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Working Paper Series

# Technology, Entrepreneurship, and Inequality

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**2002/06** **February 2002**

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February 2003

We thank Daron Acemoglu, Andrea Bassanini, David Encaoua, Fernando Galindo-Rueda, Cecilia Garcia-Peñalosa, Donatella Gatti, Marco Giarratana, Steve Klepper, Omer Moav, Thomas Moutos, Fabio Pammolli, Mauro Sylos Labini, Davide Ticchi, and Salvatore Torrisi for helpful comments and suggestions. They are not responsible for errors or omissions. Financial support from the DGXII-TSER project *Growth, Inequality and Training* (Contract N.SOE2-CT98-3073) and the CNRS Programme *Les Enjeux Economique de l'Innovation* are gratefully acknowledged.

**Abstract**

This paper links the rise of new industries populated by skill-intensive companies with the divergence in labour incomes between skills. Our model explains inequality by the fact that as the skilled workers move towards new Silicon-Valley type firms, the reduced complementarity between skilled and unskilled workers in the traditional manufacturing sectors lessens the productivity of the latter. Knowledge externalities in the modern sector produce two equilibria in which either the modern sector dominates (and inequality between skills is high), or manufacturing dominates (inequality is low).

Keywords: Technology, Entrepreneurship, Wage Inequality

JEL: J32, L22

## 1. INTRODUCTION

The information technology (IT) industries have given a great impetus to decentralised patterns of production and invention hinging on technology-based companies, entrepreneurship, clusters of firms, along with a focus on new design, innovation, and skilled-labour intensive activities. (See, e.g., Langlois and Robertson, 1992, and Baldwin and Clark, 1997. See also Hall and Ham, 2001, and Arora, Fosfuri, and Gambardella, 2001.) The IT model, which is symbolised by the Silicon Valley (Saxenian, 1994), has spread not only to other industries (e.g. biotechnology), but also across regions, including non G-8 countries like Israel, Ireland, or the Indian software industry. (See Arora *et al.*, 2001, and Arora, Gambardella, and Torrisi, 2003.)

This paper develops a model that compares some implications of the rise of these new industries with the traditional organisation of firms and sectors based upon the large integrated companies of Chandlerian memory (Chandler, 1990). Our model yields three main insights. First, our two archetypes – Silicon Valley and the Chandlerian firm – entail two different degrees of inequality between the earnings of the skilled and unskilled workers. Key to our argument is that the new industries are skill-intensive, while a distinguished feature of the Chandlerian firm is that it employs both skilled and unskilled workers, which are complementary inputs. Thus, whenever opportunities arise in the new industries, and skilled people move out of the traditional sectors to form new Silicon-Valley type firms, fewer of them are employed in the Chandlerian industries. This reduces the productivity of the unskilled workers, and hence their earnings, while keeping up the productivity (and the earnings) of the skilled workers.

Second, apart from skill-intensity, a notable feature of the new industries is that they entail knowledge externalities. In our model, this implies that the new industries will arise only if there is a critical mass of skilled workers that move to them in a co-ordinated fashion. In turn, this produces two equilibria, one in which the traditional sectors dominate (and inequality is low) and the other one in which the new industries dominate (inequality is high). Third, our model shows that the marginal effect of an increase in the relative supply of skilled people on the total income (and therefore on the total output) of the economy is always higher in the equilibrium where the new industries dominate vis-à-vis the other. The intuition is intriguing as it is a natural upshot of inequality. If the skill premium is higher, then as the marginal unskilled worker becomes skilled, the raise in her income will be higher than if the economy was in the less unequal equilibrium.

These results provide new perspectives on some issues discussed by the literature. For example, several authors have documented the growing inequality of earnings between skilled and unskilled workers (e.g. Gottschalk, 1997; Gottschalk and Smeeding, 1997; Aghion, Caroli, Garcia-Peñalosa, 1999), and an important stream of the literature has emphasised the effects produced by skill-biased technical change on the demand for skilled workers (e.g., Goldman and Katz, 1998; Berman, Bound and Machin, 1998; Machin and Van Reenen, 1998; Bresnahan, 1999; Galor and Moav, 2000; Caroli and Van Reenen, 2001; Brynjolfsson, Bresnahan, and Hitt, 2001. See Acemoglu, 2002 for a survey.) While these theories contribute to explain several features of the increase in inequality, there are some open questions – e.g., why is the growth in inequality less pronounced in some countries compared to others? This certainly depends on market forces (demand and supply of skills) and institutional differences, as argued for instance by Gottschalk and Smeeding (1997) or Acemoglu (2002 and 2003). However, it is interesting that the more pronounced inequality is in the Anglo-Saxon world, and in regions with similar institutional characteristics, which have favoured the rise of high-tech entrepreneurship and more decentralised modes of organising production. Less pronounced inequalities are in Germany or Japan, where the classical large firms still play a predominate role. Gottschalk and Smeeding (1997), among others, argue that inequality is lower in countries with centralised wage setting mechanisms. But such centralised mechanisms, and the related unionisation of workers, are correlated with the presence of the large firms. By contrast, economies with start-ups and a fair degree of entrepreneurship depend on more decentralised processes for determining people's earnings. While we do not dispute that other factors are important, the scope of this paper is to highlight that different modes of organising production and invention may also play a role, a point that has not been emphasised by the literature.

Our model addresses a few other issues. If there is complementarity between skilled and less skilled occupations – e.g. managers and production workers in the Chandlerian firms – skill-bias technical change will in any case produce an increase in the earnings of the unskilled people – although not as pronounced as that of the skilled workers. This would be a different type of inequality than that observed for instance in the US over the past 20-25 years, wherein the real wages of the unskilled workers have declined. This was also noted by Feldstein (1998) who argued that it is the latter type of inequality that ought raise our concerns about "poverty", while the first type of inequality even implies a Pareto-superior situation. A novel feature of this paper is that it explains both types of inequality. In the equilibrium where the traditional sector dominates, any increase in the degree of skill-bias technical change increases the salaries of the skilled occupations relatively more than the increase in the wages of the unskilled occupations. By contrast, in the equilibrium with the new industries, increases in the productivity of the skilled workers in the new sectors lower the wages of the unskilled workers because of the reduced complementarity across skills. The model also shows that the new industries are less likely to arise when the traditional sectors are more efficient. This is suggestive of why new IT business models, high-tech entrepreneurship, and the like, have emerged in regions without a substantial industrial tradition. Put simply, German skilled workers, with potential employment in companies like BMW, Bayer or Mercedes, have higher opportunity costs of setting up their own firms vis-à-vis Indian or Israeli engineers.

Finally, our story is similar to the one about the segregation of workers by skill found in Kremer and Maskin (1996), Acemoglu (1999), and in the organisational change and inequality section of Acemoglu (2002). However, we highlight a different mechanism that may explain segregation and inequality, viz. knowledge spillovers across firms, which is a quintessential feature of the new technology-based industries. As noted, this is what leads to our two equilibria, which is in turn our explanation for the observed differences in the degree of inequality across countries or regions. Moreover, we draw implications for the total income of the economy.

At the same time, our model offers a basis for further understanding the process of "directed technical change" suggested by Acemoglu (1998). Shifts in the relative supply of skills produce concomitant increases in the relative demand for skills because of the greater profitability of inventions that increase the relative productivity of the skilled workers. This explains the observed correlation between large share of skilled people and inequality. Our model shows that a large relative supply of skilled people is likely to imply a higher total income in the Silicon Valley equilibrium vis-à-vis the one dominated by manufacturing and the Chandlerian firms. This suggests that, as the relative supply of skills rises, skilled people may "direct" technical and organisational change towards the formation of new firms and industries that are skill-intensive, rely on knowledge externalities, etc., whereby their inventive capabilities can be best exploited. This also suggests why places like Silicon Valley, or the IT industries in Ireland, India or Israel may arise. They are all prominent examples of places in which there was not a significant established industry, and nonetheless there was an "excess supply of skills" (e.g., Bresnahan, Gambardella, and Saxenian, 2001).

The next section presents the basic set-up of the model while Section 3 shows the equilibrium allocations. Section 4 discusses the implications for inequality, and derives the demand for skills. Section 5 discusses the implications for the average income of the economy. Section 6 provides suggestive evidence. Section 7 concludes. Appendix 1 and 2 present some technical results not shown in the text.

## 2. THE MODEL

### 2.1 General Set-up

In our model there are two potential organisations of an industry. We label them the traditional and the modern sector (or industry). The traditonal sector employs both skilled and unskilled labour, which are complementary factors in production. The modern sector is intensive in skilled labour, and we assume for simplicity that it only employs skilled workers. Because this sector produces a great deal of knowledge and intangible outputs, which can be transferred at low costs, we assume that it exhibits knowledge externalities. Specifically, the performance of the industry, and the earnings of the skilled workers that operate in it, increase as a larger number of workers is employed in this sector.

The traditional sector is a stylised representation of the Chandlerian industries. Firms in these industries employ both managers or R&D personnel and manufacturing workers; or they employ marketing strategists and mere salesmen. This is a natural consequence of their integrated structure, which entails that they conduct more strategic and creative activities along with more routinary ones like final production, sales, etc. The complementarity between the two is also natural. For example, a higher number of skilled managers are likely to induce more extensive investments in advanced manufacturing technologies, which increases the productivity of the less skilled workers. Similarly, clever marketing strategists design effective procedures for enhancing the ability of their salesmen to sell their products.

The stylised representation of the modern sector is that of a design-intensive activity. The examples we have in mind are the software industry, biotechnology, semiconductors, and more generally the production of advanced services. In light of the observed characteristics of these industries in recent years, we think of our modern sector as one that hinges on entrepreneurial industries whereby skilled workers set-up new firms, and work in an environment in which knowledge circulates and spillovers are important. Knowledge spillovers are common for instance in software, where codes or programmes are re-used in other programmes, or in semiconductors, where new designs build on existing ones, or in biotechnology, where basic scientific knowledge is never reproduced totally from scratch by any new firm. Therefore, the greater the number of firms and skilled workers in the industry, the greater the knowledge that is produced, and hence the greater the basis for the spillovers. Increasing returns may not be a long-term stable feature of these industries. However, because what we have in mind is new industries in their nascent stages (like those mentioned above), we posit that at least in the rising phases a larger number of design firms implies greater opportunities for re-utilising existing basic designs or modules, spillovers, etc.

We normalise the population of workers to 1, with $K$ skilled and $1-K$ unskilled workers. The sequence of allocations is straightforward. First, people allocate between skilled and unskilled workers. We do not model this allocation, and take the supply of the two types of workers as fixed. No additional insight would be produced if we modelled the supply of skills as well. The unskilled workers, which work only in the traditional sector, obtain a wage $w$. Second, the skilled workers have to decide whether to work in the traditional or in the modern sector. Let $H$, $0 \leq H \leq K$, be the number of skilled workers that work in the traditional sector, while $H' = K - H$ work in the modern sector. The salary of the skilled workers in the traditional sector is $r$.

## 2.2 The Traditional Sector

The traditional sector produces total output $X$ through a production function $X = X(\theta \cdot H, 1-K)$, where $\theta > 0$ is a measure of the efficiency units of the skilled workers. We assume constant returns to scale, and $X(\cdot)$ is homogenous of degree 1 in $\theta \cdot H$ and $1 - K$. The firms in this sector are price-takers and the price of $X$ is normalised to 1.

Given $r$ and $w$, the first order conditions for the optimal $H$ and $(1-K)$ are

$$r = X_H \equiv \rho(\theta \cdot h) \cdot \theta \tag{1}$$

$$w = X_{(1-K)} \equiv w(\theta \cdot h) \tag{2}$$

where from now on we use subscripts to denote derivatives, and $h \equiv \frac{H}{1-K}$ is the ratio between the skilled and unskilled workers employed in the traditional sector. The form of (1) and (2) follows from the linear homogeneity of $X(\cdot)$, which implies that $X_H$ and $X_{(1-K)}$ are homogeneous of degree zero in $\theta \cdot H$ and $(1-K)$, and therefore they can be written as a function of their ratio. Finally, since the second derivatives $X_{HH}$ and $X_{(1-K)(1-K)}$ are both negative, then $\rho_h < 0$, and $w_h > 0$.

The ratio between the salary of the skilled workers and the wage of the unskilled workers is

$$z \equiv \frac{r}{w} = \frac{\rho(\theta \cdot h)}{w(\theta \cdot h)} \cdot \theta \equiv v(\theta \cdot h) \cdot \theta \qquad (3)$$

where the latter equality follows from the fact that because $\rho(\cdot)$ and $w(\cdot)$ are homogeneous of degree 0 in $\theta \cdot H$ and $(1-K)$, their ratio is homogeneous of degree 0 in the same arguments, and hence it can be written as a function of $\theta \cdot h$. Moreover, because $\rho_h<0$ and $w_h > 0$, then $v_h < 0$, and hence $z_h < 0$.

We want $\theta$ to account for skill-biased technical change in the traditional sector, as the literature has typically assumed. Skill-biased technical change means that the marginal product of the skilled labour input increases faster than of the unskilled labour. Thus, increases in $\theta$ must increase the ratio between the salary of the skilled workers and the wages of the unskilled workers, viz. $z_\theta = v_\theta \cdot \theta + v > 0$. Since $v_\theta < 0$, then skill-biased technical change implies $\left|\frac{v}{v_\theta \theta}\right| > 1$. This is equivalent to assuming that the elasticity of substitution between the two inputs is greater than 1.[1]

The intuition is that a rise in $\theta$ has two effects. First, it reduces the number of skilled relative to unskilled workers needed to produce any given output. Second, it lowers the relative price of efficient skilled labour, and so it induces the firm to increase the demand for skilled relative to unskilled workers. Only if the elasticity of substitution is greater than 1 the second effect dominates leading to an overall increase in the demand for skilled relative to unskilled workers, and therefore to increases in their relative price.

## 2.3 The Modern Sector

The externalities in the modern sector can be modelled in several ways. In Appendix 1 we propose one model. This model posits that some of the skilled workers that operate in this sector become entrepreneurs. They set-up their firms, and hire other skilled workers. The entrepreneurs gain profits $\pi$, while the skilled workers earn a salary. However, because any skilled worker in this industry can become an entrepreneur, the number of firms (and the size of each firm, measured by the number of skilled workers who act as employees) will be determined by the equilibrium condition that equates the profits of the entrepreneurs with the salary of the skilled workers employed in this

[1] To see this, take the differential of both sides of (3) with respect to $z$ and $h$, and solve for $h_z = (\theta \cdot v_h)^{-1}$. The elasticity of substitution is $[-(z/h) \cdot h_z]$. Replace $z$ from (3), and obtain $[-v/(v_h \cdot h)]$, which is the expression in the text because $v_h \cdot h = v_\theta \cdot \theta$. (The latter follows from the fact that the argument of $v(\cdot)$ is $\theta \cdot h$.) Acemoglu (2002) reports that the empirical estimates of this elasticity are between 1 and 2.

sector. Thus, we can take the profits $\pi$ to be our measure of the earnings of the skilled workers in the modern industry, viz.

$$\pi(H', \mu) \tag{4}$$

where $\pi_{H'} > 0$ is our assumption about the externalities produced by the skilled workers, and $\mu$ is a parameter that affects the profitability of this sector with $\pi_\mu > 0$. Since $H' = K - H = K \cdot (1 - h/k)$, the profits $\pi(\cdot)$ are linked to both the ratio of skilled to unskilled workers in the traditional sector $h$ and the ratio of skilled to unskilled workers in the whole economy $k \equiv \frac{K}{1-K}$. Since $\pi_{H'} > 0$, then $\pi_h < 0$ and $\pi_k > 0$.

Our interpretation of $\mu$ is that it accounts for the factors that ease the foundation of new firms, and their growth. For example, $\mu$ could proxy for the presence of adequate financial instruments for supporting new firms like venture capital, or the bureaucratic and administrative burdens associated with their foundation and operation. While we could interpret $\mu$ in other ways, cross-country differences in, say, demand or technological opportunities are less pronounced than those in the institutional or other conditions that can affect the rise of the modern industries. For instance, knowledge and technological shocks eventually spread across countries, at least across countries at the same level of development, and the same can be said about demand factors, like the demand for IT or advanced technologies. By contrast, differences in financial and other institutions, company or employment legislation, etc., are more persistent, even across countries at a similar stage of development.

## 3. EQUILIBRIUM ALLOCATIONS

The equilibrium level of $h$ is determined by equating the earnings of the skilled workers in the two industries, i.e.

$$\rho(\theta \cdot h) \cdot \theta = \pi[K \cdot (1 - h/k), \mu] \qquad (5)$$

We make the following two assumptions to simplify our treatment of the equilibrium

A1) $\rho(0) \cdot \theta > \pi(K, \mu)$

A2) $\rho(\theta \cdot k) \cdot \theta > \pi(0, \mu)$

Assumption A1 says that the profits of the new industries are bounded. Specifically, when all the skilled workers operate in the modern sector, their earnings will be smaller than those that any one of them would gain by moving to the old sector. Assumption A2 says that the modern industry needs a critical mass of skilled workers. If all the skilled workers were in the traditional sector, any workers moving to the new industry would not gain as much as she gained in the traditional sector.[2]

To characterise the equilibria we first consider the case in which the $r$-curve intersects the $\pi$-curve, and then the case in which the $\pi$-curve lies entirely below the $r$-curve. Figure 1 depicts the typical situation in which the two curves intersect. Both curves decline with $h$. This is because $r_h < 0$ (from $\rho_h < 0$) and $\pi_h < 0$. The $r$-curve is truncated at $h = k$ where all the skilled workers are employed in the traditional sector. Our assumptions A1 and A2 ensure that the $\pi$-curve intersects at least once from above

[2] These assumptions are needed to obtain the two equilibria noted below, but neither of them is crucial for our argument. Without them, either one of the two equilibria are still possible.

to the right of $h = 0$ (point B in Figure 1), and at least once from below to the left of $h = k$ (point C in Figure 1). We have the following claim.

[FIGURE 1 ABOUT HERE]

**Claim**

*The economy depicted in Figure 1 has at least two stable equilibria:*

*i)* *point A in the Figure, in which all the skilled workers are employed in the traditional sector – i.e. $h = k$. (The A-equilibrium.)*

*ii)* *point B in the Figure, a mixed equilibrium in which a small number of skilled workers are employed in the traditional sector, and the rest is employed in the modern sector – i.e. $h < k$. (The B-equilibrium.)*

*The salary of the skilled workers in the B-equilibrium is higher than the salary of the skilled workers in the A-equilibrium.*

**Proof.** Point A is a stable equilibrium. This is because in A there is no incentive for any skilled worker to move to the modern sector, as $\pi$ would remain below $r$. Point B is also a stable equilibrium. Suppose that an individual worker deviates by moving from the modern to the traditional sector. In B $r_h < \pi_h$, which implies that as $h$ increases, $r > \pi$. Hence, there is no incentive to deviate. Similarly, if the skilled worker moved from the traditional to the modern sector, $r_h < \pi_h$ implies $r > \pi$. Finally, it is apparent from Figure 1 that the equilibrium salary $r$ is higher in the B-equilibrium vis-à-vis the A-equilibrium. *QED*

Thus, if our economy is in the A-equilibrium, some co-ordination is needed for the B-equilibrium to arise. A group of skilled workers has to move jointly onto the modern sector so that $h$ drops from $k$ to just below $h_C$ in Figure 1. This makes $\pi > r$, and other skilled workers will move to the modern sector till the B-equilibrium is reached. The intuition is that because of the externalities in the use of knowledge or technology, a critical mass of activities in the modern sector is needed to make it viable given the alternative opportunities in the traditional sector.

In Figure 2 we look at the comparative static results produced by changes in $k$, $\mu$, $\theta$. If the supply of skilled workers $k$ increases, the $r$-curve is unaffected. However, its truncation point shifts to the right at $k' > k$ (Fig.2a). The A-equilibrium moves from A to A', which corresponds to a smaller salary $r$. This is the standard situation whereby the productivity of any type of input drops as a larger supply of that input is available. The $\pi$-curve shifts upward because $\pi_k > 0$. The intuition is that a greater supply of skilled workers induces greater potential externalities in the modern sector. This shifts the B-equilibrium to B' in Fig.2a, which raises the salary $r$. In sum, an expansion in the supply of skills has opposite effects under the two equilibria. In the A-equilibrium, the effect is to reduce the scarcity of skilled people, which lowers their salary. In the B-equilibrium, because of the knowledge externalities a larger set of skilled people makes each of them more productive, which increases their earnings.

[FIGURE 2 ABOUT HERE]

As $\theta$ increases, the traditional sector is more productive. The $r$-curve shifts upward, while the $\pi$-curve is unaffected. The A-equilibrium implies a higher salary $r$ (A' in Fig.2b), while the salary in the B-equilibrium drops (B' in Figure 2b). The increase in $r$ in the A-equilibrium follows from the higher productivity of the traditional sector. Its decline in the B-equilibrium occurs because as the traditional sector becomes more productive, more skilled workers move to it. This reduces the productivity of the modern sector (because of the lower externalities), which sets a lower threshold for the earnings of the skilled workers in the whole economy. With higher $\mu$, the $\pi$-curve shifts upward, while the $r$-curve is unaltered. The A-equilibrium is not affected because there is no modern sector in it. The B-equilibrium exhibits a higher equilibrium salary $r$. (Point B'' in Fig.2b.) This follows from the increased share of skilled workers that move to the modern sector, with implied greater externalities.

The discussion so far also implies that if $k$ or $\mu$ are particularly small, or $\theta$ is particularly high, the $\pi$-curve may lay entirely below the $r$-curve. In this case, $r > \pi$, $\forall h \in [0, k]$, and only the A-equilibrium exist. That is, the modern sector does not arise if either the costs of setting-up the industry, creating new firms, etc. are high (low $\mu$); or the traditional sector is efficient (high $\theta$); or there is a limited supply of skilled people, which means that there are not enough skilled workers to produce the required externalities for the modern sector to emerge.

The following Proposition then summarises the discussion in this Section about the equilibrium allocations of our economy.

**Proposition 1**

*For k or $\mu$ sufficiently large, or $\theta$ sufficiently small, our economy has two stable equilibria, one with h = k (the A-equilibrium) and the other with h < k (the B-equilibrium). The equilibrium salary r is higher in the B-equilibrium vis-à-vis the A-equilibrium. If $\mu$ or k are sufficiently small or $\theta$ sufficiently large, only the A-equilibrium exists, and the modern sector does not arise.*

## 4. INEQUALITY AND THE DEMAND FOR SKILLS

### 4.1 Inequality

From Figure 2 it is easy to see that

$$r_k^A < 0; \quad r_\mu^A = 0; \quad r_\theta^A > 0$$

$$r_k^B > 0; \quad r_\mu^B > 0; \quad r_\theta^B < 0$$

where the superscripts denote the equilibrium salary in the A- or B-equilibrium. Also, in the B-equilibrium[3]

$$h_k < 0, \; h_\mu < 0, \; \text{and} \; h_\theta > 0$$

In this section we compare the wages of the unskilled workers, $w$, and the ratio between the salaries of the skilled workers and the wages of the unskilled workers, $z \equiv \frac{r}{w}$, under the two equilibria. We take the latter to be our measure of inequality. We also study the effects of $k$, $\mu$, and $\theta$ on $w$ and $z$.

**<u>Proposition 2</u>**

*Other things being equal, the wage of the unskilled workers is higher in the A-equilibrium, $w^A > w^B$, and inequality is higher in the B-equilibrium, $z^B > z^A$.*

**<u>Proof</u>.** Simply use the fact that the expression for $w$ is (2) with $h = k$ if we are in the A-

[3] For the B-equilibrium these comparative static results can be derived analytically by totally differentiating the equilibrium condition (5), and by using the fact that in the B-equilibrium $r_h < \pi_h$. This exercise will yield expressions for $h_k$, $h_\mu$ and $h_\theta$, which can unambiguously signed. In turn, these expressions can be used to sign the derivatives of $r^B$ (which is a function of $h$) with respect to $k$, $\mu$, and $\theta$. For the A-equilibrium simply use the fact that $r^A(\theta \cdot k)$, and that it declines with $\theta \cdot k$.

equilibrium, and $h < k$ if we are in the B-equilibrium. Similarly, $z$ is (3) with $h = k$ or $h<k$. *QED*

Given that $r^B > r^A$, Proposition 2 says that the B-equilibrium is relatively better for the skilled workers, while the A-equilibrium favours the unskilled workers. The patterns of inequality are then profoundly different under the two equilibria. The reason why the unskilled workers are worse off in the B-equilibrium is that the lower supply of skilled workers in the traditional sector reduces their productivity, and hence their wages. As the modern sector moves skilled workers away from the traditional industries, the complementarity between skilled and unskilled workers in the latter penalises the unskilled workers in the economy.

As far as the effects of $k$, $\mu$ or $\theta$ are concerned, we have to take into account that in the B-equilibrium $h$ varies with these parameters as shown above. Then, by using (2) and (3), it is not difficult to see that

$$w_k^A > 0; \quad w_\mu^A = 0; \quad w_\theta^A > 0$$

$$w_k^B < 0; \quad w_\mu^B < 0; \quad w_\theta^B > 0$$

and that

$$z_k^A < 0; \quad z_\mu^A = 0; \quad z_\theta^A > 0$$

$$z_k^B > 0; \quad z_\mu^B > 0; \quad z_\theta^B < 0$$

Thus, the same parameter changes can have opposite effects on the salaries of the skilled workers, the wages of the unskilled workers, and inequality under the two equilibria.[4]

The supply of skills *k* has opposite effects in the two equilibria. In the A-equilibrium, as noted earlier, greater *k* implies that the skilled workers are relatively less scarce compared to the unskilled workers. Hence, market forces reduce their relative salary. By contrast, in the B-equilibrium, a greater *k* implies greater opportunities to exploit the knowledge externalities in the modern sector. This makes the skilled workers operating in that sector more productive, which encourages more skilled workers to join that sector. The reduced supply of skilled workers in the traditional sector then reduces the productivity of the unskilled workers.

Consider then the effects of $\theta$. This is the measure of skill-biased technical change typically used by the literature. Increases in $\theta$ do raise inequality, as suggested by the literature. In the A-equilibrium they increase both *r* and *w*, with the increase in *r* being more pronounced than the increase in *w*. This is quite different from the inequality produced by increases in $\mu$ in the B-equilibrium, in which *r* increases and *w* declines. The parameter $\mu$ is another form of skill-biased technical change. However, it is associated with a different organisational environment characterised by greater segregation of workers by skills. Here the skilled workers become more productive in sectors where there is no complementarity with the unskilled workers, and this implies inequality wherein the wages of the unskilled workers decline.

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[4] The only derivative that is not straight forward from inspecting (3) is $z_\theta^B < 0$. But this follows immediately from the fact that $r_\theta^B < 0$ and $w_\theta^B > 0$.

### 4.2 The Demand for Skills

The relative demand for skilled workers in this economy is depicted in Figure 3, where we draw *z* against *k*. We have shown that $z_k^A < 0$ and $z_k^B > 0$. We have also seen that as *k* declines the $\pi$-curve will eventually lay entirely below the *r*-curve in Figure 1. As a result, there is a threshold $k^o$ such that for $k > k^o$ the demand for skills splits into two branches, one that is upward sloping and corresponds to the B-equilibrium, and the other one that is downward sloping and corresponds to the A-equilibrium. Any vertical supply curve of skills will then intersect the demand for skills twice denoting the two equilibria. For $k < k^o$ only the downward sloping portion of the demand curve exists, and any vertical vertical supply curve will intersect the demand for skills once.

[FIGURE 3 ABOUT HERE]

Figure 3 also shows the effects of changes in $\mu$ or $\theta$. Increases in $\mu$ shift up the rising portion of the demand curve. This is because for any given *k*, $z_\mu^B > 0$. They also reduce the threshold $k^o$ after which the B-equilibrium becomes possible. This is because at $k = k^o$, where the *r*- and $\pi$-curves in Figure 1 would be tangent to each other, increases in $\mu$ will shift the $\pi$-curve upward. A lower *k* is then needed to shift the $\pi$-curve back, and obtain the tangency between the two curves again. Increases in $\theta$ shift the downward sloping portion of the demand curve up, and its rising portion down, as implied by $z_\theta^A > 0$ and $z_\theta^B < 0$. They also move the threshold $k^o$ to the right because increases in $\theta$ must be offset by increases in *k* to make the $\pi$-curve intersect the *r*-curve again.

### 4.3 The Case with No Externalities

The assumption of knowledge spillovers is not crucial for the modern sector to arise. It is however crucial for obtaining the two equilibria. Suppose that $\pi_{H'} = 0$. Instead of a downward sloping curve, the $\pi$-curve in Figure 1 would be horizontal. It is easy to see that in this case either $\mu$ is too small, and the horizontal $\pi$-curve will be entirely below the $r$-curve, or $\mu$ is high and it will lie entirely above it.[5] In the former case, only the A-equilibrium exists, while in the latter case there is only the B-equilibrium. The externalities implied by the nature of knowledge as an asset are then not crucial to explain the different patterns of inequality in the A- or B-equilibrium. But they are crucial to explain potential differences across countries in such patterns even when they face similar characteristics in terms of $k$, $\mu$ or $\theta$.

## 5. AVERAGE INCOME

In our model the marginal effect of an increase in the supply of skills $K$ on the income of the economy is always larger under the B- than under the A-equilibrium. While we formally prove this result in Appendix 2, the intuition can be explained as follows. In Appendix 2 we show that the expressions for the marginal effect of $K$ on income $Y = r \cdot K + w \cdot (1-K)$ can be written as

$$Y_K^A = r^A - w^A \qquad \text{(6a)}$$

$$Y_K^B = r^B - w^B + r_K^B K(1 - h/k) \qquad \text{(6b)}$$

where the superscripts denote the two equilibria. The interpretation of (6a) and (6b) is simple. In the A-equilibrium, as $K$ increases by one unit (and therefore $1 - K$ decreases

[5] Clearly, we relax assumption A2 here.

by one unit), the average income of the economy changes by $r^A - w^A$, i.e. by the difference between the salary that the new skilled worker gets and the foregone wage by the same worker who has now become skilled. The same occurs in the B-equilibrium, where income changes by $r^B - w^B$. Because in the B-equilibrium inequality is higher, viz. $r^B - w^B > r^A - w^A$, it follows that $Y_K^B > Y_K^A \;\; \forall K \in (0, 1)$. Thus, it is precisely because the B-equilibrium is more unequal that whenever the share of skilled workers increases, the raise in income from shifting one person between skills is higher. Moreover, as the share of skilled workers increase, the B-equilibrium exhibits more pronounced externalities. Hence, income increases by the additional term $r_K^B K(1-h/k)$, which is positive because $h < k$ and $r_K^B > 0$.

This also speaks to the relative attractiveness of the two equilibria. Because the marginal effect is higher in the B-equilibrium, then as the share of skilled workers gets larger, the total income of the economy is likely to be higher in the B-equilibrium vis-à-vis the A-equilibrium. Another way to see this is the following. Suppose that $Y_K^A = Y_K^B$. Then, if the relative supply of skills increases, the B-equilibrium will entail a higher income. More generally, as the relative supply of skilled workers increases, income in the B-equilibrium can become higher than that of the A-equilibrium, but not the other way around.

As noted in the introduction, this provides a basis to further understand the process of directed technical change suggested by Acemoglu (1998). A large share of skilled workers in the economy implies not only that the salary of the skilled workers is higher in the B-equilibrium, but also that the total output of the economy in the B-equilibrium is potentially higher. This can make the B-equilibrium attractive when there are many skilled workers around. One way to think about it is that the skilled people direct their technical and organisational change towards industry configurations and the foundation of new firms that make the most of their skills. The concept of directed technical change then takes a broader interpretation. It is not just technical innovations, but it can well encompass the development of new industry organisations and business models that change in the direction of activities that can best exploit the potential of the more educated workers.

The other side of the story is important as well. An economy with a sizable supply of less skilled people, and possibly with relatively efficient unskilled workers (e.g. Germany where production workers are said to be more educated than elsewhere, or Italy which has a high productivity in manufacturing) is attracted by the Chandlerian equilibrium. In these economies, the Chandlerian equilibrium is likely to produce a higher total output than the Silicon Valley equilibrium. At the same time, although we do not model the choice of the individuals to become skilled, the higher marginal effect of skills suggests that the social value of education is higher in the B-equilibrium. The two equilibria can then be self-reinforcing, as in the Silicon Valley equilibrium it is desirable that a larger share of people be skilled.

Institutional and other characteristics affect the attractiveness and the social desirability of the two equilibria. The best way to illustrate this is to look at the effects of $\theta$ and $\mu$ on $Y_K^A$ and $Y_K^B$. Changes in $\theta$ increase inequality in the A-equilibrium, and reduce inequality in the B-equilibrium. Moreover, in the B-equilibrium, they increase *h*. Thus, if we neglect the second order effects of $\theta$ on $r_K^B$, it follows from (6a) and (6b) that $Y_{K\theta}^A > 0$ and $Y_{K\theta}^B < 0$. This means that skill-biased technical change (in the sense of higher $\theta$) can keep the total output of the Chandlerian equilibrium above that of the Silicon Valley equilibrium even when the share of skilled workers in the economy is large. Another way to see this is that with higher $\theta$ the social value of education increases in the A-equilibrium and it decreases in the B-equilibrium. Thus, with more skill-biased technical change, a Chandlerian economy would like to invest more in education, without implying that it would also want to shift to the Silicon Valley equilibrium. In sum, there can well be economies with fairly high share of skilled people, which invest in education, and are characterised by industry organisations that hinge on Chandlerian firms. By contrast, increases in $\mu$, viz. economies that favour decentralised systems of production and invention – with low institutional barriers to entrepreneurship, limited regulation, innovative financial means like venture capital and else – will have a higher marginal effect of output under the B-equilibrium because $Y^A_{K\mu} = 0$ and $Y^B_{K\mu} > 0$.[6] It is in these economies that increases in the relative supply of skilled people is likely to make the Silicon Valley equilibrium more attractive.

## 6. A MODICUM OF EVIDENCE

To provide suggestive evidence, we start by comparing two prototypical cases: Detroit – the US capital of the automobile industry – and Silicon Valley. From the Occupational Employment Statistics (OES) of the US Bureau of Labour Statistics, we collected 2001 data on employment, average and median wages in the Detroit and San Jose Metropolitan Areas. Apart from the whole area, we picked data for two employment categories: managerial and production occupations. These are representative occupations of the kind of educated and less educated workers that we have in mind. Managerial skills are important both in the traditional industries and in

[6] Like above we neglect the second order effect of $\mu$ on $r^B_K$.

the new industries.  Even in IT and other modern technology-based industries, entrepreneurs, company partners, or any skilled employee, including those with technical backgrounds, normally perform a lot of managerial tasks, and they end up performing almost only managerial tasks as they move up their career ladder or as their companies grow.  Under production occupations, the OES gathers all kinds of production workers in manufacturing (e.g. several types of assemblers, machine operators or setters, process controllers).  Moreover, both managerial and production occupations are generic with respect to specific industries, and therefore they are not strongly influenced by the distribution of industries in a given area (like for instance chemists, computer engineers, or other industry-specific occupations).[7]

Table 1 reports data on inequality $z$ and on the employment ratios between managers and production workers in the two areas.  Both measures are higher in Silicon Valley than in Detroit.  This is consistent with the conjecture that Silicon Valley is in the B-equilibrium while Detroit is in the A-equilibrium as depicted in Figure 4, where – without loss of generality – we assumed that the relative supply of skills is vertical, and that Silicon Valley has a higher relative supply of skills.  The latter is a natural assumption to make as Silicon Valley hosts several colleges and universities, including prominent ones like Stanford and Berkeley.  Many students coming from other locations get to know the Valley and may well consider to work there.  Moreover, the Valley specialises in high-tech which attracts other educated people from the outside, including skilled immigrants, as we shall also note below.

[7] We experimented with other occupations from the OES list, like computer engineers.  This did not alter the basic evidence provided in this Section.  Moreover, the use of managers and production workers as archetypes of skilled and less skilled workers is fairly common.  See, e.g., Kremer and Maskin (1996).

The data in Table 1 however are also consistent with both Silicon Valley and Detroit being in the traditional A-equilibrium (A and A' in Figure 4.) This is because while Silicon Valley has a higher relative supply of skills, it may exhibit a higher relative demand for skills. Thus, while suggestive of the different equilibria in the two areas, the comparison between Silicon Valley and Detroit does not unambiguously imply that a B-equilibrium exists.

[FIGURE 4 ABOUT HERE]

To provide some potentially discriminating evidence, we have also compared Silicon Valley and Boston. From the OES we collected 1999-2001 data on the same variables and occupations for the Boston and San Jose Metropolitan Areas.[8] To simplify matters, we employ a CES production function $X = \left[(\theta \cdot H)^{\alpha} + (1-K)^{\alpha}\right]^{\frac{1}{\alpha}}$ with $\alpha < 1$. With this specification, expression (3) for inequality becomes $z = \theta \cdot (\theta \cdot h)^{-1/\sigma}$ where $\sigma$ is the elasticity of substitution. Our assumption that $\theta$ has a positive impact on $z$ implies that $\sigma > 1$. Define $g_z^A$ and $g_z^B$ to be the growth rates of $z$ under the two equilibria, and $g_\theta$ and $g_k$ to be the growth rates of $\theta$ and $k$. Use the fact that in the A-equilibrium $h = k$, whilst in the B-equilibrium $h < k$ and it varies with $\theta$ and $k$. We then obtain the following expressions for the growth rate of $z$

$$\sigma \cdot g_z^A = a \cdot g_\theta - g_k \qquad (7a)$$

$$\sigma \cdot g_z^B = (a-b) \cdot g_\theta + c \cdot g_k \qquad (7b)$$

[8] The OES also provide 1998 data, but the classification of the occupations was more aggregate, and it was not clear whether the managerial occupations included other categories as compared to the 1999-2001 data. To be on the safe side, we preferred to stay with the 1999-2001 figures.

where $a \equiv \sigma - 1 > 0$, $b \equiv \frac{h_\theta \cdot \theta}{h} > 0$, $c \equiv -\frac{h_k \cdot k}{h} > 0$. (For simplicity we ignore changes in $\mu$.) Thus, increases in the growth of the relative supply of skills have a positive impact on inequality in the B-equilibrium, and a negative one in the A-equilibrium.

In comparing Boston and Silicon Valley first note that we now compare two areas that are similar in terms of their distance to the technological forefront of the US economy. Boston as well hosts leading universities, and a plethora of new technological activities. This suggests that we can safely assume that the technological trends may not be that different between the two. Specifically, $g_\theta$ is likely to be similar. Second, we argue that the growth in the relative supply of skills is higher in Silicon Valley. There are several reasons. In the first place, the Pacific rim is closer to Asia, which has historically made it easier for Asian people to locate in the West Coast, as compared to the East, which is easier for the European people to reach. Not only are there more Asian people, but also today they are increasingly skilled immigrants, who come from countries in which academic degrees, and particularly engineering, technological and managerial degrees, have soared. In addition, Saxenian (1999) reports that in 1998 Chinese and Indian engineers were running one-quarter of Silicon Valley's high-tech businesses, and their companies accounted for 58,000 jobs or 14% of the total employment of the Valley. She also provides evidence of the acceleration of this trend. Chinese and Indian CEOs were running 13% of Silicon Valley technology companies started between 1980-84 and 29% of those started between 1995-98. Finally, Indians account for the top share (42.6%) of the H1-B visa petitions approved during October 1999 and February 2000 in the US. The second country is China with 9.9%. Of the total H1-B visa petitions in this period, 53.5% are for computer related occupations. (See Kapur and McHale, 2002.) This suggests that a notable fraction of the Asian immigrants have gone to the Valley to fill IT occupations. Moreover, as noted earlier, managerial occupations are an important component of the potential supply of skills for technology-based entrepreneurship. This is true of the Asian immigrants as well. Saxenian (1999) reports that Asian immigrants in the Valley are often quite skilled managerially, and the fact that they run a high share of Silicon Valley companies as CEOs is suggestive of the fact that this is a notable skill that they have.

Table 2 reports the average 1999-2001 annual growth rate of inequality $z$ and in the relative employment of managerial and production occupations in Silicon Valley and Boston. The data show that inequality and the relative employment of skills grows faster in Silicon Valley. Given (7a) and (7b), and given our conjecture that the relative supply of skills grows faster in Silicon Valley, these figures are inconsistent with the fact that Boston and Silicon Valley are both in the A-equilibrium. If this was the case, and assuming that $g_\theta$ is equal in the two areas, the difference between the two $g_z$'s would be $-\frac{1}{\sigma}\left(g_k^{SV} - g_k^{BO}\right)$, where the superscripts denote Silicon Valley and Boston. If $g_k^{SV} > g_k^{BO}$, inequality should grow faster in Boston.

[TABLE 2 ABOUT HERE]

The data in Table 2 are consistent with the fact that both Silicon Valley and Boston are in the B-equilibrium. If so, the difference between the growths in inequality would be $\frac{c}{\sigma}\left(g_k^{SV} - g_k^{BO}\right)$, which by our assumptions is positive. If only Boston was in the A-equilibrium, the difference would be $\frac{c}{\sigma} g_k^{SV} + \frac{1}{\sigma} g_k^{BO} - \frac{b}{\sigma} g_\theta$, while the difference would be the negative of this expression if only Silicon Valley was in the A-equilibrium.

As a final piece of evidence, we compare another potential candidate for a B-equilibrium, Ireland, with three leading Continental European countries – France, Germany and Italy. Ireland grew fast during the 1990s. Its growth was fuelled by technology businesses – IT in particular – and by systematic investments in R&D and education. Moreover, there is evidence that the Irish growth during the past decade has been associated with increasing inequality of earnings (O'Riain, 2000). Table 3 confirms that Ireland has a higher ratio of the 90-10 (and also of the 90-50, 50-10) percentile earnings than France, Germany and Italy. In the traditional downward sloping demand curve world, this could stem from the fact that the relative supply of skilled workers in Ireland was lower than in the three European countries. But Ireland has experienced a notable return emigration by skilled people in the 1990s, reverting the out flowing trend of the 1980s.[9] As a result of this, and of the substantial investments in education, Table 3 shows that by the end of the 1990s Ireland exhibited a share of total labour force with tertiary or even more advanced education comparable to the continental European countries.

[TABLES 3 AND 4 ABOUT HERE]

Like with the Detroit-Silicon Valley comparison, higher inequality could be produced by a higher relative demand for skills. But while Ireland has grown significantly during the 1990s, and its high-tech operations have become noticeable, it is

[9] Survey data show that in the mid-1990s almost 60% of returning Irish emigrants had a third level degree vis-à-vis 29% for non-returnees in the labour force. See Kapur and McHale (2002).

hard to think that it could exhibit a higher relative demand for skills than Germany or France. For example, Table 4 reports that in the end of the 1990s the Irish R&D share of GDP and its share of research scientists and engineers over the total labour force were still well below those of Germany and France. The Table reports other indicators that confirm this pattern. Both Germany and France have a higher number of scientific publications per million population, as well as a higher number of EPO and Triad patents per capita (viz. patents granted in all three major patent offices, USPTO, EPO, and JPO) than Ireland. Overall Germany, France, and Ireland do not have particularly different distributions of employment across high-, medium-, and low-tech manufacturing sectors, and in knowledge-intensive business services. Ireland and France have a slightly higher share of the latter, while Germany has a higher share of high-tech manufacturing sectors. Some indicators for Italy are below those of Ireland (shares of R&D and employed scientists and engineers, patents and publications per capita). At the same time, Italy has a higher share of employment in high- and medium-tech manufacturing sectors. While Ireland has a slightly higher share of employment in knowledge intensive business services than Italy, a classical indicator of development, the share of employment in agriculture, shows that, amongst our four countries, Ireland is still the economy with the largest fraction of agricultural population. All in all these figures suggest that the relative demand for skills in Ireland is likely to be less pronounced than in Germany and France and possibly comparable to Italy, but definitely not higher.

Furthermore, a recent OECD (2002) report shows that, according to several indicators, access to and the use of the new information and telecommunications technologies in Germany, France or Italy (e.g. broadband penetration rates, web sites per population) is definitely not inferior to Ireland. Since the use of these technologies typically requires more skilled workers, this offers additional evidence that the relative demand for skills cannot be higher in Ireland than in the leading Continental European countries. At the same time, Nicoletti, Scarpetta, and Boylaud (1999) measured different aspects of the stringency of regulation in OECD countries. Figure 5 reports their 0-6 index for employment protection, product market regulation, and barriers to entrepreneurship. These indices can be thought of as proxies for our parameter $\mu$. Ireland exhibits values that are well below those of Germany, France or Italy (high $\mu$). The difference in these indices looks quite more prominent than potential differences in the relative demand for skills of the Irish economy vis-à-vis continental Europe – particularly in the direction of a higher demand in Ireland. We know that our model predicts that high $\mu$ makes the B-equilibrium attractive.

[FIGURE 5 ABOUT HERE]

To conclude, one may wonder why we did not make the more classical comparison between the UK and the continental European countries. The UK exhibits a higher share of people with tertiary education (17%), along with a higher inequality than Germany, France and Italy. Again, this could stem from a higher relative demand for skills. But when compared with Germany, the latter shows a higher ratio of R&D over GDP (1.52% for the UK in 1998), a higher number of both USPTO and EPO patents per thousand population, a higher number of researchers per thousand labour force, a higher share of value added of high-tech and medium tech products as percentage of total output. (See European Commission, 2002.) Like with Ireland, it is hard to think that with such records the relative demand for skills is lower in Germany than in the UK.

The reason why we preferred to flag the Irish comparison is that in this case it is probably more obvious that the relative demand for skills cannot be higher than in Germany or France.  If one is prepared to believe that this is true of the UK as well, then the combination of higher inequality with higher relative supply of educated people may well stem from the fact that quite a few UK sectors operate under the B-equilibrium, while most German industries are in the A-equilibrium.

## 7. CONCLUSIONS

Wage inequality between skills differs across countries.  The explanation proposed in this paper is that different organisations of businesses and industries may have different implications for the productivity of the skilled and the unskilled workers.  Our emphasis on the role of the new business models is not alternative to the other explanations in the literature, which highlight differences in institutional factors like the mechanisms of wage setting.  For one reason, large integrated firms in manufacturing industries are more likely to entail unionisation of workers and centralised wage settings.

We stress the fact that rising opportunities in new skill-intensive industries reduce the extent of the complementarity between skilled and unskilled workers observed in the larger integrated firms.  Our story then suggests that the large firms, and the manufacturing sectors more generally, produce greater externalities amongst workers with different skills than the modern technology-based sectors, in which the externalities occur mostly within the same skill categories.  In sum, the large Chandlerian firm has been a notable shield against inequality across skills for many years.  At the same time, the knowledge spillovers produced by the new industries imply that the rise of such industries require co-ordination, which gives rise to multiple equilibria. This explains why even when comparing similar countries or regions, either the traditional sectors or the new business models dominate.

## APPENDIX 1

In this Appendix we propose a model that produces a remuneration like (4) for the skilled workers in the modern sector. Assume that there are *N* identical firms in the industry. Each firm employs *l* skilled workers. We model knowledge externalities by assuming that the total output *Q* of the modern industry takes the CES specification

$Q = \left( \int_0^N l_i^\beta di \right)^{\frac{1}{\beta}}$ with $\beta \in (0, 1)$. The profits of each firm are $\Pi = \frac{Q}{N} - r'l$, where we assume that each firm appropriates an equal share of the total industry output, and $r'$ is the salary of the skilled workers in this industry. The first order conditions produce the inverse demand for skilled workers in the modern sector, $r' = \frac{Q^{1-\beta}}{N} l^{\beta-1}$. Since all the firms are identical, total output can be written as $Q = N^{\frac{1}{\beta}} l$. This yields $r' = N^{\gamma-1}$, where $\gamma \equiv \frac{1-\beta}{\beta}$, and $\Pi = r' \cdot l \cdot (N-1)$.

We now assume that in order to operate our firms have to undertake administrative activities that do not directly contribute to production. Suppose that in each firm these activities require *m* skilled workers. Two things have to be noted. First, this is the (fixed) cost incurred in the new industry, as these people do not contribute to output. In economies where barriers to entrepreneurship are higher, there are high bureaucratic and administrative burdens to operate the new firms, or there are stronger regulations, a higher number of skilled workers are diverted from research, invention, or production, and they have to focus on these other tasks. Since *m* is a parameter in our model, economies with larger barriers to entrepreneurship, etc., will have a higher *m*, and indeed *m* is nothing more than the inverse of our parameter $\mu$. Second, we assume that the *m* skilled workers are the entrepreneurs. This set-up is not crucial. We could have equally assumed that each person working in the company (whether the employees or the entrepreneurs) has to spend a given fraction of time in non-productive activities, and the results would not change.

Given that *H'* skilled people work in the modern sector, the supply of skilled workers in this sector, which we label $\bar{l}$, is given by $\bar{l}N + mN = H'$, or $\bar{l} = \frac{H'}{N} - m$. Suppose that $\Pi \cdot m^{-1} > r'$. In this case the entrepreneurs earn more money than the skilled workers in the modern sector. Some skilled workers will set-up their own new firms, and they will become entrepreneurs. The supply of skilled workers $\bar{l}$ decreases and *N* increases, which reduces the gap till $\Pi \cdot m^{-1} = r'$. To see this, note that the inequality above can be written as $[\bar{l} \cdot (N-1)] > m$. The first term declines with *N*. This follows from the expression for $\bar{l}$ above, after taking the derivative of $[\bar{l} \cdot (N-1)]$ with respect to *N*, and after using the fact that because we take *N* to be sufficiently large, $\frac{N-1}{N}$ is close to 1. The equality $[\bar{l} \cdot (N-1)] = m$ then yields $N = \frac{H'}{m}$. The salary of the skilled workers in the modern industry is therefore $r' = \mu \cdot H'^{\gamma-1}$, where $\mu \equiv m^{1-\gamma}$. As long as $\beta \in (0, ½)$, then $\gamma > 1$, and *r'* increases with *H'*, as implied by (4). Note that for *r'* to increase with *H'* we need that the externalities be large enough ($\beta < ½$) to offset the reduction in the industry output appropriated by each individual firm as the number of firms *N* increases.

## APPENDIX 2

**Proposition 3**

*Other things being equal, the marginal effect of increases in the supply of skills K on the income of the economy is always higher in the B-equilibrium than in the A-equilibrium, viz.* $Y_K^B > Y_K^A \quad \forall K \in (0,1)$

**Proof.** Total income is $Y = r \cdot K + w \cdot (1-K)$, which we can write more conveniently as $Y = X + r \cdot K \cdot \left(1 - \frac{h}{k}\right)$, where *X* is the output of the traditional sector. This follows from the fact that because $X(\cdot)$ is linearly homogeneous in $\theta \cdot H$ and $(1-K)$, then $X = X_H \cdot H + X_{1-K} \cdot (1-K)$, and therefore $w \cdot (1-K) = X - r \cdot H = X - r \cdot K \cdot \left(1 - \frac{h}{k}\right)$. In the A-equilibrium, $h = k$, and the expression above denotes income under this equilibrium, which we label $Y^A$. In the B-equilibrium, $h < k$, and we have $Y^B$.

The expression for $Y_K^A$ is straightforward because $Y^A = X(\theta \cdot K, 1 - K)$. Then $Y_K^A = X_K - X_{(1-K)} = r^A - w^A$. The expression for $Y_K^B$ is a bit more involved, viz.

$$Y_K^B = X_H \cdot H_K - X_{(1-K)} + r_K^B K\left(1 - \frac{h}{k}\right) + r^B\left(1 - \frac{h}{k}\right) - r^B K\left(\frac{h_k k - h}{k^2}\right)(1-K)^{-2}$$

Use the fact that $X_H = r^B$, $X_{(1-K)} = w^B$, and $H_K = h_k(1-K)^{-1} + h$. This simplifies to $Y_K^B = r^B - w^B + r_K^B K(1 - h/k)$. Since $z^B > z^A$, then $r^B - w^B > r^A - w^A$. Moreover, $r_K^B > 0$ and $h \le k$, which implies $Y_K^B > Y_K^A \ \forall K \in (0,1)$. *QED*

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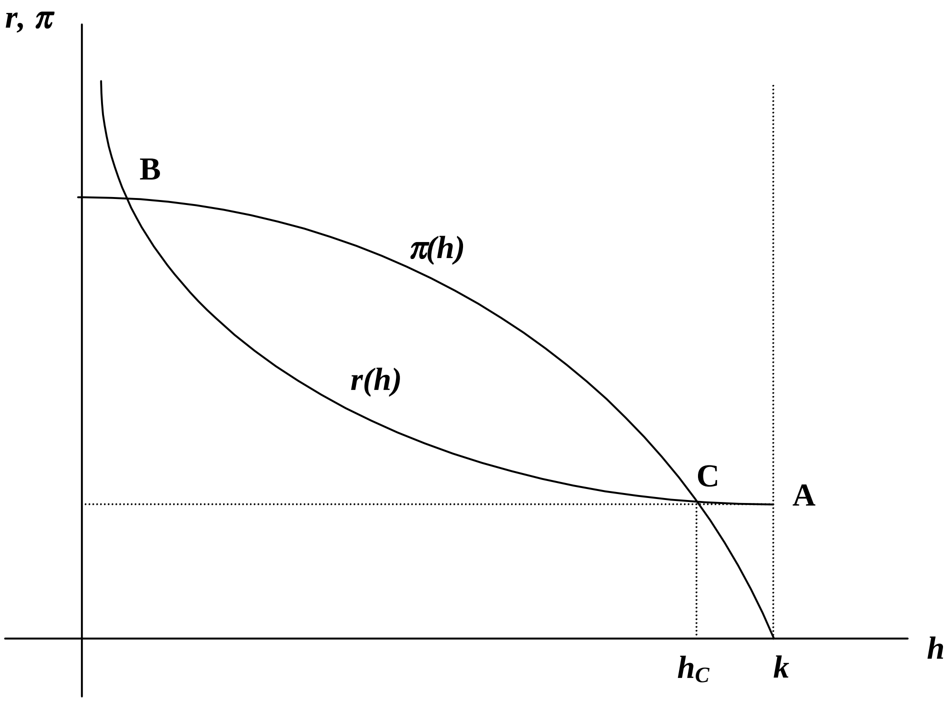
FIGURE 1
THE A- AND B-EQUILIBRIA



## FIGURE 2
## CHANGES IN $k$, $\mu$, $\theta$,

**Figure 2a: Changes in *k***

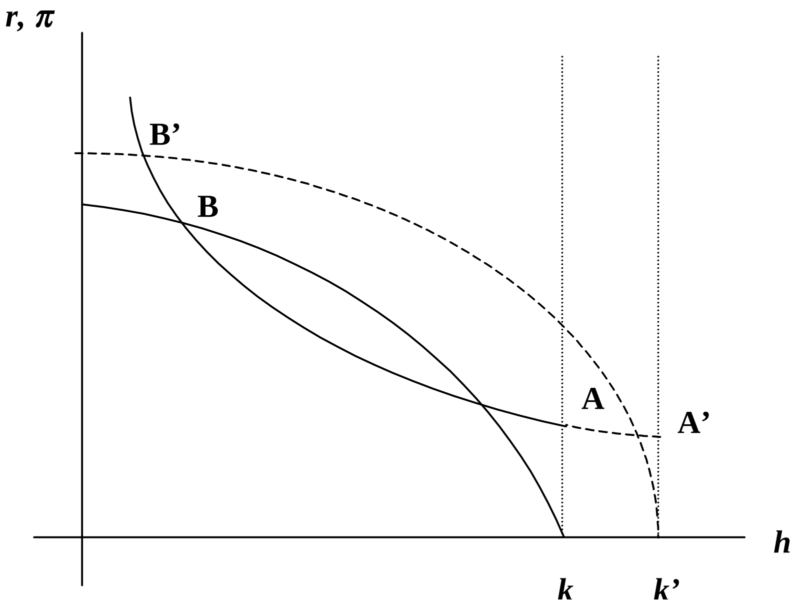



**Figure 2b: Changes in μ, θ**

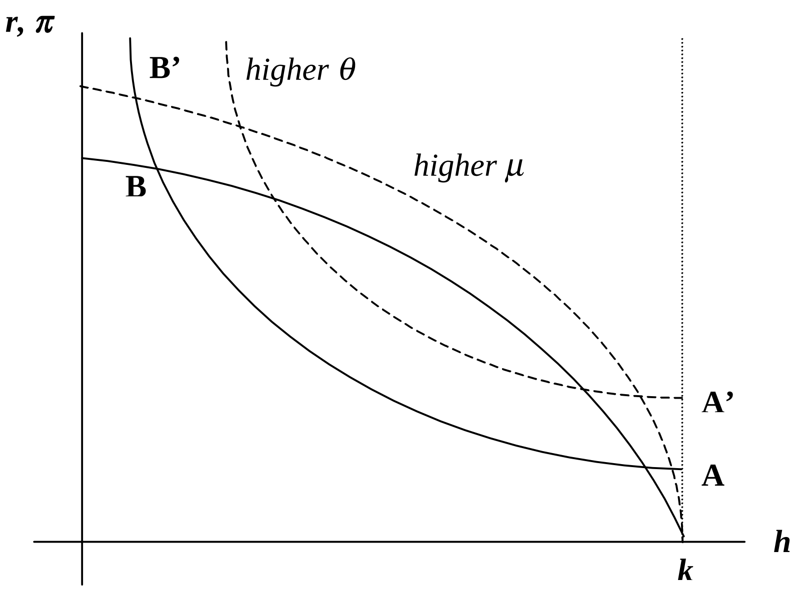


**FIGURE 3**
**THE DEMAND FOR SKILLS**

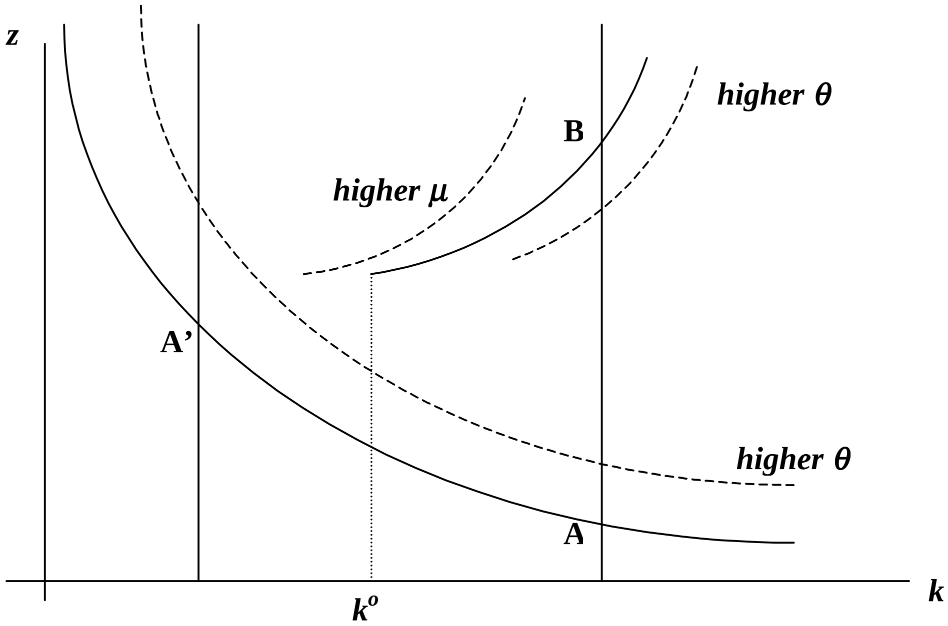



**FIGURE 4**
**SILICON VALLEY VS. DETROIT**

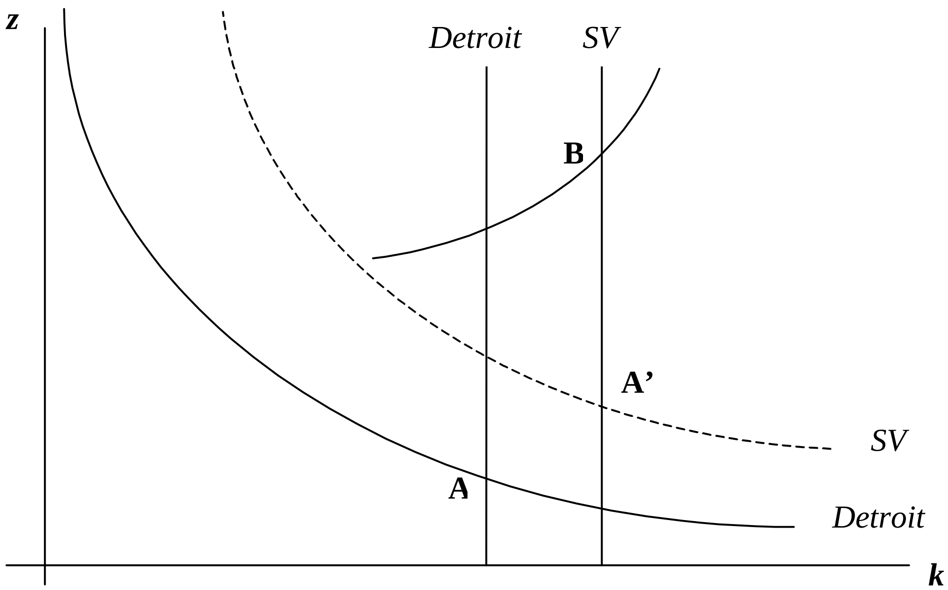


**FIGURE 5**
**STRINGENCY OF REGULATION:**
**IRELAND VS CONTINENTAL EUROPEAN COUNTRIES**
**(0-6 INDEX DEVELOPED BY NICOLETTI, SCARPETTA, BOYLAUD, 1999)**

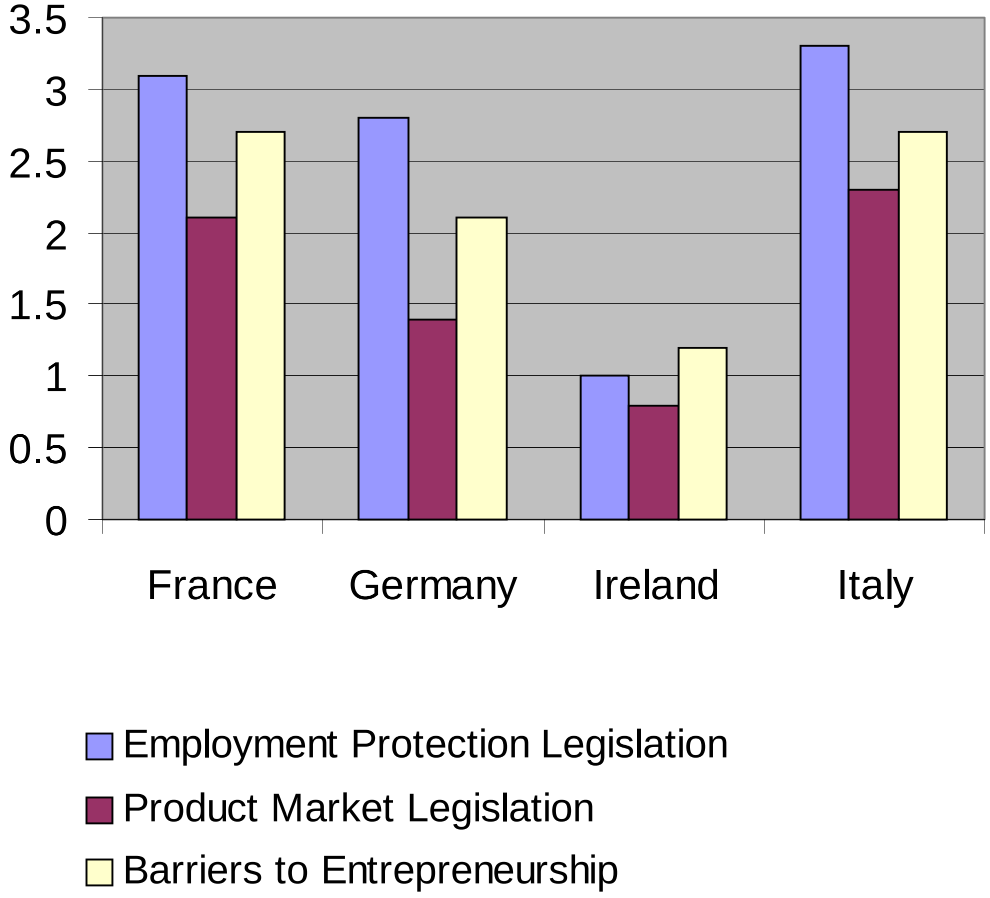


**TABLE 1**
**INEQUALITY AND RELATIVE SUPPLY OF SKILLS:**
**SILICON VALLEY VS DETROIT, 2001**

| **Inequality (z ≡ *r*/*w*)** | **Silicon Valley** | **Detroit** |
|---|---|---|
| *Managerial Occupations / Production Occupations* | 3.11 | 2.31 |

| **Supply of Skills (*k*)** | **Silicon Valley** | **Detroit** |
|---|---|---|
| *Managerial Occupations / Production Occupations* | 0.85 | 0.34 |
| *Managerial Occupations / Total Employment* | 0.08 | 0.04 |
| *Production Occupations / Total Employment* | 0.09 | 0.12 |

**TABLE 2**
**INEQUALITY AND RELATIVE SUPPLY OF SKILLS:**
**SILICON VALLEY VS BOSTON, 1999-2001**
**(AVERAGE ANNUAL GROWTH, %)**

| **Inequality (z ≡ *r*/*w*)** | **Silicon Valley** | **Boston** | **Difference** |
|---|---|---|---|
| *Managerial Occupations / Production Occupations* | 1.1 | – 2.5 | + 3.6 |
| *Managerial Occupations / Median Wage of the Area* | 2.7 | – 3.0 | + 5.7 |

| **Supply of Skills (*k*)** | **Silicon Valley** | **Boston** | **Difference** |
|---|---|---|---|
| *Managerial Occupations / Production Occupations* | 14.6 | 7.0 | + 7.6 |
| *Managerial Occupations / Total Employment* | 3.4 | –1.0 | + 4.4 |

## TABLE 3
## INEQUALITY AND EDUCATION: IRELAND VS CONTINENTAL EUROPEAN COUNTRIES

| **Country** | **Ratios between percentiles of earnings, 1998 (*)** | | | **Percentage of population that attained tertiary type-A (ISCED) and advanced research programmes education, by age group, 1999** (+) | | | | |
|---|---|---|---|---|---|---|---|---|
| | **90-10** | **90-50** | **50-10** | ***25-64*** | **25-34** | **35-44** | **45-54** | **55-64** |
| France | 3.05 | 1.92 | 1.58 | *11* | 15 | 10 | 10 | 7 |
| Germany | 3.04 | 1.85 | 1.65 | *13* | 13 | 15 | 14 | 10 |
| Ireland | 3.93 | 2.02 | 1.95 | *11* | 16 | 11 | 7 | 5 |
| Italy | 2.39 | 1.74 | 1.38 | *9* | 10 | 11 | 10 | 5 |

(*) 1996 for Italy, 1997 for Ireland
(+) 1998 for Ireland

Source: OECD. Data on Education Attainments are from OECD, *Education at Glance*, 2001.

## TABLE 4
## STRUCTURAL INDICATORS: IRELAND VS CONTINENTAL EUROPEAN COUNTRIES

| Country | Share of Employment (%), 1999 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Manufacturing | | | | | | | | | |
| | High-Tech Sectors | Medium-Tech Sectors | Low-Tech Sectors | Knowledge Intensive Services | Agriculture (*) | GERD over GDP (%) (*) | RSE over Total Labour Force (%) (*) | SP per million Population (*) | Triad Patents per million Population (*) | EPO Patents per million Population (+) |
| France | 7.2 | 5.2 | 6.4 | 13.0 | 1.4 (^) | 2.2 | 6.1 (§) | 671 | 35 | 128 |
| Germany | 10.9 | 6.7 | 6.2 | 11.9 | 2.8 | 2.3 | 6.0 | 666 | 59 | 270 |
| Ireland | 7.3 | 4.4 | 6.5 | 13.5 | 9.1 | 1.4 (§) | 5.1 (§) | 520 | 5 | 70 |
| Italy | 7.6 | 7.6 | 8.4 | 11.0 | 6.6 | 1.0 | 3.3 | 453 | 12 | 67 |

(*) 1998; (+) 2000; (§) 1997; (^) Dependent Employees, while for the other countries is all Civilian Employees.

GERD = Gross Expenditures on R&D; RSE = Research Scientists and Engineers; SP= Scientific Publications; Triad Patents = Patents granted in all three patent offices, USPTO, EPO and JPO.

Source: European Commission, DG Research, *Science, Technology and Innovation. Key Figures 2000*. EPO Patents per million population is from *Key Figures 2002*. Share of agricultural employment is from OECD.