution of managerial capabilities (which is assumed to be binary in our model for simplicity) is the driving force of firm heterogeneity in our model. However, elements of firm heterogeneity determined endogenously and the logic behind the determination in our model are fundamentally different from those in the earlier models. That is, in our model, firm heterogeneities of physical capital and human capital are the key elements that are endogenously determined, and these heterogeneities in turn lead to heterogeneity in firm size as well.

Labor mobility generated by ex ante uncertainty of managerial capabilities and the link between firm-specificities of asset and human capital are the driving forces of firm heterogeneities of physical capital and human capital, which in turn determine the average firm size in our model. Consistent with the earlier models, our model also captures the idea that a firm with higher managerial capability ends up with a larger firm size in the sense that some workers move from a low capability firm to a high capability firm in our model. See Murphy and Zabojnik (2004) for a related model, which analyze interconnections among the CEO's managerial capability, firm-specificity of the capability, and the optimal firm size. Murphy and Zabojnik (2004) show that, as the relative importance of firm-specific managerial capability decreases, the importance of the match between managerial capability and firm size increases, implying that filling CEO positions with outside hires rather than internal candidates become more likely. Firm-specificity of managerial capability is an exogenous parameter in their model.

Parallel to our contribution to the RBV literature, we contribute to the human capital theory literature by analysing the process in which firm-specificity of human capital is endogenously determined. Since the seminal contribution by Becker (1962), the distinction between general and firm-specific human capital has played an important role in the literature. Firm-specific human capital raises the productivity of the worker at his current firm but not elsewhere, whereas general human capital increases the worker's productivity at his current firm and at other firms.

To the best of our knowledge, firm-specificity of human capital is exogenously assumed in most exisiting models of human capital, but there are several recent exceptions including Morita (2001) and Lazear (2009). Our contribution to the literature is complementary to these earlier contributions, but the nature and the logic behind determination of firm-specificity in our model are fundamentally different from those in their models.

Morita (2001) proposes a model of labor market competition in which multiplicity of equilibria provides an explanation for the U.S.-Japanese differences in employment practices and the nature of technological improvement. The model assumes that, if a firm conducts continuous process improvement, the firm's technology is improved but a degree of firm-specificity is introduced. The link between continuous process improvement and the firm-specificity of training, along with labor mobility generated by stochastic worker-firm match qualities, lead to strategic complementarity, which in turn causes multiplicity of equilibria. In the Japanese equilibrium, each firm conducts continuous process improvement because other firms do so, and as a consequence training provided by such a firm becomes less effective (more firm-specific) in other firms. This lowers the turnover rate, which, in turn, increases firms' incentives to train employees. In the U.S. equilibrium, training is general, which raises the turnover rate and decreases incentives to train.

Our model is related to Morita's (2001) model in the sense that the link between firm-specificity of asset and firm-specificity of human capital, a driving force of our results, is similar to the link between continuous process improvement and firm-specificity of training. The key logic and insight, however, are different. In our model, it is ex ante uncertainty of managerial capabilities, not worker-firm match qualities, that generates labor turnover. As the importance of managerial capability increases, firms anticipate a higher labor turnover rate, and this reduces asset specificity, firm-specificity of human

capital, and firm size, in equilibrium. Comparative statics analyses with respect to the importance of managerial capability yield key results and implications in our model, whereas an explanation for cross-country differences based on multiplicity of equilibria, which does not arise in our model, is the key insight of Morita's (2001) model.

Notice that, regarding uncertainty, our focus is on uncertainty of managerial capability, whereas uncertainty in labour productivity is another important issue. Bai and Wang (2003) analyze a fixed wage contract model to study the effects of uncertainty in labor productivity on investment in firm-specific human capital (SHC), wage and the probability of separation. They find that wage and SHC are always positively correlated, but SHC investment and the probability of separation do not have a monotonic relationship. Human capital is assumed to be firm-specific in Bai and Wang's (2003) model, and hence endogenous determination of firm-specificity of human capital is not an issue there.

Lazear (2009) and Gathmann and Schönberg (2010) propose a new theory of human capital in which all skills are general but firms use them with different weights attached. The difference in skill-weights determines firm-specificity (or transferability) of the worker's skill set in their models. In Lazear's (2009) approach, workers are exogenously assigned to a firm and then choose how much to invest in each skill. In Gathmann and Schönberg's (2010) approach, each worker is endowed with a productivity in each skill and then chooses an occupation, where different occupations have different skill-weights. An important difference between these models and our model is that the difference in skill-weights is exogenously assumed in the former, whereas the degree of firm-specificity is endogenously determined in the latter.

3   The model

Consider an industry with two ex ante identical firms in a two-period setting. Only one homogenous good is produced in this industry and the price is normalized to one. Labor is the only input, and a firm's output is a summation of its employees' outputs. There exists a large number of individuals, where each individual is of measure zero. In each period, labor supply is perfectly inelastic and fixed at one unit for each individual. To keep the analysis simple, firms and individuals do not discount the future, and they are

risk-neutral.

At the beginning of period 1, each individual has the same general human capital and looks identical to the firms. Each individual can apply to a firm for employment. Each firm i simultaneously makes a first-period wage offer $w_{i,1}$ to hire desired number of individuals from its applicants. Let n_i denote the number of firm i's first-period employees. Individuals not employed by a firm become self-employed and remain so until the end of period 2, earning $\omega > 0$ per period.

Each firm's production efficiency is determined by its managerial capability and the level of its asset specificity, where managerial capability is interpreted as representing the ability of a firm's top management to develop an effective strategy and a unique competitive position. The realization of firm i's managerial capability a_i is given by $a_i = k + x_i$, where x_i reflects a mean-preserving shock according to a symmetric binary distribution with $\Pr(x_i = x) = \Pr(x_i = -x) = \frac{1}{2}$ and $k (\geq 0)$ is the mean of the managerial capability. This specification is consistent with the widely held view that the ability of a firm's top management is mostly innate, and difficult to observe or assess ex ante. Each firm i's managerial capability a_i becomes common knowledge at the end of the period 1 operation.

Higher managerial capability a_i increases firm i's production efficiency by increasing its worker's output. Notice that the difference of managerial capabilities between a high-capability and a low-capability firm, $2x$, represents the sensitivity of firms' production efficiency to their managerial capabilities. Hence we interpret that the parameter x represents the importance of managerial capability, which increases as firms' productivity becomes more sensitive to the difference of their managerial capabilities. In contrast, the parameter k does not capture the importance of managerial capability because it remains constant whether the firm's managerial capability is high or low.

Also at the beginning of period 1, each firm i can invest $z_i \geq 0$ in its level of asset specificity at a cost of $c(z_i) \geq 0$, where $c(\cdot)$ is a convex function. The asset specificity refers to the extent to which a firm tailors its non-human asset for its particular use. To obtain closed-form solutions in the analysis, let $c(z) = \frac{1}{2}\theta z^2$ and $\theta > 0$.

Each firm chooses its level of asset specificity at the same time as making its first-period wage offer to individuals, and commits to the investment level. Any worker employed by a firm in period 1 acquires a certain level of industry specific skill, which

increases the worker's second-period productivity by d (a positive constant). At the same time, a worker gets familiarized with the specificity of his first-period employer i's asset through learning-by-doing in period 1. If the worker is retained by the same firm in period 2, his familiarity with asset specificity increases his second-period productivity by $f(z_i)$, where $f(0) = 0$ and $f'(z_i) > 0$ for all $z_i \geq 0$. That is, a higher level of asset specificity increases a worker's second-period productivity if the worker has already familiarized with it. Taken together, if a worker stays with his period 1 employer i in period 2, his second-period production efficiency is $d + f(z_i)$, whereas, if a worker switches his employers between periods 1 and 2, his second-period production efficiency is d. Without loss of generality, we assume that $d = 1$. And to obtain closed-form solutions, let $f(z_i) = sz_i$ where $s > 0$. Here s captures the importance of a firm's asset specificity on its retained workers.

To produce the good, each worker also requires employer supervision. Assume that firm i's per worker supervision cost is bn_i in each period, where $b > 0$. That is, as the number of workers increases, each worker's net output declines because each worker receives less supervision from the employer.[3] Each firm i's period 1 profit is

$$n_i a_i - bn_i^2 - \frac{1}{2}\theta z_i^2 - W_{i,1},$$

where $W_{i,1}$ denotes firm i's first-period total wage bill.

At the beginning of period 2, each firm i can make its second-period wage offer w_{ij} ($i \neq j$) to poach firm j's employees, and can also make offer w_{ii} to retain its period 1 employees. Each worker can apply for one firm. Each firm can hire a desired number of workers from its applicants. If a worker applied for a firm and not hired, then the worker must take an outside option. Note that, when a firm makes wage offers, it knows its realization of managerial capability. Hence, the wage offer can be different across retained workers and new hires. Let $m_i(> -n_i)$ denote either the number of firm i's newly hired workers in the second period if $m_i \geq 0$, or the number of dismissed workers

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[3]See Zábojník and Bernhardt (2001) and DeVaro and Morita (2013) for a similar specification.

if $m_i < 0$. Each firm i's period 2 profit is

$$\begin{cases} n_i(a_i + 1 + sz_i) + m_i(a_i + 1) - b(n_i + m_i)^2 - W_{i,2} & \text{if } m_i \geq 0 \\ (n_i + m_i)(a_i + 1 + sz_i) - b(n_i + m_i)^2 - W_{i,2} & \text{if } m_i < 0 \end{cases},$$

where $W_{i,2}$ denotes firm i's second-period total wage bill. Firm i expands in its firm size if the net change in the number of workers in period 2 is positive; firm i contracts in its firm size if the net change in the number of workers is negative. A firm stays unchanged in its size only if it does not expand nor contract.

The timing of the game is as follows.

Period 1

[Stage 1] Each individual can apply to a firm or become self-employment. Each firm i simultaneously makes first-period wage offers $w_{i,1}$ to hire desired number of individuals from its applicants, where $i = 1, 2$. At the same time, each firm chooses its level of asset specificity z_i by incurring a cost. Each individual can apply to a firm or become self-employed. Individuals choose to work for a firm when indifferent between accepting wage offers and self-employment. Self-employed workers remain so for both periods, earning a wage ω each period.

[Stage 2] Each firm i that employed n_i workers at Stage 1 produces $n_i a_i$ units of the good. At the same time, firm i's managerial capability $a_i = k + x_i$ is realized and becomes common knowledge.

Period 2

[Stage 3] Each firm i can offer $w_{ij}(i \neq j)$ to the other firm's period 1 employees, and can offer w_{ii} to retain its period 1 employees. Each worker can apply for one firm. Each firm can hire a desired number of workers from its applicants. No workers who were self-employed in period 1 can be employed by a firm in the industry for period 2 production.[4]

[Stage 4] Each firm i produces the good according to its workers' production efficiency, in which each retained worker produces $a_i + 1 + sz_i$ units and each new worker produces

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[4]Even though we allow this possibility, no firms employ self-employed workers for period 2 production if ω is large enough. See footnote XYZ for details.

1 unit.

4 Analysis

In this section, we consider the symmetric Subgame Perfect Nash Equilibria (SPNE) in pure strategy. That is, each firm i chooses the same level of asset specificity and hire the same number of first-period workers in equilibrium.

We focus on equilibria in which a strictly positive number (measure) of workers move from one firm to the other at the beginning of period 2 whenever the realizations of managerial capability are different in both firms, given that in reality expansion and contraction of firm size are common in most industries. Proposition 1 identifies necessary and sufficient conditions for such an equilibrium to exist, and characterizes the equilibrium. Proposition 2 and 3 then present comparative statics results on the level of asset specificity, the firm size and the expected labor turnover rate in the equilibrium. Note, all proofs are in the Appendix.

Suppose that there exists an equilibrium in which a strictly positive number of workers switch employers in period 2 when firms' managerial capabilities are different. Consider a Stage 3 subgame where the uncertainty of managerial capability is realized. There are four cases, namely $a_i > a_j$, $a_i < a_j$, $a_i = a_j = k + x$, and $a_i = a_j = k - x$. First consider the case where firm i realizes its higher managerial capability and firm j realizes its lower ability; $(a_i, a_j) = (k + x, k - x)$. If firm i expands in its firm size, firm i makes offers $w_{ij} = k + x + 1 - 2b(n_i + m_i)$ to hire $m_i (> 0)$ new workers, where $k + x + 1 - 2b(n_i + m_i)$ is the expected productivity of firm j's first-period employee in firm i given m_i new workers are employed. While firm j contracts in its firm size and is willing to offer $w_{jj} = k - x + 1 + s z_j - 2b(n_j + m_j)$ to retain $n_j + m_j$ period 1 employees where $m_j < 0$. Also, firm i makes offers to retain its period 1 employees such that w_{ii} equals to these workers' expected productivity in firm j given all i's period 1 employees are retained; it means $w_{ii} = k - x + 1 - 2b(n_j + m_j)$.

In the equilibrium, both firms offer the same second-period wage to workers in firm j such that $w_{ij} = w_{jj}$. This condition, plus the condition that the desired number of workers from expansion equals that from contraction in the equilibrium, we obtain $m_i = -m_j = \frac{1}{4b}[2x - s z_j - 2b(n_i - n_j)] \equiv m_i^E(n_i, z_j, n_j)$. Then, the equilibrium second-

period wage for workers retained in firm j and newly hired in firm i becomes $\frac{1}{2}[2 + 2k + sz_j - 2b(n_i + n_j)] \equiv w_{-i,2}^E(n_i, z_j, n_j)$; while firm i offers $\frac{1}{2}[2 + 2k - sz_j - 2b(n_i + n_j)] \equiv w_{i,2}^E(n_i, z_j, n_j)$ to retain all its period 1 employees (see Claim 1 in the Appendix for details).

Further notice that, in the case where firm i expands and firm j contracts in the equilibrium, the following condition must hold:

$$0 < \frac{1}{4b}[2x - sz_j - 2b(n_i - n_j)] < n_j. \tag{1}$$

The right-hand side of condition (1) holds with strictly inequality; otherwise, firm j will shut down. Hence, in the SPNE outcome where both firms realize different managerial capabilities, the firm realizing higher capability expands and the other realizing lower capability contracts in their sizes. Firm i's second-period profit conditional on $a_i = k + x$ is given by

$$
\begin{aligned}
\pi_i^E(z_i, n_i, z_j, n_j) &\equiv n_i(k + x + 1 + sz_i) + m_i^E(n_i, z_j, n_j)(k + x + 1) \\
&\quad - b(n_i + m_i^E(n_i, z_j, n_j))^2 - (n_i w_{i,2}^E(n_i, z_j, n_j) + m_i^E(n_i, z_j, n_j)w_{-i,2}^E(n_i, z_j, n_j))
\end{aligned}
\tag{2}
$$

Next consider the case where firm i learns its lower managerial capability and firm j learns its higher capability; $(a_i, a_j) = (k - x, k + x)$. Let $w_{i,2}^C(z_i, n_i, n_j)$ and $m_i^C(z_i, n_i, n_j)$ be defined analogously given firm i retains some of its period 1 employees and thus contracts in its firm size. In the similar vein as the analysis in previous case, we obtain that firm i's second-period profit conditional on $a_i = k - x$ is given by[5]

$$
\begin{aligned}
\pi_i^C(z_i, n_i, n_j) &\equiv (n_i - m_i^C(z_i, n_i, n_j))(k - x + 1 + sz_i) \\
&\quad - b(n_i - m_i^C(z_i, n_i, n_j))^2 - (n_i - m_i^C(z_i, n_i, n_j))w_{i,2}^C(z_i, n_i, n_j).
\end{aligned}
\tag{3}
$$

Now consider a Stage 3 subgame where both firms realize the same managerial capabilities, $a_i = a_j$. In this case, firm i's period 1 employees has the same expected productivity in the other firm j. Each firm i thus offers the same second period wage $a_i + 1 - 2b(n_i + m_i)$ to the workers in the other firm. Then, in the equilibrium $m_i = 0$ holds

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[5]The condition $0 < m_i^C(z_i, n_i, n_j) < n_i$ also holds in the equilibrium. It is the same as condition (1) given that we focus on symmetric equilibrium.

and there is no labor mobility. That is, each firm retains all of its first-period employees and stays unchanged in its firm sizes in the equilibrium. Let $w_{i,2}^S(a_i, n_i) \equiv a_i + 1 - 2bn_i$. Then firm i's second-period profit conditional on $a_i = a_j$ is given by

$$\pi_i^S(z_i, n_i) \equiv n_i(a_i + 1 + sz_i) - bn_i^2 - n_i w_{i,2}^S(a_i, n_i). \tag{4}$$

Note that $\pi_i^S(z_i, n_i)$ is independent of managerial capability when $a_i = a_j$ (see Claim 1 in the Appendix for details). Hence, given that the equilibrium is symmetric and strictly positive number of workers move across firms whenever both firms have different managerial capabilities, each firm i's expected profit in period 2 is

$$
\begin{aligned}
\pi_{i,2}(z_i, n_i, z_j, n_j) &\equiv \Pr(a_i > a_j)\pi_i^E(z_i, n_i, z_j, n_j) \\
&\quad + \Pr(a_i < a_j)\pi_i^C(z_i, n_i, n_j) + \Pr(a_i = a_j)\pi_i^S(z_i, n_i),
\end{aligned}
\tag{5}
$$

where the probability of each outcome (a_i, a_j) is $\frac{1}{4}$.

At Stage 1, each firm i offers the same first-period wage $w_{i,1}$ to hire individuals from its applicants, given that firms and individuals are ex ante identical. An individual who receives an offer from firm i at Stage 1 anticipates his/her second-period wage will be $w_{i,2}^E(n_i, z_j, n_j)$ if $a_i > a_j$ at Stage 3, $w_{i,2}^C(z_i, n_i, n_j)$ if $a_i < a_j$, and $w_{i,2}^S(a_i, n_i)$ if $a_i = a_j$. Since 2ω is the lifetime wage for self-employed individuals, $w_{i,1} + E[w_{i,2}(z_i, n_i, z_j, n_j)] = 2\omega$ holds for a worker employed by firm i where

$$
\begin{aligned}
E[w_{i,2}(z_i, n_i, z_j, n_j)] &= \Pr(a_i > a_j)w_{i,2}^E(n_i, z_j, n_j) \\
&\quad + \Pr(a_i < a_j)w_{i,2}^C(z_i, n_i, n_j) + \Pr(a_i = a_j)w_{i,2}^S(a_i, n_i).
\end{aligned}
\tag{6}
$$

Hence $w_{i,1} = w_{i,1}(z_i, n_i, z_j, n_j)$ where

$$w_{i,1}(z_i, n_i, z_j, n_j) \equiv 2\omega - E[w_{i,2}(z_i, n_i, z_j, n_j)]. \tag{7}$$

Since firm i's period 1 profit is $n_i a_i - bn_i^2 - \frac{1}{2}\theta z_i^2 - W_{i,1}$, firm i's expected overall profit is $\Pi_i(z_i, n_i, z_j, n_j)$ in equilibrium, where

$$\Pi_i(z_i, n_i, z_j, n_j) \equiv n_i[k + E(x_i) - bn_i - w_{i,1}(z_i, n_i, z_j, n_j)] - \frac{1}{2}\theta z_i^2 + \pi_{i,2}(z_i, n_i, z_j, n_j). \tag{8}$$

In equilibrium, firm i chooses (z_i, n_i) to maximize expected overall profit $\Pi_i(z_i, n_i, z_j, n_j)$. The necessary first-order conditions that define the equilibrium level of asset specificity and the equilibrium number of first-period workers are $(\partial/\partial z_i)\Pi_i(z_i, n_i, z_j, n_j) = 0$ and $(\partial/\partial n_i)\Pi_i(z_i, n_i, z_j, n_j) = 0$ for each firm i. Given that we focus on the symmetric equilibrium $(z_i, n_i) = (z_j, n_j) = (z^*, n^*)$, the first-order conditions imply (see Claim 1 in the Appendix for details)

$$z^* = \frac{8s(1 - 2\omega + 2k) - 2xs}{32b\theta - 9s^2}. \tag{9}$$

$$n^* = \frac{(1 - 2\omega + 2k)(32b\theta - s^2) - 2xs^2}{4b(32b\theta - 9s^2)}. \tag{10}$$

The second-order conditions further require (see Claim 2 in the Appendix for details) that the following condition must hold:

$$32b\theta - 9s^2 > 0. \tag{11}$$

Suppose that $32b\theta - 9s^2 > 0$. From equation (9), $z^* > 0$ implies the following condition holds in the equilibrium:

$$x < 4(1 - 2\omega + 2k). \tag{12}$$

Also, in equilibrium the condition (1)—$0 < m_i^E(n^*, z^*, n^*) < n^*$—must hold, where $m_i^E(n^*, z^*, n^*) = \frac{1}{4b}(2x - sz^*)$. It further implies the following condition on x:

$$\frac{4s^2(1 - 2\omega + 2k)}{32b\theta - 8s^2} < x < \frac{(1 - 2\omega + 2k)(32b\theta + 7s^2)}{2(32b\theta - 5s^2)}. \tag{13}$$

That is, conditions (11), (12), and (13) are necessary for the existence of a unique and symmetric equilibrium, in which positive number of workers switch employers whenever firms' managerial capabilities are different. We then find (see Claim 3 in the Appendix for details) that conditions (11), (12), and (13) is equivalent to an intermediate range of $x \in (\underline{x}, \bar{x})$ where $0 < \underline{x} \equiv \frac{4s^2(1 - 2\omega + 2k)}{32b\theta - 8s^2} < \bar{x} \equiv \min\{4(1 - 2\omega + 2k), \frac{(1 - 2\omega + 2k)(32b\theta + 7s^2)}{2x(32b\theta - 5s^2)}\}$.

Then, Proposition 1 below tells us that the condition of $x \in (\underline{x}, \bar{x})$ is not only necessary but also sufficient for the existence of a unique symmetric equilibrium.

Proposition 1. *There exists a unique symmetric equilibrium in which a strictly positive number of workers move from one firm to the other whenever the realizations of both*

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firms' managerial capabilities are different in period 2, if and only if $x \in (\underline{x}, \bar{x})$. The equilibrium is characterized by each firm i's level of asset specificity and number of first-period workers $(z_i, n_i) = (z^*, n^*) = \left(\frac{8s(1-2\omega+2k)-2xs}{32b\theta-9s^2}, \frac{(1-2\omega+2k)(32b\theta-s^2)-2xs^2}{4b(32b\theta-9s^2)} \right)$.

Proposition 1 can be understood as follows. If the difference between high and low managerial capability is too small, labor mobility will not occur since the workers in the firm facing low capability still have relatively high productivity once been retained. If the difference between high and low managerial capability is too large, a firm underwent contraction will completely shut down given that the productivity of its workers is relatively high in its rival firm.

Also note that in equilibrium $m_i^E(n^*, z^*, n^*) = m_i^C(z^*, n^*, n^*) \equiv m^*$ and $w_{i,2}^C(z^*, n^*, n^*) = w_{-j,2}^E(n^*, z^*, n^*) \equiv w_2^{Switch}$, and let $w_{i,2}^E(n^*, z^*, n^*) \equiv w_2^{Retain}$ and $w_{i,1}(z^*, n^*, z^*, n^*) \equiv w_1^*$. Then, in the equilibrium each firm chooses the level of asset specificity z^*, makes first-period wage offer w_1^* to hire n^* workers at Stage 1. At Stage 3 if both firms have different managerial capabilities, firm i who realizes higher managerial capability retains all its first-period employees at wage w_2^{Retain} and expands in its firm size by hiring m^* workers from firm j $(j \neq i)$ at wage w_2^{Switch}, whereas firm j contracts in its firm size and retains $n^* - m^*$ workers at second-period wage w_2^{Switch}. Hence if $a_i \neq a_j$, there exists a strictly positive number of workers, m^*, moving from the low-capability firm to the high-capability firm in the equilibrium. At Stage 3 if $a_i = a_j$, each firm i retains all its first-period workers at the second-period wage $w_{i,2}^S(a_i, n^*)$ and stays unchanged in its firm size; thus there is no labor mobility. Then, the expected number of workers who switch their employers at the beginning of period 2 is $\frac{1}{4}(2m^*)$, and each firm i's expected labor turnover rate is $\frac{1}{4}\left(\frac{2m^*}{n^*}\right)$ in the equilibrium.

We will now turn to comparative statics on the equilibrium level of the asset specificity z^* and the firm size n^*, and the expected equilibrium turnover rate $\frac{1}{4}\left(\frac{2m^*}{n^*}\right)$. Note that the period 1 number of workers n^* can be interpreted as average firm size measured by employment since n^* determines each firm's expected number of workers over two periods.

Proposition 2. *As the importance of managerial capability (captured by x) increases, the level of asset specificity decreases, the average firm size decreases, and the expected labor turnover rate increases in the equilibrium.*

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The key result here is that, as the importance of managerial capability increases, the expected number of workers who switch their employers (expected labor mobility) in period 2 becomes larger, and each firm's asset specificity and average employment size decreases. The logic behind this result can be explained as follows. When firm i chooses the level of its asset specificity and the number of workers it employs in period 1, it estimates the expected number of its first-period employees that the firm will retain for second-period operation, and the expected number of workers that the firm hires from its rival firm j in period 2. A higher importance of managerial capability increases the difference of period 2 productivity between a high-capability and a low-capability firm. Then, as the importance of managerial capability increases, each firm anticipates a larger number of workers switch their employers in period 2 if both firms' managerial capabilities turn out to be different. Hence a higher importance of managerial capability decreases the expected number of retained workers, and it increases the expected number of workers who switch employers. Holding the initial number of workers constant, this reduces each firm's incentive to choose higher specificity of its asset. This is because higher firm-specificity increases a worker's period 2 productivity only if the worker was employed by the same firm in period 1 to be familiarized with the nature of the firm-specificity.

Lower firm-specificity of asset, in turn, reduces each firm's incentive to hire workers in period 1 through two channels. First, lower firm-specificity reduces period 2 output of a retained worker. Second, lower firm-specificity increases the fraction of workers who switch employers in period 2 if the two firms realize different managerial capability. These two effects together reduce the expected period 2 productivity of each period 1 worker, implying that the number of workers employed by each firm in period 1 decreases as the importance of managerial capability increases. The last result of Proposition 2 naturally follows from the key result mentioned above. As the importance of managerial capability increases, the expected labor turnover rate, measured by the ratio of expected number of workers who switch their employers in period 2 to the number of first-period workers, increases unambiguously in the equilibrium.

Proposition 3. *As the importance of a firm's asset specificity (captured by s) increases, the level of asset specificity increases, the average firm size increases, and the expected labor turnover rate decreases in the equilibrium.*

Recall that in period 1 firm i estimates the number of workers it will retain and hire from the rival firm in period 2, respectively. As the importance of firm i's asset specificity increases, firm i will retain more of its first-period employees during the contraction phase, while hire fewer workers from its rival during the expansion phase since new workers become relatively less productive in firm i. This implies that each firm anticipates a smaller number of workers switch their employers in period 2 if the realized managerial capabilities are different. Lower expected labor mobility, along with the higher return from retained workers (captured by s), implies that a firm has higher incentive to choose a higher level of asset specificity. These two effects are mutually reinforcing because the higher level of asset specificity reduces the expected turnover rate by increasing the retained workers' productivity. The results of the average firm size and expected turnover rate follow through the logic analogous to the one explained for Proposition 2.

5 Discussion

5.1 An application to the TCE prediction on uncertainty

Our theoretical framework enriches a prediction of TCE on the relationship between uncertainty and governance structure. As mentioned in Introduction, a standard prediction of TCE is that, in line with asset specificity and frequent transactions, higher uncertainty makes vertical integration more likely.

Our model incorporates uncertainty of each firm's managerial capability, where the degree of uncertainty increases as the importance of managerial capability shock increases. A key prediction of our model can then be restated in terms of uncertainty as follows: Higher uncertainty increases labor mobility, which in turn reduces the degree of each firm's asset specificity. Then, applying another standard prediction of TCE that higher degree of asset specificity makes vertical integration more likely, our model implies a mediation process where the uncertainty (exogenous variable) affects vertical integration through asset specificity (an intermediate variable or a mediator).

Consider estimating the following structural equations with such mediation process:

$$Y_i = \beta_0 + \beta_1 M_i + \beta_2 X_i + \epsilon_{i1}, \tag{14}$$

$$M_i = \gamma_0 + \gamma_1 X_i + \epsilon_{i2}, \tag{15}$$

where X_i and M_i represents the observed level of uncertainty and asset specificity, respectively, and Y_i is the observed vertical integration choice.[6] In this mediation process, the total effect of the uncertainty can be decomposed into direct and indirect effects. The direct effect equals the effect of uncertainty on vertical integration choice that is not transmitted by the mediator—asset specificity. This direct effect thus corresponds to the TCE prediction where the coefficient β_2 is positive. On the other hand, our model points out that there exists an indirect effect of the uncertainty on vertical integration going through asset specificity, in which the coefficient γ_1 is negative. The total effect of the uncertainty on vertical integration thus equals $\beta_2 + \gamma_1 \beta_1$. Notice that TCE predictions also require β_1 be positive. Hence, the sign of $\beta_2 + \gamma_1 \beta_1$ is indeterminate. When uncertainty's (negative) indirect effect outweighs its (positive) direct effect, our model predicts that uncertainty makes vertical integration less likely. This prediction is opposite to the standard TCE prediction. The structural equations thus imply a richer relationship between uncertainty and governance structure.

Another implication of this setting is that it highlights a twofold estimation challenge. First, an endogeneity problem exists in a regression model if only asset specificity is included in the explanatory variables. A similar point has been made by Macher and Richman (2008)'s empirical TCE review article. They state "Virtually all of the [empirical] studies examined in this survey treat the specificity of assets and the level of a firm's investment in those assets as exogenous. These are, however, choice variables ... should therefore be treated as endogenous." Here we identify one cause (i.e., exclusion of uncertainty) of such endogeneity of asset specificity.

Second, if the underlying regression model has the structure as in equations (14) and (15), estimating uncertainty effect in a single linear regression model with asset specificity included in explanatory variables as in equation (14) (i.e., without considering

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[6]The key identification assumption for such causal mechanism, a process in which a causal variable of interest influences the outcome, is error terms ϵ_{i1} and ϵ_{i1} are uncorrelated. See Imai, Keele and Yamamoto (2010) and Imai, Keele, Tingley and Yamamoto (2011) for the proofs and discussions under which $\hat{\gamma_1}\hat{\beta_1}$ is a valid estimator (i.e., asymptotically consistent) of the indirect (mediation) effect.

the indirect effect of uncertainty) results in multicollinearity problem. Because there is a linear relationship between uncertainty and asset specificity. Consequently, the resulting estimate can be either imprecise or numerically inaccurate even though it is not biased. Our structural equations thus reconcile the seemingly mixed results of uncertainty effect on vertical integration in TCE empirical literature.[7]

Specifically, Lieberman (1991) finds in his study of chemical products that volatility in the firm's downstream detrended market sales appears to have little influence on integration decisions. Anderson and Schmittlein (1984) find in their study of the electric components industry, "Contrary to the transaction cost model, neither frequency of transactions nor interaction of specificity and environmental uncertainty [forecast error in sales] is significantly related to integration." By using data from multiple industries, Norton (1988) finds in the industries of motels and refreshment places that detrended percentage variations in retail sales have negative effect on integration choice, in which the negative effect in the latter industry is significant. Notice that the studies referred to above adopt the variance of detrended sales or of forecasting errors or the instability of market shares as their empirical measures for uncertainty.[8] This uncertainty measure is consistent with our model environment since our model predicts that higher uncertainty results in higher labor mobility, leading to higher volatility of market share. But these empirical studies, in fact, test the TCE prediction that β_2 is positive, ignoring the indirect channel that our model identifies. As a result, their estimates are imprecise and may have sizable change due to high degree of multicollinearity. Also, the insignificant or negative sign of their uncertainty coefficient, despite not lending support to TCE prediction on the surface, can still be compatible under our setup.

5.2 An application to different phases of an industry's life cycle

The second application concerns the idea that the importance of managerial capability shock can differ as an industry goes through stages of its life cycle (Helfat and Peteraf, 2003). For example, as an industry evolves from infancy stage, firms typically undergo

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[7]For review articles, see Shelanski and Klein (1995); Lafontaine and Slade (2007); Macher and Richman (2008). As argued by Macher and Richman (2008), although TCE predictions have earned empirical success in many of its central tenets, several prior empirical studies do not lend support to the role of uncertainty in the decision of vertical integration.

[8]This type of uncertainty measure, as mentioned by Lafontaine and Slade (2007), is common in the empirical literature.

revolutionary technological changes that is characterized by Schumpeter's "creative destruction" (Agarwal, Sarkar and Echambadi, 2002; Winter, 1984). Thus, a business's success critically depends on the quality of its strategic decision making because firms during this stage are surrounded by a high level of uncertainty about the needs of customers, the products and services that will prove to be the most desired, and the best configuration of activities and technologies to deliver them. Whereas in the mature phase of an industry, institutional structures become clear and the opportunity for radical innovation is few. It follows that firms during this stage face lower level of uncertainty, and thus strategic decision making is less important for them.[9] These arguments suggest that the importance of managerial capability shock is higher during the early phase of an industry's life cycle with revolutionary technological changes and higher level of uncertainty, while the degree tends to be lower in the mature phase of an industry with less technological advancement and lower level of uncertainty. Our model then predicts that labor mobility is higher, specificity of asset and human capital is lower, and average firm size is smaller in the early or growing phases of an industry's life cycle and vice-versa in the later or mature phases.

These predictions are consistent with empirical and observational evidence. Concerning firm size, Dinlersoz and MacDonald (2009) show that average firm size, measured by employment (but not output), in U.S. manufacturing industries from 1963 until 1997 falls over time during the rapid entry phase of the industry's life-cycle, where the rapid entry phase occurs during the first stage of life cycle and when there exists greater technological improvement. In addition, using manufacturing firm data from Portugal, Italy, and Spain, respectively, Cabral and Mata (2003), Angelini and Generale (2008), and Segarra and Teruel (2012) all confirm that the firm size distribution of employees clearly skewed to the right (most of the mass is on small firms) and the skewness tends to diminish with firm age.[10] That is, the smaller the firm size, the younger the firm. Since young firms account for a much higher fraction in the starting stages of an industry's

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[9]See also empirical study by Katila and Shane (2005). Using data on firms' efforts to commercialize technological inventions, they find that firms' innovation activity in response to market competitiveness differs depending on firm newness. Giving that entries of new firms occur mostly during the early stage of an industry's life cycle, this finding suggests that the importance of managerial capability shock differs across different life cycle stages.

[10]Cabral and Mata (2003) consider the cohort of firms that entered Portuguese manufacturing in 1984 and follow them until 1991. Angelini and Generale (2008) study the firm size distribution of employees by pooling Italian manufacturing firm data in 1992, 1995, 1998, and 2001. Segarra and Teruel (2012) use Spanish manufacturing firms data in both 2001 and 2006.

life cycle, this result also implies average firm size tends to be smaller during the earlier life cycle stages.

Concerning labor mobility, Benner (2002) studies labor markets in Silicon Valley and points out that, "The rapid turnover and volatility in employment in Silicon Valley is integrally connected to the nature of competition in the region's high-technology industries. In these industries, markets and technology change extremely rapidly and in unpredictable ways." Notice that, compared with U.S. automobile industry, Silicon Valley is considered as high-tech clusters consisting of relatively young firms or startups with concentrated entrepreneurship,[11] reflecting a growing stage of the industry evolution.

5.3   An application to U.S.-Japanese differences

The U.S. and Japan have been considered representing two contrasting employment systems, which attracts significant attention in the literature of international comparison in how internal labor markets operate. By capturing the interconnections among asset specificity, acquisition of firm-specific human capital, managerial capability, and labor mobility, our model offers new explanations for and predictions on the U.S.-Japanese differences based on the cross-country differences in the importance of both managerial capability and firm-specificity of asset.

Acemoglu, Aghion and Zilibotti (2006) argue in their analysis of technology frontiers and firm selection that managerial skill is more important for undertaking innovative activities than for adopting and imitating existing technologies from the world technology frontier. They then point out, based on their analysis of the correlation between distance to the frontier and R&D intensity using data from the OECD sectoral database, that innovation becomes more important as the economy approaches the world technology frontier and there remains less room for adoption and imitation. Following their analysis and argument, we argue that the importance of managerial capability was substantially lower in Japan than in the U.S. when most Japanese industries were catching up with the West in the postwar growth period (Okimoto, 1989).

On the other hand, as the economy makes the transition from industrial capitalism

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[11]Zhang (2003) shows that, in Silicon Valley, more than half of the 2002 top 40 technology companies were not even founded two decades ago.

to post-industrial capitalism, modern economies are becoming increasingly knowledge intensive which renders the disadvantage to the firms that heavily rely on physical assets. For example, Iwai (2002) points out that, in the new era of post-industrial capitalism, the physical assets have surrendered their central position to the knowledge-based human assets that money can no longer buy and control.[12] The advent of knowledge economy thus reduces the importance of firm-specificity of asset across the world. But different countries have different paths in making their transition to the knowledge economy. Based on the knowledge assessment methodology (KAM) developed by World Bank Institute that traces the challenges and opportunities of major economies' transition to knowledge-based economy from 1995, the U.S. has a better shape than Japan in their development of knowledge economy (Shibata, 2006). Following this reasoning, we argue that the importance of firm-specificity of asset is higher in Japan than in the U.S.

Combining the above argument where Japan has lower importance of managerial capability and higher importance of firm-specificity of asset compared with U.S., the predictions of our model point out to the same direction. That is, labor mobility was lower, and specificity of asset and human capital was higher in Japan than in the U.S., especially in the catching up period.[13]

These predictions are consistent with empirical and observational evidence. Concerning labor mobility, it was found that the labor turnover rate was much higher in U.S. than in Japan (see Hashimoto and Raisian, 1985; Mincer and Higuchi, 1988). Hashimoto and Raisian (1985), for instance, found that the 15-year job retention rates of the male population between the early 1960s and the late 1970s were much higher in Japan than in the United States across all age groups. Concerning firm-specific human capital, Koike (1977, 1988) found, in his comparative analysis of Japanese and U.S. industrial relations, that Japanese workers acquired more firm-specific human capital through rotation among related jobs (see also Dertouzos, Lester and Solow, 1989; Ito, 1991). Concerning

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[12]Also, Drucker (1993) for example, has argued that in the new economy, knowledge is not just another resource alongside the traditional factors of production—labor, capital, and land—but the only meaningful resource today.

[13]In an alternative approach where promotion serves as a signal of the worker's ability, Owan (2004) shows that late-promotion practice which commonly observed in Japanese firms results in low turnover rate and long-term employment relationship; whereas early-promotion practice which is commonly observed in U.S. results in the opposite effects. Moreover, Chang and Wang (1995) explain the lower turnover rate and higher human capital accumulation in Japan than in the U.S. Their model is characterized by multiple equilibria and is analyzed in the framework where current employers have superior information on the abilities of their employees.

specificity of asset, we are unaware of direct observations or evidence. However, it is well known that Japanese firms conducted continuous process improvement more than U.S. firms did in the postwar growth period.[14] As argued by Morita (2001), if a firm conducts continuous process improvement, the technology is improved but a degree of specificity is introduced. This is because, in general, continuous process improvement involves a number of small changes and modifications, which lead to highly firm-specific technologies. This then suggests that specificity of asset was higher in Japanese firms than in the U.S. firms in the postwar growth period.

The Japanese economy has already caught up with the West, and most Japanese industries have got much closer to the world technology frontier. This increases the importance of managerial capability in which undertaking innovative activities now becomes crucially sensitive to higher managerial capability. Our model then predicts that the degree of the U.S.-Japanese differences become smaller. That is, labor mobility had increased, and specificity of asset and human capital has decreased in Japan. In reality, however, such transitions in Japan are likely to take place rather slowly due to vested interests and institutional inertia embedded in the Japanese economic system (Lincoln, 2001). Several empirical studies have been undertaken recently to find out whether or not the Japanese employment system has exhibited significant changes, but findings are not clear-cut thus far.[15]

6   Conclusion

We have developed a model of labor market competition that captures the link between capability of a firm's top management, specificity of a firm's asset, and firm-specificity of human capital. Firm-specificity of asset is a key concept in the RBV of the firm and TCE, and distinction between general and firm-specific human capital has played an important role in the human capital theory literature. We have contributed to these literatures by proposing a model in which the degree of firm-specificity is endogenously determined,

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[14]See Morita (2001) for a review of evidence.

[15]For example, Kambayashi and Kato (2017) study labor mobility and conduct cross-national analysis of micro data from Japan Employment Status Survey and U.S. Current Population Survey. They find that, on the one hand, core employees (age of 30-44 with at least five years of tenure) in Japan continued to enjoy much higher job stability than the U.S. counterparts consistently over the last twenty-five years. On the other hand, job stability for mid-career hires and youth employees deteriorated in Japan over the last twenty-five years, whereas there was no comparable decline in job stability in the U.S. counterparts.

where labor mobility generated by ex ante uncertainty of managerial capabilities and the link between firm-specificities of asset and human capital are the driving forces of the endogenous determination. Furthermore, our theoretical framework enriches a prediction of TCE on the relationship between uncertainty and governance structure by indicating that higher uncertainty can make vertical integration less likely. Given that the importance of managerial capability differs across industries, countries and time, our theoretical results yield empirical implications and predictions from a previously unexplored perspective.

Appendix

Proof of Proposition 1:

Proof of Proposition 1:

Suppose that there exists a symmetric equilibrium characterized by $(z_i, n_i) = (z^*, n^*)$ for each i, in which a strictly positive number of workers switch employers in period 2 whenever the realizations of managerial capability are different in both firms. In the text, it has been shown that conditions (11), (12), and (13) are necessary for such an equilibrium to exist. Here, in Claim 1–3 below, we present proof of some computational details that have not been presented in the text.

Claim 1: In a symmetric equilibrium where a strictly positive number of workers switch employers in period 2 whenever the realizations of managerial capability are different in both firms, each firm i chooses $z_i = z^* = \frac{8s(1-2\omega+2k)-2xs}{32b\theta-9s^2}$ and $n_i = n^* = \frac{(1-2\omega+2k)(32b\theta-s^2)-2xs^2}{4b(32b\theta-9s^2)}$.

Proof of Claim 1: Suppose that there exists an equilibrium in which a strictly positive number of workers switch employers in period 2 when firms' managerial capabilities are different. First notice that in the Stage 3 subgame, firm i's second-period profit conditional on $a_i = k + x$ and $a_i \neq a_j$ is $\pi_i^E(z_i, n_i, z_j, n_j) = n_i(k + x + 1 + sz_i) + m_i^E(n_i, z_j, n_j)(k+x+1) - b(n_i + m_i^E(n_i, z_j, n_j))^2 - (n_i w_{i,2}^E(n_i, z_j, n_j) + m_i^E(n_i, z_j, n_j) w_{-i,2}^E(n_i, z_j, n_j))$ as analyzed in the text, implying that

$$
\pi_i^E(z_i, n_i, z_j, n_j) = \frac{1}{16b}\{4\left[(b(n_i + n_j) + x)^2 + 4bsn_iz_i\right] \tag{16}
$$
$$
+ 4s(3bn_i - bn_j - x)z_j + (sz_j)^2\},
$$

given $m_i^E(n_i, z_j, n_j) = \frac{1}{4b}[2x - sz_j - 2b(n_i - n_j)]$, $w_{i,2}^E(n_i, z_j, n_j) = \frac{1}{2}[2 + 2k - sz_j - 2b(n_i + n_j)]$, and $w_{-i,2}^E(n_i, z_j, n_j) = \frac{1}{2}[2 + 2k + sz_j - 2b(n_i + n_j)]$. Second notice that, if firm i contracts and firm j expands, the equilibrium size of of expansion/contraction can be solved analogously, which is $\frac{1}{4b}[-2x - sz_j - 2b(n_i - n_j)]$. This case where firm i contracts and firm j expands can be ruled out since $-2x - sz_j - 2b(n_i - n_j) < 0$ for any symmetric equilibrium—a contradiction. Third, it cannot be the case that firm i retains only some of its period 1 employees and firm j $(j \neq i)$ hires some workers from i in the equilibrium. The reason is as follows. Suppose firm i retains $n_i - l_i$ of its period 1 employees, where $l_i > 0$, and hire $r_i (> 0)$ workers from firm j in which the size of the expansion is positive

and equals $r_i - l_i$; firm j retains $n_j - r_j$ of its period 1 employees, where $r_j > 0$, and hire $l_j(> 0)$ workers from firm i in which the size of contraction is $r_j - l_j$. Then, firm i offers $k + x + 1 - 2b(n_i + r_i - l_i) \equiv w_{i,O}^E$ to hire r_i outside workers and firm j offers $k - x + 1 + sz_j - 2b(n_j - r_j + l_j) \equiv w_{j,R}^C$ to retain $n_j - r_j$ of its period 1 employees, in which $w_{i,O}^E = w_{j,R}^C$ and the size of expansion $r_i - l_i \equiv m_i$ equals that of contraction $r_j - l_j \equiv -m_j$ in equilibrium. We have $m_i = -m_j = \frac{1}{4b}[2x - sz_j - 2b(n_i - n_j)]$. Similarly, firm i offers $k + x + 1 + sz_i - 2b(n_i + r_i - l_i) \equiv w_{i,R}^E$ to retain $n_i - l_i$ of its period 1 employees and firm j offers $k - x + 1 - 2b(n_j - r_j + l_j) \equiv w_{j,O}^C$ to hire l_j outside workers, in which $w_{i,R}^E = w_{j,O}^C$ in equilibrium. The implied expansion/contraction size in equilibrium from this later case is $\frac{1}{4b}[2x + sz_i - 2b(n_i - n_j)]$. Given that $\frac{1}{4b}[2x - sz_j - 2b(n_i - n_j)] \neq \frac{1}{4b}[2x + sz_i - 2b(n_i - n_j)]$ for any symmetric equilibrium, firm i (expansion firm) will retain all its period 1 employees.

Consider the Stage 3 subgame where $(a_i, a_j) = (x - k, k + x)$. If firm i contracts and firm j expands in their firm sizes, firm i makes offers $w_{ii} = k - x + 1 + sz_i - 2b(n_i + m_i)$ to retain $n_i + m_i$ ($m_i < 0$) workers from its period 1 employees where $k - x + 1 + sz_i - 2b(n_i + m_i)$ is the expected productivity of firm i's first-period employee in i given $n_i + m_i$ of them are retained. While firm j is willing to offer $w_{ji} = k + x + 1 - 2b(n_j + m_j)$ to hire $m_j(> 0)$ new workers, where $k + x + 1 - 2b(n_j + m_j)$ equals the expected productivity of firm i's first-period employees in firm j. In the equilibrium, both firms offer the same second-period wage to the workers in firm i such that $w_{ii} = w_{ji}$, and the number of workers from contraction equals that from expansion, $-m_i = m_j \equiv m_i^C(z_i, n_i, n_j)$. We obtain $m_i^C(z_i, n_i, n_j) = \frac{1}{4b}[2x - sz_i + 2b(n_i - n_j)]$. Then, the equilibrium second-period wage for workers retained in firm i and newly hired in firm j becomes $\frac{1}{2}[2 + 2k + sz_i - 2b(n_i + n_j)] \equiv w_{i,2}^C(z_i, n_i, n_j)$. Notice that, if firm i expands and firm j contracts in the equilibrium, the expansion/contraction size is $\frac{1}{4b}[-2x - sz_i + 2b(n_i - n_j)]$. This equilibrium can be ruled out given $-2x - sz_i + 2b(n_i - n_j) < 0$ for any symmetric equilibrium—a contradiction. Further notice that, $0 < m_i^C(z_i, n_i, n_j) < n_i$ holds in the equilibrium, which suggests $0 < \frac{1}{4b}[2x - sz_i + 2b(n_i - n_j)] < n_i$. This condition is the same as the condition (1) in the equilibrium. Lastly, notice that firm i will not hire some of firm j's workers while maintaining the contraction size, $m_i^C(z_i, n_i, n_j)$, in the equilibrium. Because this does not hold for symmetric equilibrium as analyzed in the previous paragraph. Then, firm i's second-period profit conditional on $a_i = k - x$ is $\pi_i^C(z_i, n_i, n_j) = (n_i - m_i^C(z_i, n_i, n_j))(k -$

$x+1+sz_i) - b(n_i - m_i^C(z_i, n_i, n_j))^2 - (n_i - m_i^C(z_i, n_i, n_j))w_{i,2}^C(z_i, n_i, n_j)$, implying that

$$\pi_i^C(z_i, n_i, n_j) = \frac{1}{16b}[2x - sz_i - 2b(n_i + n_j)]^2. \tag{17}$$

Next consider the Stage 3 subgame where both firms have the same managerial capabilities, $a_i = a_j$. First note that it cannot be the case that one firm expands and the other contracts given that either $-sz_j + 2b(n_i - n_j) \ngtr 0$ or $-sz_i + 2b(n_j - n_i) \ngtr 0$ (the gap of realized managerial capability is now 0) under symmetric equilibrium. Then, both firms must stay unchanged in their firm sizes in the equilibrium. That is, each firm i will offer the wage to the extent that the expected productivity from the outside workers are the same at the level $a_i + 1 - 2b(n_i + m_i)$ where $m_i = 0$ holds in the equilibrium. That is, each firm i make offers $w_{i,2}^S(a_i, n_i) = a_i + 1 - 2bn_i$ to retain all of its first-period employees. Then firm i's second-period profit conditional on $a_i = a_j$ is $\pi_i^S(z_i, n_i) = n_i(a_i + 1 + sz_i) - bn_i^2 - n_i w_{i,2}^S(a_i, n_i)$, implying that

$$\pi_i^S(z_i, n_i) = n_i(sz_i + bn_i). \tag{18}$$

Consequently, in the equilibrium each firm i's expected profit in period 2 is $\pi_{i,2}(z_i, n_i, z_j, n_j) = \Pr(a_i > a_j)\pi_i^E(z_i, n_i, z_j, n_j) + \Pr(a_i < a_j)\pi_i^C(z_i, n_i, n_j) + \Pr(a_i = a_j)\pi_i^S(z_i, n_i)$, where $\Pr(a_i > a_j) = \Pr(a_i < a_j) = \frac{1}{4}$ and $\Pr(a_i = a_j) = \frac{1}{2}$.

Also, $w_{i,1} + E[w_{i,2}(z_i, n_i, z_j, n_j)] = 2\omega$ holds for a worker employed by firm i in the equilibrium where $E[w_{i,2}(z_i, n_i, z_j, n_j)] = \Pr(a_i > a_j)w_{i,2}^E(n_i, z_j, n_j) + \Pr(a_i < a_j)w_{i,2}^C(z_i, n_i, n_j) + \Pr(a_i = a_j)w_{i,2}^S(a_i, n_i)$ and 2ω is the lifetime wage for self-employed individuals. Note that $w_{i,2}^C(z_i, n_i, n_j) = w_{-j,2}^E(z_i, n_i, n_j)$ so that the second-period wage of the new workers who are hired by expansion firm is actually determined by contraction firm's strategic variables. By substituting the value of $w_{i,2}^E(z_i, n_i, z_j, n_j)$, $w_{i,2}^C(z_i, n_i, z_j, n_j)$, and $w_{i,2}^S(a_i, n_i)$, we obtain

$$E[w_{i,2}(z_i, n_i, z_j, n_j)] = 1 + k + \frac{1}{8}[s(z_i - z_j) - 4b(3n_i + n_j)]. \tag{19}$$

Then, we find $w_{i,1} = w_{i,1}(z_i, n_i, z_j, n_j)$ where

$$w_{i,1}^*(z_i, n_i, z_j, n_j) = 2\omega - (1 + k) - \frac{1}{8}[s(z_i - z_j) - 4b(3n_i + n_j)]. \tag{20}$$

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Hence, each firm i's expected overall profit is $\Pi_i(z_i, n_i, z_j, n_j) = n_i E(a_i) - bn_i^2 - \frac{1}{2}\theta z_i^2 - W_{i,1} + \pi_2(z_i, n_i, z_j, n_j)$, implying that

$$
\begin{aligned}
\Pi_i(z_i, n_i, z_j, n_j) &= n_i[k + E(x_i) - bn_i - w_1(z_i, n_i, z_j, n_j)] - \frac{1}{2}\theta z_i^2 \qquad (21)\\
&\quad + \frac{1}{4}\pi_i^E(z_i, n_i, z_j, n_j) + \frac{1}{4}\pi_i^C(z_i, n_i, n_j) + \frac{1}{2}\pi_i^S(z_i, n_i)\\
&= \frac{1}{64b}\{\{-8b^2(5n_i - n_j)(3n_i + n_j) + 8x^2 - 4sx(z_i + z_j) + s^2(z_i^2 + z_j^2)\\
&\quad + 4b[sn_j(z_i - z_j) + n_i(16 - 32\omega + 15sz_i + sz_j + 32k) - 8\theta z_i^2]\},
\end{aligned}
$$

where $\pi_i^E(z_i, n_i, z_j, n_j)$, $\pi_i^C(z_i, n_i, n_j)$, and $\pi_i^S(z_i, n_i)$ are defined in the equations (16), (17), and (18) respectively. Let compute the partial derivatives of $\Pi(z_i, n_i, z_j, n_j)$. We find

$$
\begin{aligned}
(\partial/\partial z_i)\Pi_i(z_i, n_i, z_j, n_j) &= \frac{s}{32b}[2b(15n_i + n_j) - 2x + sz_i] - \theta z_i,\\
(\partial/\partial n_i)\Pi_i(z_i, n_i, z_j, n_j) &= 1 - 2\omega + 2k + \frac{1}{16}[15sz_i + sz_j - 4b(15n_i + n_j)].
\end{aligned}
$$

Given that $(z_i, n_i) = (z_j, n_j) = (z^*, n^*)$ in the symmetric equilibrium, the first-order conditions imply

$$
\begin{cases}
\left(\frac{s}{32b}\right)(sz^* - 2x) + (sn^* - \theta z^*) = 0\\
1 - 2\omega + 2k + sz^* - 4bn^* = 0
\end{cases}
. \qquad (22)
$$

Solving the simultaneous equations, we obtain $z^* = \frac{8s(1 - 2\omega + 2k) - 2xs}{32b\theta - 9s^2}$ and $n^* = \frac{(1 - 2\omega + 2k)(32b\theta - s^2) - 2xs^2}{4b(32b\theta - 9s^2)}$ in the equilibrium. $\qquad\square$

Claim 2: In a symmetric equilibrium where a strictly positive number of workers switch employers in period 2 whenever the realizations of managerial capability are different in both firms, condition (11) presented in the text is necessary for each firm i's choice $(z_i, n_i) = (z^*, n^*)$.

Proof of Claim 2: Let us check the second-order condition of firm i's maximization problem over its profit function $\Pi_i(z_i, n_i, z_j, n_j)$ to rule out candidate critical point under different parameterization. We have $(\partial^2/\partial z_i^2)\Pi_i(z_i, n_i, z_j, n_j) = \frac{s^2}{32b} - \theta$, $(\partial^2/\partial n_i^2)\Pi_i(z_i, n_i, z_j, n_j) = -\frac{15}{4}b$, and $(\partial^2/\partial z_i\partial n_i)\Pi_i(z_i, n_i, z_j, n_j) = (\partial^2/\partial n_i\partial z_i)\Pi_i(z_i, n_i, z_j, n_j) = \frac{15}{16}s$. Hence, the first-order leading principal minor of $D^2\Pi_i(z_i, n_i, z_j, n_j)$ is negative and the second-order

leading principal minor of $D^2\Pi_i(z_i, n_i, z_j, n_j)$ is $\frac{15}{128}(32b\theta - 8.5s^2)$. That is, $D^2\Pi_i(z_i, n_i, z_j, n_j)$ is negative definite over all $z_i \geq 0$ and $n_i \geq 0$ if $32b\theta - 8.5s^2 > 0$. We need to show that there does not exist a range of parametrization for the existence of symmetric equilibrium such that $8.5s^2 < 32b\theta < 9s^2$ holds for the solution $z^* > 0$ and $n^* > 0$.

Suppose $8.5s^2 < 32b\theta < 9s^2$ holds. Then given that the denominator of z^* is negative, $x \geq 4(1 - 2\omega + 2k)$ implies $1 - 2\omega + 2k > 0$ must hold. Also, given $0 < m_i^E(n^*, z^*, n^*) < n^*$ where $m_i^E(n^*, z^*, n^*) = \frac{1}{4b}(2x - sz^*)$, we have $\frac{(1-2\omega+2k)(32b\theta+7s^2)}{2(32b\theta-5s^2)} < x < \frac{4s^2(1-2\omega+2k)}{32b\theta-8s^2}$. Notice that $\frac{(32b\theta+7s^2)}{2(32b\theta-5s^2)} - \frac{4s^2}{32b\theta-8s^2} = \frac{(32b\theta)^2-288b\theta s^2-16s^4}{2(32b\theta-5s^2)(32b\theta-8s^2)} = \frac{(32b\theta-8s^2)(32b\theta-2s^2)+32b\theta s^2}{2(32b\theta-5s^2)(32b\theta-8s^2)} > 0$ given $32b\theta - 8.5s^2 > 0$. That is, the range of x satisfying $\frac{(1-2\omega+2k)(32b\theta+7s^2)}{2(32b\theta-5s^2)} < x < \frac{4s^2(1-2\omega+2k)}{32b\theta-8s^2}$ is an empty set. We thus complete the proof. $\qquad \square$

Claim 3: For any given parameterization, there exists unique values $\bar{x}$ and $\underline{x}$, respectively, such that conditions (11), (12), and (13) hold if and only if $x \in (\underline{x}, \bar{x})$. There exists a range of parameterizations in which $0 < \underline{x} < \bar{x}$.

Proof of Claim 3: Suppose $x < 4(1 - 2\omega + 2k)$ so that condition (12) holds. Then, $4(1 - 2\omega + 2k) > 0$ must hold. Using condition (11) and $4(1 - 2\omega + 2k) > 0$, we have $4(1 - 2\omega + 2k) > \frac{4s^2(1-2\omega+2k)}{32b\theta-8s^2}$. Concerning the case where $x < \frac{(1-2\omega+2k)(32b\theta+7s^2)}{2(32b\theta-5s^2)}$ so that the RHS of inequality (13) holds. We find $\frac{(1-2\omega+2k)(32b\theta+7s^2)}{2(32b\theta-5s^2)} - \frac{4s^2(1-2\omega+2k)}{32b\theta-8s^2} = \frac{(1-2\omega+2k)}{2(32b\theta-5s^2)(32b\theta-8s^2)}[(32b\theta)^2 - 288b\theta s^2 - 16s^4] = \frac{(1-2\omega+2k)}{2(32b\theta-5s^2)(32b\theta-8s^2)}[(32b\theta - 8s^2)(32b\theta - 2s^2) + 32b\theta s^2] > 0$, given condition (11) and $4(1 - 2\omega + 2k) > 0$. Let $x \in (\underline{x}, \bar{x})$ where $\bar{x} = \min\{4(1 - 2\omega + 2k), \frac{(1-2\omega+2k)(32b\theta+7s^2)}{2x(32b\theta-5s^2)}\}$ and $\underline{x} = \frac{4s^2(1-2\omega+2k)}{32b\theta-8s^2}$ such that the range of x satisfying this condition is non-empty. Note that $\frac{4s^2(1-2\omega+2k)}{32b\theta-8s^2} > 0$. This implies the result. $\qquad \square$

Claim 1–3, along with the analysis presented in the text, imply the following necessary part of the proposition: "Suppose that there exists a unique symmetric equilibrium in which a strictly positive number of workers move from one firm to the other whenever the realizations of both firms' managerial capabilities are different in period 2. Then $x \in (\underline{x}, \bar{x})$ where $0 < \underline{x} < \bar{x}$ must hold." We now check sufficiency. Suppose that $0 < \underline{x} < x < \bar{x}$ holds, and that each firm i chooses $(z_i, n_i) = (z^*, n^*) = \left(\frac{8s(1-2\omega+2k)-2xs}{32b\theta-9s^2}, \frac{(1-2\omega+2k)(32b\theta-s^2)-2xs^2}{4b(32b\theta-9s^2)}\right)$. First note that $z^* > 0$ and $n^* > 0$ hold given $0 < \underline{x} < x < \bar{x}$. Then, following the procedure in the text and Claim 1, firm i's optimal

decision in period 2 is to expand in its firm size if $(a_i, a_j) = (k + x, k - x)$, to contract in its firm size if $(a_i, a_j) = (k - x, k + x)$, and to stay unchanged in its firm size if $a_i = a_j$. This is the case if the condition (1) $(0 < \frac{1}{4b}[2x - sz_j - 2b(n_i - n_j)] < n_j)$ holds, suggesting each firm i's expected overall profit at Stage 1 is $\Pi_i(z_i, n_i, z_j, n_j)$. Notice that, $0 < \frac{1}{4b}[2x - sz_j - 2b(n_i - n_j)] < n_j$ holds true for $(z_i, n_i) = (z_j, n_j) = (z^*, n^*)$. That is, if $0 < \underline{x} < x \le \bar{x}$, there exists a symmetric equilibrium with the following properties: (i) $(z_i, n_i) = (z^*, n^*) = \left(\frac{8s(1-2\omega+2k)-2xs}{32b\theta-9s^2}, \frac{(1-2\omega+2k)(32b\theta-s^2)-2xs^2}{4b(32b\theta-9s^2)} \right)$ where $z^* > 0$ and $n^* > 0$; (ii) at Stage 1, each firm chooses the level of asset specificity z^* and makes first-period wage offer w_1^* to n^* individuals, and employs n^* workers; (iii) at Stage 3 if both firms have different managerial capabilities, firm i who realizes higher managerial capability retains all its first-period employees at wage w_2^{Retain} and expands in its firm size by hiring m^* workers from firm j $(j \neq i)$ at wage w_2^{Switch}, whereas firm j contracts in its firm size and retains $n^* - m^*$ workers at second-period wage w_2^{Switch}; if $a_i = a_j$, each firm i retains all its first-period workers at the second-period wage $w_{i,2}^S(a_i, n^*)$ and stays unchanged in its firm size; (iv) the expected number of workers who switch their employers at the beginning of period 2 is m^* conditional on both firms have different managerial capabilities.

Finally, if $0 < \underline{x} < x < \bar{x}$, the symmetric equilibrium described in the previous paragraph is also unique. Because the implied condition (11) $(32b\theta - 9s^2 > 0)$ ensures that $\Pi_i(z_i, n_i, z^*, n^*)$ is globally concave over all $z_i > 0$ and $n_i > 0$, and the only solution satisfying both $(\partial/\partial z_i)\Pi_i(z_i, n_i, z^*, n^*) = 0$ and $(\partial/\partial n_i)\Pi_i(z_i, n_i, z^*, n^*) = 0$ for each firm i is $(z_i, n_i) = (z^*, n^*)$. This completes the proof of the proposition. $\square$

Proof of Proposition 2 and 3:

(i) Note $z^* = \frac{8s(1-2\omega+2k)-2xs}{32b\theta-9s^2}$, we find $\frac{\partial z^*}{\partial x} = \frac{-2s}{32b\theta-9s^2} < 0$ given $32b\theta - 9s^2 > 0$. Also, $\frac{\partial z^*}{\partial s} = \frac{[8(1-2\omega+2k)-2x](32b\theta-9s^2)+[8s(1-2\omega+2k)-2xs](18s)}{(32b\theta-9s^2)^2} > 0$ given $8s(1 - 2\omega + 2k) - 2xs > 0$ and $32b\theta - 9s^2 > 0$.

(ii) Note $n^* = \frac{(1-2\omega+2k)(32b\theta-s^2)-2xs^2}{4b(32b\theta-9s^2)}$, we find $\frac{\partial n^*}{\partial x} = \frac{-2s^2}{4b(32b\theta-9s^2)} < 0$. Also, $\frac{\partial n^*}{\partial s} = \frac{32s[4(1-2\omega+2k)-x]}{(32b\theta-9s^2)^2} > 0$ given $8s(1 - 2\omega + 2k) - 2xs > 0$.

(iii) Note $m^* = \frac{1}{4b}(2x - sz^*)$, we find $\frac{\partial m^*}{\partial x} = \frac{1}{4b}(2 - s\frac{\partial z^*}{\partial x}) > 0$ given $\frac{\partial z^*}{\partial x} < 0$. Then given $\frac{\partial n^*}{\partial x} < 0$ and $\frac{\partial m^*}{\partial x} > 0$, we find $\partial(\frac{1}{4}\frac{2m^*}{n^*})/\partial x = \frac{1}{(2n^*)^2}[\frac{\partial m^*}{\partial x}(2n^*) - m^*(\frac{\partial n^*}{\partial x})] > 0$. Also, we

find $\frac{\partial m^*}{\partial s} = -\frac{1}{4b}\left(z^* + s\frac{\partial z^*}{\partial s}\right) < 0$ given $z^* \geq 0$ and $\frac{\partial z^*}{\partial s} > 0$. Then given $\frac{\partial n^*}{\partial s} > 0$ and $\frac{\partial m^*}{\partial s} < 0$, we find $\partial(\frac{1}{4}\frac{2m^*}{n^*})/\partial s = \frac{1}{(2n^*)^2}[\frac{\partial m^*}{\partial s}(2n^*) - m^*(\frac{\partial 2n^*}{\partial s})] < 0$. $\qquad\square$

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