Labor mobility and inter-industry wage variation

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Abstract

This paper offers a new explanation for the empirically observed inter-industry wage variation. We represent an industry by a small open economy with inter-firm labor mobility. Each industry is characterized by a degree of learning-by-doing, learning-by-hiring, inter-firm mobility costs and technological level. In this economy we analyze how these features affect the wage level of the industry. The variety of knowledge within an industry and its capital intensity is also analyzed. Results show that industries with high learning-by-hiring and low mobility costs generally pay higher wages. More learning-by-doing and higher technological level in an industry is also giving higher wages. Results provide new hypotheses to be tested and are consistent with the finding that more capital intensive industries pay higher wages.

1 Introduction

Inter-industry wage differences have been widely documented. They are found to be large and persistent across time and countries (Dickens and Katz, 1987; Krueger and Summers, 1987; Murphy and Topel, 1990). Although there are some theories on the existence of such wage variation, empirical testing does not get a general consensus on which theory prevails. Moreover, there is always left some inter-industry wage variation unexplained. The result most widely accepted for its robustness is that more capital-intensive industries as well as more profitable ones tend to pay higher wages for the same work and type of worker. There is a need for new theories to explain such regularities and provide new hypotheses to be tested.

In this paper we present a theoretical explanation for these inter-industry differences. In contrast to some of the hypotheses offered so far, such as the efficiency wage theory, we rely on competitive markets where workers are paid their marginal productivity.

We characterize an industry using four main elements: learning-by-doing, learning-by-hiring, inter-firm mobility costs and technological level. We argue that all of these factors matter in determining the wage level of an industry.

Learning-by-doing refers to the knowledge that a worker gains as a by-product of doing her job. By learning-by-hiring we mean the ability of a firm to get external knowledge through hiring new employees who have this knowledge from other firms. This ability of a firm to poach external workers depends among other things on the costs of moving across firms, which we call inter-firm mobility costs. The space distribution of an industry is probably the main determinant of mobility costs, although other factors such as the cultural or social background of the worker may also affect them. Finally, the fourth factor is the technological level which is self-explanatory.

We assume labor market segmentation in the sense that each industry has a fix supply of labor. You may think of individuals having strong tastes on which industry to work, or industries requiring specific worker characteristics (Dickens and Lang, 1988).

Moreover, we assume that mobility of workers within an industry goes together with knowledge diffusion. That is workers have embodied knowledge and when they move between firms their knowledge travels with them. Evidence on the transfer of knowledge through labor mobility (learning-by-hiring) refers especially to the mobility of technical or R&D personnel in high-tech or R&D intensive industries (Saxenian, 1994; Zucker, Darby and Brewer, 1998; Almeida and Kogut, 1999). In our model only experienced workers can move between firms. We also assume that heterogeneity of knowledge brings extra productivity to the firm. There is evidence that innovation comes easier when there is exchange of knowledge among scientists, technicians or researchers in general (Peri, 2005; Leonard and Sensiper, 1998; Ettlie, 1980; Sakakibara, 1997). Different points of view, different expertise together may innovate faster than a homogeneous group of workers. Furthermore, the latter literature puts especial emphasis on tacit knowledge, which requires face-to-face contact among individuals. We introduce this observation in our model by assuming that workers can exchange knowledge only within the firm.

The model gives six main predictions about the inter-industry wage disparities. Ceteris paribus, an industry pays higher wages than the rest when:

- The learning-by-hiring component is more important in this industry.
- Costs for the mobility of workers across firms are lower.
- When the industry productivity depends on a wider variety of knowledge.
- When there is large complementarity between different types of experienced workers (they are further from perfect substitutes).
- The industry offers more learning-by-doing opportunities to its workers.
- The industry is technologically advanced.

Other papers have addressed the inter-industry wage differential issue. Those within a competitive framework sustain that workers sort by ability across industries (Kremer, 1993) or that working conditions differ across industries (compensating differences theory). These differences in workers' ability or working conditions would explain the existence of inter-industry wage variation.

Another work within the competitive framework is that of Zabojnik and Bernhardt (2001). They provide a model where workers' investment in human capital is determined by firm and industry characteristics. The mechanism is as follows. Workers invest in costly human capital in order to get promoted. The wages of winners and losers are not fixed by the firm, but competitively. All firms in the industry may bid for the promoted workers. They get as a result that the promotion premium differs across firms and industries.

In contrast to these theories, efficiency wage models give reasons why firms in a particular industry may find it profitable to pay workers above their competitive level. High payment in order to induce high effort when monitoring costs are substantial can be one example (Shapiro and Stiglitz, 1984). Several papers have analyzed empirically these hypotheses. However, they reach contradictory results. For instance, while Murphy and Topel (1987) find evidence on the sorting theory, Krueger and Summers (1988) present evidence against it. Furthermore, most of the existing literature agrees that a substantial part of wage variation is left unexplained.

The main contribution of this paper is to offer a new explanation for the observed inter-industry wage differences. New industry characteristics are introduced that had not been considered in this literature, namely learning-by-hiring, mobility costs, learning-by-doing, variety of knowledge and complementarity of experienced workers. Additionally, we introduce a new modeling of labor mobility in a competitive framework which may turn out useful for other purposes than the only ones presented in this paper.

Labor mobility has been analyzed at least in three lines of literature. First, labor economists use matching models to explicitly analyze inter-firm labor mobility (Jovanovic, 1979). This class of models rests on three main assumptions: heterogeneity of worker's productivity across firms, individual contracting and imperfect information. Workers want to move to another firm when either they realize they are in a low-productivity-match or they learn about an alternative prospective offer. A typical result is then that labor mobility increases total output. Notice that mobility occurs because of the imperfect information assumption. Workers get more efficiently distributed across firms as new information is revealed.

The second line of research argues that it is the result of human capital investment decisions. Young workers look for jobs with low wages but with high learning component. When they get older, they move with their acquired human capital towards better paid jobs and less learning opportunities (Becker, 1962; Moen, 2005). A main issue always present in this literature is to disentangle who should pay for the training costs.

The third group of economists tackles labor mobility introducing an element of specificity in the learning-on-the-job that allows workers to get some rents. Competitors are willing to pay high wages to experienced workers to learn their embodied specific knowledge, so workers will either move to competitors or be better-paid by their current employer who wants to retain them.[1]

[1]Fosfuri, Motta and Ronde (2001) use this argument to analyze whether a firm should export or go multinational. If it goes multinational, its technology may become spread into the local firms through labor mobility. In Franco and Filson (2000), workers evaluate whether to start up a new firm after having learned-in-the-job. Combes and Duranton (2001) and Combes and Duranton (2006) are also in this strand of literature while considering a duopoly model with reciprocal poaching of labor. Fosfuri and Ronde (2004) have

A common feature of these models is the presence of some market power (either monopoly or duopoly models). As rivalry in product market competition intensifies, firms get more concerned about keeping information private, so they pay higher wages to their workers in order to prevent them from moving to competitors.

In contrast to the human capital theory, learning is free in this later literature, since it is a by-product of production. What both strands of literature, human capital and specific knowledge, have in common is that knowledge is embodied in workers, which increases workers' productivity. Our work is within the specific knowledge literature in the sense that learning-by-doing is for free and knowledge is embodied in workers, but it is developed in a framework of perfect competition.

The paper is organized as follows. The next section introduces the model of labor mobility with knowledge diffusion. Section 3 describes the symmetric equilibrium, which is used in section 4 for a comparative static analysis. In section 5 we discuss and compare our results with the existing empirical evidence on inter-industry wage disparities, concluding the paper.

2 The model

We define an industry as a small open economy. Agents can borrow or lend money at an exogenous fix interest rate r_t. There are firms and workers in the industry. Let us denote by F_t the number of firms in the industry each period. They are identical in everything except that each firm has a different type of knowledge. As noted in the previous section, we assume segmented labor markets in the sense that there is a fix supply of labor per industry. Workers live for two periods and each generation has a measure N_t of individuals ready to work in a particular industry.

When individuals are young they work in a firm as unexperienced workers (L_t). By working in the firm they learn the specific knowledge of the firm without any cost (learning-by-doing), so that, at the beginning of next period, there is a positive amount of senior workers with the knowledge developed in each firm. We call them experienced workers.

In each period firms may hire their own experienced workers and external experienced workers. Denote by λ_{it}^{j} the amount of experienced workers from firm j that are hired by firm i in period t, $j \neq i$. As already stated above, they

a two-firm two-period model with cumulative innovation where technology spillovers arise through labor mobility. Gersbach and Schmutzler (2003) show how the effect of product market competition on incentives to innovate depends on spillovers being exogenous or endogenous (through labor mobility).

have embodied knowledge type j. We call them poached workers. Similarly, let η_{it} be the amount of own experienced workers hired by the same firm i at period t, which have knowledge type i. They are called retained workers.
The production function of each firm is $Y_{it} = H_{it}^{\alpha} K_{it}^{\beta} (B_t L_{it})^{(1-\alpha-\beta)}$ where H_{it} is a measure of effective units of human capital, K_{it} is physical capital, B_t is a measure of the productivity level of young workers and L_{it} is the total young employment of firm i ($i = 1, ...F$). We define human capital as an asymmetric CES function on all types of experienced workers hired by the firm.

$$H_{it} = [(\eta_{it} A_{it})^{\sigma} + p \sum_{j \neq i} (\lambda_{it}^{j} A_{jt})^{\sigma}]^{1/\sigma}, \qquad (1)$$

where A_{jt} is a measure of the knowledge of the type-j worker and p is a parameter which lies between 0 and 1 and measures the ability of **learning-by-hiring** of the firm.
We assume that $A_{it} > B_{t-1}$, which means that workers learn while working in the firm. We refer to it as **learning-by-doing**.
In contrast, learning-by-hiring refers to the ability of a firm to acquire external knowledge through hiring external workers (poaching). We consider it may be limited by three main factors: the intrinsic characteristics of the knowledge in question (whether it is firm or industry-specific); the degree of capacity of firms to acquire such external knowledge (concept of absorptive capability of firms developed by Cohen and Levinthal (1990)), and finally, the type of environment where firms develop their tasks (e.g. institutions, local legal system which may enforce or not clauses not-to-compete, strongly defend trade secrets, etc.).[2] When one or several of these factors diminish the potential of learning-by-hiring, the parameter p will be low, and vice versa.
Notice that the asymmetry in the CES function appears because we assume that knowledge from own workers (A_{it}) is fully accessible by the firm while knowledge from poached workers may be less accessible, i.e. $p \in [0, 1]$.
Knowledge in our model has two dimensions: variety and level of knowledge. The subindex i in A_{it} indicates the **type of knowledge** (in which firm the worker learnt his knowledge), while the **level of knowledge** is indicated by the particular value of A. In general the level of knowledge may be different across firms. Variety of knowledge is ensured by assuming that each firm has

[2]There is empirical evidence that shows how important differences in legal systems may be in determining the rate of labor mobility of a region when learning-by-hiring is relevant. Hyde (1998), Gilson (1999) and Valetta (2002) argue that Silicon Valley was originated in California precisely because there clauses not-to-compete have weak enforceability. Almeida and Kogut (1999) point out at the importance of "social institutions that support a viable flow of ideas within the spatial confines of regional economies" for creating the externalities that foster innovation (p.916).

a different type of knowledge.
With such specifications, we obtain a functional form for output similar to the one derived in Romer (1990), but instead of different types of capital goods, here we have different types of human capital. In the conventional specification, total human capital is implicitly defined as being proportional to the sum of all the types of human capital, assuming perfect substitutability among them. We allow for some level of complementarity among different types of human capital. In our case the elasticity of substitution between different types of experienced workers is $\frac{1}{1-\sigma}$. We assume that they are imperfect substitutes, that is that $\sigma < 1$.

$$Y_{it} = [(\eta_{it} A_{it})^{\sigma} + p \sum_{j \neq i} (\lambda_{it}^{j} A_{jt})^{\sigma}]^{\frac{\alpha}{\sigma}} K_{it}^{\beta} (B_t L_{it})^{1-\alpha-\beta}. \qquad (2)$$

We assume decreasing returns to all inputs ($0 < \alpha < 1$,$0 < \beta < 1$ and $\alpha + \beta < 1$). The parameter B_t converts raw quantities of unexperienced labor into efficiency units. We assume it is the same for all firms. It is like to say that all young workers have the same level of education before they enter the industry.
Notice that even though the production function has constant returns to scale, the number of industries matters because it determines the variety of knowledge in the economy. Moreover, we assume that without workers there is no access to knowledge.
Notice also that the CES functional form of the human capital measure ensures that variety of knowledge within the firm improves productivity. The interpretation is that exchange of knowledge matters for productivity. Moreover, we allow for the interaction of knowledge to happen only when two workers work in the same firm, which is coherent with the idea that tacit knowledge is important for innovation and needs face-to-face contact to be transmitted.
We assume perfect competition in the product market to be able to isolate the exchange of knowledge effect on the labor market. To simplify we assume that all firms can sell all the product at a given price, which we normalize to 1.
At the beginning of each period there is a measure $L_{i,t-1}$ of experienced workers for each type of knowledge in the industry ($i = 1, ...F$). Moreover, there is a positive cost for workers to move from one firm to the other, which we denote by m. It may include the real cost of changing place of residence as well as the subjective cost associated to it.
We consider the case of perfect competition in the labor market, so that firms take wages as given. Let w_t^i be the wage for young workers and ω_{it} the wage of type i experienced workers paid by firm i in period t. Notice that the wage

of experienced workers ω_{it} has to be greater than w_t^i to induce experienced workers to work. Otherwise they would prefer to work as unexperienced ones. Let ω_{jt}^i be the wage paid by a firm j to the experienced workers type i. For this type of workers to move to firm j, they must be paid at least as much as in firm i plus **mobility costs**, that is, $\omega_{jt}^i \geq \omega_{it} + m$. Since the labor market is perfectly competitive, the former condition holds with equality in equilibrium and an experienced worker is indifferent between moving or staying. In such a case we assume that workers are willing to change firm.
Each firm i decides the amount η_{it} of own experienced workers to retain, the amount λ_{it}^j of experienced workers to poach from each firm j ($j \neq i$), the amount of young workers to hire L_{it} and the amount of physical capital K_{it} to rent. We assume full depreciation of physical capital.
The problem of the firm is the following:

$$\begin{gathered}\max_{\eta_{it},\lambda_{it}^j,L_{it},K_{it}}((\eta_{it}A_{it})^\sigma + p\textstyle\sum_{j\neq i}(\lambda_{it}^j A_{jt})^\sigma)^{\frac{\alpha}{\sigma}} K_{it}^\beta (B_t L_{it})^{1-\alpha-\beta} - \\ -w_t^i L_{it} - \omega_{it}\eta_{it} - \textstyle\sum_{j\neq i}\omega_{it}^j \lambda_{it}^j - R_t K_{it} \\ \text{subject to } \omega_{it}^j \geq \omega_{jt} + m, \\ \text{and } w_{it} < \omega_{it}.\end{gathered}$$

Note that it is a static problem. It only involves variables at period t.
The first order conditions for this problem are:

$$\alpha\eta_{it}^{\sigma-1}A_{it}^\sigma K_{it}^\beta (B_t L_{it})^{1-\alpha-\beta}((\eta_{it}A_{it})^\sigma + p\sum_{j\neq i}(\lambda_{it}^j A_{jt})^\sigma)^{\frac{\alpha}{\sigma}-1} = \omega_{it}, \tag{3}$$

$$p\alpha(\lambda_{it}^j)^{\sigma-1}A_{jt}^\sigma K_{it}^\beta (B_t L_{it})^{1-\alpha-\beta}((\eta_{it}A_{it})^\sigma + p\sum_{s\neq i}(\lambda_{it}^s A_{st})^\sigma)^{\frac{\alpha}{\sigma}-1} = \omega_{jt} + m \ \forall j \neq i, \tag{4}$$

$$(1-\alpha-\beta)((\eta_{it}A_{it})^\sigma + p\sum_{j\neq i}(\lambda_{it}^j A_{jt})^\sigma)^{\frac{\alpha}{\sigma}} K_{it}^\beta B_t^{1-\alpha-\beta} L_{it}^{-\alpha-\beta} = w_t^i, \tag{5}$$

$$\beta((\eta_{it}A_{it})^\sigma + p\sum_{j\neq i}(\lambda_{it}^j A_{jt})^\sigma)^{\frac{\alpha}{\sigma}} K_{it}^{\beta-1}(B_t L_{it})^{1-\alpha-\beta} = R_t. \tag{6}$$

Equation (3) equalizes marginal productivity of retained workers in firm i to their wage.
Equation (4) does the same for workers poached from firm j by firm i. Notice that we already introduce the equilibrium result that the first constraint is binding.
Similarly, equation (5) is the marginal productivity of young workers equal to their wage.
Finally, equation (6) sets marginal productivity of physical capital to the marginal cost, which is the rental payment R_t. In equilibrium it must happen that the rental rate equals the interest rate plus the depreciation rate

($R_t = r_t + 1$) in order to ensure no arbitrage possibilities in the economy. Notice that since marginal productivity of poached workers at $\lambda_{it}^{j} = 0$ is infinity for all i,j (see equation 4) and there is no cost of adapting variety of knowledge, all firms will poach workers from all the other firms in the industry to access the whole range of knowledge.[3] Moreover, firms will always want to retain some of their own workers because the marginal productivity of retained workers when the industry retains zero workers is infinite (from equation 3).[4]

Since there is a perfect capital market, individuals care about maximizing their life-time income, which depends on which firm they start working. Then they can save or borrow to allocate inter-temporally their consumption according to their preferences. In equilibrium it must happen that all workers within an industry have the same life-time income in present value.

$$w_{it} + \frac{\omega_{i,t+1}}{1 + r_{t+1}} = w_{jt} + \frac{\omega_{j,t+1}}{1 + r_{t+1}} \quad \forall i \neq j. \tag{7}$$

Notice that although an experienced worker type i poached by firm j earns $\omega_{jt}^{i} = \omega_{it} + m$, he incurs a cost m by moving, so the total available income when he is experienced reduces to ω_{it}. Thus, equation (7) refers as much to stayers as to movers.

Next we present the clearing market conditions for the labor market. Equation (8) refers to the market for young workers and equation (9) to the experienced workers' market.

$$\sum_{i=1}^{F} L_{it} = N_t, \tag{8}$$

$$\sum_{j \neq i} \lambda_{jt}^{i} + \eta_{it} = L_{i,t-1} \ \forall i = 1, ...F, \tag{9}$$

In the left-hand side of equations (8) and (9) there is the total demand for young workers and experienced workers type i, respectively. The right-hand side shows the total supply of these types of workers. These equations together with equation (7) determine w_{it} and ω_{it}.

[3] We could limit the number of firms from which to poach workers by introducing a cost of adaptation of external knowledge which increases with the variety of knowledge. This would complicate the analysis without giving any new insights into the model.

[4] These conditions are sufficient but not necessary to obtain positive labor mobility in equilibrium. The necessary condition for positive labor mobility is that the marginal productivity of the first worker type i willing to move is lower in her firm of origin than in any other firm. Similarly, the condition for having some retained workers in equilibrium is that the marginal productivity of the first retained worker is higher than the marginal productivity of this type of worker in any other firm when all workers of his type are working for that firm.

3 The symmetric equilibrium

We look at the symmetric equilibrium. This is when all levels of knowledge are the same across firms, although the type of knowledge keeps being different for each firm. In such a case $A_{it} = A_t \ \forall i$. Moreover, all firms hire the same amount of young workers each period. This implies that there is the same amount of experienced workers of each type at the beginning of each period ($L_{i,t} = \frac{N_t}{F_t} \forall i$). There is no population growth neither technological growth (N_t, F_t, B_t and A_t are constant overtime). Notice that given all these conditions there is no need for time subscripts anymore.

Definition 1 *Given a constant exogenous interest rate r, the symmetric equilibrium is characterized by the vector of variables η, λ, L, K and the prices w, and ω that solve the following system of equations:*

$$\alpha\eta^{\sigma-1}A^{\alpha}K^{\beta}(BL)^{1-\alpha-\beta}(\eta^{\sigma}+p(F-1)\lambda^{\sigma})^{\frac{\alpha}{\sigma}-1} = \omega, \tag{10}$$

$$p\alpha\lambda^{\sigma-1}A^{\alpha}K^{\beta}(BL)^{1-\alpha-\beta}(\eta^{\sigma}+p(F-1)\lambda^{\sigma})^{\frac{\alpha}{\sigma}-1} = \omega + m, \tag{11}$$

$$(1-\alpha-\beta)(\eta^{\sigma}+p(F-1)\lambda^{\sigma})^{\frac{\alpha}{\sigma}}A^{\alpha}K^{\beta}B^{1-\alpha-\beta}L^{-\alpha-\beta} = w, \tag{12}$$

$$\beta(\eta^{\sigma}+p(F-1)\lambda^{\sigma})^{\frac{\alpha}{\sigma}}A^{\alpha}K^{\beta-1}(BL)^{1-\alpha-\beta} = r+1, \tag{13}$$

$$L = \frac{N}{F}, \tag{14}$$

$$(F-1)\lambda + \eta = L. \tag{15}$$

Equations (10) to (13) come from the firm's problem and equations (14) and (15) are the labor market clearing conditions. There is missing equation (7) from the previous section, which becomes an identity in a symmetric equilibrium.

Notice that we can write the firm production function as:

$$Y = (\frac{A}{B})^{\alpha}B^{1-\beta}(\eta^{\sigma}+p(F-1)\lambda^{\sigma})^{\frac{\alpha}{\sigma}}K^{\beta}L^{1-\alpha-\beta} \tag{16}$$

This allows us to distinguish between the effect of learning-by-doing and the technological level. Let us denote $(\frac{A}{B})^{\alpha}$ the **learning-by-doing** component of the total factor productivity (TFP) and $B^{1-\beta}$ the **technological level** of the industry. Let us do two observations on this decomposition. When $\frac{A}{B} > 1$ there is learning-by-doing in the industry. When A and B grow in the same proportion, then the learning-by-doing component is not affected and the technological level increases.

In the next section we calibrate this symmetric equilibrium and compute a comparative static analysis to identify how each parameter affects wages in this economy.

4 The comparative static analysis

We want to explain inter-industry differences in wage levels. Using the previous model we want to analyze how industries with different levels of learning-by-hiring capabilities, different mobility costs, different learning-by-doing possibilities and different initial productivity of workers have different wage levels. In order to do so, we calibrate the model and pursue a comparative static analysis on the symmetric equilibrium.

For the calibration we take standard values of the basic parameters. We assume each period has 25 years. α takes the value 0.35 and β takes 0.33. For σ there is no previous literature, so we take an arbitrary value for the baseline parametrization, 0.5. This sigma-value corresponds to an elasticity of substitution among different types of experienced workers of 2%.

We give arbitrary numbers to the rest of the parameters ($A = 100, B = 5, N = 100, F = 10$) in order to have interior solutions. We assume a 5% annual interest rate, which corresponds to a 2.4% interest rate in 25 years. Results are robust to changes in the parametrization baseline.

Figures 1 to 6 show graphically the relationships between the parameters of the model and its main variables.

Recall that parameter p represents the learning-by-hiring ability of the firm, m is a measure of the inter-firm mobility costs and F corresponds to the number of firms as well as to the variety of knowledge in the industry. The ratio $\frac{1}{1-\sigma}$ is the elasticity of substitution between different types of experienced workers.

Variations in the parameter A tell us about differences in learning-by-doing (see equation 16), while variations in B maintaining $\frac{A}{B}$ constant refers to changes in the technological level of the industry.

Figure 1 describes how **learning-by-hiring** affects the industry variables. As expected, the learning-by-hiring potential (p) of an industry is positively related to the labor mobility rate of this industry as well as to the firm production net of mobility costs, the capital-labor ratio and the wages for all type of workers.

Intuitively, a higher learning-by-hiring ability directly affects the production level. It also increases the marginal productivity of all types of labor. This translates in higher demand for all types of workers and since supply is inelastic, wages must increase in equilibrium. Marginal productivity of poached workers increases relatively more than that of retained workers (p enters twice in the marginal productivity of poached workers), which explains why labor mobility increases with higher learning-by-hiring. Finally, the marginal productivity of physical capital increases, and since the total amount of labor per firm remains fix, the capital-labor ratio of firms also increases.

Figure 2 reveals how a change in **mobility costs** affects the variables of the model. An increase in the mobility costs means that the economy will have to direct more resources to cover them, which provokes a decrease in the firm production net of these costs. They also increase the cost of poaching workers, so firms will substitute them for retained workers that are now relatively cheaper.
The mobility of labor in equilibrium will be reduced. More retained workers implies that their marginal productivity is lower, so the wage for experienced workers decreases. Since each firm hires less external workers, their complementarity benefits are lower and the marginal productivity of physical capital and young workers are lower too. Then, the capital-labor ratio and the wage for young workers also diminish. Notice however, that the wage for young workers is much less affected than the wage for experienced workers.
In our model the parameter F refers at the same time to the number of firms and the **variety of knowledge** in the economy. Actually even if we have a constant returns to scale technology, the number of firms matters because it also determines the variety of knowledge. Thus, we want to interpret this parameter with the latter meaning.
Figure 3 shows the results when we increase F and N proportionally, so that each firm has always the same size. This allows us to isolate the variety of knowledge effect from the size effect.
The greater the variety of knowledge, the greater the firm net production. Moreover, since each firm is poaching workers from all the other firms in the market, the total demand for each type of experienced workers increases. Thus the total experienced worker's wage increases unambiguously. This will reduce the amount of retained workers in equilibrium, meaning that the firm labor mobility must increase.
Even if each firm is now poaching less experienced workers from each other, there are more firms in the industry, so the total amount of labor mobility per firm increases. The marginal productivity of physical capital and that of young workers increase. Then, capital-labor ratio and wages for young workers increase too.
We obtain similar results when keeping N constant. The only difference is then that two effects are at work, the increase in variety of knowledge and a decrease in the number of workers per firm as F increases. In general then results show that firm net production decreases except when the complementarities among experienced workers are big enough (σ small) to compensate for the decrease in the amount of workers per firm. In any case aggregate net production increases unambiguously.
An increase in the **elasticity of substitution** between the different types of experienced workers ($\frac{1}{1-\sigma}$) makes it less important for productivity to have

different types of these workers. There are less learning opportunities of mixing different types of workers, which translates in less production, as can be seen in figure 4. This affects also to the demand of such workers that diminishes as well as their wages. Marginal productivity of young workers decreases and their wage does so too. The capital-labor ratio decreases.
Figure 5 represents the changes in the variables when we increase A. Following the decomposition of total firm productivity in equation (16) we interpret an increase in A as a larger **learning-by-doing** offered to the workers in this industry. Increasing A keeping B constant affects the learning-by-doing component of the TFP only.
Higher learning-by-doing implies that experienced workers have larger knowledge, so they are more productive. Production increases as well as the wages of experienced workers. It also affects the productivity of young workers, who earn more when there is more learning-by-doing. The labor mobility rate and the capital-labor ratio increase too.
Finally, the effects of an increase in the level of knowledge of young workers (B) is reported in figure 6. Actually, we are increasing here both productivity parameters A and B so that the learning-by-doing component of TFP ($\frac{A}{B}$) keeps unaffected and the **technological level** (B) grows.
These changes affect positively all the variables of analysis. It increases the marginal productivity of all types of labor, thus their wage level does the same. Production is larger, there is more mobility of workers and the capital-labor ratio increases.
In the next section we discuss our results and relate them to the empirical evidence on inter-industry wage differences.

5 Concluding discussion

The main stylized facts about inter-industry wage variation can be summarized as follows (Krueger and Summers, 1987; Murphy and Topel, 1987; Dickens and Katz, 1987):

1. There exist large and persistent wage differences across industries.
2. Inter-industry wage differences are similar across developed countries.
3. More capital-intensive industries tend to pay higher wages.
4. Industries that pay high to some type of workers tend to pay high to all type of workers.
5. Industries with higher profits tend to pay higher to their workers.

6. Bigger firms tend to pay higher than smaller ones.

The two main theories that want to explain this phenomenon are the efficiency wage theory and the sorting of workers.
The main idea behind the efficiency wage theory is that shirking problems are more severe in some industries. Where these problems are more severe and monitoring more costly, industries may pay higher-than-competitive wages in order to motivate the worker to exert the maximum effort. This non-competitive theory would explain some of the variation in wages across industries.
The second theory says that workers sort into different industries according to some unobservable characteristics. The industries that pay higher wages are those that attract high-productivity workers.
The existing empirical testing of these two hypotheses does not reach a consensus and the puzzle remains unresolved.
In this paper we argue that several characteristics of the industries could be related to this wage differential. In particular we argue that industries differ in six concepts:

1. Their learning-by-hiring ability (acquiring external knowledge through hiring new workers), which depends on the type of knowledge in the industry (whether it is firm-specific or industry-specific), on the absorptive capacity of firms and on the institutional environment where the industry develops.

2. Their inter-firm mobility costs. They may depend on the spatial distribution of the industry as well as on institutional variables, such as the easiness to find information about job offers within the industry.

3. Their variety of knowledge. The importance of different types of knowledge for firm productivity.

4. The elasticity of substitution of different types of experienced workers.

5. The learning-by-doing offered to their workers. This may create non-observable heterogeneous workers across industries.

6. The technological level of the industry.

If these six industry characteristics are common across countries and do not change overtime, they can account for the stability found in the wage structure.
Our results show that industries with higher learning-by-hiring and larger

variety of knowledge pay higher wages to both unexperienced and experienced workers.
Similarly, when an industry is spatially concentrated or mobility costs are low, wages are larger.
The more complementarities among different type of experienced workers, the better paid are all the workers in the industry.
Finally, the more learning-by-doing in the industry and the more advanced technologically it is, the better it pays to its workers.
Moreover we find that industries which pay higher wages are also those that have a higher capital-labor ratio, in agreement with the empirical findings.
Although we have perfect competition in the product market, we argue that if industries with a high-profit rate are those with a high-learning component and high technological level, then our results would be consistent with the observation that they tend to pay high wages. With the existence of market power firms are more concerned to keep their knowledge private and pay higher wages to their workers in order to deter their moving to competitors. This result has been developed in Combes and Duranton (2006) among others. Thus, if industries with high concentration levels are those where learning-by-doing is more important, both results, market competition and learning-by-doing, reinforce each other and wages should be definitely larger there than in other industries.
Zabojnik and Bernhardt (2001) offer an alternative theory based on industry heterogeneity. They introduce investment in human capital and corporate tournaments. Their model implies that worker in bigger firms and in more technology intensive and profitable industries acquire more human capital and receive higher wages and benefits. Although with a very different approach, we find similar results, namely that more learning-by-doing as well as more advanced technological industries pay better their workers.

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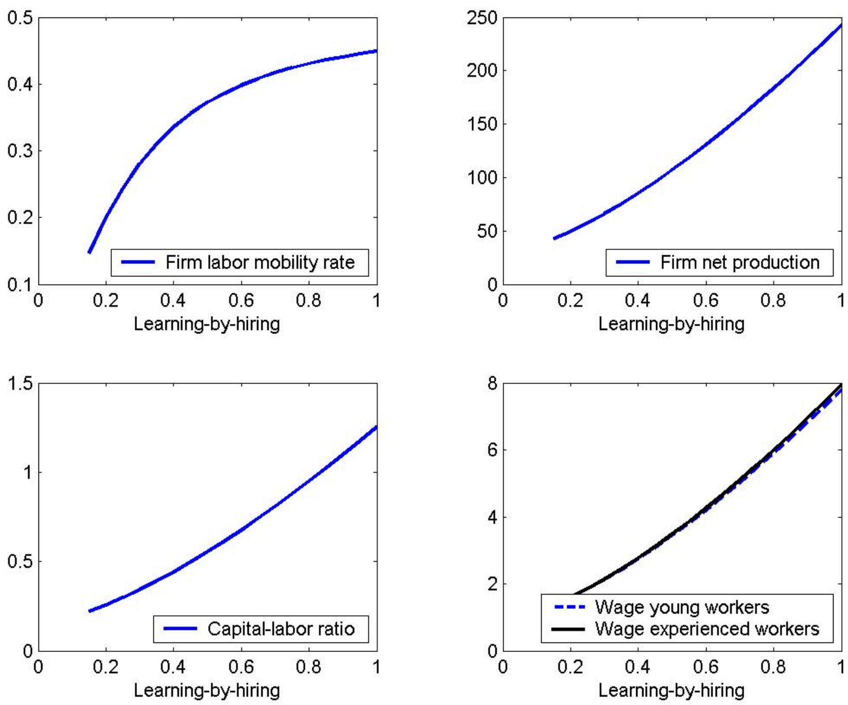

Figure 1: Effects of changing p on the steady state main variables. Simulation results.

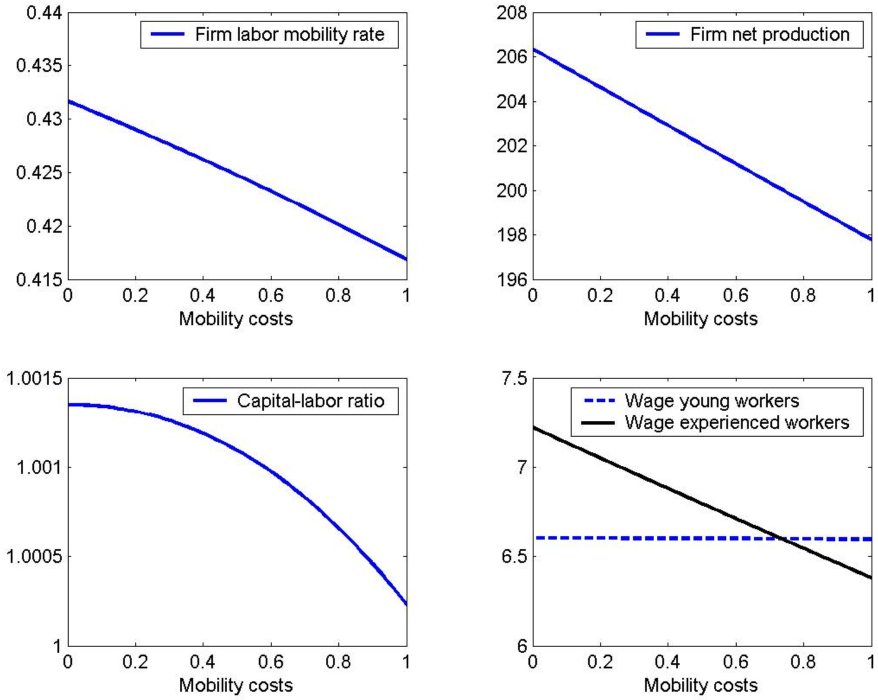

Figure 2: Effects of changing m on the steady state main variables. Simulation results.

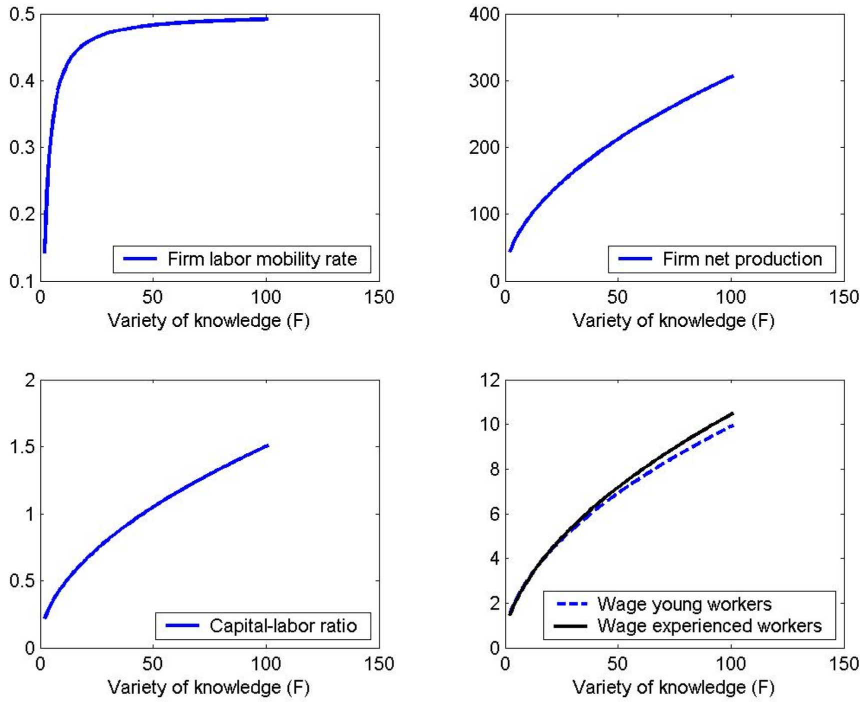

Figure 3: Effects of changing F on the steady state main variables keeping $\frac{N}{F}$ constant. Simulation results.

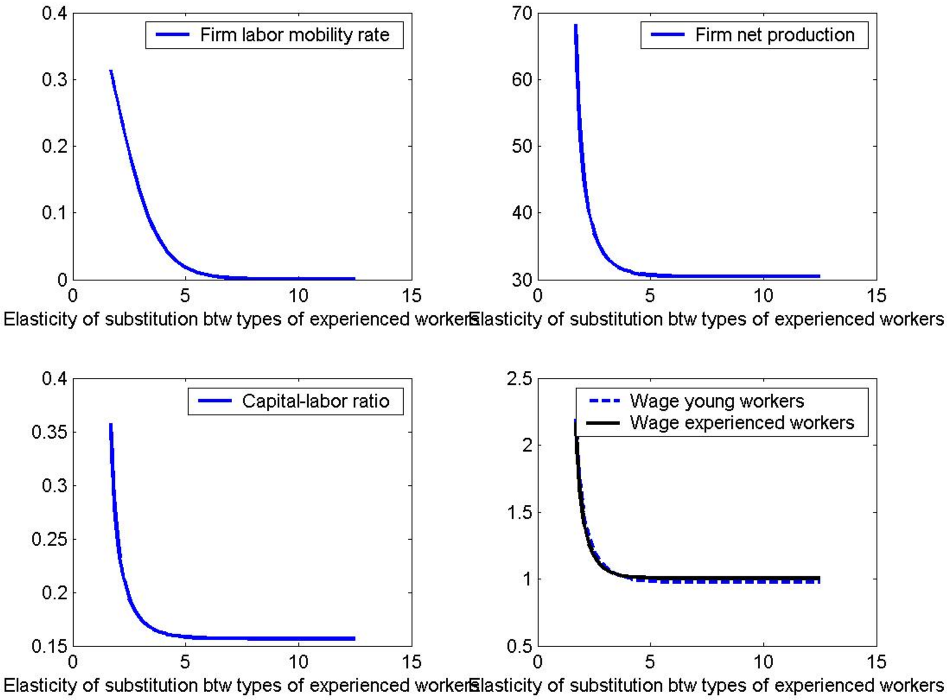

Figure 4: Effects of changing the elasticity of substitution between types of experienced workers ($\frac{1}{1-\sigma}$) on the steady state main variables. Simulation results.

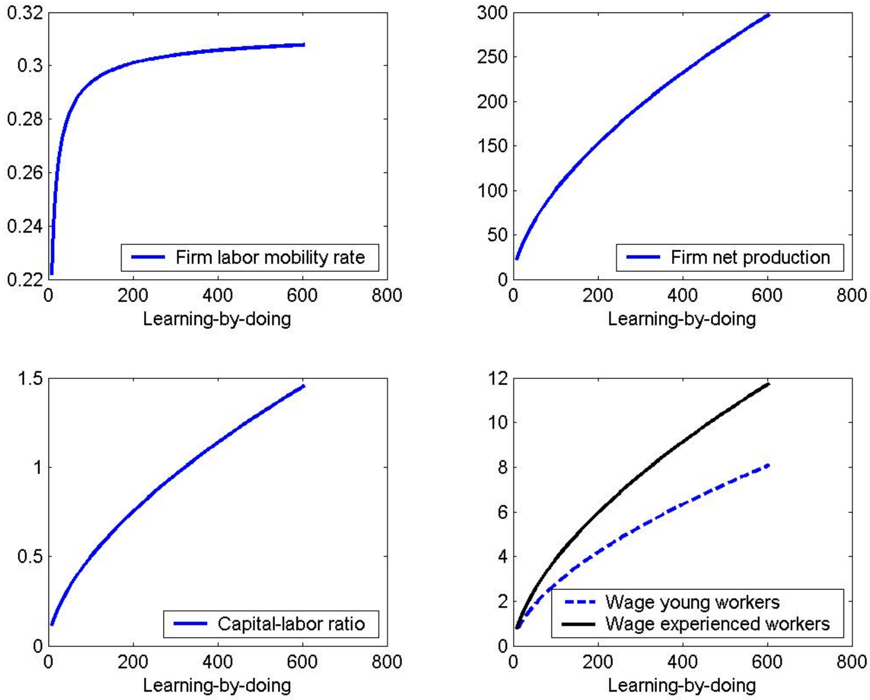

Figure 5: Effects of changing A on the steady state main variables. Simulation results.

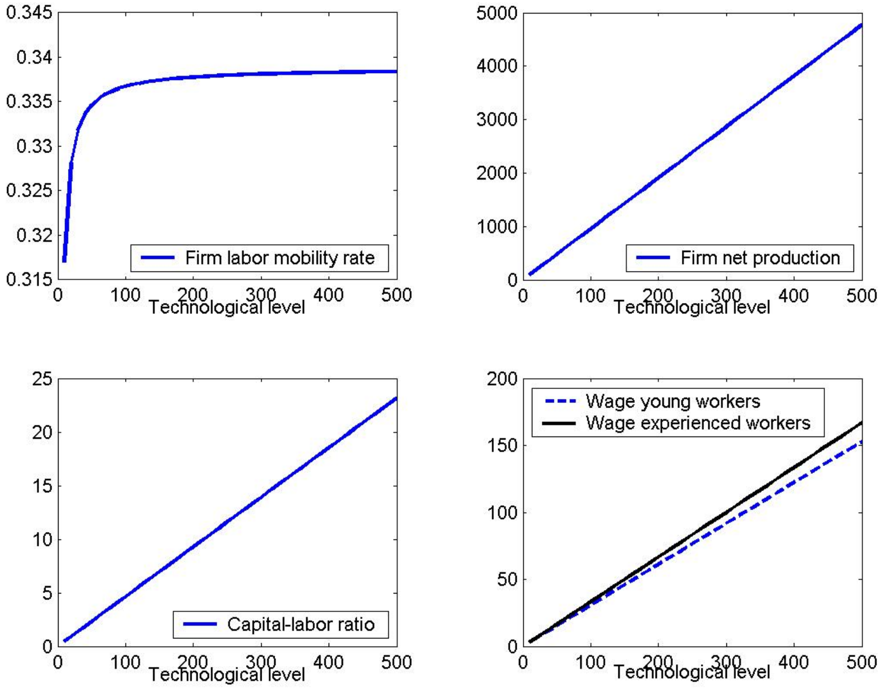

Figure 6: Effects of changing B on the steady state main variables, keeping $\frac{A}{B}$ constant. Simulation results.