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SEARCH IN THE LABOR MARKET, INCOMPLETE CONTRACTS AND GROWTH

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Abstract

This paper shows that search in the labor market has important effects on accumulation decisions. In a labor market characterized by search, employment contracts are naturally incomplete and this creates a wedge between the rates of return and marginal products of both human and physical capital. This implies that when a worker invests more in his human capital, he increases the rate of return on physical capital. However, provided that these factors are complements in the production function, this will increase the desired level of investment for firms. Then, because physical capital is not being paid its marginal product, the rate of return on all human capital goes up. Thus in this model there are *pecuniary increasing returns to scale* in human capital accumulation in the sense that the more human capital there is, the more profitable it is to accumulate human capital. Applying this argument conversely, the presence of pecuniary increasing returns in physical capital accumulation also follows. We therefore obtain both human and physical capital externalities that look in reduced form similar to those of Lucas (1988) and Romer (1986). But these effects are not in the technology of production, instead they are derived through the interactions in the labor market. We show that pecuniary increasing returns imply that there exist optimal factor shares of capital and labor that maximize the rate of long-run growth. When we introduce the possibility of unemployment, a new source of multiplicity also arises; when more firms enter unemployment is lower, and worker who face lower risk of unemployment are more willing to accumulate human capital. When workers invest more n human capital, it is more profitable for firms to enter, thus we can have an equilibrium with low unemployment and high growth as well as a high unemployment-low growth equilibrium. We also show that depending on the matching technology, there may be an education race among workers. This can be beneficial as it counteracts the underinvestment problem but it may also lead to overinvestment under certain situations. Finally we also show that a negative wage formation externality is created when technology choice is endogenized.

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1) Introduction

Progress of knowledge is undoubtedly the most important engine of growth. Yet, despite the fact that most of the new productive knowledge can quickly spread across countries, we still observe significantly different long-run growth performances. This leads many to believe that the incentives to acquire and apply this knowledge, therefore, the rewards to physical and human capital, differ across economies. Although many factors ranging from social regard (e.g. Sawyer (1949), Baumol (1990), Cole et al (1991)) to coordination across sectors (e.g. Rosenstein-Rodan (1943), Murphy et al (1989)) are obviously important in this process, the rewards to various skills and by implication the rate of return on physical capital are determined in the labor market. Therefore to understand how much of the available stock of knowledge will be exploited and extended by a society we need to study the organization of the labor market and the institutions governing trade *within* productive units. If trade necessary for productive relationships does not generate a high enough return to capital, sufficient investment will not be forthcoming. But neither will sufficient human capital be accumulated if various skills are not appropriately rewarded.

The main thesis of this paper is that many of the important features in the labor market, in particular search, will create a wedge between the marginal product of labor and the wage rate (and also between the marginal product of physical capital and its rate of return) and that this will introduce important external effects in the process of human and physical capital accumulation. The role of human and physical capital externalities as a cause of divergent growth performance have respectively been emphasized by Lucas (1988,1990) and by Romer (1986). Lucas assumes that when a worker increases his education, all other workers also experience increased productivity, therefore there exists a technological externality in human capital accumulation. The seminal paper by Romer, on the other hand, assumes that technological social increasing return exist in physical capital accumulation. Although we know that external effects are not necessary for endogenous growth (e.g. Uzawa (1965), Rebelo (1991)), due to the fact that we observe long-run differences in growth performances, that external effects in human capital are plausible and that human capital accumulation over the life-cycle of individuals is very non-uniform, these effects still play a prominent role in the study of growth. However, social increasing returns as formulated by Lucas and Romer do not only suggest that the level of growth will be low compared to the first-best, but they also lead to the *amplification* of the inefficiencies because of the interaction among agents: when an agent invests less, everyone else's output and productivity will be lower and they too will be induced to invest less. In other words, the presence of amplification implies that each agent's optimal level of investment is increasing in an economy wide average and that there exist strategic complementarities (Cooper and John (1988)). However, a possible objection to the mechanisms put forward by these models is that it is not clear what underlies such technological externalities and that in many situations the importance of technological externalities *within a time period* seem limited. This paper will show that even when such technological externalities are absent, search in the labor market will introduce *pecuniary social increasing returns to scale*[1] within a time period. That is, as workers invest more in their human capital, they do not affect others'

[1] This paper uses this term because the logical alternative pecuniary externality is often used when there is no market failure but only distributional effects. As in the case of pecuniary externalities, our effects do not originate from missing markets. However, because prices are not always equal to marginal cost in all markets, market mediated interactions still lead to increasing returns and inefficient levels of investment.

productivity but they increase *the rate of return* on other workers' human capital. Further, the same argument applies to firms' physical accumulation decisions and pecuniary increasing returns in physical capital accumulation are also present. The externalities we emphasize do not only lead to lower than optimal growth but they imply similar equilibrium strategies as Lucas' and Romer's technological externalities, thus they also lead to the *amplification* of the inefficiencies.

Although I believe these effects to be general, this paper will try too illustrate them by means of a very simple model[2]. Suppose that output is produced by a partnership of a worker and an entrepreneur and both parties need to undertake some ex ante investment, the worker in human capital and the entrepreneur in physical capital. First-best level of output will be produced if both parties are paid their marginal product and in practice there are two ways of ensuring this. First, human and physical capital can be traded in a competitive (Walrasian) market. Second, ex ante complete contracts can be written to determine the rewards of the different factors of production. However, when trade in the labor market is not regulated by the Walrasian auctioneer but requires bilateral search, both of these solutions run into problems. First, search implies that most workers cannot costlessly move from one firm to another and that the human capital embodied in the labor services of a worker is subject to a degree of immobility. Therefore, wages will be determined by bargaining on the quasi-rents created by this immobility and likewise for the rate of return on physical capital. Second, search introduces an

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[2] In particular, we will use a model of constant returns to scale in order to make the points as clearly as possible. A different strategy would be to choose a technology that exhibits increasing returns *at the firm level* and show that the interactions shown here nonetheless create decreasing returns to the investment of each individual. This is possible by choosing the functional forms right but whether these functional forms are plausible is a question left unanswered.

anonymity and workers do not know who their future employers will be and as a result, cannot contract with them. Thus a natural *incompleteness of contracts* is introduced by the presence of search in the labor market.

It follows that in the absence of the Walrasian auctioneer and complete contracts, wages and rates of return on capital will not be equal to the marginal products of these factors but instead will be related to the average product. Now the rest of the story comes together: as a worker invests more, he increases the average human capital that a firm expects to employ and because the return to both factors are positively related to average products, entrepreneurial profits will also increase. Next assume naturally that human and physical capital are complements. This implies that an increase in the average human capital increases the average product of physical capital and firms find it more profitable to invest. Consequently, the average level of physical capital also increases and now by the same argument that physical capital is not paid its marginal product, the rate of return on human capital goes up. Thus by increasing his investment in human capital, the worker has increased the rate of return on capital and indirectly, the rate of return on the human capital investments of other workers (indirectly because this effect comes into operation only when firms respond to the initial investment). We thus end up with *increasing returns* similar to Lucas' but they are pecuniary not technological. The same argument naturally applies to physical capital investments too, and therefore in our economy, pecuniary increasing returns in physical capital accumulation also exist.

It is useful at this stage to relate our main mechanism to earlier literature. The search literature, most notably Diamond (1982), Mortensen (1982) and Pissarides (1984), has stressed that "*actions taken now by one agent affect the probability distribution over future states that* *others experience*" (Mortensen (1982, p.968)) and that this process leads to externalities. We instead emphasize the externalities created by actions that affect the value of future matches and analyze this in a general equilibrium setting with bilateral investment. Grout (1984) had pointed out that underinvestment would arise when the investors could not capture the whole of the surplus they create because of ex post hold-up problems. The new result we obtain is that if the actions (investments) are complements in the production of surplus (as human and physical capital will naturally be), higher investment by agents on the one side of the market increases the desired investment of the other side but then by the initial externality, increases the return to all the agents on the side that invested more initially. This is similar to the amplification mechanism mentioned above and to the *social increasing returns to scale* that the endogenous growth literature has emphasized but assumed to be technological. It is worth emphasizing that all our results hold in the presence of constant returns in all functions including the search technology and work through market mediated actions. This is what differentiates is from Diamond (1982) where trading externalities are built in the search technology. Next note that the bilateral ex ante investment aspect and the ensuing *pecuniary increasing returns* imply that in contrast to Mortensen (1982) or Hosios (1989), no possible allocation of property rights over the surplus can ensure efficiency. In this sense, this paper is related to the property rights literature (e.g. Grossman and Hart (1986), Hart and Moore (1989)) where incompleteness of contracts leads to underinvestmnet and the allocation of property rights can help by changing the division of rents. However, this literature does not obtain the economy-wide increasing returns nor does it derive the incompleteness of contracts from bilateral search. Becker (1962)'s seminal contribution is also related since it shows how, in the presence of competitive markets, efficiency will be obtained in a situation with ex ante investment. Our main difference is the presence of search in the labor market aspect which prevents the competitive wage determination. Acemoglu (1993) analyzes a model that includes on-the-job-training rather than ex ante human capital investments (such as education) and shows how thick market externalities can arise in this context, again due to labor market imperfections. Davis (1993) and Caballero and Hammour (1993) respectively show how the effects emphasized by Grout (1984) will influence the composition of job qualities and the efficiency of job destruction and creation decisions. Finally Van Der Ploeg (1987) uses Grout's effect in a growth context to show the possibility of suboptimal growth rates. However, all of these papers have one sided investment. As a result, the amplification of inefficiencies (and the possibility of multiplicity) of my paper are absent in these models.

The framework described above also implies that although the division of the surplus can never ensure efficiency, it will determine the degree of externalities in the human and physical capital accumulation. From this observation a relationship between the factor shares and the rate of long-run growth follows. More specifically, we find that there exists an optimal division of social surplus between capital and labor. The relationship between Total Factor Productivity (TFP) growth and the factor share of physical capital as reported by Chenery et al (1986) is shown in Figure 1. A quick look at this Figure shows such a relationship[3] which is of course no

[3] The data in Chenery et al (1986), Table 2.2, pp 20-22, are compiled from a number of different studies for 24 countries and for 8 countries there are two observations for different (non-overlapping) time periods. The curve is derived by regressing (1+TFP growth) on capital share and the square of capital share where both terms are highly significant. The two outliers on the right-hand side are Turkey and India, but leaving these two out does not change the shape of the curve radically. The regression implies that the growth rate of TFP is maximized at a labor share of 62%.

more than a preliminary encouraging sign for the effects emphasized in this paper.

The rest of the paper extends the theoretical framework to obtain a number of new results. First, a multiplicity of equilibria is possible when unemployment is allowed and endogenized. The intuition is a simple extension of the above economic mechanism. Unemployment is inversely related to the number of firms that enter the market (i.e. vacancies as in Pissarides (1985)). Thus as more firms enter unemployment falls. As the risk of being unemployed is lower, workers are willing to invest more in their human capital. Yet, since wages are not equal to the marginal product of labor, as workers invest more, firms make more profits and are more eager to open new jobs which reduces unemployment. Thus we can have an equilibrium with high unemployment and low growth as well as an equilibrium with low unemployment, high investment in human capital and a high growth rate for output.

Second, since search imperfections underlie all our results, it is worthwhile to investigate the importance of different matching technologies. In particular, certain societies have institutions that bring high human capital people together with firms that have the highest demand for these people (e.g. an "elitist" education system) in contrast to other societies that may match people randomly and then let job changes to achieve the final allocation. We show that "efficient matching" does not change the results in our basic model. However, in the presence of unemployment, giving priority in job matching to highly skilled workers creates an education race since more human capital increases the chances of getting better jobs. As workers invest more, as well as the positive externality emphasized above, they also create a negative externality because they reduce the employment probability of other workers. This can be beneficial since it is countering the underinvestment in human capital. However, as a result of this "race", some workers may end-up overinvesting in human capital while others naturally become "discouraged" and choose not to invest at all despite the fact that they are identical to the workers who invest aggressively in human capital. As a result, an endogenous inequality may arise in this economy. It is interesting to contrast this to the usual signalling story that workers may obtain too much education. Signalling models maintain that workers are ex ante heterogenous and that high quality workers overinvest in education to distinguish themselves. Here, workers are all equally productive but in equilibrium some choose to drop out of the labor market completely while the rest overinvest in education.

Finally, we turn to technology choice. The question we ask is whether technology choices create new externalities. We find the answer to be affirmative. When mobility costs are small, firms create a *negative wage formation externality* when they choose the more advanced technology because they increase the wages that all workers receive. A pecuniary externality will exist even when the labor market is competitive but will not introduce any inefficiencies. But, in the presence of labor market frictions, this negative wage formation externality can lead to advanced technologies being adopted even when they are not sufficiently profitable. Therefore, as it is argued to be the case for Singapore by Young (1992) and also for many other developing countries by development economists, an economy may move into advanced technologies too quickly and in contrast to Young's argument about Singapore, such phenomena may not only be the result of faulty government action but also a coordination failure.

The plan of the paper is as follows. The next section describes the basic environment and determines the competitive allocation. Section 3 discusses wage determination with search, derives the decentralized equilibrium and illustrates the presence of pecuniary increasing returns.

Section 4 endogenizes unemployment and compares different matching mechanisms. Section 5 turns to technology choice and shows how the wage formation externality arises and how it can lead to unprofitable technologies being adopted in equilibrium.

2) The Basic Model and The Competitive Allocation

Consider the following overlapping generations model: each generation lives for two periods. At every instant, there is a continuum of two types of agents; workers and entrepreneurs each with measure equal to 1. Each worker makes a human capital decision in the first period of his life. This human capital decision involves the extent to which this worker wants to learn and extend the stock of knowledge that is already present in the economy (e.g. education). There is no consumption in this period. In the second period, the worker sells his labor services which embody the human capital he has accumulated. In this period the worker also consumes all his returns. On the other side of the market, entrepreneurs invest in their entrepreneurial skills in the first period of their lives and again only consume in their second period. Production takes place in partnerships of one worker and one firm.

This is certainly a very stylized economy, but these assumptions are only adopted for simplification. In particular we can extend the model so that the decision to be a worker or entrepreneur is endogenous. We can allow agents to consume in both periods of their lives or let them have longer lives (these would introduce relative price effects in consumption and investment decisions thus complicate the analysis). In a similar vein, it is certainly a simplifying assumption to have entrepreneurs accumulate skills rather than physical capital and we will often think of this as physical capital. This again is not crucial for our results but merely enable us to obtain closed forms. Finally, the simple overlapping generations set-up necessitates the assumption that agents benefit from the stock of knowledge of their parents. However, it can be seen that all our results would remain unchanged if we use a model similar to Rebelo (1991) where human capital, as well as physical capital, is accumulated by infinitely lived agents. In all of our analysis, the crucial assumption will not be one of those but that both workers and entrepreneurs need to undertake their respective investments before the production stage.

The production function of a partnership takes the following form;

(1) $$y_t = A h_t^{\alpha} z_t^{1-\alpha}$$

where h_t is the human capital level of the worker and z_t is the skill level of the entrepreneur. The utility function of each worker is given by

(2) $$v_w(c_t, l_{t-1}) = c_t - \frac{l_{t-1}^{1+\gamma}}{1+\gamma} H_{t-1}$$

where l_{t-1} is the human capital investment of a worker born at t-1, γ is a positive parameter and H_{t-1} is the stock of human capital in the economy defined as

(3) $$H_{t-1} = \int_0^1 h_{t-1}^i di$$

where superscript i denotes worker i and will be dropped whenever this will cause no confusion. The human capital of the worker, h_t, is given by the following equation

(4) $$h_t = (1 + l_{t-1})(1-\delta) H_{t-1}$$

This formulation assumes that the worker absorbs and extends the stock of knowledge of either his parents or of the society by his human capital investment, l_{t-1}. Interpreting the utility function (2) in this way, we can argue that the cost of effort is proportional to H_{t-1} because the worker has to absorb this information (or alternatively higher human capital inherited from the earlier generations increases the value of leisure). According to (4), human capital depreciates at the rate δ if no further human capital investment is undertaken by the worker. The utility is maximized subject to (5) and the budget constraint

$$c_t \leq W_t = w_t h_t \tag{5}$$

where W_t is the income level of the worker and w_t is the wage rate per unit of human capital. Each entrepreneur has a similar utility function given by

$$v_e(c_t, e_{t-1}) = c_t - \frac{e_{t-1}^{1+\gamma}}{1+\gamma} Z_{t-1} \tag{6}$$

where e_{t-1} is the investment of the entrepreneur and Z_{t-1} is the stock of entrepreneurial skills of the economy at time t-1 and is defined similarly as

$$Z_{t-1} = \int_0^1 z_{t-1}^i \, di \tag{7}$$

and also

$$z_t = (1+e_{t-1})(1-\delta) Z_{t-1} \tag{8}$$

which has a similar explanation to (4). Each entrepreneur maximizes her utility, (6), subject to (8) and a budget constraint

$$c_t \leq R_t = r_t z_t \tag{9}$$

where R_t is the total income of the entrepreneur and r_t is the return to entrepreneurial skill.

The equilibrium of this economy consists of (i) an investment decision for each worker and firm; (ii) given the distribution of types of workers and firms, an allocation of workers to firms and (iii) a wage level for each level of human capital and a rate of return for each level of entrepreneurial skill. The economy will be in equilibrium iff (a) given the distribution of types, their allocation and their payments are in equilibrium, and (b) given the final rewards, the ex ante investment decisions are optimal. We start with the Walrasian system which is frictionless and all allocations take place at one point in time. That is, the auctioneer calls out wage schedule as a function of human capital levels and rates of return on entrepreneurial capital and trade stops when all markets clear. Note first that the allocation problem with competitive markets is straightforward (e.g. Kremer (1993)); the most skilled worker will be allocated to the most productive entrepreneur because the marginal willingness to pay for the best worker is highest when the level of capital is highest.

In the Walrasian equilibrium, for each pair of worker and firm, the wage rate and the rate of return on entrepreneurial capital are determined as follows:

(10)
$$w_t = w(h_t, z_t) = \alpha h_t^{\alpha-1} z_t^{1-\alpha}$$
$$r_t = r(h_t, z_t) = (1-\alpha) h_t^{\alpha} z_t^{-\alpha}$$

Given these wage rates, the equilibrium accumulation decisions are given as;

(11)
$$l_{t-1} = \{\alpha(1-\delta) A w(h_t, z_t)\}^{\frac{1}{\gamma}}$$
$$e_{t-1} = \{(1-\alpha)(1-\delta) A r(h_t, z_t)\}^{\frac{1}{\gamma}}$$

which set the marginal cost of investment equal to the marginal benefit. This gives us our first result which like all others in this paper is proved in the appendix.

Proposition 1

The competitive economy has a unique balanced growth path along which it grows at the rate g^c where $g^c = (1 + \{\alpha^{\alpha}(1-\alpha)^{1-\alpha} A(1-\delta)\}^{\frac{1}{\gamma}})(1-\delta) - 1$ and has z/h ratio equal to $(1-\alpha)/\alpha$. The unique balanced growth path is globally stable. The competitive equilibrium is Pareto Optimal.

This economy intratemporaly fully efficient in the sense that more human capital investment by a worker will not increase the welfare of other workers and firms more than it reduces the pay-off to the worker. In particular, increasing all agents' investments by 1% in this model, this will not be Pareto improving move. We thus say that this model does not exhibit *social increasing returns*. This is similar to the growth model of Uzawa (1965) or Rebelo (1991) and is different from Romer (1986) or Lucas (1988). In Lucas' and Romer's models, an agent would improve welfare at a given point in time by investing more because of the external effects and moreover, each agent wants to invest more when others increase their investment because of the technological increasing returns to scale. These features are absent in the model with competitive labor markets. Nevertheless, this economy maybe thought not to be intertemporally efficient because the current generation does not take into account the positive externality that it creates on the productivity of future generations by investing more. However, this is not true and the competitive allocation is Pareto Optimal[4]. This is because there is no way that the future generations can compensate the current generation for the increased investment (i.e. each generation only consumes in only period) and it is therefore not possible to increase investment and then by a series of redistributions to make all agents better-off.

3) Search, Incompleteness of Contracts and Pecuniary Increasing Returns

We now turn to an economy in which productive partnerships are formed via anonymous

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[4] This is obviously not the only Pareto optimal outcome. Yet it is the only one in the set of Pareto optimal outcomes that can be achieved by a competitive price system and also the one that maximizes the welfare of the current generation. Throughout the paper we will use the term Pareto optimal to refer to this allocation.

random matching. At the beginning of the second period of their lives (i.e. after the investment decisions have been made), workers and entrepreneurs are matched one-to-one, so that no worker nor entrepreneur remains unemployed (see next section, on this). Note that this economy has an explicit time dimension; investment decisions are taken first and allocations and equilibrium prices are determined later. Combined with the presence of mobility costs, this will introduce a classic hold-up situation. Although how much each agent has invested may be contractible, they cannot write a contract with their partner to relate their payments to this investment level because the identity of their partner is unknown at the time of investment. Further, since changing partners at the search stage is costly, they have to share the surplus within the partnership and an agent who invests more has no way of making sure that he or she will receive the return of this higher investment. This implies that workers' and entrepreneurs' returns are in general related to the average product of their investment (as well as, or instead of, the marginal product). In the main body of the paper we will assume that the search imperfections lead to a wage determination rule whereby the worker obtains a proportion β of the total surplus, thus wages and rates of return on capital only depend on average product. Next sub-section will offer a general equilibrium search and wage determination model which implies precisely this result as the equilibrium. Of course other assumptions on technology and bargaining would imply different sharing rules. Nevertheless, all our qualitative results would go through whenever wages are different from marginal products irrespective of the magnitude of the wedge. We also assume that matching is random so that there is an equal probability that a worker will meet each entrepreneur irrespective of his human capital and the capital level of the entrepreneurs. Naturally, in equilibrium some agents may decide to change partners so the equilibrium allocation will not be random. In our basic model, however, all agents will have chosen the same level of ex ante investment and in equilibrium matches will not be broken.

(i) Wage Determination

Let us assume that once a pair is formed, both parties incur a cost equal to ϵ when they change partners. This can be interpreted as a monetary or non-monetary mobility cost or a flow loss since finding a new partner will take time[5]. We will show that in our framework, even for very small values of ϵ, the rates of return will be completely decoupled from the marginal products. We also make a crucial assumption that in this search environment where it is costly to change partners, no agent can simultaneously bargain with more than one party and Bertrand type competition is ruled out. Thus our bargaining stage will be similar to Shaked and Sutton (1984) which is an extension of Rubinstein's (1982) framework. More precisely we assume the following structure. The firm makes a wage demand (node A in Figure 2) which can be refused by the worker (node B). If the worker refuses, she can at no cost make a counter offer (node C) or decide to leave and find a new partner at cost ϵ (to both parties). If he makes an offer, the entrepreneur can refuse this (node D) and quit again at cost ϵ and if she decides to continue with bargaining, Nature decides whether the firm or the worker will make the last offer (node E)[6].

[5] With a finite number of agents, when a worker (or entrepreneur decides to end bargaining and find a new partner, no new partners may exist. This would imply that switching partners would be even less attractive. Since we have a continuum of agents, we can avoid this problem by assuming that there always exists some unmatched agents so that switching partners is always possible, yet the set of unmatched agents may be of measure zero.

[6] We have chosen nature to move at node E to simplify the game tree, however an alternative game form where the worker and the entrepreneur asymmetrically alternate in making offers would do equally well as long as there is some sort of discounting (e.g. a small probability that

The probability that the worker will make the offer is denoted by β. This structure in a simple way captures the importance of institutional regulations that determine the balance of power between workers and firms. If β is high, the worker has a strong bargaining position and vice versa.

Lemma 1:

With homogenous agents and random matching, for all positive values of ϵ, $W_i=\beta y$ is the unique equilibrium of the economy-wide wage determination game provided that all pairs use the same extensive form, where y is the total output of each pair in this economy.

This lemma tells us that even with small search frictions, there may be a large wedge between the marginal product of factors of production and their rates of return. The intuition is simple. If the worker could ensure that when he leaves the firm, he would get his marginal product and the entrepreneur likewise would get her marginal product, the pair would just bargain over the surplus, ϵ. However, in general equilibrium, when the worker leaves, he will meet another firm and enter a very similar bargaining situation. In fact, if the firm he meets is exactly the same as the one he is bargaining with, he cannot expect anything better and hence his outside option will not be binding and bargaining will take place over the whole of the pie.

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the game will end without agreement after a rejection). However, applying the Nash solution irrespective of the extensive form would not be satisfactory since this does not correspond to the equilibrium of a well specified bargaining game unless we assume that rather agents being able to exercise their outside options, nature decides whether they will stay within the relationship or go out (see Binmore, Rubinstein and Wolinsky (1986)).

Nevertheless, the special nature of this result should be noted. First, it does not always hold in the presence of heterogenous agents, the worker (or the entrepreneur) may be moving to a better partner. Second, we are not allowing Bertrand type competition so that a worker is never able to bargain with two firms simultaneously[7]. If we allow a firm to meet two workers (or vice-versa) with a certain probability, then there will be a closer relationship between the rates of return and the marginal products but the competitive outcome will not be achieved unless we remove the mobility costs completely.

We will therefore assume that wages are always equal to a proportion β of the total surplus (but see section 5). This is partly motivated by the analysis of the game form but more generally, we know that in the presence of search imperfections, wages will not be equal to the marginal product of labor and thus vary with average (total) product and our formulation captures this in a very simple (albeit extreme) way.

(ii) Search In the Labor Market and Pecuniary Increasing Returns

In this section a worker who is in a match with total output y^i obtains $W^i=\beta y^i$ and matching is random. This implies that each worker has an equal probability of meeting each entrepreneur and likewise for each entrepreneur. Therefore, the expected income of a worker with human capital h_t conditional on the average investment of entrepreneurs is given as

$$W(h_t,\int(z_t^i)^{1-\alpha}di)=\beta Ah_t^\alpha\int(z_t^i)^{1-\alpha}di \tag{12}$$

[7] This is natural in our context. If a worker is bargaining simultaneously with two firms they will both get zero surplus. Thus ex ante a firm will have no incentive to contact a worker who is already in negotiation with or employed by another firm. However, it has to be borne in mind that a lot of the job turnover is without the experience of unemployment spell, yet whether this allows workers to bargain with two firms simultaneously is unclear.

The worker will always obtain a proportion β of the total output which will depend on the capital level of the entrepreneur z_t^i as well as his investment h_t. The expected income of an entrepreneur with capital z_t is similarly given by

$$R\left(\int (h_t^i)^\alpha di, z_t\right) = (1-\beta) A z_t^{1-\alpha} \int (h_t^i)^\alpha di \tag{13}$$

Thus, total incomes are not directly related to marginal but only to average product and consequently, the marginal reward to one more unit of investment is proportional to average product. This implies the following investment rules;

$$\begin{aligned} l_{t-1} &= \left\{\beta\alpha(1-\delta) A h_t^{\alpha-1} \int (z_t^i)^{1-\alpha} di\right\}^{\frac{1}{\gamma}} \\ e_{t-1} &= \left\{(1-\beta)(1-\alpha)(1-\delta) A z_t^{-\alpha} \int (h_t^i)^\alpha di\right\}^{\frac{1}{\gamma}} \end{aligned} \tag{14}$$

The difference between these expressions and (11) are worth noting. In both pecuniary interactions are present. However, in (14) they take the form of *pecuniary increasing returns to scale*. By increasing its investment level a worker has a first order impact on the welfare of firms in contrast to (11) where the only impact was through the equilibrium rates of returns and thus was of second-order. Moreover, when a worker increases his human capital investment, this also has a first-order impact on the desired investment level of all the entrepreneurs. And by the same argument, the increase in the entrepreneurs' investment decision will have a first-order impact on the welfare and desired investment level of all workers. This is the channel which introduces ***pecuniary increasing returns*** and ***amplification*** in the accumulation decisions; by investing less workers (firms) not only create a negative impact on the welfare of other workers and firms but are also reducing their desired investment level.

Proposition 2:

The decentralized search economy with random matching has a unique balanced growth path along which it grows at the rate g^d where $g^d = (1 + \{\alpha^\alpha(1-\alpha)^{1-\alpha}\beta^\alpha(1-\beta)^{1-\alpha}(1-\delta)A\}^{\frac{1}{\gamma}})(1-\delta) - 1$ and is less than g^c. The unique balanced growth path is globally stable but is Pareto dominated by the competitive equilibrium. The decentralized economy exhibits pecuniary increasing returns in the sense that a 1% increase in all agents investment will make everyone better off.

(iii) The Role of Institutions, Property Rights and Second-Best

Inspection of the growth rate of the decentralized equilibrium, g^d, shows that it depends on β, the way that total output is shared among workers and entrepreneurs. This will in general depend on the institutional structure of the economy (i.e. in our discussion β was exogenous[8]) and perhaps also on the allocation of property rights. Although it is clear that investment and education subsidies financed by non-distorionary taxation could restore efficiency, it may be more appropriate to assume that the government does not have the possibility of implementing such a subsidy scheme and whether it could achieve efficiency by changing institutions and property rights as captured by β. This is also an important question because we know from Mortensen (1982), Grout (1984) and Hosios (1989) that a reallocation of property rights can sometimes achieve first-best. However, in our model, due to the bilateral investment aspect, such a way of achieving efficiency is not possible (this is also the case in Diamond (1982), Grossman and Hart (1986), Hart and Moore (1989)).

[8] It can be argued that in Rubinstein's (1982) framework with alternating offers, β will only depend on discount factors. Yet, in real world bargaining situations many other features seem to be more important in determining the relative bargaining strength.

Proposition 3:

$\beta=\alpha$ achieves the highest balanced growth but never achieves Pareto optimality

The intuition is straightforward, α captures by how much total output increases by one more unit of human capital investment and (1-α) is the incremental contribution of entrepreneurial investment to output. For second-best efficiency, workers should receive a proportion α of the total product they create and firms a proportion (1-α). This also makes it clear that if only one of the parties had an ex ante investment, first best could be achieved. Alternatively, efficiency can be restored if the share of the worker (and the entrepreneur) can be conditioned upon their ex ante investments. However, this requires more than a straightforward reallocation of property rights. In particular, since it is not known who will form a pair, even though ex ante investments may be contractible, efficient provision of incentives requires multilateral contracts conditional upon ex ante investments. Although we can envisage situations in which a social planner can implement a system of this sort, the decentralized equilibrium cannot easily achieve this.

Since our analysis so far implies that property rights and factor shares of labor and capital will be important in accumulation decisions, it is important to investigate whether there is any evidence in favor of such a hypothesis. It is interesting to note that many economic historians emphasize the importance of institutions and property rights (e.g. North (1981), Mokyr (1990)) in the industrialization process. The role of institutions is of course crucial in determining the balance of powers between labor and capital and how the national output is divided between these factors. Eichengreen (1993) emphasizes the importance of these issues in the post-war European growth with particular emphasis how institutional developments influenced the balance between labor and capital and consequently the rate of return on physical capital and Bean and Crafts (1993) discuss the same issues for the UK. Both of these papers emphasize the incentives to invest in physical capital and the importance of bargaining in this process (though the Grout (1984) effects). However, human capital is equally important. Countries like Japan and Germany stand out among OECD counties in the emphasis they place on education and training (e.g. Hashimoto (1991), Soskice (1992), OECD (1991)) and have experienced relatively successful growth spells. Mokyr (1990) points out that at the time of the industrial revolution, Britain was no more advanced than continental Europe in scientific knowledge (in fact Kuhn (1967) describes Britain as scientifically backward) but rewarded human capital (e.g. artisans) more. Our simple minded plot in Figure 1 also suggests that increasing the factor share of capital may not always be a productivity boosting strategy.

(iv) Efficient Matching

Is random matching an important assumption? It may be as we will see in the next section. In the presence of efficient matching, with more investment, not only the average product goes up but also the likelihood of being employed and ending up with a good job increases. In contrast for our basic model, corollary to Proposition 2 shows that efficient matching does not influence the equilibrium allocations.

Corollary to Proposition 2:

With efficient instead of random matching all the results of Proposition 2 hold.

The intuition is simple. Efficient matching, even more than random matching, implies that all workers (entrepreneurs) should have the same return in equilibrium. In our basic model, this is only possible if they all choose the same level of ex ante investment and in this case, efficient and random matching are very similar. We will see in the next section that when agents can end-up in different situations ex post (e.g. employed and unemployed), efficient matching will introduce new effects.

4) Unemployment, Multiple Growth Paths and Consequences of Efficient Matching

In this section we will relax the assumption that all workers find employment. This will introduce a number of new effects. First, an interesting interaction between unemployment and human capital accumulation will arise. Secondly, we will be able to illustrate some of our results in a simpler framework without explicit investment on the part of entrepreneurs. Thirdly, a new source of multiplicity of equilibria will be obtained. Finally, we will see that in general efficient matching may lead to very different outcomes than random matching.

In order to illustrate these points we will maintain the labor side as above, however remove the investment decision of the entrepreneurs and instead only allow them to decide whether to enter the market or remain idle. The production function of a partnership is now given by

$$y_t = Ah_t \tag{16}$$

However the worker cannot produce anything by himself[9]. The utility function of the

---

[9] - Note that by removing the investment decisions of the entrepreneurs, we are reducing the extent of increasing returns, thus making the multiplicity of equilibria harder but also more transparent.

entrepreneurs is

$$(17) \qquad v_e(c_t, e_{t-1}) = c_t - \mu(E_{t-1}) e_{t-1} H_{t-1}$$

where e_{t-1} only takes the values 0 or 1. The former denotes the entrepreneur deciding to be inactive (or active in another -non-growth- sector), whereas $e_{t-1} = 1$ implies that the entrepreneur has decided to allocate her talents to production. E_{t-1} is the measure of active entrepreneurs. The cost of becoming productive depends upon H_{t-1} because in the same way as the worker has to absorb the stock of knowledge of the society so does the entrepreneur. It also depends upon E_{t-1}, the number of agents who decided to become entrepreneurs at time t-1 since there may be decreasing returns as the entrepreneurial market becomes congested[10]. A formulation that captures the idea that the costs to entrepreneurship are related to search is to derive μ(E) from the standard matching function (e.g. Pissarides (1990)). According to this interpretation, each entrepreneur incurs a set-up cost η_0 and also decides how many vacancies to open. When there are more open vacancies, the probability that each vacancy will get filled is smaller and each entrepreneur needs to open more vacancies. Note in particular that in this interpretation, the matching technology can be constant returns to scale as found by Blanchard and Diamond (1990); thus in no point we will require increasing returns in the search technology. But, our arguments would also go through with decreasing returns or limited increasing returns in the search technology as well. The crucial ingredient is that the probability of vacancy getting filled is decreasing in the number of vacancies. To capture all these features we will assume that the search technology takes a Cobb-Douglas form where the number of jobs (or active employers)

10. This type of congestion would follows from search, product or factor market competition. If this type of decreasing returns are not present, we would have two extreme equilibria, one in which all entrepreneurs are active and one where none are.

is given as $E=V^{\nu}U^{\xi}$ where U is the number of workers looking for a job (which is equal to 1 in our model) and V is the number of vacancies. The key assumption for us is that $\nu<1$. This implies;

(18)
$$\mu(0)=\eta_0$$
$$\lim \mu(E)_{E\to 1}=\infty$$

The intuition is simple. As the number of vacancies goes to zero, the probability that a vacancy gets filled is 1, thus an entrepreneur can become active at no cost. When all entrepreneurs are active, each entrepreneur needs to open a very high number of vacancies to be active. Since in general not all entrepreneurs enter the market, there will be unemployment among workers. In particular as E entrepreneurs become active, the unemployment (rate) will be given as $u_t=1-E_{t-1}$.

a) Random Matching and Suboptimal Growth

Random matching implies that each worker has a probability $(1-u_t)$ or E_{t-1} of ending up with an entrepreneur. Since we assumed that the worker's human capital is not productive when he is not matched with an entrepreneur, the expected return of the worker is

(19)
$$\beta(1-u_t)Ah_t$$

Note that given the utility function (2), the worker's utility is linear in money income, so he is risk-neutral. Thus utility maximization would imply

(20)
$$l_{t-1}^{r}=\{(\beta(1-u_t)A(1-\delta)\}^{\frac{1}{\gamma}}$$

The investment decisions of workers and the growth rate of this economy will be even further distorted due to the presence of unemployment in (20); in particular, the higher is the unemployment rate of the economy, the lower will the growth rate be. However this is only a partial equilibrium result since unemployment is also endogenous, so the correlation between unemployment and growth will depend on which structural variables differ across economies or time periods (see Aghion and Howitt (1992), Bean and Pissarides (1992), Acemoglu (1993)).

Next we need to determine the unemployment rate in this economy. For this we turn to the behavior of the entrepreneurs. Entry will stop only when return to entrepreneurship is equal to the cost, thus

$$\mu(E_{t-1})=(1-\beta)A(1-\delta)(1+\{\beta E_{t-1}A(1-\delta)\}^{\frac{1}{\gamma}}) \tag{21}$$

Inspection (20) and (21) show in a very simple way the presence of *pecuniary increasing returns to scale*. When an entrepreneur decides to enter the market, all workers are made better off because the probability that they will be unemployed falls. And in response to this they decide to invest more - equation (20). When workers invest more, all entrepreneurs are made better off because they share the increased productivity of the workers. This amplification of the initial inefficiencies also leads to the possibility of multiplicity of equilibria as the Figure 3 shows. The two curves that denote the left and right-hand sides of (20) are both increasing in E_{t-1} and can intersect more than once and equilibria with different unemployment and growth rates are possible.

At this stage it is also instructive to look at the efficient outcome in this economy. For this purpose we can distinguish between the "first-best" where a social planner would avoid the matching imperfections and can thus make sure that only workers who will be employed undertake the investment and the "second-best" where the social planner is subject to exactly the same matching imperfections as the decentralized economy. In the case of first-best, the efficient investment is obviously $l^*=\{A(1-\delta)\}^{1/\gamma}$. This is also the investment level and the growth rate that a competitive labor market without matching imperfections would achieve. However, in the presence of matching imperfections, the social planner can only achieve the second-best, or the constrained optimal allocation. In this case, all workers will have to invest in their human capital and some of them, just as in the decentralized outcome, will be unemployed and not use their skills. However, the crucial difference is that the social planner will internalize the pecuniary increasing returns and instead of setting the ex ante investment given by (20), he would choose $l^{**}(E)=\{A(1-\delta)E\}^{1/\gamma}$, thus in investing in human capital, he will take into account that entrepreneurs could also be benefiting from this investment level. Similarly, in (21) entrepreneurs ignore the positive externalities they are creating. Thus (21) would be replaced by

(21') $$\mu'(E)=A(1-\delta)(1+\{A(1-\delta)E\}^{1/\gamma})$$

We can now state;

Proposition 4:

Consider the economy described above. If $\eta_0>(1-\beta)A(1-\delta)$, there will exist either one equilibrium with no activity or three balanced growth path equilibria with different unemployment rates[11]. Equilibrium with lower unemployment Pareto dominates the ones with higher unemployment and all equilibria are constrained and unconstrained Pareto inefficient and pecuniary increasing returns are present.

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[11] Note that because of our simple setting, the equilibrium at time t does not affect the likelihood of high or low unemployment equilibrium at time t+1. Therefore, there exist non-balanced growth equilibria in which there is high growth and low unemployment for a number of periods and low growth and high unemployment for some other periods.

b) Efficient Matching and Overinvestment

Labor market institutions differ in how they bring people together. Certain societies have institutions designed to put highly skilled people in certain specific jobs, such as an "elitist" education system or a segregated labor market, while others rely less on such institutions. A possible objection to our analysis so far that relied on random matching is that it ignores the role of such institutions which may to a large extent remedy, underinvestment problems. We saw that this was not the case in our basic model by allowing for the extreme form of efficient matching. However, when agents can end-up in different states and their human capital influences their likelihood of being in one state or the other, efficient matching will have different implications.

Since workers who have higher human capital will be allocated to firms before other workers, each will increase his likelihood of being employed by investing more. This creates an education race among the workers and as a result human capital may be accumulated faster than in the Pareto optimal outcome. This is because in contrast to the previous cases in which workers only created a positive externality on fellow workers by their investment decisions, now they also create a negative externality since more investment reduces other workers' employment probabilities.

Equilibrium will be when no worker can increase his pay-off by investing more in human capital which implies that all workers should be indifferent between being employed and unemployed. This would require some workers to choose a high investment in human capital and be matched with the entrepreneurs while others do not invest in human capital and remain unemployed. Suppose this is not the case. Then an unemployed worker can increase his human capital slightly above those of the employed, obtain a job and be better-off. It follows that with efficient matching we no longer have involuntary unemployment of workers but we still have unemployment of productive human capital. Workers who could put their skills to productive use are not doing so and potentially productive resources are remaining idle. This perhaps suggests that involuntary versus voluntary unemployment is not a particularly informative distinction in the context of human capital accumulation.

The equilibrium condition in this case is

(22)
$$\frac{(l_{t-1}^{e})^{1+\gamma}}{1+\gamma}=\beta A(1-u_t)(1-\delta)$$
$$l_{t-1}^{e}=\{\beta A(1-u_t)(1-\delta)(1+\gamma)\}^{\frac{1}{1+\gamma}}$$

Firstly note that if unemployment is sufficiently low and β sufficiently close to 1, l_{t-1} can be higher than the constrained optimum. It can even be higher than the unconstrained optimum (i.e. the growth rate that an economy without matching frictions would achieve). This is because the negative externaltiy created by the racing aspect can potentially dominate the positive externality we have emphasized so far.

Now combining this with the zero profit condition of the entrepreneurs and again bearing in mind that $u_t=1-E_{t-1}$, we can determine the equilibrium of this economy as follows.

(23)
$$\mu(E_{t-1})=(1-\beta)A(1-\delta)(1+\{\beta AE_{t-1}(1-\delta)(1+\gamma)\}^{\frac{1}{1+\gamma}})$$

Since both sides are increasing in E, a multiplicity of equilibria is again possible.

Proposition 5:

In the economy described in this subsection, if $\eta_0 > (1-\beta)A(1-\delta)$, there will exit exist on equilibrium with no activity or three balanced growth equilibria. In all equilibria with positive activity, some workers overinvest in human capital while others choose not to invest at all. This economy may grow faster than the constrained optimum. If $E > \frac{(1-\delta)^{1/\gamma}}{\beta(1+\gamma)}$, the economy with E entrepreneurs will grow faster than the competitive economy without matching imperfections.

Similar to the case with random matching, pecuniary increasing returns are present and multiplicity of equilibria is possible. Also note that the economy growing faster than the constrained or unconstrained optimum is inefficient and workers in particular end up worse off. The intuition underlying the multiplicity is the same as before, but the possibility of overinvestment is new and driven by the negative externality that the education race creates. A number of points are worth noting. First, the education race will often be socially beneficial because it will counteract the positive externalities emphasized so far. However, it is also possible for the negative externality created by the education race to more than offset the positive externality and this would lead to overinvestment. Second, it is interesting to note that the possibility of overinvestment in education in order to obtain better jobs is similar to signalling models. Yet the underlying mechanism and the assumptions are very different. In our model, all workers are identical but in equilibrium some of them become naturally "discouraged" and effectively leave themselves out of the labor market. Finally, note that these effects may also lead to endogenous inequalities across dynasties if we assume that workers do not only absorb the stock of knowledge of the society as a whole but partly those of their parents. Discouraged workers choose to accumulate little or no human capital and as a result, their offsprings will be naturally discouraged too.

5) Technology Choice, Wage Determination and Multiplicity of Equilibria

This section has two objectives. The first is a theoretical one; we want to investigate how, in the presence of sufficient heterogeneity, outside options of the workers will influence equilibrium allocations and wage determination. For this reason, we consider the possibility of two types of firms with different productivity levels and study wage determination explicitly as in Section 3(i). The second is the conjecture that certain economies may sometimes move into advanced technologies too quickly. This point has been emphasized by Young (1992) for Singapore where it is argued that this rapid rate of technology adoption has not allowed Singapore to exploit the possible productivity gains in each sector. Here we will rely on a different mechanism that implies the possibility of too quick adoption of advanced technologies.

We maintain the model as in the previous section and assume matching to be random. The only difference is that instead of deciding whether to enter the market or not, entrepreneurs only have a technology choice. They can decide to stay with their existing technology at no cost, which has productivity A_1 or by incurring a cost equal to kH_{t-1} to adopt a more productive technology with productivity A_2. We first start with the case of high switching costs (ϵ tending to infinity) which will imply that outside options are never binding and will give us a multiplicity of equilibria similar to that of the last section.

a) High mobility costs

We denote the proportion of firms that adopted the high fixed cost technology by τ. High mobility costs imply that a worker will produce with the first firm he is matched with and get a proportion β of the surplus. This implies that a worker of human capital h, will have an expected wage equal to $\beta\{(1-\tau)A_1+\tau A_2\}h$. Thus the optimal human capital investment of the worker is given as

(24)
$$I_{t-1}^{m}(\tau)=\{\beta((1-\tau)A_1+\tau A_2)(1-\delta)\}^{\frac{1}{\gamma}}$$

When all firms are expected to use the low fixed cost technology, the human capital investment of the workers will be given by

(25)
$$I_{t-1}^{m}(0)=\{\beta A_1(1-\delta)\}^{\frac{1}{\gamma}}$$

In contrast when all firms are expected to adopt the technology with the higher marginal product, workers will optimally chor : the higher level of human capital investment

(26)
$$I_{t-1}^{m}(1)=\{\beta A_2(1-\delta)\}^{\frac{1}{\gamma}}$$

The profitability of the new investment for the entrepreneurs is obviously increasing in the level of the workers' human capital. In turn, workers are willing to invest more in human capital when all the firms possess the new technology because their average product is higher. Therefore as in the previous sections, investment in this technology is subject to *pecuniary increasing returns*. By investing in the new technology firms are making workers better-off and when workers invest more in response, all firms experience increased profits. As a result of this increasing returns, we have;

Proposition 6:

As $\epsilon \rightarrow \infty$, if

(27)
$$(1-\beta)A_1\{\beta A_1(1-\delta)\}^{\frac{1}{\gamma}} > (1-\beta)A_2\{\beta A_1(1-\delta)\}^{\frac{1}{\gamma}} - k$$

and

(28)
$$(1-\beta)A_1\{\beta A_2(1-\delta)\}^{\frac{1}{\gamma}} < (1-\beta)A_2\{\beta A_2(1-\delta)\}^{\frac{1}{\gamma}} - k$$

there exist two pure strategy symmetric Nash equilibria, one in which the high cost technology is adopted and one in which it is not.

Intuitively, for the new technology to be productive, a large scale of production is required. In terms of our model, this corresponds to workers choosing a high level of human capital investment. However, workers will only do this when they expect high rewards, i.e. high average products and this will be the case when all their future partners are expected to choose the more productive technology.

b) Small Mobility Cost

When the mobility cost, ϵ, is small new interactions are introduced at the wage determination stage. For this reason we explicitly go back to the wage determination model of section 3(i). A worker's outside option may be binding when it is matched with the low technology entrepreneurs. Here we have to model what happens after the worker decides to switch. We assume that he is randomly matched with an entrepreneur from the set of unmatched entrepreneurs (which as before we assume may be of measure zero but is never empty). Thus the worker knows that he will find a new partner if he pays the switching cost ϵ. In particular let us assume that the proportion of entrepreneurs with the high fixed cost technology is equal to τ, the unconditional probability of an entrepreneur possessing the more productive technology[12]. Thus if the worker keeps moving until matched with a more productive entrepreneur his expected cost will be ϵ/τ. Therefore the wage rate that a worker with human capital h receives when matched with a less productive firm has to be given as

$$w_1 = \max\{\beta A_1 h, \beta A_2 h - \frac{\epsilon}{\tau}\} \tag{29}$$

for him not to switch. This equation is straightforward to explain. The outside option of the worker is what he can get in a more productive firm minus the cost of moving to such a firm. If this is less than his share of the pie he will obtain his share and if it is more, his outside option would be binding and he would obtain his outside option (irrespective of whether the initial partnership continues). In the previous sections, the outside option was never binding whereas it is now.

From equation (29), we can see that as a firm invests, the outside of option of all workers will go up and all firms using the old technology have to pay higher prices. This looks very much like a pecuniary externality that is present in competitive models as well (as the

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[12] This is not strictly correct in general since we must use the conditional probability that an unmatched entrepreneur has the more productive technology. But we will only look at τ tending to zero and infinity, and in both cases (29) applies exactly.

demand for labor increases, the wage rate goes up). However, because of the non-competitive forces in the labor market, this interaction can have first-order welfare effects on other agents. In particular, this externality will tend to encourage other firms to adopt the new technology. When there is too little investment in this economy, the presence of this externality may be welfare improving. However, it is also possible, as we will see, for an unproductive new technology to be adopted.

As more firms invest in the new technology, the wage rate that worker expect per unit of human capital goes up and as a result, workers prefer to invest more. Next, note that for firms that have adopted the advanced technology, wages are still set with reference to average product. Thus these firms make more profits as workers increase their investments. On the other hand, low technology firms also have to pay the same wages but as a result, they benefit less. Thus as more firms invest, the low technology firms are made worse-off and the advanced technology becomes more attractive. This effect can be strong enough to overturn the positive externality emphasized in the last subsection and create a *negative wage formation externality*[13].

To analyze the interaction in this case more carefully, let $\epsilon \to 0$. In this case, from (29) workers can always obtain $\beta A_2 h$ (either they meet or switch to a high productivity firm or their outside option is binding when they bargain with a low productivity firm). Anticipating this, they choose their human capital investment equal to $l_{t-1}(1)$ as in (26) above.

At this level of human capital investment, return to low technology is proportional to

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[13] If the two types of firms were very similar, the negative externality imposed by the more productive firm on the less productive types would be very small. This is the reason why in the basic model, this externality did not feature.

(30) $$\{A_1(1+\{\beta A_2(1-\delta)\}^{\frac{1}{\gamma}})-\beta A_2(1+\{\beta A_2(1-\delta)\}^{\frac{1}{\gamma}})\}$$

Whereas the return to choosing the more productive technology will be

(31) $$\{(1-\beta)A_2(+1+\{\beta A_2(1-\delta)\}^{\frac{1}{\gamma}})-k\}$$

Thus when all other firms choose the more productive technology it is profitable to do so if

(32) $$(A_2-A_1)(1+\{\beta A_2(1-\delta)\}^{\frac{1}{\gamma}})>k$$

Proposition 7:

As $\epsilon\to 0$, if (27) and (32) are satisfied, there exist two symmetric pure strategy equilibria, one in which the high productivity technology is adopted and one in which the low productivity technology is used. The advanced technology can be adopted even when it is not socially optimal to do so.

Thus as a result of the negative wage formation externality, the economy may move into new technologies too quickly. When a high number of firms are expected to adopt this technology, firms anticipate that they will have to pay higher wages even when they do not possess the new technology and the higher human capital of workers may make the new technology sufficiently attractive. However, it has to be borne in mind that most of the time, the negative externality will be counteracting the positive externality we have emphasized so far, thus it will often reduce the inefficiencies. Yet, since it can also more than offset the positive externality, it is true that

6) Conclusion

The main argument of this paper is that imperfections in the labor market have important effects on accumulation decisions. Search and related imperfections create a wedge between the marginal product of factors of production and their rates of return and thus distort the investment incentives for accumulable factors. Also because of search, a natural incompleteness of contracts is induced and this prevents the possibility of providing the right incentives at the ex ante investment stage. However this is only tip of the iceberg; when there exist more than one accumulable factors and these factor are complements in the productions function, we obtain *amplification* of the underinvestment inefficiencies and *pecuniary increasing returns*. When workers accumulate less human capital, this not only depresses the growth rate but also reduces the profitability of physical capital investment since the wage rate is not equal to the marginal product of labor. As a result, there will be less physical investment but, by the same argument this depresses the rate of return on human capital and all the workers will also want to invest less. Consequently the original inefficiency is amplified and increasing returns are obtained as in Romer (1986) and Lucas (1988), yet the externalities are not technological but derived from interactions in the labor market.

The paper shows that this type of framework implies that labor market institutions have a direct impact on the rate of growth and that an optimal distribution of income across factors exist. Further, allowing for non-competitive labor markets enables us to investigate a number of different issues. First, depending on the form of matching, an "education race" may be induced among workers. Those who have more human capital obtain priority in the labor market, thus workers accumulate human capital to get ahead of other workers. This may mitigate the effects of underinvestment but it may also lead to too much human capital in equilibrium and also induce endogenous inequality across otherwise identical workers. Second workers are willing to accumulate more human capital when future unemployment is lower because there is a smaller probability that their human capital will be of no use. However, the more human capital is accumulated by the workers, the more profits the firms make and the more vacancies they are willing to open, which in turn reduces unemployment. Therefore, a new source of multiplicity of equilibria is obtained. Finally, we also showed that a negative wage formation externality also exists. Firms that invest in more advanced technologies force the rest to pay higher wages.

Many of the effects suggested in this paper require more research. First, equilibrium wage determination with small mobility costs and heterogenous workers and firms needs to be fully solved. Although the effects emphasized in this paper will definitely survive there, new effects may also be introduced. For instance, whether with sufficient heterogeneity, small mobility costs create a "large" divergence between marginal products and rates of return; whether non-symmetric equilibria exist where, as in our section 4, some workers naturally become discouraged. It will also be interesting to investigate what the extent of equilibrium misallocation of workers to firms will be with non-negligible mobility costs. Second, a more forward looking model of capital accumulation would be useful. Using such a model, the quantitative effects of the mechanisms proposed in this paper can be evaluated. Third, a careful investigation of the empirical relationship between factor shares and growth rate of output and of productivity will be informative.

FIGURE 1

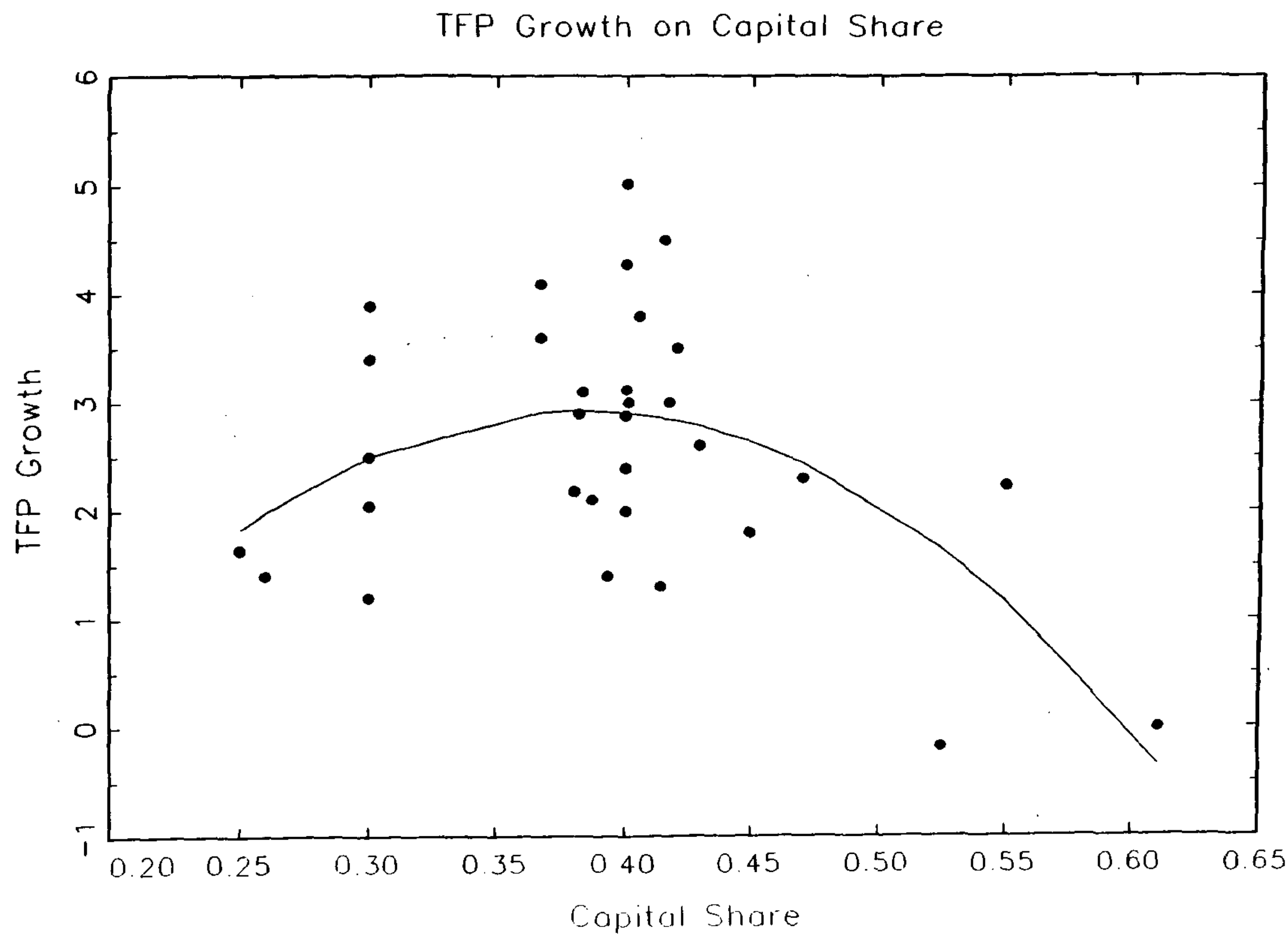
TFP Growth on Capital Share
TFP Growth
Capital Share
6
5
4
3
2
1
0
-1
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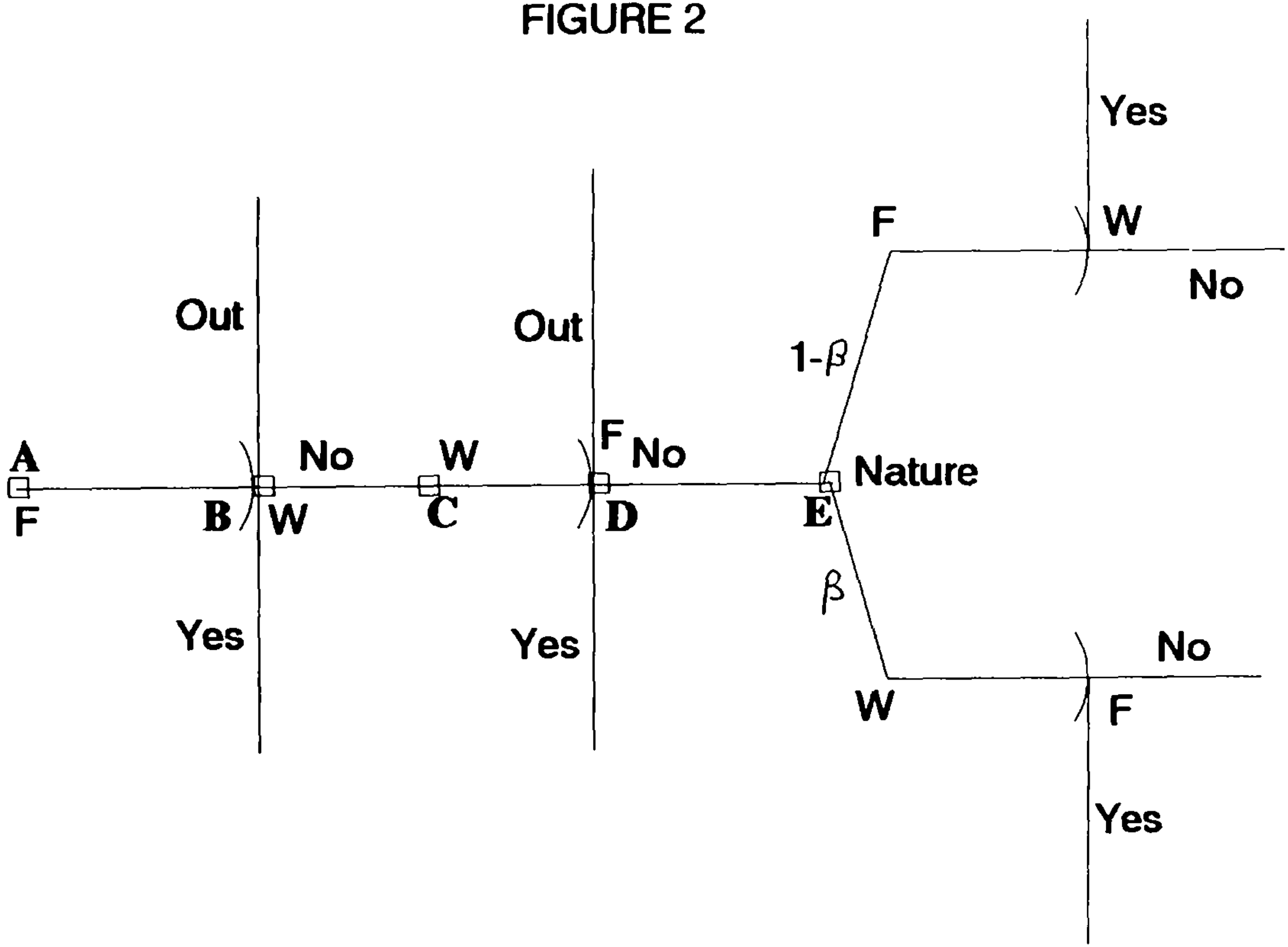
FIGURE 2



Yes
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1-β
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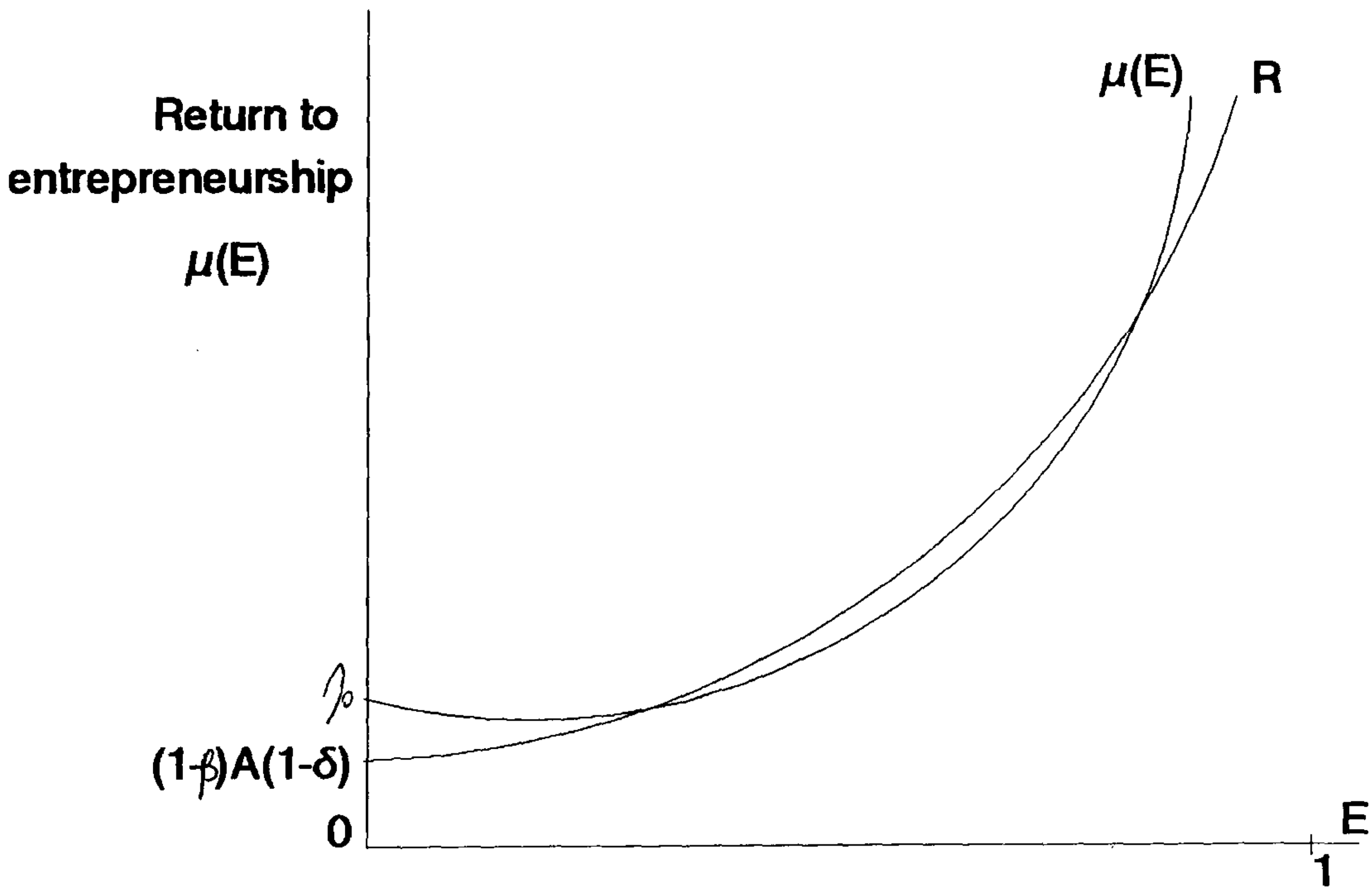
Yes

FIGURE 3


Return to
entrepreneurship
μ(E)
μ(E)
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γ_0
(1-β)A(1-δ)
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1

Appendix

Proof of Proposition 1: (11) defines optimal decision rules. Substituting from (12) we get

$$\text{(A1)} \qquad \frac{l_{t-1}(1+l_{t-1})}{e_{t-1}(1-e_{t-1})}=\frac{\alpha}{1-\alpha}\frac{Z_{t-1}}{H_{t-1}}$$

for all pairs. Balanced growth is only possible when the growth rate of Z_t and that of H_t are equal which implies investment levels

$$\text{(A2)} \qquad l_{t-1}=e_{t-1}=\{\alpha^{\alpha}(1-\alpha)^{1-\alpha}A(1-\delta)\}^{\frac{1}{\gamma}}$$

(A2) makes sure that both H_t and Z_t grow at the same rate and output will also grow at this rate g^c. Equation (A1) also implies that if z/h ratio is less than $(1-\alpha)/\alpha$, more entrepreneurial capital than human capital will be accumulated, and vice versa if the ratio is more than $(1-\alpha)/\alpha$. Thus the balanced growth path is globally stable.

Pareto optimality follows from the observation that this allocation maximizes the welfare of generation t given H_{t-1} and Z_{t-1} and that there is no possibility of redistribution welfare across generations, so increasing the investment of current generation to improve the welfare of future generations will not be Pareto improving action. QED

Proof of Lemma 1: Consider the extensive form in Figure 1 and let us denote the supremum expected return of the entrepreneur by V^S_E. If the game reaches node E, the expected return of the worker is βy and that of the firm is $(1-\beta)y$. Next consider node D; since all pairs are playing the exact same game, the entrepreneur cannot expect more than $V^S_E-\epsilon$ from changing partners. On the other hand, she can say no and stay in the reach node E and obtain βy. Therefore at node

C the worker has to offer the firm $\max\{V^S_E-\epsilon,(1-\beta)y\}$. Now move to node B, the worker can say no and continue with bargaining in which case the game will proceed to node C and he will obtain $y-\max\{V^S_E-\epsilon,(1-\beta)y\}$. Alternatively, he can say no and leave to obtain his outside option. Since we are after the supremum of the pay-off set of the firm, let us suppose that the worker gets his infimum, denoted by V^I_W. It follows that at node A, the supremum of the pay-off set of the entrepreneur is

$$V_E^S = y - \max\{V_W^I - \epsilon, y - \max\{V_E^S - \epsilon, (1-\beta)y\}\} \tag{A3}$$

Now noting that $V^S_E+V^I_W=y$, this equation has a unique solution which is $V^S_E=(1-\beta)y$.

We can now repeat the above argument with the infimum of the pay-off set which will imply that $V^I_E=(1-\beta)y$. Thus given the extensive form, there is a unique equilibrium irrespective of the value of ϵ (as long as it is not equal to zero) in which the worker receives βy. QED

Proof of Proposition 2: Equation (14) implies that all workers face the same distribution of returns and their problem is concave, thus they will all choose the same level of human capital investment and the same argument applies to entrepreneurs. Imposing this condition we obtain

$$\frac{l_{t-1}(1+l_{t-1})}{e_{t-1}(1+e_{t-1})} = \frac{\alpha\beta}{(1-\alpha)(1-\beta)} \frac{Z_{t-1}}{H_{t-1}} \tag{A4}$$

for all pairs. Balanced growth is only possible when the growth rate of Z_t and that of H_t are equal which implies

$$l_{t-1} = e_{t-1} = \{\alpha^{\alpha}(1-\alpha)^{1-\alpha}\beta^{\alpha}(1-\beta)^{1-\alpha}A(1-\delta)\}^{\frac{1}{\gamma}} \tag{A5}$$

and therefore the economy grows at the rate g^d as given in the text. By the same argument as above, if the z/h ratio is different than the one consistent with balanced growth, i.e. $\alpha\beta/(1-\alpha)(1-\beta)$, transitory dynamics will bring the economy back to balanced growth.

Both on and off the balanced growth path, all agents can be made better off, if a Social Planner imposes the competitive investment levels, therefore the dynamic equilibrium is inefficient. The last thing to prove is that pecuniary increasing returns are present in the sense that a 1% increase in all agents investment will make everyone better-off. Consider such a change. The impact on the welfare of a worker will be proportional to

(A6) $$(1-\delta)(1-\alpha)(1-\beta)Ah_t^{\alpha}z_t^{-\alpha}dz_t+\{(1-\delta)\alpha\beta Ah_t^{\alpha-1}z_t^{1-\alpha})-l_{t-1}^{\gamma}\}dh_t$$

The coefficient of dh_t is equal to zero by the first-order condition and thus the effect on the welfare of he worker will be positive. A similar term applies for the welfare of the entrepreneurs and they too are better-off. Thus a 1% increase in the investments of all current agents makes all current agents (and so, all future agents) better-off and the economy us subject to *pecuniary increasing returns*. QED

Proof of Proposition 3: Straightforward maximization of g^d gives $\beta=\alpha$ but by the above argument is still Pareto dominated. QED

Proof of Corollary to Proposition 2: Efficient matching implies that all workers should have the same level of utility. Suppose this is not the case so that worker j has higher utility than worker i. If worker i has lower human capital than j, then i can choose ξ more than j and be better off. So this cannot be an equilibrium. Also if i has more human capital he would like to reduce his human capital investment. Thus this cannot be an equilibrium. The same argument applies to firms and hence they too should have the same utility level. Given that the problem we have is convex, this can only be possible, if they all choose the same level of ex ante investment. But in this case all workers are homogenous and so are all entrepreneurs so wage determination with efficient matching gives exactly the same outcome as random matching.

Next to show that l_{t-1} and e_{t-1} as given by Proposition 2 are the unique equilibria. Suppose that we have higher levels of investment. Then a worker (or entrepreneur) can reduce their investment, they will still receive a proportion β of the surplus but at this level, first-order conditions (14) do not hold, thus they will be better-off. This argument however does not apply when (14) holds, we thus have the unique equilibrium given by Proposition 2. The rest of the proposition trivially follows. QED

Proof of Proposition 4: Random matching again implies that all workers facing the same convex maximization problem and they will all choose the same level of investment. Thus the intersections of the two curves denoting the right and left-hand sides of (21) characterize all the equilibria. When no entrepreneur enters, workers do not invest in human capital at all. If η_0 is greater than $(1-\beta)A(1+\delta)$, at this level of human capital, an entrepreneur who deviates and decides to enter would not make enough profits to cover her start-up costs. However, we also know from (18) that if all firms want to be active, this is infinitely costly for the last firm, thus in the neighborhood of 1, $\mu(E)$ is vertically above the curve that denotes returns to active entrepreneurship. Therefore, if the two curves will intersect at all they must intersect at least two more times. The presence of pecuniary increasing returns can be demonstrated by exactly the same method as in the proof of Proposition 2 and the Pareto dominance also follows. QED

Proof of Proposition 5: As in the proof of Corollary, efficient matching implies that all workers should have the same level of utility irrespective of whether they are employed or not. Suppose otherwise. Then a worker could obtain more human capital then the least skilled employed worker and by efficient matching would obtain the job in preference to this worker and he would be better off. This can only be the case if the employed overinvest sufficiently in human capital so that they are no better off than an unemployed worker who receives no wage but also who has not incurred the cost of human capital accumulation. Thus all workers who invest in human capital find a job for sure and the rest does not invest at all. Equation (22) follows and the zero profit condition for entrepreneurs is appropriately modified. Comparing (22) to the first-best investment level, $I^* = \{A(1-\delta)\}^{1/\gamma}$, the last part of the proposition follows. QED

Proof of Proposition 6: Substitute (25) and (26) in the profits of an entrepreneur with and without the new technology and we obtain conditions (27) and (28). QED

Proof of Proposition 7: First consider the case in which ϵ is positive and τ tends to zero. This implies that the worker will have to switch infinitely many partners before finding some with the high technology and thus his outside option is not binding and he always receives $\beta A_1 h$. This gives us the same value of $I_{t1}(0)$ and condition (27) for investment in the less productive technology to be an equilibrium.

Next consider the case with $\tau \to 1$ and $\epsilon \to 0$. Equation (29) for the wage rate implies that a firm without the more productive technology has to pay exactly the same wage rate as the more productive firms. (30) and (31) follow directly as the returns to low and high technology and their comparison gives (32).

For the new technology to be accepted in the first-best we need

(A7) $$A_2(1+\{A_2(1-\delta)\}^{\frac{1}{\gamma}})-k-\Delta UC>A_1(1+\{A_1(1-\delta)\}^{\frac{1}{\gamma}})$$

where $\Delta UC.H_{t-1}$ is the utility cost of higher investment for each worker. It is straightforward to see that (A7) is more restrictive than (32) even when ΔUC is set equal to zero. Thus, advanced technologies that would not be adopted in the first-best can still be adopted in the decentralized economy if ϵ is small enough. QED

References

Acemoglu, D. (1993);"Labor Market Imperfections and Thick Market Externalities From Innovation" MIT mimeo.

Aghion, P. and P. Howitt (1992);"Growth and Unemployment" mimeo.

Baumol, W. (1990);"Entrepreneurship: Productive, Unproductive and Destructive" *Journal of Political Economy* Vol. 98, 893-921.

Bean, C. R. and N. Crafts (1993);"Britain, 1945-1992" Paper Presented in CEPR Conference on The Economic Performance of Europe After the Second World War.

Bean, C. R. and C. A. Pissarides (1992);"Unemployment, consumption and Growth" Centre For Economic Performance Discussion Paper No. 100.

Binmore K., A. Rubinstein and A. Wolinsky (1986); *Rand Journal of Economics*

Caballero, R. and M. Hammour (1993);"On the Timing and Efficiency of Job Creation and Destruction" MIT mimeo.

Cooper, R. and A. John (1988); "Coordinating Coordination Failures in Keynesian Models" *Quarterly Journal of Economics* Vol 103, pp 441-65.

Davis, S. (1993);

Diamond, P. (1982); "Aggregate Demand Management in a Search Equilibrium" *Journal of Political Economy* Vol 90, pp 881-94.

Eichengreen, B. (1993);"Institutions and Economic Growth: Europe After World War II" Paper Presented in CEPR Conference on The Economic Performance of Europe After the Second World War.

Grossman, S. and O. Hart (1986);"Costs and Benefits of Ownership: A Theory of Vertical and

Lateral Integration" *Journal of Political Economy* Vol 94, 691-719.

Grout, P. (1984); "Investment and Wages in the Absence of Binding Contracts: A Nash Bargaining Approach" *Econometrica* Vol 52, pp 449-60.

Hart, O. and J. Moore (1990);"Property Rights and the Theory of the Firm" *Journal of Political of Economy* Vol 98, 1119-1158.

Hashimoteo, M. (1991);"Training and Employment Relations in Japanese Firms" in D. Stern and J. M. Ritzen *Market Failures in Training?* Springer-Verlag.

Kremer, M. (1993);"The O-Ring Theory of Economic Development" *Quarterly Journal of Economics*, 551-575.

Kuhn, T. (1967);*The Essential Tension: Selected Studies in Scientific Tradition and Change* University of Chicago Press.

Lucas, R. E. (1988);"On the Mechanics of Economic Development" *Journal of Monetary Economics* Vol 22, 3-42.

Lucas, R. E. (1990);"Why Doesn't Capital Flow From Rich To Poor Countries" *American Economic Review Papers and Proceedings*, 92-96.

Mortensen, D. (1982);"Property Rights and Efficiency in Mating, Racing and Related Games" *American Economic Review,* Vol 72, 968-979.

Mokyr, J (1990); *The Levers of Riches: Technological Creativity and Economic Progress*, Oxford University Press, New York.

Murphy, K., A. Shleifer and R. Vishny (1989); "Industrialization and the Big Push" *Journal of Political Economy* Vol 97, pp 1003-26.

North, D. (1981); *Structure and Change in Economic History* New York, W. Norton.

OECD (1991);*The Employment Outlook* July 1991.

Rebelo, S. (1991);"Long Run Policy Analysis and Long Run Growth" *Journal of Political Economy* Vol 99, 500-521.

Pissarides, C. (1985); "Short-run Equilibrium Dynamics of Unemployment, Vacancies and Real Wages" *American Economic Review* Vol 75, pp 676-90.

Pissarides, C. (1990); *Equilibrium Unemployment Theory* Oxford, Basil Blackwell.

Romer, P. (1986);"Increasing Returns and Long-run Growth" *Journal of Political Economy* Vol 94, pp 1002-37.

Rosenstein-Rodan, P. N. (1943);"Problems of Industrialization of Eastern and Southern-Eastern Europe" *Economic Journal* Vol 53, 202-211.

Rubinstein, A. (1982);"Perfect Equilibrium In a Bargaining Model" *Econometrica* Vol 50, 97-109.

Sawyer, J. (1954);"In Defence of An Approach" *Explorations in Entrepreneurial Activity* Vol 7, 273-286.

Shaked, A. and J. Sutton (1984); Econometrica

Soskice, D. (1992);"Reconciling Markets and Institutions: The German Apprenticeship System" mimeo.

Young, A. (1992);"A Tale of Two Cities" *NBER Macroeconomics Annual* 1993

Uzawa, H. (1965);"Optimal Technical Change in an Aggregative Model of Economic Growth" *International Economic Review* Vol 6, 18-31.

van Der Ploeg, F. (1987);"Trade Unions, Investment and Employment: A Non-cooperative Approach" *European Economic Review* Vol 31, 1465-1492.