

Firm Dynamics, Labor Mobility, and Specific Human Capital

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Abstract

Firm-specific human capital loses its value if the firm exits the industry. This paper explores this simple but important link by developing a new firm-dynamics model that incorporates workers, their accumulation of specific human capital, and their mobility. In my model, a firm's production efficiency is determined by the levels of its managerial ability and its workers' firm-specific human capital. I demonstrate that the importance of managerial ability, through its connection to firm-specific human capital, systematically influences firm dynamics and employment practices. Equally important, the model offers a new perspective on the welfare consequences of apparently anticompetitive entry restrictions by investigating how such restrictions affect labor market characteristics. My framework offers a new explanation for the US-Japanese differences in employment practices and labor market characteristics, and predicts that the differences tend to become smaller as Japan catches up and deregulates.

JEL classification numbers: J41, J63, L10, L50, M20, M50.

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1 Introduction

Firm dynamics have substantial impacts on labor mobility. Several studies of plant-level employment have found that a substantial amount of employment is lost due to plant contractions and failures even in expanding industries and regions, while a substantial amount of employment is created due to plant openings and expansions even in contracting industries and regions. At the level of individual workers, a substantial percentage of workers is displaced from the employer due to plant closings and contractions. See Section 2 for empirical findings concerning the connection between firm dynamics and labor mobility. At the same time, there are also important connections between labor mobility and firm-specific human capital investment, because specific human capital possessed by a worker loses its value if the worker leaves his/her current employer.

This paper develops a new model that captures the interconnections between firm dynamics, labor mobility, and specific human capital accumulation in a single theoretical framework. Models of firm and industry dynamics that allow for entry, exit, and firm heterogeneity and/or idiosyncratic shocks have been previously developed in the literature (see Jovanovic, 1982; Hopenhayn, 1992; Ericson and Pakes, 1995, among others). For example, in his seminal contribution to this literature, Jovanovic (1982) developed a model in which the efficiency of firms in an industry is different across firms, and no firm knows its true efficiency (which is captured as true cost) *ex ante*. True efficiency is gradually revealed through economic activity. In the equilibrium, efficient firms grow and survive, while inefficient firms decline and exit.

Despite significant contributions made by models previously developed in the literature, the models do not incorporate one important aspect of reality, which is that most firms *employ workers* to produce outputs. The present paper attempts to fill this important gap in the literature by developing a new model of firm dynamics that incorporates workers, their accumulation of specific human capital, and their mobility.

Consider an industry in a two-period setting, where entry and exit of firms is free in each period. A firm must employ a worker to produce outputs in my model. Each firm's production efficiency is determined by the levels of its managerial ability and its worker's firm-specific human capital, where managerial ability is interpreted representing the firms' ability to develop an effective strategy and create a unique competitive position. I assume that no firm knows its own managerial ability *ex ante*,¹ and simplify the learning aspect of the model by assuming that each firm's managerial ability becomes public knowledge at the end of the first period of its

¹This assumption 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*. See footnote 9 on page 6.

operation. In the equilibrium, each first-period entrant provides a certain level of firm-specific human capital to its worker, and continues to operate in the second period if its second-period production efficiency turns out to be higher than the expected production efficiency of second-period entrants. If a firm exits the industry, its workers are separated from it and consequently the workers' firm-specific human capital loses its value.

The connection between firm dynamics and firm-specific human capital yields the following key result: a firm's survival rate decreases (or, equivalently, a firm's exit rate increases) as the importance of managerial ability increases. Each first-period entrant has an advantage over second-period entrants, because it has a worker who has already accumulated a certain level of firm-specific human capital. As the importance of managerial ability increases, the advantage associated with firm-specific human capital becomes relatively less important, which results in a lower survival rate of the first-period entrants in the equilibrium. A lower firm survival rate, in turn, results in a higher labor turnover rate. Anticipating a lower survival rate, first-period entrants have lower incentives to train their workers, and hence the equilibrium level of firm-specific human capital becomes lower. This makes the tenure-wage profile less steep in the equilibrium. The model also yields similar comparative statics results concerning the importance of firm-specific human capital.

A novel aspect of the comparative statics results outlined above is that the importance of a firm's managerial ability, through its connection to firm-specific human capital, has systematic influence on firm dynamics, labor market variables, and employment practices. This yields empirical implications and predictions from a previously unexplored perspective, given that the importance of managerial ability can differ across industries, and across time and countries within the same industry. For example, in an industry undergoing revolutionary technological changes (such as information-technology related industries), a business's success critically depends on the quality of its strategic decision making, because these industries face 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 industries facing lower levels of uncertainty, strategic decision making is less important. This argument suggests that the importance of managerial ability is higher in industries facing a higher level of uncertainty, while its importance is lower in industries facing lower levels of uncertainty. See Section 3 (sixth-eights paragraphs after Proposition 2) and Section 5 for more discussions along this line.

Equally important, my framework offers a new perspective on the welfare consequences of entry restrictions by capturing the connection between firm dynamics and firm-specific human

capital accumulation. I demonstrate this in Section 4 by considering an extension of the model in which the government can control firm dynamics to a certain degree by imposing entry restrictions, which in turn affects firms' incentives to invest in specific human capital. Novelty here is that it captures the effects of entry restrictions on labor market characteristics. I demonstrate that entry restrictions can mitigate the underinvestment problem in specific human capital, which can result in a higher consumer surplus, as well as a higher total surplus. My approach is complementary to, but fundamentally different from, the approach taken by previous papers in the theoretical industrial organization literature (see Mankiw and Whinston, 1986; Suzumura and Kiyono, 1987), which demonstrated the "excess-entry theorem" by focusing on the effects of entry restrictions on the strategic interactions among firms.

In reality, there are important interconnections among firms' strategic decisions, such as market entry and exit, the nature of their employment practices such as specific human capital investment, and resulting labor-market characteristics such as labor mobility. Nevertheless, in most previous theoretical analyses, firms' strategic behaviors and their employment practices have been treated separately under industrial-organization theoretical models and labor-theoretical models, respectively.² The present paper is one of several recent attempts to address such interconnections in a single theoretical framework.³

Although the connection between specific human capital and labor mobility has been previously explored in the literature (see Parsons, 1972; Mortensen, 1978; Jovanovic, 1979b, among others), the present paper is, to the best of my knowledge, the first to explore a model that captures interconnections among firm dynamics, labor mobility, and specific human capital accumulation in a single model. It is motivated by the significant impacts of firm dynamics on labor mobility on the one hand, and by the important connection between labor mobility and

²As an important exception, there is a small literature that theoretically analyzes the effect of product-market competition on managerial incentives (see for example Hart, 1983; Hermalin, 1992; Schmidt, 1997; Raith, 2003). Schmidt (1997) pointed out that there are surprisingly few theoretical papers on this subject despite its importance.

³For other papers along this line, see for example Chari and Hopenhayn (1991); Wang (2002); Mailath, Nocke, and Postlewaite (2004). Chari and Hopenhayn (1991) analyzed the connection between firms' adoption of new technology and workers' accumulation of "vintage-specific" skills (skills that are specific to a technology of a particular vintage), and explored its implications on the diffusion of new technology; Wang (2002) analyzed the connection between product-market conditions and job design, and explored its implications on explanations for heterogeneity of human resource management practices across countries, industries, and firms; and Mailath, Nocke, and Postlewaite (2004) analyzed the interaction between a firm's choice of business strategy and its manager's incentive for investing in "business-strategy-specific" human capital, and explored its implications on the organization of business activities.

firm-specific human capital on the other. By exploring relationships between firm dynamics and firm-specific human capital, I present novel comparative statics results regarding the importance of managerial ability, as well as a new perspective on the welfare consequences of entry restrictions, as outlined above.

In regards to theoretical analyses of job separations, several authors have previously developed models of labor-market search and matching (see Burdett, 1978; Jovanovic, 1979a), which provide explanations for the following established empirical finding: the probability of separation declines with both labor-market experience and firm-specific seniority. Complementary to these previous models that focus on voluntary separations, my model focuses on involuntary separations by incorporating firm dynamics into the analysis.

In Section 5, I apply my framework to explanations for and predictions on the US-Japanese differences in labor mobility, wage structures, and accumulation of human capital. The US-Japanese differences in the post-war period have attracted substantial attention; it has been found that in Japan, the labor turnover rate is much lower, earnings-tenure profiles are more steeply sloped, and the level of specific human capital is much higher than in the United States. I argue that the importance of managerial ability was substantially higher in the United States for a certain duration in the postwar period when most Japanese industries were in the process of catching up with the West.⁴ The comparative statics results outlined above then provide an explanation for the differences from a previously unexplored perspective. Also, concerning the current trends and the future changes, the results predict that the differences tend to become smaller in the process of Japan's catch-up and deregulation.

The rest of the paper is organized as follows: Section 2 presents empirical findings on the connection between firm dynamics and labor mobility. Section 3 presents a model of firm dynamics that incorporates workers, their accumulation of specific human capital, and their mobility. It then characterizes the perfect foresight equilibrium of the model, presents comparative statics results, and discusses the real-world relevance of the results. Section 4 explores a new perspective on the welfare consequences of entry restrictions by analyzing how such restrictions affect labor market characteristics in my framework. Section 5 applies my theoretical framework to explanations for and predictions on US-Japanese differences in labor mobility, wage structures, and accumulation of human capital. Section 6 summarizes and concludes.

⁴This argument is based on Acemoglu, Aghion, and Zilibotti (2004). See Subsection 3.2 and Section 5 for details.

2 Related Empirical Findings

In this short section, I present previous empirical findings concerning the connection between firm dynamics and labor mobility. Firm dynamics have substantial impacts on labor mobility. Several studies of plant-level employment have found that gross employment flows, consisting of the number of positions added in new and growing plants and the number of existing positions lost in contracting and closing plants, are substantially larger than aggregate net employment growth.⁵ Dunne, Roberts, and Samuelson (1989) identified this pattern in US manufacturing employment over the 1963-1982 period using the Census of Manufacturers. They found that between 1977 and 1982, for example, total manufacturing employment declined by 3.8%. This net change was composed of an increase in employment of 17.6% and 11.7% due to plant openings and expansions respectively, and reductions of 15.4% and 17.7% due to plant contractions and closings respectively. Importantly, they found that over 70% of the turnover in employment opportunities occurs across plants within the same two-digit industry and geographic region. In other words, a substantial amount of employment is lost due to plant contractions and failures even in expanding industries and regions, while a substantial amount of employment is created due to plant openings and expansions even in contracting industries and regions.

At the level of individual workers, a substantial percentage of workers is displaced from the employer due to plant closings and contractions. The Displaced Workers Surveys (DWSs) contain information regarding displaced workers in the United States, where displacement is defined as involuntary separation based on the operating decisions of the employer, such as a plant closing, an employer going out of business, or a layoff from which the worker was not recalled (Farber, 1997).⁶ Farber (1997) analyzed the seven DWSs from 1984 to 1996 to examine the incidence of job loss from 1981 to 1995, and found that adjusted three-year job loss rates during the period ranged between 9% and 15%.⁷ Also, a substantial percentage of job separation is due to plant closings and contractions. According to an analysis of the Panel Study of Income Dynamics (PSID) by Polsky (1999), on average 36% of job separators were job losers for the periods 1976-1981 and 1986-1991 in the United States, and the percentage was higher for older

⁵See Dunne, Roberts, and Samuelson (1989) and references therein.

⁶The DWSs have been administered every two years since 1984 as a supplement to the monthly Current Population Survey. Each DWS from 1984-1992 asked workers whether they were displaced from a job at any time in the preceding five-year period, while the 1994 and 1996 DWSs asked workers whether they were displaced from a job at any time in the preceding three-year period.

⁷Farber (1997) computed three-year job loss rates as the number of workers who report having lost a job in the three calendar years before the survey date divided by employment at the survey date.

workers.⁸

3 Firm Dynamics and Specific Human Capital

3.1 The Model

Consider an industry that produces a homogeneous good in a two-period setting. In each period t ($=1, 2$) the industry faces a demand schedule given by $Q_t = D(P_t)$, where $P_t \geq 0$ and $Q_t \geq 0$ denote the price and the aggregate output in period t respectively, $D(P) \geq 0$ and $D'(P) < 0$ for all $P > 0$, and $\lim_{P \rightarrow 0} D(P) = +\infty$. Entry and exit of firms is free in each period, where each firm is of measure zero so that it is too small to affect prices. The production requires labor input; a firm can produce one unit of the good in a period if it employs one worker in that period, and the firm can produce nothing otherwise. No firm can employ more than one worker. There is a large number of ex-ante identical individuals, and in each period labor supply is perfectly inelastic and fixed at one unit for each individual. Each individual can earn a reservation wage of $w > 0$ per period in a competitive labor market outside this industry. Individuals display no disutility of effort, and firms and individuals are both risk neutral. To keep the analysis simple, they do not discount the future.

Each firm's production efficiency is determined by its managerial ability and the level of its worker's firm-specific human capital, where managerial ability is interpreted representing a firm's ability to develop an effective strategy and create a unique competitive position. Let a denote the managerial ability and a_i denote the realization of firm i 's managerial ability, which is a random draw from a uniform distribution between 0 and 1. Assume that a_i is ex-ante unknown to all agents including firm i itself and becomes common knowledge at the end of the first period of firm i 's operation. 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*.⁹

⁸Polsky (1999) used a "reason for new position" question in the PSID to classify job separators into job losers and quitters. He classified a worker as a job loser if the worker gave "company folded, changed hands, employer moved out of town or went out of business" or "laid off or fired" as a reason for his or her separation. According to Polsky's probit estimates, the probability of job loss conditional on a job separation for workers aged 45-54 rose 12% relative to workers aged 25-34.

⁹As 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." Mabey and Ramirez (2004) found, based on 1,400 telephone interviews in

In period 1, each firm i can provide a level of firm-specific human capital denoted $h_i \in [0, H]$ with its period 1 employee by incurring a cost of $d(h_i)$ (≥ 0) per employee, where $d(\cdot)$ is a convex function.¹⁰ To obtain closed form solutions in the analysis, let $d(h) = \frac{1}{2}h^2$. The level of firm-specific human capital is observable but not verifiable, and so wage contracts contingent upon it are not feasible. To keep the analysis simple, assume that firm-specific human capital affects the second-period production efficiency only. If a firm continues to operate in the second period, the return from its investment in specific human capital is shared with its employee through wage bargaining.¹¹ Given that the return from firm-specific human capital is deterministic, managerial ability is the only source of uncertainty in this model. The qualitative nature of the results, however, is unchanged under an alternative assumption that the return from specific human capital is also uncertain. See the next subsection (third and fourth paragraphs after Proposition 2) for details.

Each firm i 's per-unit production cost (excluding the wage bill) is given by $c - xa_i$ in period 1 and $c - xa_i - \lambda$ in period 2, where $c > 0$ and $x > 0$ are given constants and λ captures the relationship between firm-specific human capital and the production efficiency of a firm. In particular, assume that $\lambda = yh_i$ if firm i employs worker j in period 2 and employed the same worker in period 1, while $\lambda = 0$ if firm i employs worker j in period 2 but did not employ the worker in period 1. Here, $x > 0$ ($y > 0$) captures the importance of managerial ability (firm-specific human capital) for production efficiency. Assume that $c > x + yH$, which guarantees that the production cost is strictly positive.

The timing of moves in the game is as follows:

Period 1:

[**Stage 1**] Firms simultaneously make first period wage offers to the individuals. Each individual can apply to a firm for first-period employment. Each firm employs one individual from the applicants, or no individuals if there are no applicants. If an individual is not employed by the firm or if he/she has not applied for any firm, he/she can earn the reservation wage $w > 0$ for

seven European countries (Norway, Denmark, Germany, France, Romania, Spain, and the UK), that the belief that managers and leaders are “born not made” continues to prevail in Europe: all countries except for Germany rate innate ability/personality as the most important factor in making an effective manager.

¹⁰The qualitative nature of the results is unchanged under an alternative setup in which each worker acquires a level of firm-specific human capital by incurring costs.

¹¹Gibbons and Waldman (1999) argue that this is a useful approach by pointing out that human-capital investment levels are typically not specified in contracts, and it is not clear that such investment levels are even contractible variables. Furthermore, they point out that post-training wages are not typically specified in a contract, and can often be renegotiated after training has taken place. This approach suggests underinvestment in specific human capital due to a hold-up problem.

period 1 in a competitive labor market outside this industry.

[**Stage 2**] If firm i employs worker j in the first period, firm i chooses $h_i \in [0, H]$.

[**Stage 3**] Each firm i that employed a worker at Stage 1 produces one unit of the good. At the same time, a_i is realized and becomes common knowledge.

Period 2:

[**Stage 4**] Each firm that operated in period 1 can bargain against its first-period employee on his/her second-period wage, which is determined as the outcome of the generalized Nash bargaining process. Each employee's bargaining strength is given by $b \in (0, 1)$. The outside option of the firm is to employ another individual at the wage of w or to exit the industry, while the outside option of the worker is to earn the reservation wage w in a competitive labor market outside the industry. At the same time, a firm that did not operate in period 1 can employ an individual at the reservation wage w and enter the industry.

[**Stage 5**] Each firm i that employed a worker at Stage 4 produces one unit of the good. At the same time a_i is realized if firm i did not operate in period 1.

3.2 An Analysis of the Model

Consider a perfect foresight equilibrium that is characterized by a price sequence (P_1, P_2) . I focus on equilibria in which a strictly positive measure of firms operates in each period.¹² In the equilibrium all agents (firms, potential entrants, and individuals) make optimal decisions based on the anticipation of a particular price sequence (P_1, P_2) , and their behavior does in fact give rise to the same (P_1, P_2) . Given free entry and exit of firms, for every entrant in period t ($=1, 2$) the present discounted value of its expected overall profit is zero in the equilibrium. Also, given that there is a large number of ex-ante identical and risk-neutral individuals, and that every individual can earn a reservation wage $w > 0$ per period in a competitive labor market outside the industry, the present discounted value of every individual's expected overall wage is $2w$ in period 1 in the equilibrium. The market clears in each period in the equilibrium.

I focus on perfect foresight equilibria in which a strictly positive number (measure) of firms enter and exit the industry at the beginning of period 2, given that in reality entries and exits

¹²There is a possibility of a trivial equilibrium in which a strictly positive measure of firms operates in period 1 but no firms operate in period 2. One way to rule out this equilibrium is to assume that $D(P) > 0$ for all $P \geq 0$.

of firms are common in most industries.¹³ 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 exit rate of firms, the level of specific human capital, and the slope of the earnings-tenure profiles in the equilibrium. Throughout the analysis, I assume $H > \max\{\frac{1}{2}\frac{(1-b)xy}{x-(1-b)y^2}, \frac{x}{2y}\}$, which guarantees that the optimal level of firm-specific human capital is interior in the equilibrium. Note, proofs of the propositions are presented in the Appendix.

Suppose that there exists a perfect foresight equilibrium characterized by a price sequence $(P_1, P_2) = (P_1^*, P_2^*)$ where $P_1^* > 0$ and $P_2^* > 0$, in which a strictly positive measure of firms enter and exit the industry at the beginning of period 2. In what follows, we will first identify necessary conditions for such an equilibrium to exist.

In the equilibrium, each second-period entrant employs a worker at the reservation wage w , and its expected production cost is $c - \frac{1}{2}x$. Since each second-period entrant earns zero expected profit in the equilibrium, $P_2^* = c + w - \frac{1}{2}x$ must hold. Consider firm i that employed worker j at Stage 1 and chose h_i at Stage 2 in the equilibrium. If firm i continues to employ worker j in period 2, its second-period production cost (excluding the wage bill) is $c - xa_i - yh_i$ and the firm must pay at least w (the reservation wage) in order to employ worker j in period 2. Then firm i continues to operate in period 2 if and only if $P_2^* - (c - xa_i - yh_i + w) \geq 0 \Leftrightarrow a_i \geq \underline{a}(h_i, P_2^*)$, where $\underline{a}(h, P_2)$ (call it a cut-off managerial ability) is defined by

$$\underline{a}(h, P_2) \equiv \frac{c+w-P_2-yh}{x} \text{ if } h \leq \frac{c+w-P_2}{y}, \text{ and } 0 \text{ otherwise.}$$

Suppose that firm i 's managerial ability a_i turns out to be greater than or equal to the cut-off level $\underline{a}(h_i, P_2^*)$ at Stage 3. Then, at Stage 4 firm i and worker j bargain over worker j 's second-period wage, where the worker's bargaining strength is $b \in (0, 1)$ and his/her threat point is the reservation wage w . Firm i 's outside option is to exit the industry and earn zero profit or to employ another worker with wage w and continue operating in period 2. Firm i 's second-period profit under the latter option is $P_2^* - (c - xa_i + w)$, and hence its threat point is $\max\{P_2^* - (c - xa_i + w), 0\}$. We then find that worker j 's second-period wage (which is determined

¹³See Geroski (1995) for a survey of the empirical literature. For example, Dunne, Roberts, and Samuelson (1988) analyzed the pattern of firm entry and exit in 387 four-digit US industries in the period 1963-1982 by using a new data set that had been constructed from the individual plant-level data collected in the five Censuses of Manufacturers during the period. They found that, after deleting the smallest firms in each industry, the average entry rate varied from 30.7% to 42.7% across census years, while the average industry exit rate varied from 30.8% to 39.0%. Although there was substantial variation across industries, both entry and exit rates were at least 10% in most four-digit industries.

as the outcome of the generalized Nash bargaining process) is $w_2(a_i, h_i, P_2^*)$, where $w_2(a, h, P_2)$ is defined by

$$w_2(a, h, P_2) \equiv w + bS(a, h, P_2). \quad (1)$$

Here, $S(a, h, P_2) \equiv P_2 - (c - xa - yh) - w - \max\{P_2 - (c - xa + w), 0\}$, which is the surplus gained by reaching an agreement in the bargaining.¹⁴ This in turn implies that firm i 's second-period production cost plus wage bill is $C_2(a_i, h_i, P_2^*)$, where $C_2(a, h, P_2)$ is defined by

$$C_2(a, h, P_2) \equiv c - xa - yh + w_2(a, h, P_2). \quad (2)$$

At Stage 2, firm i chooses the level of firm-specific human capital h_i without knowing its own managerial ability a_i . Firm i makes this choice under the anticipation that it will continue to operate in period 2 and earn second-period profit of $P_2^* - C_2(a_i, h_i, P_2^*)$ if it realizes managerial ability $a_i \geq \underline{a}(h_i, P_2^*)$, and will exit the industry if $a_i < \underline{a}(h_i, P_2^*)$. Hence firm i chooses $h_i \in [0, H]$ to maximize $\pi(h_i, P_2^*)$, where $\pi(h, P_2)$ is defined by

$$\pi(h, P_2) \equiv \int_{\min\{\underline{a}(h, P_2), 1\}}^1 (P_2 - C_2(a, h, P_2)) da - \frac{1}{2}h^2. \quad (3)$$

Note, $\pi(h_i, P_2^*)$ is firm i 's second-period expected profit minus its cost for providing the firm-specific human capital of level h_i . Through the maximization exercise we find (see Claim 1 in the Appendix for details) that $x - (1 - b)y^2 > 0$ must hold, and every firm i that employed a worker at Stage 1 chooses $h_i = h^*$ at Stage 2 in the equilibrium, where

$$h^* \equiv \frac{1}{2} \frac{(1 - b)xy}{x - (1 - b)y^2}. \quad (4)$$

This implies that the firms' exit rate is \underline{a}^* in the equilibrium, where

$$\underline{a}^* \equiv \underline{a}(h^*, P_2^*) = \max\left\{\frac{1}{2} \frac{x - 2(1 - b)y^2}{x - (1 - b)y^2}, 0\right\}. \quad (5)$$

Since the exit rate is strictly positive in the equilibrium, the following condition must hold:

$$x - 2(1 - b)y^2 > 0. \quad (6)$$

Note that under this condition we have that $0 < \underline{a}^* < \frac{1}{2}$.

Every firm that employs a worker at Stage 1 offers the same first-period wage (denoted by w_1) in the equilibrium, given that firms and individuals are ex-ante identical. A worker employed by firm i at Stage 1 anticipates that his/her second-period wage will be $w_2(a_i, h^*, P_2^*)$ if firm i

¹⁴See e.g. Chang and Wang (1996) and Zájbojník (1998) for similar formulations of worker-firm bargaining.

realizes $a_i \geq \underline{a}^*$ at Stage 3, and w if $a_i < \underline{a}^*$. The first-period present discounted value of the worker's expected overall wage is then $w_1 + \int_0^{\underline{a}^*} w da + \int_{\underline{a}^*}^1 w_2(a, h^*, P_2^*) da$. Given that there is a large number of ex-ante identical and risk-neutral individuals, and that every individual can earn a reservation wage $w > 0$ per period outside the industry, firms in the equilibrium choose $w_1 = w_1^*$ such that $w_1^* + \int_0^{\underline{a}^*} w da + \int_{\underline{a}^*}^1 w_2(a, h^*, P_2^*) da = 2w$ holds. Hence we find

$$w_1^* = w - \int_{\underline{a}^*}^1 (w_2(a, h^*, P_2^*) - w) da. \quad (7)$$

In the equilibrium, every firm i that employs a worker at w_1^* at Stage 1 provides the worker with level h^* of specific human capital by incurring $\frac{1}{2}(h^*)^2$ as a training cost. Since its expected production cost is $c - \frac{1}{2}x$, the expected value of its first-period cost is $c - \frac{1}{2}x + w_1^* + \frac{1}{2}(h^*)^2 \equiv C_1^*$. Firm i operates in period 2 if it realizes the managerial ability of $a_i \geq \underline{a}^*$ with the second-period total cost of $C_2(a_i, h^*, P_2^*)$. Hence the first-period discounted value of its overall expected cost is $C_1^* + \int_{\underline{a}^*}^1 C_2(a, h^*, P_2^*) da$, and the zero profit condition implies that the following condition must hold:

$$P_1^* + \int_{\underline{a}^*}^1 P_2^* da = C_1^* + \int_{\underline{a}^*}^1 C_2(a, h^*, P_2^*) da. \quad (8)$$

We then find (see Claim 2 in the Appendix for details) that

$$P_1^* = c + w - \frac{1}{2}x - \frac{1}{8} \frac{x^2[x - (1-b)^2y^2]}{[x - (1-b)y^2]^2}. \quad (9)$$

Given $P_1^* > 0$, the following condition must hold:

$$c + w > \frac{1}{2}x + \frac{1}{8} \frac{x^2[x - (1-b)^2y^2]}{[x - (1-b)y^2]^2}. \quad (10)$$

Given $(P_1, P_2) = (P_1^*, P_2^*)$, the demand for the good in period t ($= 1, 2$) is $D(P_t^*)$. Since the market clears in each period and each operating firm produces one unit of the good, the measure of firms that enter and operate in period 1 is $D(P_1^*)$ in the equilibrium. Since the exit rate is \underline{a}^* , $(1 - \underline{a}^*)D(P_1^*)$ firms continue to operate in period 2. Since the second-period demand for the good is $D(P_2^*)$, the measure of the second-period entrants is $D(P_2^*) - (1 - \underline{a}^*)D(P_1^*)$ in the equilibrium. Then the following condition must hold for a strictly positive measure of firms to enter at the beginning of period 2 in the equilibrium:

$$D(P_2^*) - (1 - \underline{a}^*)D(P_1^*) > 0. \quad (11)$$

Thus far we have found that conditions (6), (10) and (11) are necessary for the existence of a perfect foresight equilibrium in which a strictly positive measure of firms enter and exit the

¹⁵The model allows a possibility for the first-period wage to take a negative value. This can be avoided by assuming that the reservation wage w is large enough. A sufficient condition for this is $w > \frac{x^2y^2}{4[x - (1-b)y^2]^2}$.

industry at the beginning of period 2. Concerning condition (11) we have that $(1 - \underline{a}^*)D(P_1^*)$ is strictly increasing in y while $D(P_2^*)$ is independent of y . We then find that conditions (6), (10) and (11) are all satisfied if the value of y is small enough (see Claim 3 in the Appendix for details). Proposition 1 below tells us that this condition is not only necessary but also sufficient, and the equilibrium is a unique equilibrium under this condition.

Proposition 1: For any given parameterization, there exists a unique value $\bar{y} \geq 0$ such that the following property holds: There exists a unique perfect foresight equilibrium in which a strictly positive measure of firms enter and exit the industry at the beginning of period 2, if and only if $y < \bar{y}$. The equilibrium is characterized by the price sequence $(P_1, P_2) = (P_1^*, P_2^*) = (c + w - \frac{1}{2}x - \frac{1}{8} \frac{x^2[x-(1-b)^2y^2]}{[x-(1-b)y^2]^2}, c + w - \frac{1}{2}x)$. There exists a range of parameterizations in which $\bar{y} > 0$.

In the equilibrium, $D(P_1^*)$ firms operate in period 1. Each of the $D(P_1^*)$ firms employs a worker at the wage of w_1^* at Stage 1 and provides the worker with level h^* of specific human capital at Stage 2. At Stage 4, every firm i whose managerial ability a_i turns out to be greater than or equal to the cut-off level $\underline{a}^* \in (0, \frac{1}{2})$ continues to operate in period 2 by employing its first-period employee at the second-period wage of $w_2(a_i, h^*, P_2^*)$, while every firm i with $a_i < \underline{a}^*$ exits the industry. Hence the firms' exit rate, which is equal to the labor turnover rate, is \underline{a}^* in the equilibrium. Then, of the $D(P_1^*)$ firms that operated in period 1, $(1 - \underline{a}^*)D(P_1^*)$ firms continue to operate in period 2 and $D(P_2^*) - (1 - \underline{a}^*)D(P_1^*) > 0$ new firms enter at the beginning of period 2.

I will now turn to comparative statics of the equilibrium exit rate $\underline{a}^* = \frac{1}{2} \frac{x-2(1-b)y^2}{x-(1-b)y^2}$, the equilibrium level of firm-specific human capital $h^* = \frac{1}{2} \frac{(1-b)xy}{x-(1-b)y^2}$, and the steepness of the tenure-wage profile in the equilibrium. Concerning the tenure-wage profile, consider an individual who has been employed by firm i at the first-period wage $w_1^* = w - \int_{\underline{a}^*}^1 (w_2(a, h^*, P_2^*) - w) da$. In period 2, the worker is employed by firm i at the second-period wage $w_2(a_i, h^*, P_2^*)$ if firm i realizes $a_i \geq \underline{a}^*$, and earns the reservation wage w elsewhere if $a_i < \underline{a}^*$. Hence, his/her second-period expected wage conditional upon being employed by the first-period employer is $w'_2 \equiv \frac{1}{1-\underline{a}^*} \int_{\underline{a}^*}^1 w_2(a, h^*, P_2^*) da$. I will interpret $w'_2 - w_1^*$ to be the steepness of the tenure-wage profile in the equilibrium. Note, (1) and (7) above together imply that the tenure-wage profile is upward-sloping in the equilibrium. This is because workers' productivity (cost effectiveness) increases with tenure, and the return from the higher productivity is shared between the worker and the employer in period 2 which in turn implies that the second-period wage is higher than

the first-period wage in the equilibrium.¹⁶

Proposition 2: As the importance of managerial ability (captured by x) increases, the firms' exit rate increases, the level of firm-specific human capital investment decreases, and the tenure-wage profile becomes less steep in the equilibrium.

The key result here is that the firms' exit rate is increasing in the importance of managerial ability. This result arises from the connection between firm dynamics and firm-specific human capital through the following logic: A first-period entrant continues to operate in period 2 if its second-period production efficiency is higher than the expected production efficiency of second-period entrants. Each first-period entrant has an advantage over second-period entrants because it has a worker who has already accumulated a certain level of firm-specific human capital. Hence, even if the managerial ability of a first-period entrant turns out to be less than average, it could still continue to operate in the second period. As the importance of managerial ability increases, the relative importance of firm-specific human capital declines. This reduces first-period entrants' advantage associated with firm-specific human capital, and hence fewer first-period entrants with "lower than average" managerial ability survive in the second period.¹⁷ As a consequence, the firms' exit rate increases.

To algebraically observe that the connection between firm dynamics and specific human capital is the driving force of the result, let us suppose y (which captures the importance of specific human capital) is equal to zero. Then, the equilibrium exit rate becomes $\underline{a}^* = \frac{1}{2} \frac{x-2(1-b)y^2}{x-(1-b)y^2} = \frac{1}{2}$. That is, in the absence of firm-specific human capital, the firms' exit rate is independent of the importance of managerial ability.

The result does not depend on the model specification that the firm's managerial ability is the only source of uncertainty in the model. To see this, let us consider what happens if there is uncertainty regarding the returns from firm-specific human capital investment as well. In particular, suppose that if a first-period entrant firm i continues to operate and employ its first-period worker in period 2, its second-period production cost (excluding the wage bill) is now given by $c - xa_i - y\theta_i h_i$. Here, the uncertainty regarding firm-specific human capital is

¹⁶Complementary to the productivity-based reasoning, Lazear (1979, 1981) demonstrated that wages grow with experience, even if productivity does not. In his framework, senior workers receive high salaries not because they are so much more productive than junior workers, but because paying senior workers higher wages produces appropriate work incentives for junior workers. See also Salop and Salop (1976) for an explanation based on self-selection of workers.

¹⁷Regardless of the importance of managerial ability, every first-period entrant whose managerial ability turns out to be higher than average continues to operate in period 2.

captured by θ_i , which is a random draw from a known distribution function between $\underline{\theta}$ and $\bar{\theta}$ ($\bar{\theta} > \underline{\theta} \geq 0$). Assume that both a_i and θ_i are ex-ante unknown and become common knowledge at the end of the first period (at Stage 3), and are mutually independent.

In this variant of the model, each first-period entrant firm i continues to operate in period 2 if its second-period production cost $c - xa_i - y\theta_i h_i$ is lower than the expected production cost of second-period entrants $c - \frac{1}{2}x$. This condition is equivalent to $a_i \geq \frac{1}{2} - \frac{y}{x}\theta_i h_i$. On the other hand, the analogous condition is $a_i \geq \frac{1}{2} - \frac{y}{x}h_i$ in the original model, where the return from firm-specific human capital is deterministic (in particular, θ_i is equal to one for all i). Each of these two conditions tells us that each first-period entrant becomes less likely to survive as x increases (note, the right-hand sides of these conditions, $\frac{1}{2} - \frac{y}{x}\theta_i h_i$ and $\frac{1}{2} - \frac{y}{x}h_i$, are both increasing in x). The key logic here is that as the importance of managerial ability increases, the relative importance of firm-specific human capital (captured by $\frac{y}{x}$) declines, which in turn reduces first-period entrants' advantage associated with firm-specific human capital. The logic does not depend on whether returns from human capital investment are uncertain or deterministic.

Other results of Proposition 2 naturally follow from the key result mentioned above. As the importance of managerial ability increases, the exit rate of firms as well as the separation rate of workers increase. Anticipating this, first-period entrants have lower incentives to train their workers in period 1, and this reduces the equilibrium level of firm-specific human capital investment. Since the return from firm-specific human capital is shared between a worker and his/her employer through the second-period wage bargaining, the lower level of specific human capital and the higher exit rate result in a lower second-period expected wage, which in turn implies that firms have to offer higher first-period wages to attract workers in period 1. The result is that the equilibrium tenure-wage profile becomes less steep as x increases.

In what follows, I will discuss the real-world relevance of the comparative statics results presented above, based on the idea that the importance of managerial ability can differ across industries. An argument that is consistent with this idea can be found in Porter (1996).¹⁸ Porter pointed out that it is the core role of a firm's top management to develop or re-establish a clear strategy, where the development of an effective strategy means the top management's deliberate choice of a distinctive set of activities undertaken by the firm in order to deliver a unique mix of value to customers. He then argued that developing a strategy in a newly emerging industry or in a business undergoing revolutionary technological changes is particularly difficult, because in

¹⁸See also empirical studies by Ely (1991) and Hogan and Sigler (1998), who found that sensitivity of CEO compensation to firm performance significantly differs across industries. Assuming that the sensitivity captures the importance of managerial ability for firm performance, this finding suggests that the importance of managerial ability differs across industries.

such industries the firm's management faces a high level of uncertainty about customers' needs, the products and services that will prove to be the most desired, and the best configuration of activities and technologies to deliver them.¹⁹

This argument suggests that the importance of managerial ability tends to be higher in industries with higher levels of uncertainty, such as high-tech industries, while it tends to be lower in matured industries with lower levels of uncertainty.²⁰ Proposition 2 then predicts that firm's exit rate and labor turnover rate are both high in high-tech industries such as the semiconductor industry, and evidences that support this prediction can be found in several case studies. For example, in his study of labor markets in Silicon Valley, Benner (2002) pointed out as follows: "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. Those firms that succeed are those that are able to innovate by developing both new products and improved production processes to shorten the time-to-market." According to Benner, of the 100 largest Silicon Valley companies in 1985, only 19 still existed and were in the top 100 in 2000. While more than half of the top 100 companies in the 2000 listing of Silicon Valley's largest firms were not on the list only ten years previously.²¹

The results can also be applied to differences across countries and time. Acemoglu, Aghion, and Zilibotti (2004) argued 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 pointed out that innovation becomes more important as the economy approaches the world technology frontier and there remains less room for adoption and imitation. This argument indicates that the importance of managerial ability tends to be higher in an industry that has reached or approached

¹⁹A related discussion is found in Hayek (1945). Hayek pointed out that, "It is, perhaps, worth stressing that economics problems arise always and only in consequence of change. So long as things continue as before, or at least as they were expected to, there arise no new problems requiring a decision, no need to form a new plan", where "planning" is defined as the complex of interrelated decisions about the allocation of available resources.

²⁰Consistent with this argument, in his study of the US semiconductor industry, Angel (1994, p. 4-5) pointed out that, "In an era of intensified global competition, it is the ability to anticipate and create new market opportunities, to develop new products ahead of competitors, and to reconfigure manufacturing processes rapidly in response to changing production requirements that offers the best prospect for long-term profitability of firms and industries."

²¹See also Saxenian (1996), who pointed out that, "By the 1970s, Silicon Valley was distinguished by the highest levels of job-hopping in the nation. Average annual employee turnover in local electronics firms exceeded 35% and was as high as 59% in the region's small firms. It was almost unheard of for a technical professional in Silicon Valley to have a career in a single company."

the technology frontier than in an industry that is far behind it. Elaborating on this argument, I apply my framework to explanations for and predictions on US-Japanese differences in Section 5.

I will now turn to the comparative statics results with respect to the importance of firm-specific human capital.

Proposition 3: As the importance of firm-specific human capital (captured by y) increases, the firm's exit rate decreases, the level of firm-specific human capital investment increases, and the tenure-wage profile becomes steeper in the equilibrium.

Recall that each first-period entrant has an advantage over second-period entrants because it has a worker who has already accumulated a certain level of firm-specific human capital. This advantage becomes more substantial as the importance of firm-specific human capital increases, and hence this reduces the exit rate of first-period entrants. The lower exit rate, along with the higher return from firm-specific human capital (captured by y), implies that firms have higher incentives to train their employees in the first period. These two effects are mutually re-enforcing because the higher level of firm-specific human capital reduces firms' exit rate by increasing the advantage possessed by first-period entrants. The result on the tenure-wage profile follows through the logic analogous to the one explained above for Proposition 2.

As a final point to the analysis section, note that in my model the exit of firms (that is, firm closure) is the sole source of job separation. This appears to capture only a fraction of involuntary separations, which in reality is also caused by firm contraction, lay-offs, and being fired. It can, however, be interpreted that my model captures job separation due to firm contraction as well. To see this, consider the following variant of the model: In the beginning of period 1, there exist a certain number of firms that conduct an existing business in an industry. The business is stable so that all firms will continue to operate in period 2 without contraction or expansion, no more firms enter, and no job separation occurs. Suppose that a new business opportunity arises in the industry at the beginning of period 1. The existing firms as well as new entrants can conduct the new business in period 1 where they are equally uncertain about their managerial abilities for the new business, and entry and exit of firms is free at the beginning of period 2.²² Let us suppose that this new business has the same structure as the model analyzed above, where the demand schedule associated with this new business is given by $Q_t = D(P_t)$, $t = 1, 2$.

²²The qualitative nature of the results would be unchanged under an alternative assumption that existing firms are more likely to have a higher managerial ability than new entrants.

In this variant of the model, the same results as the ones from the original model follow, except that job separation is now due not only to firm closure but also to firm contraction. That is, if an existing firm in the industry conducts new business in period 1 and exits from it at the beginning of period 2, then the job separation associated with it is due to firm contraction because the firm remains in the industry and continues to conduct the stable, existing business. On the other hand, if a new entrant in the industry conducts new business in period 1 and exits from it at the beginning of period 2, job separation is due to firm closure because the firm exits from the industry.

4 A Welfare Consequence of Entry Restrictions

This section explores a new perspective on the welfare consequences of entry restrictions by analyzing its effects on labor market characteristics in my framework. Is free entry desirable for social efficiency? This important question has been addressed in the theoretical industrial organization literature. Mankiw and Whinston (1986) and Suzumura and Kiyono (1987) showed that in homogeneous final-product markets with Cournot oligopoly and fixed set-up costs, level of entry in the free-entry equilibrium is always socially excessive (see also von Weizsacker, 1980; Perry, 1984). It has often been argued that this theoretical result (often called “excess-entry theorem”) can provide a justification for enforcing entry regulations as a way of improving welfare.

Strategic interaction among firms in the product market plays a central role in these earlier models. Complementary to, but fundamentally different, from this approach, my analysis focuses on the effects of entry restrictions on labor market characteristics.

Consider the following extension of my model. Recall that, in the original model where the second-period entry is free, a strictly positive measure of firms $N_f \equiv D(P_2^*) - (1 - \underline{a}^*)D(P_1^*) > 0$ (the subscript f stands for free entry) enter the industry at the beginning of period 2 in the unique perfect foresight equilibrium when $y < \bar{y}$. In this extension, everything is the same as in the original model except that a government can impose an entry restriction in the following way. At Stage 0 (before Stage 1) the government can announce $N_r \in [0, N_f]$, which is the maximum measure of firms that are allowed to enter the industry at the beginning of period 2 (that is, at Stage 4). If the government imposes an entry restriction, the subsequent Stage 1 subgame is called an entry-restriction subgame, and the Stage 1 subgame without entry restriction is called the free-entry subgame (which is the same as the original model). In an entry-restriction subgame, the government, at Stage 4, charges an entry tax per firm so that N_r firms enter the

industry and each second-period entrant earns zero expected profit in the equilibrium.

I will consider a perfect foresight equilibrium of each subgame, and show that entry restrictions can enhance welfare in this model. Note, an alternative way to incorporate entry restrictions in the model is that the government, at Stage 0, announces whether it will allow free entry or prohibit entry at the beginning of period 2. Under this alternative setup, it can be shown that there exists a range of parameterizations in which the prohibition of entry enhances welfare. Note also that in order to focus on the main logic behind welfare consequences of entry restrictions in this framework, the extension considered here allows the government to impose an entry restriction for period 2 only. The qualitative nature of the results is however unchanged under an alternative setup in which the government can impose entry restrictions for both periods 1 and 2. See the second to the last paragraph of this section for details.

Lemma 1 characterizes the perfect foresight equilibria of entry-restriction subgames. Note, if the government chooses $N_r = N_f$, the entry restriction is not binding and so the corresponding perfect foresight equilibrium is the same as that of the free-entry subgame.

Lemma 1: Suppose that $y < \bar{y}$ holds, where \bar{y} is as defined in Proposition 1. There exist functions $\hat{P}_1(N)$, $\hat{P}_2(N)$ and $\hat{a}(N)$ with the following property: An entry-restriction subgame represented by any given $N_r \in [0, N_f]$ has a unique perfect foresight equilibrium characterized by the price sequence $(P_1, P_2) = (\hat{P}_1(N_r), \hat{P}_2(N_r))$ and the exit rate $\hat{a}(N_r)$, where $D(\hat{P}_2(N_r)) - (1 - \hat{a}(N_r))D(\hat{P}_1(N_r)) = N_r$ holds. $\hat{P}_1(N)$ ($\hat{P}_2(N)$) is continuous and strictly increasing (decreasing) in N for all $N \in [0, N_f]$, where $\hat{P}_1(N_f) = P_1^*$ and $\hat{P}_2(N_f) = P_2^*$. Also, $\hat{a}(N)$ is continuous and strictly increasing in N for all $N \in [0, N_f]$, where $0 < \hat{a}(N) < \underline{a}^*$ for all $N \in [0, N_f)$ and $\hat{a}(N_f) = \underline{a}^*$.

Lemma 1 tells us that, in the entry-restriction subgame represented by $N_r \in [0, N_f]$, the equilibrium second-period price $\hat{P}_2(N_r)$ is greater than $P_2^* = c + w - \frac{1}{2}x \equiv C_N$. In the free-entry equilibrium, the zero profit condition implies that the second-period price P_2^* is equal to C_N , which is the expected cost (including the wage bill) of the second-period entrant. Under the entry restriction, the government charges a second-period entry tax of $\hat{P}_2(N_r) - C_N$ per unit so that every second-period entrant earns zero expected profits. In the equilibrium of any entry-restriction subgame, every entrant in period t ($=1,2$) earns zero expected profits, and in period 1 the present discounted value of every individual's expected overall wage is $2w$. Hence I define the equilibrium total surplus by

$$W(N_r) \equiv \int_{\hat{P}_1(N_r)}^{\infty} D(P)dP + \int_{\hat{P}_2(N_r)}^{\infty} D(P)dP + (\hat{P}_2(N_r) - C_N)N_r, \quad (12)$$

where $\int_{\hat{P}_t(N_r)}^{\infty} D(P)dP$ is the consumer surplus in period t , and $(\hat{P}_2(N_r) - C_N)N_r$ is the total entry tax the government receives. Since there is no entry tax in the free-entry subgame, the equilibrium total surplus of the free-entry subgame is defined by $\int_{P_1^*}^{\infty} D(P)dP + \int_{P_2^*}^{\infty} D(P)dP$, which is equal to $W(N_f)$, given $\hat{P}_2(N_f) = P_2^* = C_N$. Also, let $CS(N_r) \equiv \int_{\hat{P}_1(N_r)}^{\infty} D(P)dP + \int_{\hat{P}_2(N_r)}^{\infty} D(P)dP$, which is the equilibrium consumer surplus.

Proposition 4: Entry restrictions can increase the total surplus and the consumer surplus. More precisely, there exists $N_r^* \in [0, N_f]$ such that $W(N_r^*) > W(N_f)$ and $CS(N_r^*) > CS(N_f)$.

The logic here is as follows. Think back to the free-entry equilibrium. When each firm chooses the level of specific human capital that it provides to its employee in the first period, the firm anticipates that, if it continues to operate in the second period, it must share the return from the specific human capital with its employee through a second-period wage bargaining. Since the firm cannot capture the entire return, it chooses a level of specific human capital that is below the socially optimal level. This is a version of the standard underinvestment problem in specific human capital where post-training wages are determined by bargaining.

An entry restriction represented by $N_r \in [0, N_f]$ reduces the second-period supply of the good, which in turn implies that the equilibrium second-period price $\hat{P}_2(N_r)$ becomes higher than the free-entry level P_2^* in order for the second-period market to clear. This yields the following two welfare consequences. On the one hand, this makes the second-period operation more attractive, and hence reduces the equilibrium exit rate. Every firm anticipates a lower exit rate as a consequence of the entry restriction, which increases its incentive to provide specific human capital to its employee in the first period. This mitigates the underinvestment problem, and hence can increase the total surplus. On the other hand, given that $\hat{P}_2(N_r) > P_2^* = C_N$ holds under the entry restriction, some first-period entrants whose second-period costs are higher than C_N (which is the expected cost of the second-period entrants) continue to operate in the second period. That is, the cut-off level of managerial ability under the entry restriction is lower than the socially optimal level. This effect reduces the total surplus.

Suppose that the government imposes a small entry restriction in the sense that N_r is strictly less than but close to N_f , so that the equilibrium exit rate becomes slightly below the free-entry level \underline{a}^* . Then the increment of the level of specific human capital provided by firms is small, but this affects all firms that operate in the first period. The small entry restriction also implies that the cut-off level of managerial ability is slightly below the socially optimal level, and hence a small number of first-period entrants whose managerial abilities are slightly lower than the socially optimal cut-off level survive in period 2. That is, the effect of the entry restrictions

on investment in specific human capital is of first order, while its effect on managerial ability is of second order. Hence, at the margin, the former positive welfare consequence of the entry restriction dominates the latter negative effect, and hence entry restrictions can increase the total surplus. Also, given that the entry tax is zero when $N_r = N_f$, entry restrictions can enhance the consumer surplus as well at the margin.

In summary, the government can control firm dynamics by imposing a certain degree of entry restrictions, which in turn affects labor mobility and hence firms' incentives to invest in specific human capital. Entry restrictions can mitigate the underinvestment problem in specific human capital at the cost of lower average managerial ability, and this can improve welfare in my framework. This approach focuses on the welfare consequence of entry restrictions on labor market characteristics, while the complementary approach previously taken in the theoretical industrial organization literature ("excess-entry theorem") has focused on the welfare consequence of the strategic interaction among firms in the product market. In my analysis, entry restrictions can enhance the consumer surplus as well as the total surplus, while in the excess-entry theorem entry restrictions enhance the total surplus at the cost of the lower consumer surplus.

I end this section by making two final points. First, as pointed out above, the qualitative nature of the results is unchanged under an alternative extension in which the government can impose entry restrictions for both periods 1 and 2. In particular, suppose that at Stage 0 the government announces $N_{r1} \geq 0$ and $N_{r2} \geq 0$, which denote the maximum measure of firms that are allowed to enter the industry at the beginning of periods 1 and 2, respectively. It can be shown that the total surplus is maximized when the government imposes entry restrictions for both periods 1 and 2. As in the extension considered above, the second-period entry restriction mitigates the underinvestment problem in specific human capital at the cost of lowering the cut-off level of managerial ability below the socially optimal level, while the latter inefficiency can be mitigated by imposing an entry restriction in the first period in this extension. Details of the analysis are available upon request.

Second, it seems important to note that these theoretical results do not automatically imply that the government in the real world can enhance welfare by restricting entry. In reality, there are a number of other factors to be taken into account. For example, as pointed out by Itoh, Kiyono, Okuno-Fujiwara, and Suzumura (1991), the government may not be able to obtain sufficient information for effectively implementing entry restrictions. Also, even if it is possible, the government might have to incur substantially high costs to obtain such information. In real-world policy discussions, such negative aspects as well as potentially positive aspects of

entry restrictions should be deliberately taken into account, and my contribution to this line of investigation is to offer a previously unexplored perspective on the welfare consequences of entry restrictions.

5 An Application to the US-Japanese Differences

In this section, I apply my theoretical framework to explanations for and predictions on the US-Japanese differences in labor mobility, wage structures, and accumulation of human capital.

5.1 Background

Different countries exhibit different patterns in labor mobility, wage structures, and accumulation of human capital. In particular, US-Japanese differences in the post-war period have attracted substantial attention. Concerning labor mobility, it has been found that the labor turnover rate is much higher in the United States 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. Regarding wage structures, Hashimoto and Raisian (1985) analyzed data from the 1980 *Basic Survey of Wage Structure* for Japan, and data from the 1979 *Current Population Survey* for the United States, and found that earnings-tenure profiles are more steeply sloped in Japan than in the United States (see also Mincer and Higuchi, 1988). That is, they found that growth rates in earnings attributable to firm-specific tenure are substantially greater in Japan than in the United States for all firm-size groups.

Concerning firm-specific human capital, Koike (1977, 1988) found, in his comparative analysis of Japanese and US industrial relations, that Japanese workers acquire more firm-specific human capital through rotation among related jobs (see also Dertouzos, Lester, and Solow, 1989; Ito, 1992). Also, levels of firm-sponsored training are higher in Japanese firms than in US firms as pointed out by a number of authors such as Mincer and Higuchi (1988), Dertouzos, Lester, and Solow (1989), Ito (1992), and MacDuffie and Kochan (1995). According to MacDuffie and Kochan (1995), the International Assembly Plant Study, a survey of 90 motor vehicle assembly plants in 24 countries, found that Japanese companies' plants in Japan gave their newly hired workers an average of 364 hours of training compared to only 42 hours in US companies' plants in North America. The study also found a significant difference in the training of experienced workers.

Several authors have proposed models characterized by multiple equilibria to explain the lower turnover rate and higher human capital accumulation in Japan (or Germany) than in the United States (see, for example, Prendergast, 1989; Glaeser, 1992; Chang and Wang, 1995; Acemoglu and Pischke, 1998). These are adverse selection models, where informational asymmetry on workers' abilities plays a central role in explaining differences. Morita (2001) proposed a model in which strategic complementarity arises from the connection between continuous process improvement and firm-specificity of human capital, and the resulting multiplicity of equilibria provides an explanation for a set of stylized differences in US-Japanese work organizations and labor market practices. Owan (2004) extended the standard model of job assignment with asymmetric learning to two-dimensional worker characteristics (ability and match quality), and argued that the model provides a consistent explanation for the US-Japanese differences in labor mobility, promotion, training and earning distribution based on different parameterizations that characterize each country.²³ Hashimoto (1995) considered the cost of investing in the reliability of information exchanged within the firm. Hashimoto hypothesized that in Japan the investment costs have been lower, and their marginal cost curves more elastic, than those in the United States during the post-war years, and explored their ramifications for the US-Japanese differences.

5.2 Explanations for and predictions on the differences

By capturing the interconnections between firm dynamics, labor mobility, and specific human capital, my theoretical framework offers new explanations for and predictions on the US-Japanese differences based on the cross-country difference in the importance of managerial ability. It also provides a complementary explanation based on the different degrees of governmental interventions into product markets by capturing the effects of entry restrictions on labor market characteristics.

Difference in the importance of managerial ability

Acemoglu, Aghion, and Zilibotti (2004) argued 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 pointed 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

²³See also Ishida (2004) for a related analysis.

important as the economy approaches the world technology frontier and there remains less room for adoption and imitation.

Following their analysis and argument, I argue that the importance of managerial ability (captured by x in my model) was substantially higher in the United States than in Japan when most Japanese industries were catching up with the West in the postwar period, until the mid-1970s (Okimoto, 1989). Proposition 2 presented in Section 3 then implies that the exit rate of firms is lower in Japan, which in turn means that the labor turnover rate is lower. It also implies that the level of firm-specific human capital accumulation is higher and the slope of the earnings-tenure profile is steeper in Japan than in the United States. This provides an explanation for the US-Japanese differences while the Japanese economy was catching up with the West. Also, since the lower exit rate means a lower cut-off managerial ability, my model predicts that the average managerial ability (which represents a firm's ability to develop an effective strategy) is lower in Japanese firms than in US firms. This is consistent with Porter, Takeuchi, and Sakakibara (2000), who argue through a number of case studies that, although many Japanese firms have achieved very high operational effectiveness, they are less capable in identifying and implementing innovative strategies to sustain their competitive advantage.

Entry regulation

Throughout the post-war period, the Japanese government invoked a fairly sophisticated system of interventionist economic policy to promote steady growth, technological innovations, and international competitiveness (Suzumura and Okuno-Fujiwara, 1987). A guiding principle of Japanese industrial policy has been the regulation of so-called "excessive competition" (Suzumura and Kiyono, 1987), and the Japanese government often restricted entries into industries. On the other hand, the degree of such governmental intervention has been much lower in the United States. As demonstrated in the previous section, such entry restrictions in my theoretical framework lower the firm's exit rate and the labor turnover rate, which in turn increases the level of firm-specific human capital accumulation and makes the earnings-tenure profile more steeply sloped. Hence, entry restrictions that have often been imposed by the Japanese government yield another explanation for the US-Japanese differences.

What does my model predict concerning the current trends and the future changes of the US-Japanese differences? 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 ability which is crucial for undertaking innovative activities. Also, the degree of entry restrictions imposed by the Japanese government has become lower in light

of the recent trend of deregulation that started in the early 1990s.²⁴ In my framework, these factors suggest that the degree of the US-Japanese differences tends to become smaller. That is, it predicts that the firm's exit rate and the labor turnover rate increase, the level of firm-specific human capital accumulation declines, and the slope of the earnings-tenure profile becomes flatter in Japan. Consistent with this prediction, Clark and Ogawa (1992) and Hashimoto and Raisian (1992) found that the slope of the earnings-tenure profile for large Japanese firms became somewhat flatter in the 1980s than in the 1970s.²⁵ Concerning labor turnover rate, Kato (2001) compared the 10-year job retention rates of Japanese employees for the 10-year period prior to the burst of the bubble economy (1977-1987) and the post-bubble period (1987-1997). Kato found that the job retention rates fell noticeably for younger employees (ages 20-24 and 25-29) and middle age employees with short tenure (ages 30-34, 35-39, and 40-44 with 0-4 years of tenure), while the job retention rates fell only by a smaller amount for older employees.

In reality, such transitions in Japan seems to be taking place slowly (see Genda and Rebick, 2000; Lincoln, 2001) due to vested interests and institutional inertia embedded in the Japanese economic system. Lincoln (2001) argues that deregulation in Japan has proceeded slowly because of the strong vested interests of government bureaucrats. Also, although educational reforms have been recently introduced in Japan to foster creativity, innovative activities, and flexibility through decentralizing its education system, the Japanese tradition of a standardized education system with centralized control is proving difficult to change (Muta, 2000).²⁶

6 Summary and Conclusion

This paper has developed a new firm-dynamics model that incorporates workers, their accumulation of specific human capital, and their mobility. Models of firm and industry dynamics that allow for entry, exit and firm heterogeneity and/or idiosyncratic shock have been previously developed in the literature. Despite their significant contributions, they do not explicitly incorporate one important aspect of reality, which is that most firms employ workers to produce

²⁴Suzumura and Okuno-Fujiwara (1987) argued that the anticompetitive nature of Japanese industrial policy became weaker after the first oil crisis that occurred in 1973.

²⁵See also Ariga, Brunello and Ohkusa (2000) for another recent evidence consistent with this trend.

²⁶Although the Japanese education system has successfully produced a homogeneous and group-oriented labor force that is well versed in basic skills, it has not fostered creativity, individual initiatives, and entrepreneurship (Ito, 1996; Green, 2000; Muta, 2000). As Herbig and Jacobs (1999) point out, such an education system appears to be better suited to adapting existing ideas than to fostering innovative activities, where the latter has become increasingly important as the Japanese economy approaches the world technology frontier.

outputs. The present paper has attempted to fill this important gap in the literature by exploring a simple but important link that firm-specific human capital loses its value if the firm exits the industry.

I have demonstrated that the importance of a firm's managerial ability, through its connection to firm-specific human capital, systematically influences firm dynamics, labor market variables, and employment practices. This has yielded empirical implications and predictions from a previously unexplored perspective, given that the importance of managerial ability can differ across industries, and across time and countries within the same industry.

Equally important, my framework has offered a new perspective on the welfare consequences of entry restrictions. I have analyzed an extension of the model in which the government can control firm dynamics to a certain degree by imposing entry restrictions, and demonstrated that entry restrictions can mitigate the underinvestment problem in specific human capital, which can result in a higher consumer surplus, as well as a higher total surplus. Novelty here is that the analysis captures the effects of entry restrictions on labor market characteristics. My approach is complementary to, but fundamentally different from, the approach taken by previous papers in the theoretical industrial organization literature, which has focused on the effects of entry restrictions on strategic interactions among firms.

I have applied my framework to explanations for and predictions on US-Japanese differences in labor mobility, wage structures, and accumulation of human capital. The model has provided a novel explanation for lower labor turnover rates, steeper earnings-tenure profiles, and higher levels of investment in firm-specific human capital, which persisted in Japan for a certain duration in the postwar period when Japan was in the process of catching up with the West. Concerning current trends and future changes, the model has predicted that the differences tend to become smaller in the process of Japan's catch-up and deregulation.

7 Appendix

Proof of Proposition 1: Suppose that there exists a perfect foresight equilibrium characterized by a price sequence $(P_1, P_2) = (P_1^*, P_2^*)$ where $P_1^* > 0$ and $P_2^* > 0$, in which a strictly positive measure of firms enter and exit the industry at the beginning of period 2. In the text it has been shown that conditions (6), (10) and (11) are necessary for such an equilibrium to exist. Here, in Claims 1 and 2 below I present proofs of some mathematical/computational details that have not been presented in the text.

Claim 1: In the equilibrium every firm i that employed a worker at Stage 1 chooses $h_i = \frac{1}{2} \frac{(1-b)xy}{x-(1-b)y^2} \equiv h^*$ at Stage 2, where $x - 2(1-b)y^2 > 0$ must hold.

Proof: In the equilibrium there must exist a strictly positive measure of firms that operate in period 1 and exit the industry at the beginning of period 2 with a non-zero probability. Let firm k be such a firm. Following the same procedure and using the same notations as in the text, firm k chooses $h_k \in [0, H]$ at Stage 2 and exits the industry with probability $\underline{a}(h_k, P_2^*) = \frac{1}{2} - \frac{y}{x}h_k > 0$ in the equilibrium. This implies $h_k \in [0, \frac{x}{2y})$ and $\underline{a}(h_k, P_2^*) \in (0, \frac{1}{2}]$. Also, following the same procedure and using the same notations as in the text, we find that $h = h_k$ is the solution to the maximization problem $\max_{h \in [0, H]} \pi(h, P_2^*)$. Given $\underline{a}(h, P_2^*) \leq \frac{1}{2}$,

$$\begin{aligned} \pi(h, P_2^*) &= \int_{\underline{a}(h, P_2^*)}^1 (P_2^* - C_2(a, h, P_2^*)) da - \frac{1}{2}h^2 \\ &= \int_{\underline{a}(h, P_2^*)}^1 [P_2^* - (c + w - xa - yh) - bS(a, h, P_2^*)] da - \frac{1}{2}h^2, \end{aligned}$$

where $S(a, h, P_2^*) = [P_2^* - (c - xa - yh) - w - \max\{P_2^* - (c - xa + w), 0\}]$. Given $P_2^* = c + w - \frac{1}{2}x$, we have $P_2^* - (c + w - xa) \geq 0 \Leftrightarrow a \geq \frac{1}{2}$. This implies that

$$\begin{aligned} \pi(h, P_2^*) &= \int_{\underline{a}(h, P_2^*)}^1 [P_2^* - (c + w - xa)] da - \int_{\underline{a}(h, P_2^*)}^{\frac{1}{2}} b[P_2^* - (c + w - xa)] da \\ &\quad + (1 - \underline{a}(h, P_2^*))(1 - b)yh - \frac{1}{2}h^2. \end{aligned}$$

Given $\underline{a}(h_k, P_2^*) = \frac{1}{2} - \frac{y}{x}h_k \in (0, \frac{1}{2}]$ and $P_2^* - (c + w - x\underline{a}(h_k, P_2^*)) = yh_k$, we find $\frac{\partial}{\partial h} \pi(h_k, P_2^*) = (1 - \underline{a}(h_k, P_2^*))(1 - b)y - h_k = \frac{1}{2}(1 - b)y - \frac{x - (1-b)y^2}{x}h_k$. Suppose $x - (1-b)y^2 \leq 0$ so that $\frac{\partial}{\partial h} \pi(h_k, P_2^*) > 0$ for all $h_k \in [0, \frac{x}{2y})$. We then have that $\pi(\frac{x}{2y}, P_2^*) > \pi(h, P_2^*)$ for all $h \in [0, \frac{x}{2y})$. Given $H > \frac{x}{2y}$ (by assumption), $h = h_k \in [0, \frac{x}{2y})$ cannot be a solution to the maximization problem $\max_{h \in [0, H]} \pi(h, P_2^*)$. Hence $x - (1-b)y^2 > 0$ must hold. Note that $\frac{\partial}{\partial h} \pi(0, P_2^*) = \frac{1}{2}(1 - b)y > 0$, $\frac{\partial}{\partial h} \pi(h_k, P_2^*) = 0 \Leftrightarrow h_k = \frac{1}{2} \frac{(1-b)xy}{x - (1-b)y^2}$, and $H > \max\{\frac{1}{2} \frac{(1-b)xy}{x - (1-b)y^2}, \frac{x}{2y}\}$. These together imply that $\frac{1}{2} \frac{(1-b)xy}{x - (1-b)y^2} < \frac{x}{2y}$ (which is equivalent to $x - 2(1-b)y^2 > 0$) must hold

for $h = h_k \in [0, \frac{x}{2y})$ to solve the maximization problem. Under this condition, we have that $h_k = \frac{1}{2} \frac{(1-b)xy}{x-(1-b)y^2} \equiv h^*$ is the unique solution to the maximization problem, and that $\underline{a}(h_k, P_2^*) = \frac{1}{2} \frac{x-2(1-b)y^2}{x-(1-b)y^2} > 0$.

Suppose that $x - 2(1-b)y^2 > 0$ holds. Then, following the same procedure as in the text, we find that every firm i that employed a worker at Stage 1 chooses $h_i \in [0, H]$ at Stage 2 to maximize $\pi(h_i, P_2^*)$. Note that $\underline{a}(h_i, P_2^*) > 0 \Leftrightarrow 0 \leq h_i < \frac{x}{2y}$. We then have that $\frac{\partial}{\partial h} \pi(h_i, P_2^*) = \frac{1}{2}(1-b)y - \frac{x-(1-b)y^2}{x} h_i$ for all $h_i \in [0, \frac{x}{2y})$, while $\frac{\partial}{\partial h} \pi(h_i, P_2^*) = (1-b)y - h_i$ for all $h_i \in (\frac{x}{2y}, \infty)$. Then $x - 2(1-b)y^2 > 0$ and $H > \max\{\frac{1}{2} \frac{(1-b)xy}{x-(1-b)y^2}, \frac{x}{2y}\}$ together imply that $h_i = \frac{1}{2} \frac{(1-b)xy}{x-(1-b)y^2} \equiv h^*$ is the unique optimum for every firm i . *Q.E.D.*

Claim 2: Condition (8) presented in the text implies that $P_1^* = c + w - \frac{1}{2}x - \frac{1}{8} \frac{x^2[x-(1-b)^2y^2]}{[x-(1-b)y^2]^2}$.

Proof: Condition (8) is equivalent to $P_1^* + (1 - \underline{a}^*)(c + w - \frac{1}{2}x) = c - \frac{1}{2}x + (2 - \underline{a}^*)w - \int_{\underline{a}^*}^1 w_2(a, h^*, P_2^*) da + \frac{1}{2}(h^*)^2 + \int_{\underline{a}^*}^1 [c - xa - yh^* + w_2(a, h^*, P_2^*)] da$. Using $P_2^* - (c+w) + x\underline{a}^* + yh^* = 0$, we find that $P_1^* = c + w - \frac{1}{2}x + \frac{1}{2}(h^*)^2 - \frac{1}{2}(1 - \underline{a}^*)^2x$. Then $h^* = \frac{1}{2} \frac{(1-b)xy}{x-(1-b)y^2}$ and $\underline{a}^* = \frac{1}{2} \frac{x-2(1-b)y^2}{x-(1-b)y^2}$ imply the result. *Q.E.D.*

Next we establish Claim 3.

Claim 3: For any given parameterization, there exists a unique value $\bar{y} \geq 0$ such that conditions (6), (10) and (11) presented in the text hold if and only if $y < \bar{y}$. There exists a range of parameterizations in which $\bar{y} > 0$.

Proof: Suppose $y < \sqrt{\frac{x}{2(1-b)}}$, so that condition (6) ($x - 2(1-b)y^2 > 0$) holds. Using $1-b > (1-b)^2$ we find $\frac{d}{dy} \left\{ \frac{x-(1-b)^2y^2}{[x-(1-b)y^2]^2} \right\} > \frac{2(1-b^2)y}{[x-(1-b)y^2]^2} > 0$, which implies that RHS of inequality (10) is strictly increasing in y . Next we show that $(1 - \underline{a}^*)D(P_1^*)$ is strictly increasing in y . We have that $1 - \underline{a}^* = \frac{x}{2[x-(1-b)y^2]}$, which is strictly increasing in y . Concerning $D(P_1^*)$, $\frac{d}{dy} \left\{ \frac{x-(1-b)^2y^2}{[x-(1-b)y^2]^2} \right\} > 0$ implies that $D(P_1^*)$ is strictly increasing in y , and hence $(1 - \underline{a}^*)D(P_1^*)$ is strictly increasing in y . Given $D(P_2^*) = D(c + w - \frac{1}{2}x)$ is independent of y , this implies the first result, where $\bar{y} \in [0, \sqrt{\frac{x}{2(1-b)}}]$. Note that inequality (10) holds when $y = 0$, given $c > x + yH$. Note also that $(1 - \underline{a}^*)D(P_1^*) \rightarrow \frac{1}{2}D(c + w - \frac{5}{8}x)$ as $y \rightarrow 0$. This implies that $\bar{y} > 0$ holds if and only if $D(c + w - \frac{1}{2}x) > \frac{1}{2}D(c + w - \frac{5}{8}x)$, which holds under a range of parameterizations. This implies the second result. *Q.E.D.*

Claims 1-3, along with the analysis presented in the text, imply the following necessity part of the proposition: “Suppose that there exists a perfect foresight equilibrium in which a strictly positive measure of firms enter and exit the industry at the beginning of period 2. Then, $y < \bar{y}$ must hold.” We now check sufficiency. Suppose that $y < \bar{y}$ holds, and that

$(P_1, P_2) = (c + w - \frac{1}{2}x - \frac{1}{8} \frac{x^2[x-(1-b)^2y^2]}{[x-(1-b)y^2]^2}, c + w - \frac{1}{2}x) = (P_1^*, P_2^*)$. First note that $P_1^* > 0$ and $P_2^* > 0$ hold given $y < \bar{y}$. Consider firm i that employed worker j at Stage 1. Given $y < \bar{y}$ ($\Rightarrow x - 2(1-b)y^2 > 0$), firm i 's unique optimal choice at Stage 2 is $h_i = \frac{1}{2} \frac{(1-b)xy}{x-(1-b)y^2} \equiv h^*$ as shown in the proof of Claim 1. Then, following the same procedure and using the same notations as in the text, firm i continues to operate in period 2 if and only if $a_i \geq \underline{a}^*$ (where $0 < \underline{a}^* < \frac{1}{2}$), and worker j 's second-period expected wage is $\int_0^{\underline{a}^*} w da + \int_{\underline{a}^*}^1 w_2(a, h^*, P_2^*) da$. Since all individuals anticipate this at Stage 1, every firm must offer the first period wage $w_1 \geq w_1^*$ to hire a worker at Stage 1. Then the analysis presented in the text implies that, if $y < \bar{y}$, there exists a perfect foresight equilibrium with the following properties: (i) $(P_1, P_2) = (P_1^*, P_2^*)$ where $P_1^* > 0$ and $P_2^* > 0$, (ii) at Stage 1, measure $D(P_1^*)$ of firms employ workers at the first-period wage $w_1 = w_1^*$, (iii) at Stage 2, every firm i that hired a worker chooses $h_i = h^*$, (iv) at Stage 4, every firm i that operated in period 1 continues to employ its first-period employee at the second-period wage $w_2(a_i, h^*, P_2^*)$ if $a_i \geq \underline{a}^*$, while every firm i exits the industry if $a_i < \underline{a}^*$, and (v) at Stage 4, measure $D(P_2^*) - (1 - \underline{a}^*)D(P_1^*) > 0$ of new firms enter and operate in period 2.

Finally we prove that the equilibrium described in the previous paragraph is the unique perfect foresight equilibrium if $y < \bar{y}$. In any perfect foresight equilibrium, $P_2 > c + w - \frac{1}{2}x \equiv P_2^*$ cannot hold because second-period entrants can make strictly positive expected profits if $P_2 > c + w - \frac{1}{2}x$. Then Claim 4 below proves the uniqueness and completes the proof of the proposition.

Claim 4: Suppose that $y < \bar{y}$ holds. Then there does not exist a perfect foresight equilibrium in which $P_2 < P_2^*$ holds.

Proof: Suppose such an equilibrium exists, and let $P_2 = \tilde{P}_2 = P_2^* - \psi$, where $\psi > 0$. Consider firm i that employed worker j at Stage 1 and chose h_i at Stage 2 in the equilibrium. Following the same procedure and using the same notations as in the text, we have that $h = h_i$ solves the maximization problem $\max_{h \in [0, H]} \pi(h, \tilde{P}_2)$. Suppose $\underline{a}(h_i, \tilde{P}_2) \geq 1$. Then given $\tilde{P}_2 < P_2^*$ there does not exist a strictly positive measure of firms that operate in period 2. This implies that $\underline{a}(h_i, \tilde{P}_2) < 1 \Leftrightarrow h_i > \frac{2\psi-x}{2y}$ must hold. Then, noting $\underline{a}(h_i, \tilde{P}_2) > 0 \Leftrightarrow h_i < \frac{x+2\psi}{2y}$, we find that $\frac{\partial}{\partial h} \pi(h_i, \tilde{P}_2) = (1 - \underline{a}(h_i, \tilde{P}_2))(1-b)y - h_i = \frac{\tilde{P}_2 - (c+w)+x}{x}(1-b)y - \frac{x-(1-b)y^2}{x}h_i$ if $h_i < \frac{2\psi+x}{2y}$, while $\frac{\partial}{\partial h} \pi(h_i, \tilde{P}_2) = (1-b)y - h_i$ if $h_i > \frac{2\psi+x}{2y}$. Then $x - 2(1-b)y^2 > 0$ (implied by $y < \bar{y}$) implies that $h_i = \frac{(1-b)y[\tilde{P}_2 - (c+w)+x]}{x - (1-b)y^2} = \frac{(1-b)y(\frac{1}{2}x - \psi)}{x - (1-b)y^2}$ is the unique optimum if $\psi < \frac{1}{2}x$, while $h_i = 0$ is the unique optimum if $\psi \geq \frac{1}{2}x$. Note, $(1 - \underline{a}(h_i, \tilde{P}_2))(1-b)y - h_i = 0$ holds if $\psi < \frac{1}{2}x$. Suppose $\psi \geq \frac{1}{2}x$. Then every firm i that employed a worker at Stage 1 chooses $h_i = 0$ at Stage 2 in the equilibrium. This implies that firm i 's minimum possible second-period cost (including the wage bill) is $c + w - x$, while $\psi \geq \frac{1}{2}x$ implies that $P_2 = \tilde{P}_2 \leq c + w - x$ in the equilibrium. This

implies that there does not exist a strictly positive measure of firms that operate in period 2, and hence $\psi < \frac{1}{2}x$ must hold.

Thus far we have found that, if there exists a perfect foresight equilibrium in which $P_2 = \tilde{P}_2 < P_2^*$, then $\psi < \frac{1}{2}x$ must hold and every firm i that operates in period 1 chooses $h_i = h(\tilde{P}_2) \equiv \tilde{h}$ in the equilibrium, where $h(P_2) \equiv \frac{(1-b)y[P_2-(c+w)+x]}{x-(1-b)y^2}$. Then, following the same procedure and using the same notations as in the text, we find that the following property holds in the equilibrium: (i) the exit rate is $\tilde{a} \equiv \underline{a}(\tilde{P}_2)$ where $\underline{a}(P_2) \equiv \underline{a}(h(P_2), P_2)$ (note that we have $h(\tilde{P}_2) \in (\frac{2\psi-x}{2y}, \frac{2\psi+x}{2y})$), which implies $0 < \tilde{a} < 1$), (ii) every firm that employed a worker at Stage 1 offers the first period wage $\tilde{w}_1 \equiv w - \int_{\tilde{a}}^1 (w_2(a, \tilde{h}, \tilde{P}_2) - w) da$, and (iii) every firm i that operates in period 1 has the expected first-period cost of $\tilde{C}_1 \equiv C - \frac{1}{2}x + \tilde{w}_1 + \frac{1}{2}(\tilde{h})^2$, and continues to operate in period 2 with the second-period cost of $C_2(a_i, \tilde{h}, \tilde{P}_2)$ if and only if $a_i \geq \tilde{a}$. This implies that the equilibrium first-period price, denoted by \tilde{P}_1 , is uniquely determined by $\tilde{P}_1 + \int_{\tilde{a}}^1 \tilde{P}_2 da = \tilde{C}_1 + \int_{\tilde{a}}^1 C_2(a, \tilde{h}, \tilde{P}_2) da$. Given $0 < \tilde{a} < 1$ we have $\tilde{P}_2 - (c+w) + x\tilde{a} + y\tilde{h} = 0$. Then, through the procedure analogous to the proof of Claim 2 above we find that $\tilde{P}_1 = c + w - \frac{1}{2}x + \frac{1}{2}(\tilde{h})^2 - \frac{1}{2}(1 - \tilde{a})^2x = c + w - \frac{1}{2}x - \frac{1}{2}(1 - \tilde{a})^2[x - (1-b)^2y^2]$, where the second equality holds because $(1 - \tilde{a})(1-b)y - \tilde{h} = 0$. Define $P_1(P_2)$ by $P_1(P_2) \equiv c + w - \frac{1}{2}x - \frac{1}{2}(1 - \underline{a}(P_2))^2[x - (1-b)^2y^2]$. Then the market clearing in period 2 requires $D(\tilde{P}_2) - (1 - \underline{a}(\tilde{P}_2))D(P_1(\tilde{P}_2)) = 0$, because $\tilde{P}_2 < P_2^*$ implies that no firms enter in period 2 in the equilibrium. We have that $\underline{a}(P_2^*) = \underline{a}^*$ and $P_1(P_2^*) = P_1^*$, and hence $D(P_2^*) - (1 - \underline{a}(P_2^*))D(P_1(P_2^*)) = N_f > 0$. Since $\underline{a}(P_2)$ is decreasing in P_2 , we have that $(1 - \underline{a}(P_2))D(P_1(P_2))$ is increasing in P_2 , which in turn implies that there does not exist a value $\tilde{P}_2 < P_2^*$ such that $D(\tilde{P}_2) - (1 - \underline{a}(\tilde{P}_2))D(P_1(\tilde{P}_2)) = 0$. This is a contradiction. *Q.E.D.*

Proofs of Propositions 2 and 3:

- (i) Note $\underline{a}^* \equiv \frac{1}{2} \frac{x-2(1-b)y^2}{x-(1-b)y^2}$. We find $\frac{\partial \underline{a}^*}{\partial x} = \frac{(1-b)y^2}{2[x-(1-b)y^2]^2} > 0$ and $\frac{\partial \underline{a}^*}{\partial y} = -\frac{(1-b)xy}{[x-(1-b)y^2]^2} < 0$.
- (ii) Note $h^* \equiv \frac{1}{2} \frac{(1-b)xy}{x-(1-b)y^2}$. We find $\frac{\partial h^*}{\partial x} = \frac{-\frac{1}{2}(1-b)^2y^3}{[x-(1-b)y^2]^2} < 0$ and $\frac{\partial h^*}{\partial y} = \frac{\frac{1}{2}x(1-b)[x+(1-b)y^2]}{[x-(1-b)y^2]^2} > 0$.
- (iii) By equation (7) and definitions of $w_2(a, h, P_2)$ and $S(a, h, P_2)$, we find $w_1^* = w - \int_{\underline{a}^*}^1 bS(a, h^*, P_2^*) da = w - \frac{b}{2}\phi_1$ where $\phi_1 \equiv \frac{yh^*(x+yh^*)}{x}$, and $w_2^* \equiv \frac{\int_{\underline{a}^*}^1 w_2(a, h^*, P_2^*) da}{1-\underline{a}^*} = w + \frac{\int_{\underline{a}^*}^1 bS(a, h^*, P_2^*) da}{1-\underline{a}^*} = w + b\phi_2$ where $\phi_2 \equiv yh^*$. From (ii) above we have that $\frac{\partial h^*}{\partial x} < 0$ and $\frac{\partial h^*}{\partial y} > 0$.

Claim 5: $\frac{\partial \phi_1}{\partial x} < 0$, $\frac{\partial \phi_2}{\partial x} < 0$, $\frac{\partial \phi_1}{\partial y} > 0$, and $\frac{\partial \phi_2}{\partial y} > 0$ hold.

Proof: Given $\frac{\partial h^*}{\partial x} < 0$, we find $\frac{\partial \phi_1}{\partial x} = \frac{y}{x^2}(x^2 \frac{\partial h^*}{\partial x} + 2xyh^* \frac{\partial h^*}{\partial x} - y(h^*)^2) < 0$ and $\frac{\partial \phi_2}{\partial x} = y \frac{\partial h^*}{\partial x} < 0$. Also, $\frac{\partial h^*}{\partial y} > 0$ implies $\frac{\partial \phi_1}{\partial y} > 0$. Finally, given $\frac{\partial h^*}{\partial y} > 0$ we find $\frac{\partial \phi_2}{\partial y} = h^* + y \frac{\partial h^*}{\partial y} > 0$. *Q.E.D.*

Noting that $w_2' - w_1^* = \frac{b}{2}(\phi_1 + 2\phi_2)$, Claim 5 implies that $w_2' - w_1^*$ is strictly decreasing in x and strictly increasing in y . *Q.E.D.*

Proof of Lemma 1: Consider an entry-restriction subgame represented by $N_r \in [0, N_f]$. Suppose that the game has a perfect foresight equilibrium characterized by the price sequence $(P_1, P_2) = (\hat{P}_1, \hat{P}_2)$, and let $\hat{a} \in [0, 1]$ denote the exit rate in the equilibrium. Suppose $\hat{P}_2 < c + w - \frac{1}{2}x$. Then no firms enter the industry at the beginning of period 2 in the equilibrium for any given $N_r \in [0, N_f]$, and hence the entry restriction is not binding. Then Claim 4 (presented in the proof of Proposition 1) implies that $\hat{P}_2 < c + w - \frac{1}{2}x$ cannot hold, and hence $\hat{P}_2 \geq c + w - \frac{1}{2}x$ must hold in the equilibrium. Given this, define $\xi \geq 0$ by $\hat{P}_2 = P_2^* + \xi$. Suppose $\hat{a} = 0$. We then have that $D(\hat{P}_2) - D(\hat{P}_1) = N_r \geq 0$, which implies $\hat{P}_1 \geq \hat{P}_2$. Suppose $\hat{P}_1 > c + w - \frac{1}{2}x$. Then a firm can make a strictly positive expected profit by employing a worker at the reservation wage w and providing no firm-specific human capital in period 1. This is a contradiction, and hence $\hat{P}_1 = \hat{P}_2 = c + w - \frac{1}{2}x$ must hold. If $\hat{P}_1 = \hat{P}_2 = c + w - \frac{1}{2}x$ holds in a perfect foresight equilibrium of the entry-restriction subgame, then the original model should also have a perfect foresight equilibrium in which $P_1 = P_2 = c + w - \frac{1}{2}x$. However Proposition 1 implies that the original model does not have such an equilibrium. This implies that $\hat{a} = 0$ cannot hold, and hence $\hat{a} > 0$ must hold.

Then, following the analogous procedure and using the same notations as in the proof of Claim 4, we find that every firm i that operates in period 1 chooses $h_i = h(\hat{P}_2) = \frac{(1-b)y(\frac{1}{2}x+\xi)}{x-(1-b)y^2} \equiv \hat{h}$ at Stage 2 in the equilibrium, where $h(P_2) \equiv \frac{(1-b)y[P_2-(c+w)+x]}{x-(1-b)y^2}$. We also find that the equilibrium exit rate is $\hat{a} \equiv \underline{a}(\hat{P}_2)$ where $\underline{a}(P_2) \equiv \underline{a}(h(P_2), P_2)$, and that the equilibrium first-period price is $\hat{P}_1 = P_1(\hat{P}_2)$ where $P_1(P_2) \equiv c + w - \frac{1}{2}x - \frac{1}{2}(1 - \underline{a}(P_2))^2[x - (1 - b)^2y^2]$. Then the market clearing in period 2 requires $\eta(\hat{P}_2) = N_r$, where $\eta(P_2) \equiv D(P_2) - (1 - \underline{a}(P_2))D(P_1(P_2))$.

Claim 6: There exists a unique continuous function $\hat{P}_2(N)$ such that $\eta(\hat{P}_2(N)) = N$ for all $N \in [0, N_f]$. Also, $\hat{P}_2(N)$ is strictly decreasing in N for all $N \in [0, N_r]$, where $\hat{P}_2(N_f) = c + w - \frac{1}{2}x$.

Proof: From the analysis of the original model we have that $\eta(c + w - \frac{1}{2}x) = N_f$. Note that $\underline{a}(P_2)$ is continuously differentiable and strictly decreasing in P_2 for all P_2 such that $\underline{a}(P_2) > 0$. This implies that $P_1(P_2)$ is continuously differentiable and strictly decreasing in P_2 , which in turn implies that $\eta(P_2)$ is continuously differentiable and strictly decreasing in P_2 for all P_2 such that $\underline{a}(P_2) > 0$. Note also that there exists a unique value $P_2^0 (> c + w - \frac{1}{2}x)$ such that $\underline{a}(P_2^0) = 0$ for all $P_2 \geq P_2^0$. We have that $P_1(P_2^0) = c + w - \frac{1}{2}x - \frac{1}{2}[x - (1 - b)^2y^2] < c + w - \frac{1}{2}x < P_2^0$. Hence $\eta(P_2^0) = D(P_2^0) - D(P_1(P_2^0)) < 0$. Then the Inverse Function Theorem implies the result. *Q.E.D.*

Note that, if $N_r = N_f$, the entry restriction is not binding and hence $\hat{P}_1 = P_1^*$, $\hat{P}_2 = P_2^*$ and $\hat{a} = \underline{a}^*$ hold where P_1^* , P_2^* and \underline{a}^* are as defined in the text. Then Claim 6 implies the

following result: Suppose that an entry-restriction subgame represented by $N_r \in [0, N_f]$ has a perfect foresight equilibrium characterized by a price sequence $(P_1, P_2) = (\hat{P}_1, \hat{P}_2)$ and an exit rate \hat{a} . Then $\hat{P}_1 = \hat{P}_1(N_r)$, $\hat{P}_2 = \hat{P}_2(N_r)$ and $\hat{a} = \hat{a}(N_r)$ hold, where $\hat{P}_1(N) \equiv P_1(\hat{P}_2(N))$ and $\hat{a}(N) \equiv \underline{a}(\hat{P}_2(N))$. Note, Claim 6 and its proof imply that $\hat{P}_1(N)$, $\hat{P}_2(N)$ and $\hat{a}(N)$ exhibit the properties described in Lemma 1.

Now, pick any $N_r \in [0, N_f]$ and let $(P_1, P_2) = (\hat{P}_1(N_r), \hat{P}_2(N_r)) = (\hat{P}_1, \hat{P}_2)$ be given. Consider firm i that employed a worker at Stage 1. Then, following the same procedure and using the same notations as in the text, we find that at Stage 2 firm i chooses $h_i \in [0, H]$ to maximize $\pi(h_i, \hat{P}_2)$. Note that $\hat{P}_2 \geq c + w - \frac{1}{2}x = P_2^*$ implies $\underline{a}(h_i, \hat{P}_2) < 1$. Then, noting $\underline{a}(h_i, \hat{P}_2) > 0 \Leftrightarrow 0 \leq h_i < \frac{x-2\xi}{2y}$, we find that $\frac{\partial}{\partial h} \pi(h_i, \hat{P}_2) = (1 - \underline{a}(h_i, \hat{P}_2))(1 - b)y - h_i = \frac{\hat{P}_2 - (c+w)+x}{x}(1 - b)y - \frac{x - (1-b)y^2}{x}h_i$ if $h_i < \frac{x-2\xi}{2y}$, while $\frac{\partial}{\partial h} \pi(h_i, \hat{P}_2) = (1 - b)y - h_i$ if $h_i > \frac{x-2\xi}{2y}$. From the proof of Claim 6 we have that $\underline{a}(\hat{P}_2) > 0$. Noting that $\underline{a}(\hat{P}_2) = \frac{c+w-\hat{P}_2}{x} - \frac{y}{x}\hat{h}$ where $\hat{P}_2 = c + w - \frac{1}{2}x + \xi$, we find that $\underline{a}(\hat{P}_2) > 0 \Rightarrow x - 2(1 - b)y^2 - 2\xi > 0$. This in turn implies that $h_i = h(\hat{P}_2) = \hat{h}$ is the unique optimum. Then, through the procedure analogous to the proof of Proposition 1 we find that any entry-restriction subgame represented by $N_r \in [0, N_f]$ has a unique perfect foresight equilibrium characterized by the price sequence $(P_1, P_2) = (\hat{P}_1(N_r), \hat{P}_2(N_r))$ and the exit rate $\hat{a}(N_r)$. *Q.E.D.*

Proof of Proposition 4: From the proof of Lemma 1 we have that $\hat{P}_1(N_r) = P_1(\hat{P}_2(N_r))$ and $\hat{a}(N_r) = \underline{a}(\hat{P}_2(N_r))$, and find that $\hat{P}_2(N_r)$ is continuously differentiable at $N_r = N_f$ (which implies that $\hat{P}_1(N_r)$ and $\hat{a}(N_r)$ are also continuously differentiable at $N_r = N_f$). Given this we compute the derivative of $W(N_r)$ evaluated at $N_r = N_f$. Note that $\hat{P}_2(N_f) - C_N = 0$ and $N_r = D(\hat{P}_2(N_r)) - (1 - \hat{a}(N_r))D(\hat{P}_1(N_r))$. We then find that $W'(N_f) = -D(\hat{P}_1(N_f))\hat{P}'_1(N_f) - (1 - \hat{a}(N_f))D(\hat{P}_1(N_f))\hat{P}'_2(N_f)$. Given $\hat{P}_1(N_r) = c + w - \frac{1}{2}x - \frac{1}{2}(1 - \underline{a}(\hat{P}_2(N_r)))^2[x - (1 - b)^2y^2]$, we find $\hat{P}'_1(N_r) = (1 - \underline{a}(\hat{P}_2(N_r)))[x - (1 - b)^2y^2]\underline{a}'(\hat{P}_2(N_r))\hat{P}'_2(N_r)$. Also, by definition of $\underline{a}(P_2)$ we find $\underline{a}'(\hat{P}_2(N_r)) = -\frac{1}{x - (1-b)y^2}$. We then find that $W'(N_f) = D(\hat{P}_1(N_f))(1 - \underline{a}(\hat{P}_2(N_f)))\hat{P}'_2(N_f)\frac{(1-b)y^2}{x - (1-b)y^2}$. Then $\hat{P}'_2(N_f) < 0$ and $0 < b < 1$ together imply $W'(N_f) < 0$. Similarly we also find $CS'(N_f) < 0$. This implies the result. *Q.E.D.*

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