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LEARNING BY DOING AND ADVERSE SELECTION: THE IMPORTANCE OF COMMITMENT*

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The analysis in Novos (1990) is extended to incorporate a richer signalling dimension. Specifically, firms observe the evolving employment histories of workers. Results show, firstly, that when firms are not integrated across tasks there is an inefficient allocation of workers across tasks. Second, when firms are integrated across tasks workers are, ex-ante, efficiently allocated across tasks. Finally, when firm structure is an endogenous choice firms will choose to be integrated. A crucial role in the analysis is occupied by the idea of a »promotion commitment.» The central role often played by personnel departments in this regard is discussed. (JEL L22, T23, T82)

1. Introduction

In a recent paper [Novos (1992)] I explored the implications of the interaction between learning by doing and adverse selection for firm structure. Integration across jobs proved to be an effective way for a firm to capitalize on the fact that it had better information about the abilities of its employees than did other firms. The analysis, however, effectively abstracted away from the fact that firms have access to the evolving employment history of workers they are considering hiring for the first time. When evaluating the employment potential of a 40 year old applicant a firm, for example, has important information about the applicant's employment history. This paper aims to explore this issue by modifying the model used in Novos (1992).

In addition to contributing to the theory of the firm both this, and my earlier, paper tie into the increasingly important literature exploring labor market outcomes under asymmetric information [Greenwald (1986), Jovanovic (1979), Ross, Taubman and Wachter (1981), Harris and Holmstrom (1982), Waldman (1984, 1989), Milgrom and Oster (1987), Ricart i Costa (1988)]. Some of these analyses (Waldman (1984), Ricart i Costa) use a set of assumptions about the timing of moves by market participants quite different from mine.

To my mind none of the various sets of assumptions dominates the others in all dimensions. It seems to me, therefore, to be not fruitful to focus on which set of assumptions is superior. One should instead focus on which aspects of the real world authors are attempting to capture by the use of a particular set of assumptions. Much of the work in the

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above-cited literature shares with this analysis the aim of capturing the idea that firms know certain key aspects of the employment histories of potential employees.

Some authors, for example, seem intent on capturing some aspects of this signalling in a two period model by »collapsing» the dynamic learning process into one period. That is, the timing of moves by market participants is such that useful information about old workers is revealed through the retain offers firms make to these workers. The timing of moves by market participants in Novos (1992), on the other hand, does not allow for this kind of information transmission. While retaining the assumption on the timing of moves by market participants the framework used here does incorporate a signalling dimension by having workers live for three periods. The central results of Novos (1992) hold under the richer specification used here. That is, first, when firms are not integrated across tasks there is an inefficient allocation of workers across tasks. Second, when firms are integrated across tasks workers are efficiently allocated across tasks. Finally, when firm structure is an endogenous choice firms will choose to be integrated.

2. *The Literature*

The literature referred to above on labor market outcomes is relevant here in giving context to the approach used both here and in Novos (1992). There is in fact an extensive literature on labor market outcomes in settings of incomplete information where workers differ in terms of their abilities. Assumptions about the information structure and the sequencing of moves by the »players» vary quite a bit.

Consider first the issue of the information structure. Some authors [Ross, Taubman and Wachter (1981), Harris and Holmstrom (1982)] have assumed that once information on ability is revealed to one firm it becomes public information. Others [Greenwald (1986), Jovanovic (1979) and Novos (1992)] maintain that this information remains private to the worker's employer. Waldman (1984, 1989), Ricart i Costa (1988) and Milgrom and Oster (1987) postulate that a firm's assignment of workers to tasks — or, promotion to partner — is observable to outside firms and thus acts as a signal of workers' abilities. In one case [Waldman (1984)] outside firms observe not only task assignments, but also wages. Finally, Lazear (1986), in a model of »raiding» assumes that outside firms have independent means of learning the worker's value to them.

The appropriateness of each of these assumptions depends in part on the particular characteristics of the job in question. While my focus here, for example, is on jobs where output, or ability, is not independently observable by outside firms or institutions, some jobs are such that one's output — e.g. academic articles — is publicly observable, enabling outside institutions to evaluate ability independently. In fact it is sometimes the case that outsiders are better able to evaluate a worker's ability. Consider for example the situation where an academic department lacks senior expertise in a substantive area within its discipline. Other departments with such expertise at the senior level are likely to be in a better position to evaluate junior members of that department.

In addition to the differences mentioned above, papers in this literature also differ in terms of the assumptions made about the timing of moves by market participants. In Waldman (1984) outside firms observe task-assignments and retain offers before making outside wage offers. Current employers are not permitted to make counter-offers. Ricart i Costa (1988) also assumed no counter-offers, but in the context of initial employers offering long-term contracts. In Milgrom and Oster (1987) the particular sequencing of wage offers is only relevant for the group of workers termed »The Invisibles». The quality of all other workers is known to outside firms. The sequencing of offers for »The Invisibles» is essentially the same as that used in this analysis. Waldman (1989) also adopts a similar approach.

I have already made the argument that none of the sets of assumptions discussed above dominates the others in all respects. To my mind the issue then becomes the motivation behind a particular set of modelling assumptions. The signalling issue warrants particular attention here. That is, in a multi-period world firms have many opportunities to observe the employment, and wage, histories of potential employees. Thus, any model which

aims to capture salient long-run features of the real world must incorporate more signalling content than that provided by initial job assignments and wages. The models mentioned above do this by essentially »collapsing» the dynamic learning process into one period of a two period model. An alternative approach is to use a model in which workers live for three periods. This analysis extends the results of my earlier paper [Novos (1992)] in this way.

3. The Non-Integrated Firm Case

3.1 The Model

The economy to be considered here is an overlapping generations economy in which workers live, and work, for three periods. N workers are born each period. Production of the economy's single consumer good — whose price is normalized at 1 — requires two inputs, good 1 and good 2. Specifically, the consumer good has the following production function: $h(g1, g2)$, where g1 denotes the quantity of good 1 and g2 the quantity of good 2. Further, $h(0, 0)=0$, $h_i(g1, g2)>0$, $(i=1,2)$, $h_1(0, g2)=\infty$, $h_2(g1, 0)=\infty$, $h_{ii}(g1, g2)<0$, $(i=1,2)$ and $h_{ij}(g1, g2)>0$, $(i, j=1,2, i\neq j)$. The inputs are not storable. In the non-integrated firm case no firm is permitted to produce both inputs. There are thus two types of firms. Type 1 firms produce good 1 and type 2 firms produce good 2.

3.1.1 Worker Behavior

Workers live, and work, for three periods, termed youth, middle age and old age. For simplicity, I will often refer to the group of middle-aged and old workers as veterans. All workers maximize the discounted sum of their expected earnings.

Workers differ in terms of their abilities.[1] A worker of ability θ produces $f(\theta)$ units of good 1, where $f(0)=0$ and $f'(\theta)>0$. Provided that he has previously been employed in production of good 1, a middle-aged or old worker of ability θ will produce $g(\theta)$ units of good 2, where $g(0)=0$ and $g'(\theta)>0$.[2] This means that all young workers will be employed in producing good 1. The allocation of all other workers across productive activities will depend on the economy's production technology for producing both the inputs and the economy's consumer good, the timing of wage offers and the set of information available to firms when they make wage offers to these workers. The mechanism by which this allocation is partially accomplished is, of course, by some middle-aged workers switching to production of good 2 in response to their receiving a better wage offer from firms producing good 2. Old workers may or may not switch from the productive activity of their middle age.[3]

A worker's ability is not a priori known either by himself or by potential employers. Each worker's ability is the realization of a random draw from a distribution $k(\theta)$, $\theta\epsilon[\theta_L, \theta_H]$. $E(\theta)$ is the mean of this distribution. How, and to whom, information is revealed is an important issue in adverse selection models. Hence,

Assumption 1.

Each worker's θ, $f(\theta)$ and $g(\theta)$ are not publicly observable. Firms only learn the θ of each of their employees after a period of employment.

The concept of an efficient allocation of veteran workers across productive activities only has significant content when comparative advantage is a factor in the economy's production technology. Thus,

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[1] *In this analysis a worker's ability will be modelled as a scalar and will be constant across job assignments. In reality, of course, workers' abilities vary across jobs. It is true, however, that by observing a worker in job A, say, one can learn something about how well that worker will perform a job related — in the sense discussed above — to job A. Thus, in my model, observing a worker's ability proxies for observing his performance at one job, and drawing inferences from this about his likely performance at related jobs.*

[2] *In the interest of simplifying the analysis I will assume that all workers are completely unproductive in the production of good 2 unless they have previously produced good 1. Dropping this assumption would not qualitatively alter the results to be presented here as long as it remained true that workers were more productive in good 2 production after producing good 1.*

[3] *It will be assumed that workers remain with their current employer if they are indifferent between moving and staying.*

Assumption 2.

$$\frac{d\left(\frac{f(\theta)}{g(\theta)}\right)}{d\theta} < 0$$

That is, a worker of ability θ has a comparative advantage in producing good 1 relative to workers of ability greater than θ, and a comparative advantage in producing good 2 relative to workers of ability less than θ.

3.1.2 Firm Behavior

Firms are risk-neutral and maximize the discounted sum of expected profits. There is free entry in the market for both inputs. Assembly of the final good will be assumed costless.[4]

In light of the presence of adverse selection in this model the timing of wage offers to veteran workers is crucial. Accordingly,

Assumption 3.

Veteran workers first receive wage offers from firms for which they did not work in the previous period of their lives. Only then do they receive offers from the firms that employed them in that previous period. Furthermore there is only one round of offers. The former set of offers will be referred to as outside offers, while the latter set of offers will be referred to as retention offers. Outside offers are publicly observable.

This is the same assumption employed by Greenwald, and Milgrom and Oster.[5]

Assumption 4.

Firms can only make spot wage contracts.

Given that ability is not publicly observable, ability contingent wage offers are unenforceable in the current context.[6] It is worth pointing out, however, that the main results of the paper hold if firms are permitted to offer long-term contracts.

Assumption 5.

$$\frac{h_2\{NE[f(\theta)],\ 2N\int_{\theta_L}^{\theta_H} g(\theta)k(\theta)d\theta\}}{h_1\{NE[f(\theta)],\ 2N\int_{\theta_L}^{\theta_H} g(\theta)k(\theta)d\theta\}} < \frac{f(\theta_H)}{g(\theta_H)}$$

This assumption ensures that the marginal value product in task 1 of a veteran θ_H ability individual is higher than his marginal value product in task 2. Now, recall that the identity of each veteran θ_H ability individual is known to some type 1 firm, while type 2 firms do not know workers' abilities when they make outside offers to middle-aged workers. Thus, when type 2 firms make an outside offer of $h_2\{NE[f(\theta)],\ 2N\int_{\theta_L}^{\theta_H} g(\theta)k(\theta)d\theta\}$ $\int_{\theta_L}^{\theta_H} g(\theta)k(\theta)d\theta$ — the average task 2 marginal value product when all veteran individuals are employed in task 2 — type 1 firms will match the offer for at least the θ_H ability middle-aged individuals. Thus, there cannot be an equilibrium in which all veteran workers perform task 2. More formally, if an equilibrium exists it will have an interior solution.[7]

3.1.3 Market Behavior

Each period young workers receive wage offers from type 1 firms. Simultaneously, veteran workers receive offers from firms they had not worked for in the previous period. Only then does each firm make offers to those

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[4] *Results would not be affected if this assumption was dropped, but that would introduce unnecessary complications into the analysis.*

[5] *Note that if the offers were made simultaneously no equilibrium in pure strategies would exist. That is, there would be no combination of outside and retain offers for which each would be optimal given the other. An equilibrium may well exist in mixed strategies.*

[6] *While Macleod and Malcomson (1989) show that there are conditions under which implicit piece-rate contracts are self-enforcing, there are a number of important differences between their framework and this one. First, here output depends solely on a worker's ability and not, as in their framework, on his effort. Second, they assume that firms and workers are infinitely-lived. In this model workers only live for three periods. I would therefore argue that assumption 4 is the appropriate one to make in this framework.*

[7] *In fact this assumption also guarantees an interior solution in the integrated structure equilibrium since the condition required there is weaker than that specified in assumption 5.*

workers it had employed in the previous period. Workers then accept their preferred offer, with some workers switching employers because the outside wage offer they received exceeded their retention offer. Production of the two inputs then takes place, followed by the assembly of the final good.

3.2 *The Market Equilibrium*

Before characterizing fully the equilibrium of the model presented above, I offer a few preliminary remarks. First, all young workers are employed in producing good 1. Second, young workers all receive the same wage because they are, at that point, indistinguishable from one another. Free entry ensures that this wage will be set such that all firms producing good 1 make zero profit over all. Finally, of course, competition ensures that firms producing good 2 also make zero profit.

Note that type 2 firms must offer all middle-aged workers they employ in a given period the same wage since these workers are all, at time of employment, indistinguishable to them. Competition implies that the wage for all workers switching to employment with type 2 firms in middle age, must equal the mean value of the output produced by these workers.

Since some middle-aged workers will work for type 1 firms while others will work for type 2 firms, both type 1 and type 2 firms make retention offers to old workers. Old workers do not all receive the same wage because their different employment histories have differentiated them to potential employers. The allocation of old workers depends on the allocation of this cohort in middle age. For one thing it is this allocation which determines whether one or two firms have precise information about a worker's ability.[8]

Proposition 1 shows that the non-integrated firm equilibrium — if it exists — has an inefficient allocation of workers across productive activities, a result analogous to that in Novos (1990).

Proposition 1: Consider an economy where workers live, and work, for three periods, and each firm produces only one of the economy's two inputs. If an equilibrium exists it will be characterized by an inefficient allocation of veteran workers across productive activities.

Proof: See Appendix.

It is worthwhile here to explain some qualitative aspects of the inefficient allocation. First, and most important, middle-aged workers are inefficiently allocated. This inefficiency occurs because type 1 firms are able to skim off, as it were, the best middle-aged workers when they make retain offers to those workers. These are exactly the workers who, as a result of the comparative advantage assumption, should be working for type 2 firms.

Specification of the allocation of old workers is not necessary for the result of Proposition 1 which refers to the allocation of veteran workers. It is more complicated than the allocation of middle-aged workers. Since the allocation of old workers to jobs works differently — and will be a central issue in the integrated structure equilibrium — it is worthwhile to discuss its characteristics in general terms. When firms make offers to old workers they know which firm each worked for in middle age. This gives valuable information. Type 2 firms, for example, know that the middle-aged workers who were retained by type 1 firms are the better workers. They will take this into account in making offers to these workers in their old age. Recall, however, that type 2 firms do not know the ability of specific workers, while the type 1 firm which employed each of these workers does have this information. Given the range of ability levels represented in this group of workers there *may* be one ability level (say L) which has the following property. It is in the interest of the type 1 firms who employed these workers in their middle age to match the outside offer made by type 2 firms to workers whose ability is at least L.[9] The existence of such an L means that some old workers will certainly be misallocated, although there may be some misallocation even if such an L didn't exist. In an overall sense, though, I conjecture that the allocation of this set of workers in old age will be »better» than that of middle-aged

[8] *At the time wage offers are made to old workers two firms know the ability of those old workers who worked for different firms in youth and middle age.*

[9] *The comparative advantage assumption adds to the uncertainty surrounding the outcome of this issue. Additional structure would be needed to resolve it definitively.*

workers.[10] It is important to note that the old age allocation of these workers is closely tied to the middle-aged allocation because this allocation provides the key signals on which type 2 firms base their offers to old workers.

Workers who switched to type 2 firms in middle age will be »marked» as the lower quality workers in their old age. Since each of these workers began his working life with a type 1 firm the ability of each of these workers is known to that type 1 firm. Each type 1 firm will be able to use this information to its advantage in making offers to this group of workers in their old age. In light of the comparative advantage assumption, type 1 firms will have an edge competing for these workers. Once again, however, one cannot specify precisely where all these workers end up in old age without more structure. For example, since the ability of these workers is known also to the (type 2) firm which employed them in middle age, it *may* be in the interest of these firms to match the offer made by type 1 firms to some of these workers. This would ensure that they remained with the type 2 firm in old age. Whether this will occur again depends on the precise nature of the allocation of middle-aged workers.

A final feature of the outcome worth pointing out is the fact that no middle-aged workers move from type 1 firms to other type 1 firms. The reason for this is basically the following. Assume that type 1 firms make an outside offer to middle-aged workers of W_1. Type 1 firms will in turn respond with a retain offer of W_1 to all their middle-aged workers whose output of good 1 will sell for at least W_1. Thus, with workers remaining with their current employer unless they get a higher offer elsewhere, the only workers accepting the outside offer will be workers whose value product is less than W_1. It is of course precisely this group of workers which type 1 firms would prefer not to hire in response to the outside offer W_1. After all, they will make negative profits on this group of newly hired middle-aged workers. Type 1 firms will thus not be willing to make the outside offer W_1 to middle-aged workers. Note that this argument holds for any W_1 in the range $[X_n^* f(\theta_L),\ X_n^* f(\theta_H)]$. Analogously, no old workers move from a type i firm to another type i firm. Milgrom and Oster refer to this phenomenon as »The Winner's Curse.»

Of course my aim here is to examine issues concerning firm integration. The next section explorers the outcome in a setting where firms are all assumed to be integrated.

4. *The Integrated Firm Case*

I need make only three changes to the model of the previous section to account for the change in firm structure. First, here I assume that all firms produce both inputs, whereas firms were restricted to producing only one input in the previous section. Second, it makes sense here to restrict the analysis to trembling hand equilibria only. I discuss this issue fully in the appendix when dealing with Proposition 2.

Third, so as to avoid multiple equilibria in the integrated structure case, I introduce

Assumption 6.

$$\frac{d\{h_2[V(\theta_S),\ L(\theta_S)]g(\theta_S)\}}{d\theta_S} > \frac{d\{h_1[V(\theta_S),\ L(\theta_S)]f(\theta_S)\}}{d\theta_S}$$

$$\forall\ \theta_S \epsilon (\theta_L,\ \theta_H),$$

where:

$$V(\theta_S) \equiv NE[f(\theta)] + 2N \int_{\theta_L}^{\theta_S} f(\theta) k(\theta)\, d\theta,\ \textit{and,}$$

$$L(\theta_S) \equiv 2N \int_{\theta_S}^{\theta_H} g(\theta) k(\theta)\, d\theta.$$

This condition says that, given the qualitative allocation of workers across jobs that emerges in the integrated firm structure, the lowest ability worker assigned to good 2 production in each potential equilibrium has a higher marginal product of final good output than his marginal product of final good output when he is assigned to producing good 1. In light of the comparative advantage assumption this does not turn out to be very restrictive, as can be verified by examination of assumption 6 in differentiated form.

Before moving on to Proposition 2 it would be useful to outline how the signalling dimension referred to earlier affects firm behavior.

[10] *At the very least some of these higher ability workers will produce good 2 in old age, which is more in accord with the comparative advantage assumption.*

When making outside offers to old workers, firms know the production assignment — and wage — these workers had in middle-age. This new signalling element is a feature of both the integrated and non-integrated structure models. However, because non-integrated firms can only make one production assignment they have less flexibility in reacting to it in a way which increases profitability. The integrated structure case is thus of more interest. Here, firms know that assigning a retained worker to good 2 production in middle-age signals the market that this worker has ability above a certain minimum level.[11] This obviously has implications for the outside offer this worker will receive in old age, and thus the offer required to retain the worker in old age. Firms will thus take the effect of a middle-age production assignment on the wages of the old into account when deciding on these middle-age assignments. This means that it will not generally be in a firm's interest to promote middle-aged workers in a socially optimal way. Specifically, a firm will only promote a middle-aged worker if the resulting increase in his middle-aged revenue product exceeds the increase in his old age wage — discounted one period — that such a promotion necessitates.

In a related context Malcomson (1984) introduced the idea that firms could make a commitment to essentially promote a certain proportion of its young workers in the second period of their lives. Essentially the idea is that firms will compete with each other to offer young workers the best ex-ante expected lifetime wage package. Following Malcomson I will assume that integrated firms are free to commit, at the time of the initial hiring decision, to promoting a certain proportion of each cohort at the end of its first period of employment.[12] This assumption is obviously only relevant for integrated firms. Note that the commitment is not only enforceable, but is also a simple one with which to verify compliance.

It should be noted that the »winner's curse» problem is now relevant not only for those veteran workers switching firms while remaining in good 1 production. A similar problem arises for the group of veteran workers switching to good 2 production at a firm different from the one which employed them in their youth. After all, the fact that firms are integrated implies that firms can use the information they have about their young employees to so effectively compete with the outside offer for good 2 production that the only workers who find it in their interest to switch employers are those whose production of good 2 is less than the real value of the outside wage offer. This means, of course, that firms will make a loss on the group of veteran workers they newly hired for good 2 production. Thus, in the integrated firm case, firms will not use the outside hiring market to produce either input. Proposition 2 demonstrates this and also shows that the integrated firm equilibrium has an efficient ex-ante allocation of workers across productive activities.[13]

Proposition 2: Consider an economy where workers live, and work, for three periods, and each firm produces both of the economy's two inputs. Further, firms are permitted to commit, at the time of hiring, to promoting a

[11] *This minimum level can be calculated by outside firms from their knowing the optimal (pure) strategies of the various players in the game.*

[12] *If I were to permit integrated firms in Novos (1992) to make a similar commitment results would remain unchanged.*

[13] *If the promotion commitment specified above was ruled out then there would be a multiplicity of integrated structure equilibria. Some of these would involve an ex-post misallocation of middle-aged workers in which too few would be promoted, even though firms have all the information necessary to promote optimally Further, when the trembling hand perfect equilibrium concept is used with no promotion commitment allowed, equilibrium is characterized by too few middle-aged workers being promoted ex-post. The misallocation observed here is much like the misallocation observed in Milgrom and Oster (1987) and Waldman (1984). If Milgrom and Oster allowed firms in their model to make a commitment on promotions like the one specified above, then the misallocation of their »Invisibles» would disappear, as they indicate in discussing their results. They do, however, make an argument that commitments such as the one proposed here would not have the desired effect in practice because firms would be able to fulfill the letter of the commitment, while evading its spirit. I would argue that the commitment could be specified so as to avoid the problem they describe. Waldman assumes that each firm hires only one young worker. It thus makes no sense in his model to allow firms to make a commitment on the proportion of workers it will promote without changing the hiring assumption. If this assumption is changed so that firms hire many young workers then the misallocation arising in Waldman's model also disappears as long as workers are risk-neutral.*

specific proportion of young workers in middle age. A unique trembling hand perfect equilibrium for such an economy exists, and is characterized by all workers remaining with their initial employers and being efficiently allocated ex-ante across productive activities. The equilibrium is characterized by the following set of wage offers:

All middle-aged workers receive the same wage, $X_{3l}f(\theta_L)$, where $X_{3l} \equiv$ the price of good 1 in the three period model.

Old workers who produced good 1 in middle age will also produce good 1 in old age, and will all receive a wage $X_{3l}f(\theta_L)$.

Old workers who produced good 2 in middle age will also produce good 2 in old age, and will all receive a wage $Y_{3l}g(\theta_{3l})$, where θ_{3l} is the ability of the lowest ability worker assigned to produce good 2 in middle, and old, age, and $Y_{3l} \equiv$ the price of good 2 in the three period model.

Finally, young workers will earn a wage such that integrated firms earn zero profit over all.

PROOF: See Appendix.

Note the effect of the signalling element discussed above. Proposition 2 shows that old workers receive a wage which depends on their middle age production assignment.[14] This is a result of the different outside offers that workers in each of these two groups command because of the signal about ability sent by their middle-age production assignment.

The reader will note that the equilibrium in Proposition 2 is ex-ante efficient. The key to this efficiency lies in the competition that arises between firms to make young workers the best promotion commitment they can without making losses. This competition ensures that firms commit to a promotion rule which ensures that, ex-ante, the appropriate proportion of workers are promoted in middle age. As long as firms are not making this commitment it will be in the interest of a single firm to marginally increase the promotion commitment so as to lure all young workers to its employ and garner all the resulting profits.[15] Note further that it was always in a firm's interest to allocate old workers optimally for two reasons. First, the wages old workers receive, although perfectly correlated with this allocation, do not depend on it. Second, since old workers are in the last period of their working lives, the allocation of old workers is of no practical signalling value to outside firms.

The argument showing that, when firm structure is endogenous, the equilibrium is characterized by firms being integrated, is relatively straightforward. I will thus not include it here. It is analogous to the argument made in Proposition 3 in Novos (1992).

It is appropriate here to consider how firms handle many personnel issues. Large firms typically have a personnel department which has responsibility for deciding upon key rules and procedures. It is the personnel department which invariably has primary responsibility for explaining to prospective employees the terms and conditions of employment. The policies and procedures established by the personnel department come, therefore, to be regarded by prospective employees, as »the rules of the game». Milgrom and Roberts (1988, p S176) have argued that »In every organization with which we have been associated, and in most of those of which we have heard, the Personnel Department is viewed by line managers and employees as unresponsive, rule-bound, and bureaucratic.» It is of course precisely in this way that the department's rules and procedures come to have credibility as commitments.[16]

It is worth pointing out here that the theory presented here does not imply that all jobs are best performed in a single firm. Nor does it imply that the integration is random. Rather,

[14] *Old workers receive the same production assignment as they did in middle age. In fact, it is never in an integrated firm's interest to assign a worker to good 2 production in middle age and then reassign him to good 1 production in old age.*

[15] *In so increasing its promotion commitment a firm will attract all young workers because it is now able to offer young workers a higher discounted present value of expected earnings.*

[16] *One might argue that a firm's management could attempt to develop an appropriate reputation as to its promotion record and, in this way, avoid the need to create a credible commitment mechanism. Even if a firm is infinitely-lived however its management is not, creating standard principal-agent problems between the owners and management. Furthermore, note that research by Stein (1987) suggests that having managers be stockholders does not solve this problem. In particular, in a world where investors are imperfectly informed about management actions, managers still behave myopically. They will therefore not take actions that develop the desired reputation for the firm.*

the theory is relevant for particular sets of activities and/or jobs. That is, one will observe jobs being performed within one firm when a worker's productivity in one or more of these jobs depends on his having done one or more of the other jobs. Thus, knowledge of the relevant relationships between jobs will enable one to make predictions about which jobs will essentially be grouped together in a firm.

5. Conclusion

This paper extends results derived in Novos (1992). Specifically, I have shown that the results on firm integration hold when a richer signalling dimension is incorporated into the model. An important feature of the analysis is the crucial role played by a promotion commitment. I have also argued that a powerful personnel department which has a strong commitment to a set of rules and procedures can send the necessary signals to prospective employees about promotion rules and procedures within the firm.

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Appendix

Proof of Proposition 1:

Let: $W^r_{M1}(\theta) \equiv$ the retention wage offer by a type 1 firm to a middle-aged worker of ability θ who worked for the firm in his youth.

$W_{Mi} \equiv$ the outside wage offer to middle-aged workers by firms of type i.

$W^r_{Oi}(\theta) \equiv$ the retention wage offer by a type i firm to an old worker of ability θ who worked for the firm in his middle-age.

$W_{Oij} \equiv$ the outside offer by a type j firm to an old worker who worked for a type i firm in his middle-age.

$X_{3N} \equiv$ the price of good 1.

$Y_{3N} \equiv$ the price of good 2.

I will now show that the qualitative nature of the equilibrium allocation of workers across productive activities will be inefficient. I will deal with each cohort in turn.

All young workers will work for type 1 firms and will receive the same wage. Recall that this is a result of the production technology.

Consider now the group of middle-aged workers. No type 1 firm can make an outside offer to these workers which will both yield nonnegative profits and attract workers. This is due to the so-called »Winner's Curse». Type 2 firms do not face the »Winner's Curse» problem, and will offer W_{M2} to those middle-aged workers who switch to them. Consider what retention offer, $W^r_{M1}(\theta)$, type 1 firms will make in response to this outside offer. Type 1 firms will only retain those workers whom they offer a wage $\geq W_{M2}$. Given that the best outside offer is W_{M2} type 1 firms will maximize their profits — on the relevant group of workers, anyway — by offering all those workers whose θ is s.t.

$f(\theta)X_{3N} \geq W_{M2}$ a wage W_{M2}. Furthermore this offer will be enough to retain all these workers.

Notice that this implies that all the workers whose θ is below the relevant cut-off value of θ will produce good 2, while all workers whose θ is greater than or equal to this cut-off value will produce good 1. This is an inefficient allocation of workers.

Since the statement of the Proposition refers to veteran workers there is no need here to deal with the allocation of old workers — which has been discussed in the text — in light of the result above on the allocation of middle-aged workers. Q.E.D.

Proof of Proposition 2:

Let $X_{3I} \equiv$ the price of good 1 in the economy where workers live for three periods and all firms are integrated.

Let $Y_{3I} \equiv$ the price of good 2 in the economy where workers live for three periods and all firms are integrated.

Let $W_1^O \equiv$ the value of good 1 output produced by a θ_L individual.

First consider what the equilibrium would look life if firms were not able to make a promotion commitment. An argument using a »Winner's Curse» type argument — cf. proposition 1 — shows that no workers switch firms in response to an outside offer. All workers receive the same retention offer, W_1^O, in middle-age — outside firms have no information with which to distinguish amongst them and, hence, their current employers only have to match the (common) outside offer to retain them all — and too few workers will be promoted in middle age. The retention offer for those old workers who produced good 1 in middle-age will also be W_1^O, while those old workers who produced good 2 in middle-age will receive a retention offer of $Y_{3I}g(\theta_{3I})$, where θ_{3I} is the ability of the lowest ability individual assigned to good 2 production in middle-age.

[*REMARK:* The reasoning leading to the above set of results is not straightforward. I will use this remark to present the basic arguments. First note that it is the »Winner's Curse» which ensures that no outside firm will ever make an offer which exceeds the value of the output produced by the least able worker in the group to which the offer is made. Since all middle-aged workers have the same employment histories the outside offer to these workers is made to all of them. That outside offer will thus equal W_1^O.[17] When outside offers are made to old workers, outside firms know which workers produced good 1 and which produced good 2 in their middle-age. This will enable them to work out the value of output produced by the least able of those workers who produced good 2 in middle-age. Denote this value by W_2^O. Thus, if outside firms offer any amount between W_1^O and W_2^O to those old workers who produced good 2 in middle-age, they cannot make negative profits even if only the least able workers in the group accept the outside offer. Of course, current employers will make the same offer to these workers and none will thus switch employers in old age. One could thus argue therefore that, since outside firms know they will never attract any old workers who produced good 2 in middle-age, the equilibrium outside offer to all old workers will be the same, namely W_1^O, the value of good 1 produced by the least able individual in the economy. It makes sense, however, to restrict oneself to trembling hand perfect equilibria only. Specifically, it makes sense to consider equilibria in which outside firms take into account the fact that current employers may make mistakes when making retention offers.

This is relevant for outside offers made to those old workers who produced good 2 in middle age. If current employers make mistakes in their retention offers to these workers then outside firms may capture some of these workers. Accordingly, the lowest revenue such a firm could get from one of these workers is W_2^O. Outside firms, in competing with one another for workers in this group they may get by »accident», will therefore bid the outside offer for these old workers to W_2^O. Under a trembling hand perfect equilibrium assumption the outside offer to old workers who produced good 2 in middle-age is W_2^O. (In the absence of the trembling hand assumption there will be a continuum of outside offers between W_1^O and W_2^O to old workers who had produced good 2 in middle age.) Since the trembling hand perfect assumption seems the most sensible I will restrict myself

[17] *The comparative advantage assumption ensures that this exceeds the value of good 2 output produced by a θ_L individual.*

to this case in the remainder of this remark. Now, in this case, employers, knowing how outside offers to old workers depend on their assignment of these workers in middle-age, will find it most profitable to assign fewer middle-aged workers to producing good 2 than is optimal. That is, firms will only assign a middle-aged worker to producing good 2 if the value of the worker's middle-aged output of good 2 was sufficiently larger than the value of his middle-aged output of good 1 to justify the firm paying him a wage W_2^o, as compared with W_1^o, in old age. Some middle-aged workers will therefore be assigned to producing good 1 even though the value of their production of good 1 is lower than the value of their production of good 2, at existing prices.]

While the allocation of middle-aged workers will not be efficient in that too few of them will produce good 2, the allocation of old workers will be efficient.[18] Old workers will be assigned as follows:

All workers whose θ is such that $f(\theta)X_{3l} \geq g(\theta)(Y_{3l})$ are used in producing good 1.

Remaining workers are used in producing good 2.

Young workers are all of course used in producing good 1.

For my purposes here it is not relevant whether the equilibrium whose allocative properties I have characterized above, exists or not. What is relevant is that such an equilibrium is clearly inefficient, primarily because too few middle-aged workers are »promoted» to good 2 production.

Let me now allow firms — if they so desire — to offer young workers a promotion commitment. That is, at the time of initial employment, firms could commit to promoting a certain proportion of this cohort in its middle-age.

Consider what happens to the equilibrium characterized above, when firms are free to make a promotion commitment. It will clearly be in the ex-ante interest of a single firm to commit to promoting a marginally higher proportion of incoming young workers — when they reach middle-age — than were promoted in the equilibrium just characterized, where no promotion commitment was allowed. In doing so such a firm would attract all incoming young workers to its employ. To see this first recall that I have already shown that in promoting too few workers in their middle age a firm's revenue from middle-aged workers is lower than it could be. Therefore, in making a commitment to promote a marginally higher proportion of young workers, this firm will increase its expected revenues — at the prices prevailing in the equilibrium characterized above — above what they were when it made no promotion commitment, as in the equilibrium characterized above. The firm therefore earns higher expected revenue than any other firm. It pays middle-aged workers W_1^o and old workers either W_1^o if they produce good 1, or $Y_{3l}g(\theta_{3l})$ if they produce good 2, where θ_{3l} is the ability of the lowest ability individual assigned to good 2 production in middle age in the equilibrium just characterized. Thus, no middle-aged or old worker earns more than his value product. The firm can therefore, while still making positive expected profits, offer these workers a wage in their youth such that the expected discounted earnings of each worker it employs ab initio will be higher at this firm than at any firm making no promotion commitment. It can thus bid all workers away from the firms making no promotion commitment.

Following this argument to its logical conclusion, the incentive for each firms to increase its promotion commitment will only stop when firms promote so as to maximize expected revenues from middle-aged workers. This will turn out to be the socially optimal level of middle-aged promotions to good 2 production.[19] Formally, firms will make a commitment to promote a proportion $1-K(\theta_{3l})$, where θ_{3l} is defined as the θ which solves the equation

[18] *See the REMARK above for an explanation of why middle-aged workers are misassigned. This argument does not apply to old workers for two reasons. Firstly, the wages of old workers, although perfectly correlated with their allocation to productive activities in old age, is not dependant on this allocation. Secondly, this allocation has no practical signalling value because old workers are in the last period of their working lives.*

[19] *This argument requires uniqueness of the equilibrium for the resulting promotion commitment to be optimal. Assumption 6 ensures this.*

(1) $f(\theta_{3I})X_{3I}=g(\theta_{3I})Y_{3I}$.

Note that (1) and the comparative advantage assumption imply that the value of output produced by workers whose ability is above/below θ_{3I} is higher when they produce good 2/1. To understand why the promotion rule implied by (1) maximizes expected revenue from middle-aged workers note that, ex-ante, this is the rule which matches promoting to good 2 production those workers whose ability is above θ_{3I}. (Note that having made such a commitment it will *never* be in the interest of a firm to promote the »wrong» workers ex-post.)

Finally, I will show that an equilibrium in which firms make the optimal middle-aged promotion commitment, exists.

For such an equilibrium to exist there must be a θ_{3I} which satisfies (1) when the marginal productivity conditions are substituted in (1) for the prices of goods 1 and 2.

This implies that there must exist a θ_{3I} which satisfies

$$(2)\quad h_1\Big\{NE[f(\theta)]+2N\int_{\theta_L}^{\theta_{3I}} f(\theta)k(\theta)\,d\theta,\ 2N\int_{\theta_{3I}}^{\theta_H} g(\theta)k(\theta)\,d\theta\Big\}f(\theta_{3I})$$

$$=h_2\Big\{NE[f(\theta)]+2N\int_{\theta_L}^{\theta_{3I}} f(\theta)k(\theta)\,d\theta,\ 2N\int_{\theta_{3I}}^{\theta_H} g(\theta)k(\theta)\,d\theta\Big\}g(\theta_{3I}).$$

Now if $\theta_{3I}=\theta_L$ the LHS of (2) > the RHS of (2), by assumption 5.

Further, if $\theta_{3I}=\theta_H$ the LHS of (2) < RHS of (2), because $h_2(g1, 0)=\infty$.

Continuity ensures that an interior solution exists. Denote this solution by θ^*_{3I}. Note that assumption 6 ensures that this solution is unique.

This unique equilibrium is also the solution of the social planner's optimization problem. After all, a social planner would solve the following problem:

$$(3)\quad \max_{\theta_S} h\Big\{NE[f(\theta)]+2N\int_{\theta_L}^{\theta_S} f(\theta)k(\theta)\,d\theta,\ 2N\int_{\theta_S}^{\theta_H} g(\theta)k(\theta)\,d\theta\Big\}f(\theta_S).$$

Finally, the first-order condition for (3) is the same as (2). Since (2) has θ^*_{3I} as a unique solution, θ^*_{3I} must also be the unique solution to the planner's problem. Q.E.D.