

**Implicit Contracts, the Great Depression, and Institutional Change:  
The Evolution of Employment Relations in U.S. and Japanese  
Manufacturing Firms, 1910–1940**

**Chiaki Moriguchi\***

Department of Economics, Northwestern University  
chiaki@northwestern.edu

First draft: April 2000, Revised version: September 2001

**Abstract**

This paper employs a game-theoretic framework and comparative historical approach to study an institutional change triggered by an extraordinary shock — the Great Depression. By characterizing “corporate welfarism” practiced by large manufacturing firms in the U.S. and Japan in the 1920s as implicit employment contracts based on internal enforcement, the paper reexamines the impact of the Depression on corporate welfarism and the subsequent evolution of employment relations in the two countries. Documenting *parallel* institutional developments in the U.S. and Japan during the two decades prior to the Depression, the paper identifies the early 1930s as a *point of bifurcation* at which two paths began to diverge. In the U.S., the repudiation of the implicit contracts by a majority of employers induced by the deep and prolonged depression caused a change in the expectations of workers and the public, leading to the advancement of explicit employment contracts based on third-party arbitration. By contrast, during a less severe depression, a majority of Japanese large companies kept their implicit contracts, while developing institutional arrangements to mitigate a negative impact of business fluctuation. The paper then attributes the *irreversibility* of the institutional change after the Depression to the endogenous formation of complementary institutions, such as union laws, enforcement agencies, and state welfare programs.

---

\*I am grateful to Lee Alston, Masahiko Aoki, Pierre Azoulay, Carliss Baldwin, Adam Brandenburger, Robert Gibbons, Claudia Goldin, Avner Greif, Robert Margo, Laura Owen, Warren Whatley, and Gavin Wright for their valuable comments and encouragement. I would also like to thank seminar participants at MIT Sloan School, University of Illinois, Northwestern University, University of Michigan, University of Pennsylvania, UCLA, and Stanford University for their helpful discussions.

## 6 Theoretical Appendix

In this appendix, I develop a simple game-theoretic model that captures the essence of corporate welfarism. In the first section, I model spot contracting and corporate welfarism as two equilibria of the repeated game between the firm and workers with non-contractable human capital, and examine the existence and efficiency of these equilibria. In the second section, I introduce an exogenous shock that changes a parameter of the repeated game, and explore its impact on equilibrium selection. In the third section, I endogenize the contractability of human capital to introduce an option to write an explicit contract. It is shown that once an explicit contract is developed, it may eliminate an implicit contract equilibrium. The results indicate a role of history in the equilibrium selection and the irreversibility of the institutional change due to the endogenous investment in complementary assets.

### 6.1 Repeated Employment Game

#### 6.1.1 Basic Stage Game

Assume that there is an infinitely-lived firm who owns productive assets and employs workers.<sup>143</sup> Using an overlapping generations framework, each worker is assumed to work for two periods, in which he is referred to as “young” and “old.” Workers contribute two types of labor inputs; contractable and non-contractable. In every period, a worker chooses the level of contractable effort  $e$  and the level of non-contractable effort  $x$ . Contractable labor inputs, such as work hours and the number of pieces assembled, are verifiable to a third party and legally enforceable. By contrast, non-contractable labor inputs, such as efforts to acquire better skills or other intangible human capital (e.g., loyalty, diligence, dependability), are unverifiable. Based on historical observations, I assume that non-contractable effort increases worker’s productivity one period later, whereas contractable effort improves contemporaneous productivity. I refer to non-contractable effort  $x$  also as “skill investment” and assume that higher  $x$  leads to the formation of better skill  $s$  in the subsequent period. Assume that the firm cannot directly observe skill investment  $x$  but observes the realized skill level  $s$  one period later. Assume also that both skill and output levels are unverifiable and non-contractable. In the following analysis, I say an employment contract is *explicit* if the contract is contingent solely on contractable variables, and is *implicit* if it is contingent on non-contractable variables.<sup>144</sup>

Consider the two-period employment game (i.e., stage game) played between the firm and an individual worker. The timing of the game is as follows. At the beginning of the first period, the firm offers an employment contract to a young worker. The young worker accepts or rejects the contract. If he rejects, he has an outside option that yields  $u^0$  per period in terms of utility. If he accepts, then he enters into employment relations with the firm and chooses the effort level  $(e_1, x_1)$ . At the end of the first period, after observing the level of  $e_1$ , the firm pays monetary compensation  $m_1$  to the worker. At the beginning of the second period, the firm observes the skill level  $s_2$  of the now old worker. The firm then again offers an employment contract. The worker either rejects or accepts the offer. If he rejects, he quits the firm

---

<sup>143</sup>The following model is based largely on Kanemoto & MacLeod (1989). See also Bull (1987); MacLeod & Malcomson (1989); Baker, Gibbons & Murphy (1994) for modelling implicit contracts.

<sup>144</sup>By this definition, even if a contract is “explicitly” spelled out, it is an implicit contract when it is contingent on unverifiable variables.

and takes an outside option that yields  $u^0$ . If he accepts, then he chooses the effort level  $(e_2, x_2)$  and the firm pays compensation  $m_2$  at the end of the second period. In this model, the firm is assumed to have all the bargaining power and make a take-it-or-leave-it offer to a worker. Note that the basic results still hold if one assumes that a worker has some bargaining power and obtains a fixed share of the surplus from the firm.

A worker enjoys positive utility from monetary compensation  $m_i$  and receives disutility from exerting effort  $(e_i, x_i)$  for  $i = 1, 2$ . His objective function or lifetime utility is given by:  $U(m_1, e_1, x_1) + \delta U(m_2, e_2, x_2)$ , where  $\delta$  is his time discount factor ( $0 \leq \delta \leq 1$ ). For simplicity, I assume that the utility function is additively separable,  $U(m_i, e_i, x_i) = u(m_i) - v(e_i) - c(x_i)$ ;  $u(\cdot)$  is strictly increasing and weakly concave; each effort takes either low or high value,  $e_i \in \{e^L, e^H\}$  and  $x_i \in \{x^L, x^H\}$ ; and  $v(e^L) = 0$ ,  $c(x^L) = 0$ ,  $v(e^H) = v$ , and  $c(x^H) = c$ . If a worker chooses  $x_i^H$  (or  $x_i^L$ ) then the firm observes the skill formation  $s_{i+1}^H$  (or  $s_{i+1}^L$ ) one period later. Every young worker is assumed to have a low skill,  $s_1 = s^L$ . Whenever a worker leaves the firm, he obtains a utility  $u^0$  in an external labor market. Note that  $u^0$  is independent from  $s$  since a worker cannot credibly communicate his skill level to outside firms.

Assume that, under constant demand conditions, the firm needs a workforce of size  $N$  every period to produce a given level of output. Let  $n_1$  and  $n_2$  be the number of young and old workers employed by the firm (i.e.,  $n_1 + n_2 = N$ ). For simplicity, assume that production technology of the firm is additively separable with respect to individual workers and defined by:  $Y = n_1 f(e_1, s_1) + n_2 f(e_2, s_2)$ . The separability assumption allows us to focus on an individual employment contract in the following analysis. The firm is risk-neutral and maximizes her objective function, the sum of discounted future profits  $\Pi = \sum_{t=1}^{\infty} \rho^{t-1} \pi_t$ , where  $\rho$  is her time discount factor ( $0 \leq \rho \leq 1$ ) and the per-period expected profit is given by  $\pi_t = Y_t - n_1 m_{1t} - n_2 m_{2t}$ .

In the following analysis, I consider two types of employment contracts; short-term and long-term. A *short-term contract* is a contract offered every period that binds for one period, while a *long-term contract* extends for two periods in which the firm offers employment security to a worker, in addition to monetary compensation. In the presence of employment-at-will principle, however, it is assumed that a long-term contract is not legally binding: neither the firm nor a worker can commit herself or himself not to leave the on-going employment relations after the first period. I will examine the conditions under which these two types of employment contracts are *subgame perfect Nash equilibrium* outcomes of the employment game.

### 6.1.2 Simple Short-term Employment Contract

First, I derive an optimal short-term contract in the two-period employment game. In the second period, which is the last period for a worker, he will not invest in human capital ( $x_2 = x^L$ ) but may exert contractable effort  $e_2$ . In principle, the firm can offer a short-term contract contingent on  $e_2$  and  $s_2$ . However, the firm cannot credibly commit herself to reward on non-contractable skill  $s_2$ , since given that the skill investment has been sunk the firm can always bring the wage down to worker's outside option in the second period. The firm thus offers a simple wage contract contingent only on contractable effort  $e_2$ . As the firm maximizes her profit given worker's participation constraint, the optimal wage contract is:  $w(e^H) = w^0$  and  $w(e^L) = 0$ , where  $w^0$  is defined by  $u(w^0) - v = u^0$ .

Given the above wage contract in the second period, a worker has no incentive to invest in human capital in the first period ( $x_1 = x^L$ ). The firm offers the same simple wage contract in the first period

to induce the contractable effort  $e_1$ . Therefore, essentially there is *no* distinction between young and old workers, since their skill levels and wages are exactly the same under the simple short-term contract. Thus the composition of the workforce  $(n_1, n_2)$  does not matter. In principle, this is equivalent to the case where the firm hires  $N$  workers from the external labor market every period. The firm's profit per period under the optimal simple short-term wage contract is:  $\pi^S = N\{y(e^H, s^L) - w^0\}$ .

### 6.1.3 Implicit Long-term Employment Contract

Next, I derive an optimal long-term employment contract. In a long-term contract, the firm promises employment guarantee for two periods and offer a compensation plan contingent on contractable and non-contractable variables. I focus on the following form of compensation plan: the firm pays  $m_1^H$  if  $e_1 = e^H$  and pays zero if  $e_1 = e^L$  in the first period; in the second period, the firm pays  $m_2^H$  if  $(e_2, s_2) = (e^H, s^H)$ , pays  $m_2^L$  if  $(e_2, s_2) = (e^H, s^L)$ , and pays zero otherwise. Suppose that a worker *believes* that the firm will honor her promise (I turn to firm's incentive compatibility condition later). Then for a worker to exert high contractable effort in both periods and to invest in skill acquisition in the first period, the following conditions must hold:

$$\begin{aligned} u(m_1^H) - v - c + \delta\{u(m_2^H) - v\} &\geq u(m_1^H) - v + \delta\{u(m_2^L) - v\}, \\ u(m_1^H) - v - c + \delta\{u(m_2^H) - v\} &\geq u^0 + \delta u^0, \\ u(m_2^L) - v &\geq u^0. \end{aligned}$$

The first condition is the incentive compatibility constraint for a worker to invest in non-contractable skill in the first period. The second condition is the individual rationality constraint for the lifetime, and the third is the individual rationality constraint for the second period. When the firm has all the bargaining power, an optimal long-term contract for the firm is the one that minimizes the labor cost  $m_1^H + \rho m_2^H$  subject to the above constraints. As shown in Kanemoto and MacLeod (1989), a unique solution to the above problem is given when all the constraints are strictly binding. Using that  $u(w^0) - v = u^0$ , we obtain  $m_1^H = w^0$ ,  $m_2^L = w^0$ , and  $m_2^H$  is determined by the equation  $u(m_2^H) = u(w^0) + c/\delta$ . In other words, in the first period, a worker receives a basic wage  $w^0$  that compensates the cost of high contractable effort  $v$ . In the second period, the worker receives a higher compensation, for the firm compensates the cost of skill investment sunk in the previous period,  $c/\delta$ , in addition to the cost of contractable effort. We use the word "bonus" to refer to the amount of compensation paid to the worker above and beyond the basic wage, that is,  $b = m_2^H - w^0$ . Since the optimal level of bonus is defined by  $u(w^0 + b) = u(w^0) + c/\delta$ , it is simple to see that  $b$  has the following property.

**Proposition 1** *The optimal bonus  $b$  is increasing in the cost of human capital investment  $c$  and decreasing in a worker's time discount factor  $\delta$ .*

Under the optimal long-term contract, the firm offers employment security to every worker and every worker stays with the firm for two periods. As a result, the workforce consists of equal number of young and skilled old workers ( $n = n_1 = n_2 = N/2$ ), and the firm hires  $n$  young workers from the labor market every period. In terms of the utility, a worker obtains the lifetime utility of  $u^0 + \delta u^0$  in the long-term

contract, as in the case of the short-term contract, since the firm captures all the surplus under the assumption.

#### 6.1.4 Introducing Reputation Mechanisms

Now I turn to the firm's incentive to honor the above long-term and implicit contract. As the contract is contingent on non-contractable variable  $s$ , it has to be enforced not by the courts but by internal enforcement mechanisms. In order to formally introduce the effect of reputations, we consider the situation in which the above two-period employment game is *infinitely repeated*.<sup>145</sup> Note that, even in a repeated game setting, when a workforce is individualized and there is no information transmission mechanism among employees within and across generations, it is profitable for the firm to renege on an individual employment contract. In other words, an effective reputation mechanism requires sufficient information transmission and the coordination of expectations among workers.<sup>146</sup>

Consider, for example, an extreme trigger strategy in which, if the firm reneges on any workers today, then all the workers in the future generations will not invest in non-contractable effort. For this strategy to be implementable, each generation of workers need to possess complete knowledge of history and share the expectations over firm's future actions. More generally, assume that, if the firm reneges on at least one worker, then  $\hat{n}$  workers in every future generation will learn about the repudiation and not invest in non-contractable effort. For the firm to honor the implicit contract, it must be the case that a gain from repudiation is smaller than a loss in future. Using simplifying notations,  $y^L = f(e^H, s^L)$  and  $y^H = y(e^H, s^H)$ , we define the productivity gain from non-contractable effort relatively to contractable effort by  $\Delta y = y^L - y^H$ . Since it is optimal for the firm to renege on all the old workers if she reneges at all, firm's incentive compatibility constraint or what I call "self-enforcement (SE) condition" can be expressed as follows:

$$nb \leq \frac{\rho}{1-\rho} \hat{n} \{\Delta y - b\},$$

or equivalently,

$$b \leq \frac{\rho \hat{n}}{(1-\rho)n + \rho \hat{n}} \Delta y.$$

In a special case in which there is complete information transmission within and across generations of workers ( $\hat{n} = n$ ), the above condition simplifies to:

$$b \leq \rho \Delta y.$$

When the SE condition is satisfied, the implicit and long-term employment contract is self-enforcing. The second proposition follows immediately.

**Proposition 2** *The maximum level of self-enforcing bonus is increasing in the firm's time discount factor  $\rho$ , the degree of information transmission  $\hat{n}$ , and the return from human capital investment  $\Delta y$ .*

In particular, when workers are individualized and share no information ( $\hat{n} = 0$ ), then no bonus is self-

---

<sup>145</sup>Note that an infinitely repeated game with discounting can be interpreted as a finitely repeated game that may randomly end at any period with a given probability.

<sup>146</sup>On this point, see Greif (1989); Kandori (1992); Greif, Milgrom & Weingast (1994).

enforcing and no investment in human capital takes place. In other words, the above proposition implies that, when the degree of information transmission is low, the firm may have an incentive to facilitate coordination and communication among employees so that she can credibly commit herself not to renege. This result is in contrast to a general view that the firm always benefits from “divide and conquer” workers.

To summarize, I derived two subgame perfect Nash equilibria in the infinitely repeated basic employment game.<sup>147</sup> The *Simple Contract Equilibrium* (SCE) is characterized by (1) short-term employment relations, (2) high contractable effort  $e^H$  and low human capital investment  $x^L$ , (3) the basic wage paid to every worker  $w^0$ . The lifetime utility of a worker is  $u^0 + \delta u^0$  and the firm earns  $\pi^S = 2n(y^L - w^0)$  every period.

The *Implicit Contract Equilibrium* (ICE), on the other hand, is characterized by (1) long-term employment relations, (2) high contractable effort  $e^H$  and high human capital investment  $x^H$ , (3) the bonus paid  $b$  to old workers in addition to the basic wage  $w^0$ , (4) the presence of “mutual trust” between the firm and workers, in which the firm expects workers to invest in human capital and workers expect the firm to reward such investment. The implicit contract is internally enforced by a reputation mechanism, in which the firm’s history is communicated across generations of workers (i.e., sufficiently high  $\hat{n}$ ). A worker receives the lifetime utility of  $u^0 + \delta u^0$ , while the firm earns  $\pi^I = n(y^L + y^H - 2w^0 - b)$  every period.

### 6.1.5 Existence and Efficiency of the Two Equilibria

I henceforth derive the conditions under which the SCE and ICE exist and examine efficiency implications comparing the two equilibria. In the following derivation, I assume a linear utility function,  $u(m) = m$ , to obtain closed form solutions  $w^0 = u^0 + v$  and  $b = c/\delta$ . I also assume complete information transmission,  $\hat{n} = n$ , in which the SE condition simplifies to  $b \leq \rho\Delta y$ .

First, consider a world with *no* contractual problem. Investment in human capital is socially desirable whenever the return from such investment exceeds its cost:

$$\Delta y \geq c.$$

This is the condition for the human capital investment to be efficient. However, the firm prefers the implicit contract to the simple contract only if the former is more profitable. That is, the firm will offer the implicit contract only if  $\pi^I \geq \pi^S$  or

$$\Delta y \geq \frac{c}{\delta}.$$

Even if the firm prefers to offer the implicit contract, the firm has an incentive to renege on the contract ex post. For the implicit contract to be self-enforcing, the SE condition must also be satisfied:

$$\rho\Delta y \geq \frac{c}{\delta}.$$

In other words, unless the SE condition holds, the ICE does not exist. On the other hand, the SCE exists as long as the profit is non-negative, that is,  $y^L - (v + u^0) \geq 0$ .

---

<sup>147</sup>As implied by the Folk Theorems, there are continuum of other subgame perfect Nash equilibria.

Let us define an *equilibrium support* as the set of parameter values under which an equilibrium in consideration exists. Denote a set of parameters in the basic employment game by  $\phi = (u^0, \rho, \delta, c, v, \Delta y)$ . The equilibrium support of the ICE is given by the non-negative profit and SE conditions:

$$\text{Support}(ICE) = \{\phi \mid y^L + y^H - \frac{c}{\delta} - (v + u^0) \geq 0 \text{ and } \rho\Delta y \geq \frac{c}{\delta}\}.$$

The equilibrium support of SCE is given by:

$$\text{Support}(SCE) = \{\phi \mid y^L - (v + u^0) \geq 0\}.$$

I assume that the support of the SCE is nonempty. In general, if the area of support in the parameter space is larger, an equilibrium is more stable (i.e., continue to exist) with respect to the perturbation of parameters. When an equilibrium has a small support, a small change in the parameters may eliminate the equilibrium. The following proposition summarizes the results concerning the existence and efficiency of the equilibria (see also Figure 1).

**Proposition 3** (1) If  $c \geq \Delta y$  then the SCE exists but the ICE does not. The firm offers the simple short-term contract and the SCE is efficient. (2) If  $c \in [\delta\Delta y, \Delta y]$  then the SCE exists but the ICE does not. The firm offers the simple short-term contract but the SCE is inefficient. (3) If  $c \in [\delta\rho\Delta y, \delta\Delta y]$  then the SCE exists but the ICE does not. The firm prefers the implicit contract to the simple contract, but the implicit contract is not self-enforcing. The SCE is inefficient. (4) If  $c \leq \delta\rho\Delta y$  then both SCE and ICE exist. The firm prefers the implicit contract to the simple contract and the ICE is efficient, while the SCE is inefficient.

A few remarks are in order. First, in the cases (2) and (3) above, the first-best outcome cannot be attained by either of the two contracts due to the fact that  $x$  is observed by the firm only through  $s$  one period later. Second, when the ICE exists it is always efficient. This result, however, hinges on the assumption of binary investment choices. More generally, if the human capital investment  $x$  is a continuous variable, there may exist inefficient ICE that implements a suboptimal level of  $x$ .<sup>148</sup> Third, the case (4) above implies that under the conditions in which the ICE exists the SCE also exists. That is, the firm and workers face the situation of *multiple equilibria*. It is important to note that the firm cannot unilaterally “select” an equilibrium in the presence of multiple equilibria. Even if the firm offers the implicit contract that is self-enforcing, the ICE may not be realized *depending on workers’ beliefs*. If workers believe that the firm will not honor her implicit contract, the contract unravels and the outcome degenerates to the SCE. Finally, the support of the ICE is larger, if the time discount factors  $\rho$  and  $\delta$  are closer to one or if the return from the human capital investment  $\Delta y$  is higher. This result is consistent with a historical observation that implicit contracts were increasingly adopted as the firm size grew and technological progress raised the return from corporate training and education. In the following analysis, I explore implications of the multiplicity of the equilibria and the dependence of the equilibrium support on the firm’s discount factor.

---

<sup>148</sup>See, for example, the results in Baker et al. (1994), Section II.

## 6.2 Exogenous Shocks and Equilibrium Selection

Building on the repeated employment game developed above, in this section, I introduce a sequence of shocks that exogenously change the parameters and examine their impact on equilibrium selection.

Suppose that there are a continuum of heterogeneous firms in the economy indexed by  $j$ , where  $j \in [0, 1]$ . For simplicity, I assume that firms differ only in their time discount factors  $\rho_j$  and that  $\rho_j$  is distributed according to a density function  $g(\cdot)$  defined over a unit interval  $[0, 1]$ . Define the *threshold value* of  $\rho$  that satisfies the SE condition:

$$\rho^* = \frac{c}{\delta \Delta y}.$$

To simplify the presentation, I consider the situation in which, as an outcome of the repeated employment game, in every firm in the economy whose discount factor is greater than or equal to  $\rho^*$ , the employer and workers play the ICE strategies,<sup>149</sup> whereas in the rest of the firms the employers and workers play the SCE strategies (see Figure 2).

### 6.2.1 Repudiation of Implicit Employment Contracts

Suppose that an exogenous and unanticipated shock shifts the density function of  $\rho$  permanently to the left,  $g(\cdot) \rightarrow g'(\cdot)$ .<sup>150</sup> The employer and workers in the firm  $j$  now face a new repeated game defined by a lower discount factor  $\rho'_j$ . Observe that, for the firms whose discount factors fall below  $\rho^*$ , the ICE strategies *no longer* constitute a subgame perfect Nash equilibrium in the new game. The employers in these firms therefore rationally repudiate the implicit contract (or equivalently, dismiss old workers without paying bonus) and switch to the simple short-term contract thereafter. Accordingly, workers in these firms revise their beliefs and the future generations of workers will choose not to invest in non-contractable effort ever after. By contrast, for the firms whose discount factors remain above  $\rho^*$ , the ICE strategies continue to be an equilibrium in the new game. Thus I obtain the following result (see also Figure 3).

**Proposition 4** *Suppose that the density function shifts from  $g(\cdot)$  to  $g'(\cdot)$ . Then in every firm  $j$  such that  $\rho'_j < \rho^* \leq \rho_j$  the equilibrium switches from the ICE to the SCE; while in every firm  $j$  for which  $\rho'_j \geq \rho^*$  the equilibrium remains to be the ICE.*

In other words, induced by the exogenous shock, the fraction  $\int_{\rho^*}^1 g(\rho) d\rho - \int_{\rho^*}^1 g'(\rho) d\rho$  of the firms in the economy repudiate their implicit contracts. If the magnitude of the shock (measured by the size of the shift of the distribution function) is bigger, a larger fraction of the firms in the economy abandon the implicit contract.

---

<sup>149</sup>That is, I implicitly assume that players' expectations are coordinated on the ICE in the presence of other equilibria.

<sup>150</sup>For analytical simplicity, I assume that a shock is unforeseeable by the players. Alternatively, retaining the assumption of perfect foresight, one can introduce a shock that arrives at every period with a given probability. I conjecture that similar results should follow when the probability of such event is sufficiently small.

## 6.2.2 A Role of History in Equilibrium Selection

Now suppose that an exogenous and unanticipated shock subsequently shifts the density function back to the right,  $g'(\cdot) \rightarrow g''(\cdot)$ . The employer and workers in the firm  $j$  now face a new repeated game defined by a higher time discount factor  $\rho_j''$ . For the firms whose discount factors exceed  $\rho^*$ , the ICE becomes a subgame perfect Nash equilibrium of the new game. However, in those firms who have repudiated the implicit contract and switched to the simple contract in the previous game, the employers and workers may continue to play the SCE strategies *regardless* of the existence of the ICE, as the SCE itself continues to be a subgame perfect Nash equilibrium in the new game (see Figure 4). This result can be summarized as follows.

**Proposition 5** *Suppose that the density function shifts from  $g'(\cdot)$  to  $g''(\cdot)$ . In every firm, the equilibrium may remain the same. In particular, in every firm  $j$  such that  $\rho_j'' > \rho^*$  and  $\rho_j' \leq \rho^*$ , the equilibrium may continue to be the SCE, despite the existence of more efficient ICE.*

In other words, even if the ICE becomes feasible in the new game, the equilibrium does not necessarily return to the ICE. In particular, if the players form beliefs over one another's actions, given the beliefs inherited from the equilibrium outcome of the previous game, the players are likely to play the SCE strategies in the new game.<sup>151</sup> Moreover, note that to repudiate the implicit contract it is sufficient for one party to deviate, whereas to return to the ICE it requires both parties to move simultaneously to the implicit contract. Neither the formation of beliefs nor coordination cost, however, is formally incorporated in the repeated game theory, offering little insight to the question of equilibrium selection in the presence of multiple equilibria. The above proposition suggests that history may play an important role in coordinating players' expectations, and consequently, there is possible *irreversibility* in the equilibrium selection even if the conditions brought about by an exogenous shock is subsequently reversed.

## 6.3 The Introduction of Explicit Employment Contract

### 6.3.1 Extended Stage Game

In this section, I extend the basic employment game to endogenize the contractability of human capital based on Baker (2000). Allowing the firms to have an option to invest in developing a “better” explicit employment contract, I examine their incentives to make such investments and show that the introduction of explicit contract may eliminate more efficient implicit employment contract.<sup>152</sup>

In the basic employment game, I assumed that the contractability of labor inputs is exogenously fixed. Now suppose that the firm can introduce a “monitoring technology” at a fixed cost  $K$  that produces a contractable proxy  $z$  for non-contractable skill  $s$ . For example, the firm may install a formal system to certify employees' skill levels or adopt a standardized method of objective performance evaluation. I assume that  $z$  is verifiable to a third party, yet it is an *imperfect* and often distortionary measure of  $s$ . Assume that  $s$  and  $z$  take either high or low value:  $s \in \{s^L, s^H\}$  and  $z \in \{z^L, z^H\}$ . Note that only  $s$

---

<sup>151</sup>See the experimental results of Van Huyck, Cook & Battalio (1997) and Camerer & Knez (2000) that support this point.

<sup>152</sup>For important works that examine the interactions of explicit and implicit contracts, see Baker et al. (1994); Schmidt & Schinitzer (1995).

(not  $z$ ) affects the level of output, i.e.,  $y^L = f(e^H, s^L)$  and  $y^H = y(e^H, s^H)$ . I continue to assume that the output level is non-contractable. Assume that the level of skill investment  $x$  in the first period will affect probabilities of  $s = s^H$  and  $z = z^H$  in the second period as follows.<sup>153</sup> Departing from the previous assumption, let  $x$  be a two-dimensional vector,  $x = (x_1, x_2) \in \mathfrak{R}_+^2$ . Assume that

$$Pr(s = s^H \mid x_1, x_2) = \alpha_1 x_1 + \alpha_2 x_2$$

and

$$Pr(z = z^H \mid x_1, x_2) = \beta_1 x_1 + \beta_2 x_2,$$

in which both  $\alpha = (\alpha_1, \alpha_2)$  and  $\beta = (\beta_1, \beta_2)$  are normalized to be unit vectors;  $\|\alpha\| = \|\beta\| = 1$ . Namely,  $\alpha$  (or  $\beta$ ) is a vector of marginal contributions of  $x$  to the realization of high value of  $s$  (or  $z$ ). If  $\alpha = \beta$  then obviously  $z$  is a perfect proxy for  $s$ . If they differ, however, then an explicit contract based on objective evaluation  $z$  provides distorted incentives in inducing optimal  $x$ . Let  $\theta$  be the angle between the two vectors  $\alpha$  and  $\beta$  and define  $\cos \theta$  as a parameter of “incentive alignment” (see Figure 5). If  $\cos \theta$  is closer to one, then  $z$  is more aligned with and thus a better measure of  $s$ . In the extreme case in which  $\alpha$  is orthogonal to  $\beta$  or  $\cos \theta = 0$ , an explicit contract based on the proxy will not induce high skill level. For example, when the firm uses seniority (i.e., firm-specific tenure) as a proxy for skill in promoting workers, workers may not have any incentive to invest in skill acquisition. For the rest of the analysis, I assume a liner utility function,  $u(m) = m$ ; a quadratic cost function for the skill investment,  $c(x) = \frac{1}{2}(x_1^2 + x_2^2)$ ; and the case of complete information transmission,  $\hat{n} = n$ .

As a benchmark, I first derive the first-best skill investment. Note that the expected social surplus generated by the investment  $x$  is

$$E[f(s(x), e) - c(x)].$$

Recalling that  $Pr(y = y^H) = Pr(s = s^H) = \alpha_1 x_1 + \alpha_2 x_2$ , it can be rewritten as:

$$(\alpha_1 x_1 + \alpha_2 x_2)y^H + (1 - \alpha_1 x_1 - \alpha_2 x_2)y^L - \frac{1}{2}(x_1^2 + x_2^2).$$

Taking the first-order conditions, the socially optimal level of  $x$  is given by:

$$x_1^* = \alpha_1 \Delta y, x_2^* = \alpha_2 \Delta y.$$

In other words, at the first-best level, the marginal cost is equal to the marginal contribution of the skill investment (see Figure 6). I now examine an optimal simple short-term contract, an optimal implicit long-term contract, and an optimal explicit contract in the extended employment game.

### 6.3.2 Simple Short-term Employment Contract

The optimal short-term contract when the firm does *not* adopt monitoring technology is identical to the simple contract in the basic stage game. That is, to every worker, in every period, the firm offers a simple wage contract contingent only on the contractable effort and the optimal short-term contract

---

<sup>153</sup>Note that two-dimensional effort is necessary in modelling a distortionary incentive, as a stochastic proxy is not sufficient in generating distortion when workers are risk neutral.

is characterized by  $w(e^L) = 0$  and  $w(e^H) = w^0 = u^0 + v$ . The equilibrium skill investment under the optimal simple short-term contract is  $x_1^S = 0$  and  $x_2^S = 0$ .

### 6.3.3 Implicit Long-term Employment Contract

In an implicit long-term contract, the firm promises a young worker employment security for two periods and offers a compensation plan contingent on both contractable and non-contractable variables;  $(m_1(e_1), m_2(e_2, s_2))$ . In particular, the firm offers “implicit bonus”  $b$  if  $s = s^H$  and zero if  $s = s^L$  in the second period, in addition to a contractual wage. I first derive a worker’s optimal choice of  $x$  given the implicit bonus, assuming that he “trusts” the firm to honor the implicit long-term contract. A worker maximizes his expected lifetime utility:

$$E[m_1(e_1) - v(e_1) - c(x) + \delta\{m_2(e_2, s_2(x)) - v(e_2)\}].$$

With respect to  $x$ , this is equivalent to maximize

$$-\frac{1}{2}(x_1^2 + x_2^2) + \delta\{(\alpha_1 x_1 + \alpha_2 x_2)b\}.$$

From the first order conditions, I obtain

$$x_1(b) = \delta\alpha_1 b, x_2(b) = \delta\alpha_2 b.$$

The firm chooses an optimal level of implicit bonus that maximizes her expected per-period profit subject to incentive compatibility and participation constraints of a worker. Under the assumption of linear utility, this is equivalent for the firm to maximize total surplus accrued from the skill investment given the incentive compatibility constraint. Noting that the effective cost of the skill investment borne by a worker is  $c(x)/\delta$ , as the investment takes place in the previous period, the expected total surplus is

$$E[f(s_2(x), e_2) - c(x)/\delta].$$

Therefore, an optimal  $b$  is the one that maximizes

$$(\alpha_1 x_1 + \alpha_2 x_2)y^H + (1 - \alpha_1 x_1 - \alpha_2 x_2)y^L - \frac{1}{2\delta}(x_1^2 + x_2^2)$$

*subject to* the incentive compatibility constraints,  $x_1 = \delta\alpha_1 b$  and  $x_2 = \delta\alpha_2 b$ . From the first-order conditions, the optimal implicit bonus is

$$b = \Delta y.$$

Accordingly, the skill investment induced by the optimal implicit contract is  $x_1^I = \delta\alpha_1 \Delta y$  and  $x_2^I = \delta\alpha_2 \Delta y$ .<sup>154</sup> Note that  $x^I$  is smaller than the first-best investment  $x^*$  (see Figure 6). The inefficiency results from the fact that the firm can compensate a worker for the skill investment only one period later, creating a discrepancy between the social and private costs of skill investment.

---

<sup>154</sup>Note that  $x^I$  is indeed a solution to the unconstrained maximization problem defined above, i.e., the incentive compatibility constraints are not binding.

Since the bonus is contingent on the non-verifiable variable, for the above implicit contract to be a subgame perfect equilibrium, the self-enforcement (SE) condition must be satisfied in the infinitely repeated game setting. I will elaborate on the SE condition later.

### 6.3.4 Explicit Employment Contract

I now derive an optimal explicit employment contract when the firm installs the monitoring technology. In the first period, the firm offers an explicit wage contract contingent on the contractable effort  $w_1(e_1)$ , which is identical to the optimal simple contract. In the second period, the firm offers an explicit wage contract contingent on the contractable effort and proxy, i.e.,  $w_2(e_2, z_2)$ . In particular, the firm offers “wage premium”  $w^p$  if  $z = z^H$  and zero if  $z = z^L$ . Consider a worker’s optimal choice of  $x$  given the explicit wage contract. A worker maximizes his expected utility:

$$E[w_1(e_1) - v(e_1) - c(x) + \delta\{w_2(e_2, z_2(x)) - v(e_2)\}].$$

Recalling that  $Pr(z = z^H) = \beta_1 x_1 + \beta_2 x_2$ , in selecting  $x = (x_1, x_2)$ , it is equivalent for a worker to maximize

$$-\frac{1}{2}(x_1^2 + x_2^2) + \delta\{(\beta_1 x_1 + \beta_2 x_2)w^p\}.$$

From the first-order conditions,

$$x_1(w^p) = \delta\beta_1 w^p, x_2(w^p) = \delta\beta_2 w^p.$$

Similarly to the case in the implicit contract, the firms sets the wage premium to maximize the expected total surplus accrued from the skill investment,

$$(\alpha_1 x_1 + \alpha_2 x_2)y^H + (1 - \alpha_1 x_1 - \alpha_2 x_2)y^L - \frac{1}{2\delta}(x_1^2 + x_2^2)$$

*subject to* the incentive compatibility constraints,  $x_1 = \delta\beta_1 w^p$  and  $x_2 = \delta\beta_2 w^p$ . I thus obtain the optimal wage premium

$$w^p = \Delta y \frac{\alpha_1 \beta_1 + \alpha_2 \beta_2}{\beta_1^2 + \beta_2^2} = \Delta y \cos \theta.$$

The last equation follows from  $\alpha_1 \beta_1 + \alpha_2 \beta_2 = \|\alpha\| \|\beta\| \cos \theta$  and  $\|\alpha\| = \|\beta\| = 1$ . The skill investment induced by the optimal explicit contract is  $x_1^E = \delta\beta_1 \Delta y \cos \theta$  and  $x_2^E = \delta\beta_2 \Delta y \cos \theta$ . Note that, depending on the relative size of  $\alpha$  and  $\beta \cos \theta$ ,  $x^E$  is not necessarily smaller than  $x^I$ . When  $\alpha = \beta$  and thus  $\cos \theta = 1$ , the optimal explicit contract coincides with the optimal implicit contract, i.e,  $b = w^p$  and  $x^I = x^E$ . Unlike the implicit contract, however, the explicit contract is legally enforced and does not require reputation mechanisms. When  $\cos \theta$  is closer to zero and  $z$  is more distortionary measure of  $s$ , the level of skill investment implementable by the explicit contract becomes smaller. In short, the advantage of the explicit contract over the implicit contract is that it does not incur the cost of internal enforcement, while it incurs the cost of imperfect proxy.

### 6.3.5 Efficiency Comparison of the Three Equilibria

In the above, I derived three subgame perfect Nash equilibria in the extended employment game, to which I refer as the *simple contract equilibrium* (SCE), the *implicit contract equilibrium* (ICE), and the *explicit contract equilibrium* (ECE). In comparing the efficiency of these equilibria, observe that a young worker always generates surplus of  $y^L - (v + u^0)$  in the respective equilibria. I thus focus on comparing the surplus created by an old worker. As the following proposition claims, although one cannot unambiguously rank the equilibrium levels of skill investment  $x$ , one can rank the levels of surplus and thus the efficiency of the three equilibria.

**Proposition 6** *The expected outputs and expected joint surplus generated by the firm and an old worker in the three equilibria can be ranked in the following order:  $Ey^S \leq Ey^E \leq Ey^I \leq Ey^*$  and  $S^S \leq S^E \leq S^I \leq S^*$ .*

Intuitively speaking, the expected joint surplus is larger in the ICE than in the ECE because  $x^I$  is in fact a solution to the *unconstrained* maximization of the expected surplus  $E[f(s_2(x), e_2) - c(x)/\delta]$ , while  $x^E$  is a solution to the *constrained* maximization of the same function. The constraint of the latter arises from the distorted incentives given to a worker. Below, I derive closed-form solutions for the respective equilibria that formally prove the above proposition.

Recall that, in the first-best outcome,  $x^* = (\alpha_1 \Delta y, \alpha_2 \Delta y)$ . The probability of realizing the high output is thus  $Pr(y = y^H | x^S) = \alpha_1 x_1^* + \alpha_2 x_2^* = \Delta y$ . The expected output of a “skilled” old worker is  $Ey^* = (\Delta y)^2 + y^L$ , while the cost of exerting  $x^*$  is  $c(x^*) = \frac{1}{2} \Delta y^2$ . Consequently, the social surplus generated by an old worker in the first-best outcome is:

$$S^* = Ey^* - c(x^*) - (v + u^0) = \frac{1}{2} \Delta y^2 + y^L - (v + u^0).$$

In the SCE,  $x^S = (0, 0)$  and  $Pr(y = y^H | x^S) = 0$ . The joint surplus generated by the firm and an old but “unskilled” worker is:

$$S^S = y^L - (v + u^0).$$

In the ICE,  $x^I = (\delta \alpha_1 \Delta y, \delta \alpha_2 \Delta y)$  and  $Pr(y = y^H | x^I) = \delta \Delta y$ . The expected output of an old worker is  $Ey^I = \delta \Delta y^2 + y^L$  and the cost of skill investment is  $c(x^I) = \frac{\delta}{2} \Delta y^2$ . The joint surplus generated by the firm and an old worker in the ICE is thus:

$$S^I = \frac{\delta}{2} \Delta y^2 + y^L - (v + u^0).$$

Lastly, in the ECE,  $x^E = (\delta \beta_1 \Delta y \cos \theta, \delta \beta_2 \Delta y \cos \theta)$  and  $Pr(y = y^H | x^E) = \delta \Delta y \cos^2 \theta$ . The expected output of an old worker is  $Ey^E = \delta \Delta y^2 \cos^2 \theta + y^L$  and the cost of skill investment is  $c(x^E) = \frac{\delta}{2} \Delta y^2 \cos^2 \theta$ . The joint surplus generated by the firm and an old worker in the ECE is:

$$S^E = \frac{\delta}{2} \Delta y^2 \cos^2 \theta + y^L - (v + u^0).$$

Note that the fixed cost  $K$  incurred by the firm to install monitoring technology is not taken into account in the definition of  $S^E$ . It is simple to observe that, as  $\cos \theta$  approaches to one,  $S^E$  approaches to  $S^I$  and, as  $\cos \theta$  approaches to zero,  $S^E$  converges to  $S^S$ .

### 6.3.6 Adoption of Monitoring Technology

Using the above results, I examine the firm's incentive to invest in the monitoring technology and initiate the explicit employment contract. Consider again the economy with heterogeneous firms indexed by  $j$  whose discount factor is  $\rho_j$ . I assume that the cost of installing monitoring technology  $K$  is constant across firms. In the following analysis, I consider the situation in which, due to the exogenous shift in the distribution function,  $g(\cdot) \rightarrow g'(\cdot)$ , a majority of the firms in the economy repudiated the implicit contract and switched from the ICE to the SCE. Assume that the players do not anticipate any subsequent shock.

First, take a firm in which an employer and workers are currently playing the ICE strategies. The employer will invest in the monitoring technology if and only if switching from the implicit contract to the explicit contract is more profitable. Recall that the firm employs  $n$  young workers and  $n$  old workers; recall also that the firm extracts all the surplus in the optimal employment contracts. The expected per-period profit of the firm  $j$  in the ICE is

$$E\pi^I = n\left\{\frac{\delta}{2}\Delta y^2 + y^L - (v + u^0)\right\} + n\{y^L - (v + u^0)\}.$$

Clearly,  $E\pi^I \geq E\pi^E$  for any parameter values of  $n, \delta, \Delta y$  and  $\cos\theta$ , if  $K$  is strictly positive.

Next, consider a firm who is playing the SCE strategies. This firm will adopt the monitoring technology and switch from the simple contract to the explicit contract *provided* the latter is more profitable than the former. The expected per-period profit of the firm  $j$  in the ECE is thus

$$E\pi^E = n\left\{\frac{\delta}{2}\Delta y^2 \cos^2\theta + y^L - (v + u^0)\right\} + n\{y^L - (v + u^0)\} - (1 - \rho'_j)K,$$

while the expected per-period profit of the firm  $j$  in the SCE is

$$E\pi^S = 2n\{y^L - (v + u^0)\}.$$

It is simple to show that  $E\pi^E \geq E\pi^S$  if and only if  $\rho'_j \geq \hat{\rho}$ , where the threshold value of discount factor  $\hat{\rho}$  is defined by:

$$\hat{\rho} = 1 - \frac{n\delta\Delta y^2 \cos^2\theta}{2K}$$

The above results can be summarized as follows (see also Figure 7).

**Proposition 7** *Suppose that a monitoring technology with fixed cost  $K$  becomes available under the density function  $g'(\cdot)$ . In every firm  $j$  such that  $\rho'_j \geq \rho^*$ , the equilibrium remains to be the ICE as the firm has no incentive to invest in the monitoring technology for any  $K > 0$ . In every firm  $j$  such that  $\hat{\rho} \leq \rho'_j < \rho^*$ , the technology is adopted and the equilibrium switches from the SCE to the ECE; whereas in every firm  $j$  such that  $\rho'_j < \hat{\rho}$ , the equilibrium remains to be the SCE. The threshold discount factor for technology adoption  $\hat{\rho}$  decreases, as the degree of incentive alignment  $\cos\theta$  improves and the fixed cost  $K$  declines.*

In other words, if the monitoring technology becomes available, then the fraction  $\int_{\hat{\rho}}^{\rho^*} g'(\rho)d\rho$  of the firms in the economy will install the technology and switch to the explicit contract. The better and less expensive is the monitoring technology, more firms will adopt it. On the other hand, those firms who maintain the implicit contract will not invest in such technology regardless of its quality and price.

### 6.3.7 Irreversibility of Equilibrium Selection

Now, I turn to the self-enforcement (SE) conditions in the extended employment game and explore the impact of introducing explicit contract on the feasibility of implicit contract. First, consider the case in which the monitoring technology does not exist. In this case, as in the basic game, when the firm reneges on the implicit contract, the employer and workers switch to the simple contract – the worst equilibrium outcome in the stage game – ever after. The SE condition *without* monitoring technology is thus given by:

$$nb \leq \frac{\rho}{1-\rho} \{E\pi^I - E\pi^S\},$$

or equivalently,

$$b \leq \frac{\rho}{1-\rho} \frac{\delta}{2} \Delta y^2.$$

Let us define the threshold value of firm's discount factor  $\rho^*$  that satisfies the above condition with equality. Recalling that  $b = \Delta y$ , I obtain a closed-form solution:

$$\rho^* = \frac{1}{1 + \frac{\delta}{2} \Delta y}.$$

Now suppose that the monitoring technology becomes available. Then, once the implicit contract is broken, the firm has an option to adopt the technology and switch to the explicit and legally enforceable employment contract thereafter. Note that the firm prefers to do so when the explicit contract is more profitable than the simple contract, i.e.,  $\rho \geq \hat{\rho}$ . The SE condition *with an option* for installing monitoring technology is then given by:

$$nb \leq \frac{\rho}{1-\rho} \{E\pi^I - E\pi^E\},$$

or equivalently,

$$b \leq \frac{\rho}{1-\rho} \frac{\delta}{2} \Delta y^2 (1 - \cos^2 \theta) + \frac{\rho K}{n}.$$

Define the threshold value of  $\rho^{**}$  at which the above condition holds with equality, which is given by:

$$\rho^{**} = \frac{1}{1 + \frac{\delta}{2} \Delta y (1 - \cos^2 \theta) + \frac{K}{n \Delta y}}$$

Lastly, consider the case in which the firm has *sunk* the investment in monitoring technology and are currently playing the ECE strategies. In this case, when the players try to return to the ICE, their fallback positions after the repudiation of implicit contract are given by the explicit contract. Thus the SE condition *with* monitoring technology *in place* is:

$$b \leq \frac{\rho}{1-\rho} \frac{\delta}{2} \Delta y^2 (1 - \cos^2 \theta).$$

Define the threshold value of  $\rho^{***}$  at which the above condition holds with equality, which is given by:

$$\rho^{***} = \frac{1}{1 + \frac{\delta}{2} \Delta y (1 - \cos^2 \theta)}$$

Obviously,  $\rho^{**} < \rho^{***}$  holds. The following proposition follows.

**Proposition 8** *The threshold discount factors for the SE conditions  $\rho^{**}$  and  $\rho^{***}$  rise as the degree of incentive alignment  $\cos\theta$  increases. For any  $\cos\theta > 0$  and  $K > 0$ ,  $\rho^* < \rho^{***}$ . If  $\cos\theta$  is high,  $K$  small, and  $n$  large, then  $\rho^* < \rho^{**}$ .*

The proposition indicates that, once the monitoring technology is in place it is difficult for the firm to return to the ICE, as the existence of the technology undermines the self-enforceability of the implicit contract (i.e.,  $\rho^* < \rho^{***}$ ). There also is a possibility that the availability of the technology per se undermines the existence of the ICE (i.e.,  $\rho^* < \rho^{**}$ ). This case follows only if the quality of monitoring technology is sufficiently high and there are sufficient scale economies in adopting the technology.

In short, the introduction of explicit contracts based on a contractable but imperfect objective measure may *replace* more efficient implicit contract. Consider the situation in which, after the firms installed the monitoring technology under  $g'(\cdot)$ , the distribution function shifts back to the right from  $g'(\cdot)$  to  $g''(\cdot)$  (see Figure 8). Now with the monitoring technology, the fraction  $\int_{\hat{\rho}}^{\rho^{***}} g''(\rho)d\rho$  of the firms in the economy remains to be in the ECE, as the ICE is no longer an option for these firms (see Figure 9). This result indicates that, once the ICE breaks down due to an exogenous shock, the endogenous adoption of monitoring technology (or more generally, investment in complementary assets) may create *irreversibility* in the process of equilibrium selection.

One must note, however, that the firm may choose to “dismantle” the monitoring technology in order to realize the more efficient ICE. There are a few reasons that this may not follow. First, dismantling the technology itself may be costly. Second, although removing the technology will eliminate the ECE and revive the ICE, the equilibrium may go back to the SCE, instead of the ICE, depending on workers’ beliefs. Third, under the explicit contract, old workers in the firm have invested in  $x$  to attain a high value of  $z$ . As these workers have vested interests in keeping the current contractual regime, they may block the firm’s attempt to abolish the explicit contract.

## References

- Baker, G. (2000), Distortion and risk in optimal incentive contracts, mimeography, Harvard Business School.
- Baker, G., Gibbons, R. & Murphy, K. J. (1994), ‘Subjective performance measures in optimal incentive contracts’, *Quarterly Journal of Economics* **109**, 1125–1156.
- Bull, C. (1987), ‘The existence of self-enforcing implicit contracts’, *Quarterly Journal of Economics* **102**, 147–159.
- Greif, A. (1989), ‘Reputation and coalitions in medieval trade: Evidence on the maghribi traders’, *Journal of Economic History* **49**, 857–872.
- Greif, A., Milgrom, P. & Weingast, B. (1994), ‘Coordination, commitment, and enforcement: The case of the merchant guild’, *Journal of Political Economy* **102**(4), 745–776.
- Holmström, B. & Milgrom, P. (1991), ‘Multitask principal-agent analyses: Incentive contracts, asset ownership, and job design’, *Journal of law, economics, and organization* **7**, 24–52.
- Kandori, M. (1992), ‘Repeated games played by overlapping generations of players’, *Review of Economic Studies* **59**, 81–92.
- Kanemoto, Y. & MacLeod, B. (1989), ‘Optimal labor contract with non-contractible human capital’, *Journal of the Japanese and International Economies* **3**, 385–402.
- MacLeod, B. & Malcomson, J. (1989), ‘Implicit contracts, incentive compatibility, and involuntary unemployment’, *Econometrica* **57**(2), 447–480.
- Schmidt, K. & Schinitzer, M. (1995), ‘The interaction of explicit and implicit contracts’, *Economics Letters* **48**, 193–199.

## Figures for Theoretical Appendix

Figure 1: Existence and Efficiency of Equilibria

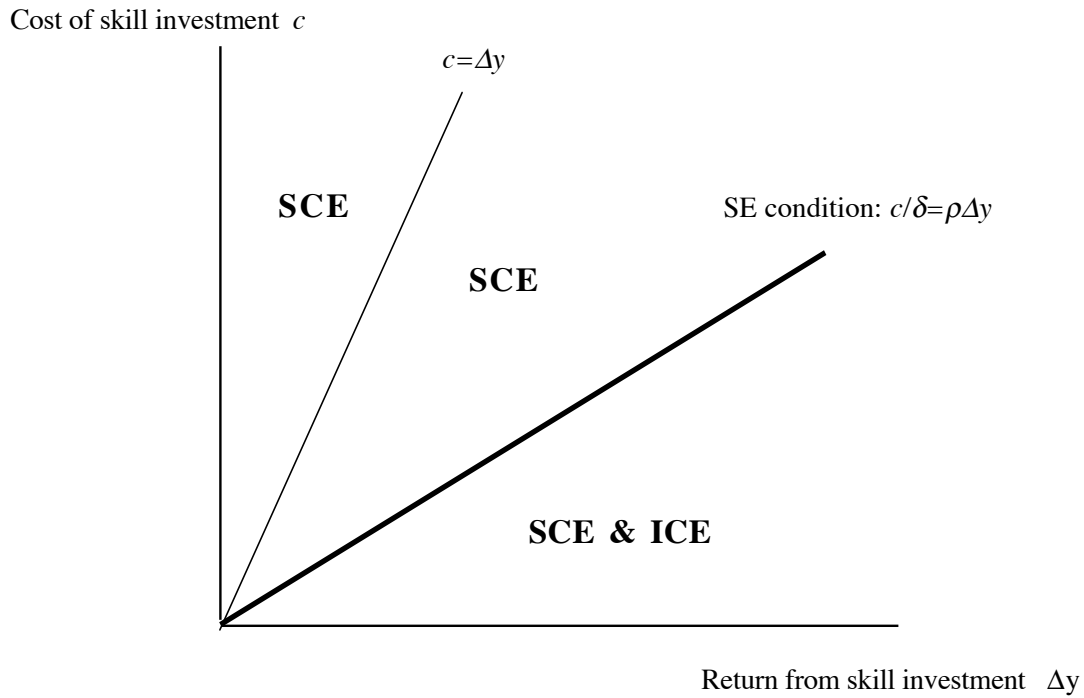
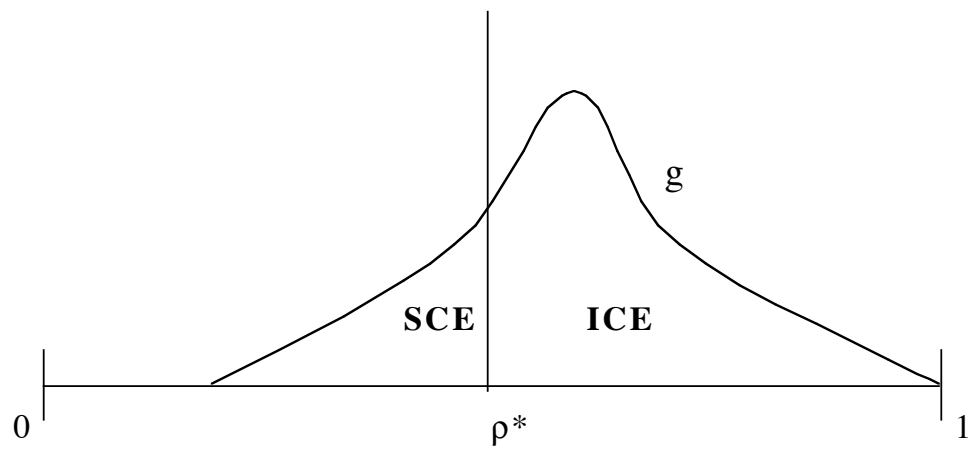
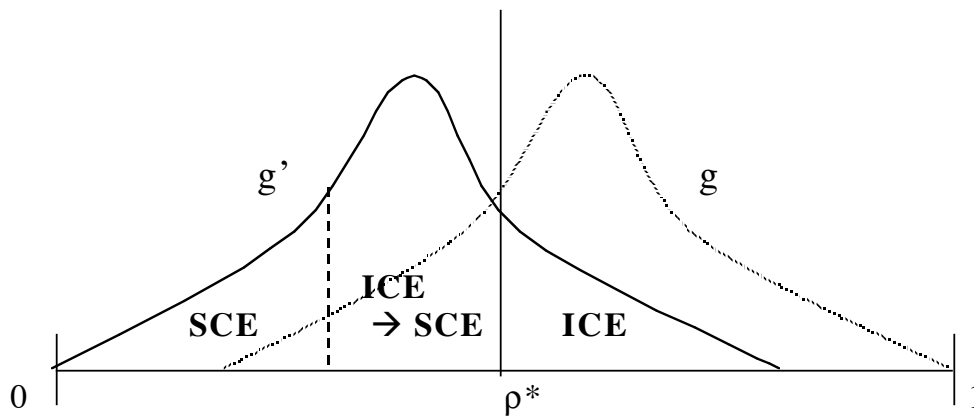


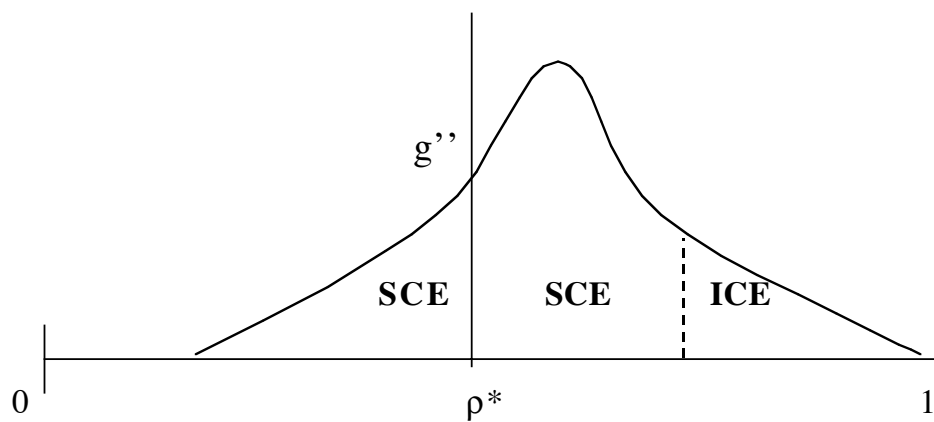
Figure 2: Distribution of Firms' Discount Factors



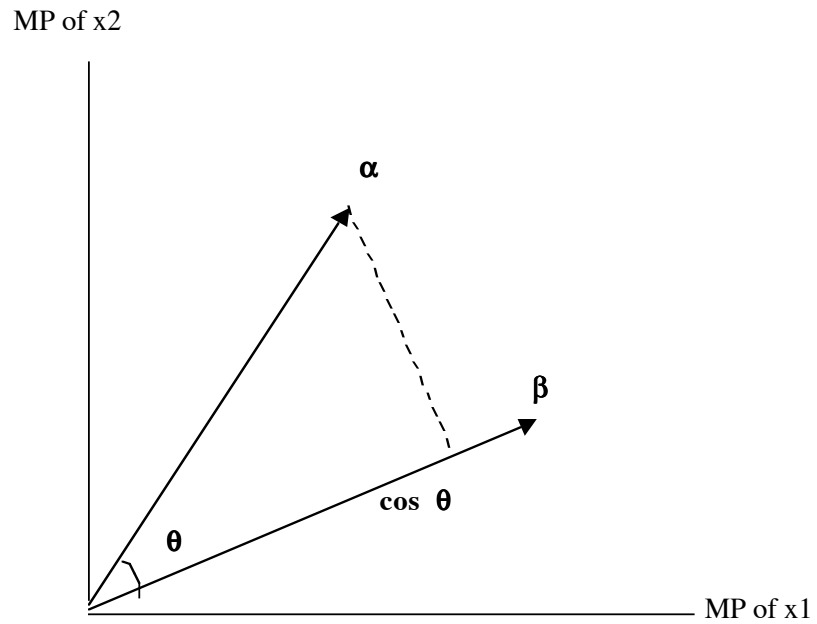
**Figure 3: Repudiation of Implicit Contracts**



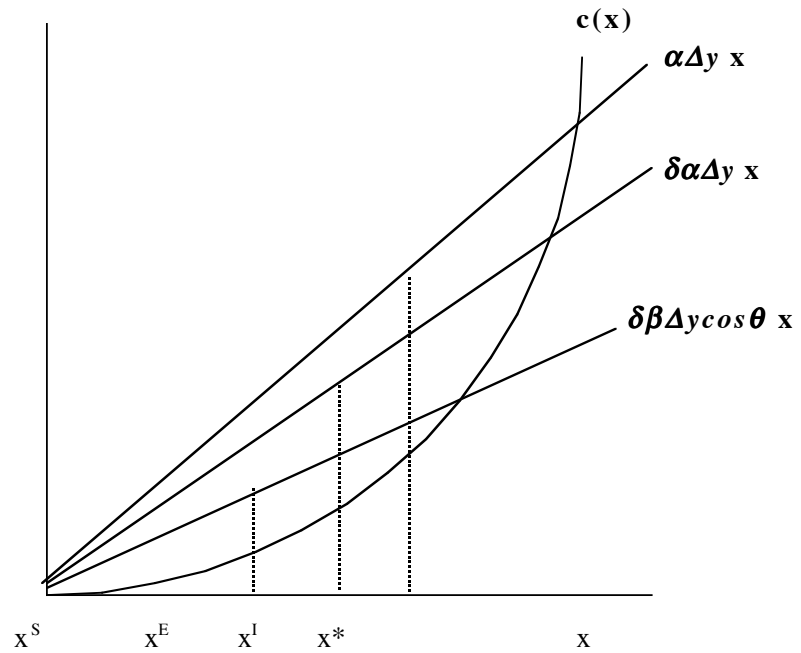
**Figure 4: Equilibrium Selection by "History"**



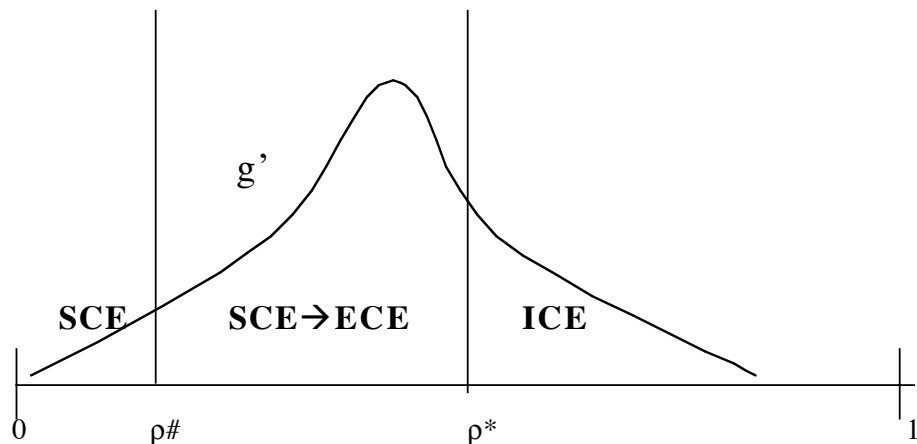
**Figure 5: Alignment between Skill and Proxy**



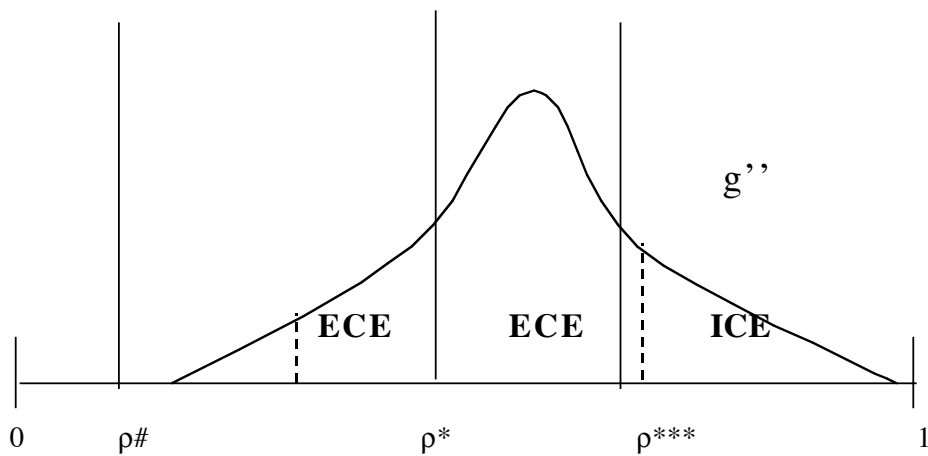
**Figure 6: Equilibrium Skill Investment Levels**



**Figure 7: Adoption of Monitoring Technology**



**Figure 8: SE Condition with Monitoring Technology**



**Figure 9: Irreversibility of the Equilibrium Selection**

