On the industry experience premium and labor mobility

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Abstract

There is evidence that experience premium differs across industries. We propose a theoretical model for explaining these differences. We assume that labor mobility brings external knowledge to the firm, which increases its productivity. We find that industry experience premium is decreasing in inter-firm mobility costs, while increasing in the learning-by-doing and the technological level of the industry. Moreover, it has a U-shape relationship with the level of learning-by-hiring, the substitutability between different types of experienced workers and the variety of knowledge in the industry. Results are consistent with the empirical findings that R&D-intensive industries have steeper wage profiles.

1 Introduction

There is evidence that experience premium differs across industries. This paper proposes a theoretical explanation for these inter-industry differences in experience premium. In our model, the level of labor mobility across firms influences the experience premium. Consequently, the determinants of labor mobility affect also the experience premium of the industry.

There are four main assumptions in our model. First, mobility of workers within an industry induces 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 specially to the mobility of technical or R&D personnel in high-tech or R&D intensive industries (Saxenian, 1994; Zucker et al., 1998; Almeida and Kogut, 1999). In our model only experienced workers may have incentives to move between firms.

Second, we assume that all the knowledge learned in the firms is industry-specific. In such a case, experienced workers do not have economic incentives to move to another industry, since their knowledge would be of no value there. Therefore, there is no mobility of workers across industries. Sullivan (2008)'s results indicate that knowledge is industry-specific for managers and professionals, although it is not so for blue collar workers. Notice that since industry experience premium is the return to the learning relevant to the industry, it would not exist without industry-specific knowledge.

Third, we 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 or different expertises together may innovate faster than a homogeneous group of workers. Furthermore, the latter literature emphasizes 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.

Finally, it is assumed that markets are perfectly competitive, so workers are paid their marginal productivity. We solve first for the industry equilibrium and then perform a comparative static analysis to get the inter-industry results.

This paper makes two main contributions. Firstly, we provide a theory on differences in wage growth across industries. New industry characteristics are introduced that had not been considered in the literature, namely learning-by-hiring, mobility costs, learning-by-doing, variety of knowledge and complementarity of experienced workers. Secondly, we propose an alternative

way of modeling inter-firm labor mobility within the neoclassical framework, which leads to an extended Total Factor Productivity. In particular, we obtain that the TFP depends on the technological level, the learning-by-doing and the composition of labor within the firm.

Our paper contributes to two open controversies. The first controversy is about which economic theory prevails in explaining wage growth. The second controversy refers to the empirical relevance of firm, industry and general experience on wage growth.

Regarding the first controversy, there are three main theories that explain wage growth.[1] According to the *human capital theory*, the wage growth is explained by worker's productivity growth, through training or learning-by-doing (Becker, 1962). Industries which offer more training should provide a steeper wage profile according to this theory. Moreover, human capital theory predicts that firm-specific training leads to both, a steeper wage profile and lower labor mobility. Lazear (1981) proposes a second theory, the *delayed compensation theory*. He argues that firms postpone part of the payment to motivate workers to work hard in the first period. In this case, we would observe steeper profiles in those industries where worker's effort is less observable. Third, and within the *matching theory*, incomplete information on worker's productivity may explain why wages grow with tenure (Jovanovic, 1979). In this case, wage growth is purely a result of the quality of matching. All of these theories predict that workers who are offered a steeper wage profile should be less likely to leave the firm. We add an alternative theory to this controversy. Although our paper conforms with the human capital theory, since wage growth comes from an increase in worker's productivity, we propose a model where it is compatible to have a steep wage profile and a high level of labor mobility. Our results are consistent with the evidence found in Levine (1993) that establishments with high returns to tenure do not have low levels of labor turnover.

The second controversy is about the empirical relevance of firm, industry, occupation and general experience on wage growth. There is a handful of empirical studies showing that differences in returns to industry tenure exist. Neal (1995), Parent (2000) and Sullivan (2008) support the role of industry tenure on the wage scheme. They give evidence that workers receive compensation for industry-specific skills instead of firm-specific skills. According to their results worker's experience in an industry and not firm tenure matters for the wage profile. Moreover, Sullivan distinguishes the industry experience effect for different occupations and finds that it is sig-

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[1]For some examples of papers testing these theories see Altonji and Shakotko (1987), Abraham and Farber (1987), Barth (1997) and Brown (1989).

nificant for managers (23% wage increase after five years of experience in an industry) and for professionals (14.3% of wage growth after five years in the industry), while it is much lower for other occupations. Using German data Dustmann and Meghir (2005) find that returns to industry tenure are 1% per year for skilled workers and zero for the unskilled. They also find, however, that general experience pays substantially more to skilled workers, while firm tenure provides high returns to unskilled workers. Allen (2001) gives evidence that wage growth varies across industries. This is the only paper we are aware of that explicitly allows for differences in wage growth across industries. One of his results is that R&D-intensive industries have steeper wage profiles than industries with little R&D activity. Our model is consistent with this result and proposes some other industry characteristics that should be taken into account when studying wage growth.

The rest of the paper is organized as follows. The next section introduces the model of an industry with labor mobility and knowledge diffusion. Section 3 describes the symmetric equilibrium. In section 4 results are presented, first the solution for the case of zero mobility costs and then the comparative static analysis with positive mobility costs. In section 5 we briefly discuss the main limitations of the model. In section 6 we conclude the paper.

2   The model

Consider an industry with F_t firms each period. They are identical in everything except that each firm has a different type of knowledge. All types of knowledge are useful only within the industry (industry-specific). We assume segmented labor markets in the sense that there is a fixed supply of labor per industry.[2]

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. 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 the 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 at period t, $j \neq i$. As already stated above, they have embodied knowledge type j. We call them poached workers. Similarly,

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[2]As we argue in the end of section 3, this assumption, although it may seem very restrictive, does not affect our results.

let η_{it} be the amount of own experienced workers hired by the same firm i at period t, which have knowledge type i. We call them retained workers.

The production function of each firm is $Y_{it} = H_{it}^{\alpha}(B_t L_{it})^{(1-\alpha)}$ where H_{it} is a measure of effective units of human 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.

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

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.[3]

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.).[4] When one or several of these factors diminish the potential of learning-by-hiring, the parameter p will be low, and vice versa.

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 learned his knowledge), while the *level of knowledge* is indicated by the particular value of A_{it}. In general the level of knowledge may be different across firms. Variety of knowledge is ensured by assuming that each firm has a different type of knowledge.

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[3]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. $p \in [0,1]$.

[4]There is empirical evidence that shows how differences in legal systems influence 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 clauses not-to-compete have weak enforceability in that state. 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).

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, we have different types of human capital.[5] 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. Instead, 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, $0 < \sigma < 1$.[6] The output is given by:

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

We assume decreasing returns to each input $(0 < \alpha < 1)$. The parameter B_t converts raw quantities of unexperienced labor into efficiency units. We assume it is the same for all firms, which means that all young workers have the same level of education when entering the industry. Notice that even though the production function has constant returns to scale, the number of firms 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 firm productivity is increasing with the variety of knowledge. The interpretation is that exchange of knowledge matters for productivity. 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 in order to isolate the exchange of knowledge effect in 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 the 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 of young workers and ω_{it}

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[5]Funke and Strulik (2000) and Sorensen (1999) use the Romer model to develop an endogenous growth model with human capital accumulation.

[6]Note that the production function evaluated at $\sigma = 0$ is not well-defined and the Cobb-Douglas function cannot be derived.

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 the *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 the 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 ($j \neq i$) and the amount of young workers to hire L_{it}.

The problem of the firm is to maximize the discounted sum of future profits. In our specification each period is independent from each other. In particular we assume that the technological parameters A_{it} and B_t are exogenous and do not depend on firm decisions. Moreover, we assume that firms do not take into account how their decision on how many young workers to hire today will affect the amount of their type of experienced workers in the next period. The firm cannot write long-term contracts to make sure that the workers will not leave the firm in the next period. Therefore, the firm cannot forecast how many of the young workers today will remain working in the firm tomorrow. Then the firm's problem can be expressed as a period by period maximization.[7]

Given the competitive wages w_t^i, ω_{jt} and ω_{it}^j such that $\omega_{it}^j \geq \omega_{jt} + m$ and $\omega_{it} \geq w_t^i$, the problem of the firm is the following:

$$\max\nolimits_{\eta_{it}, \lambda_{it}^j, L_{it}, K_{it}} ((\eta_{it} A_{it})^\sigma + p \sum\nolimits_{j \neq i} (\lambda_{it}^j A_{jt})^\sigma)^{\frac{\alpha}{\sigma}} (B_t L_{it})^{1-\alpha} - $$
$$- w_t^i L_{it} - \omega_{it} \eta_{it} - \sum\nolimits_{j \neq i} \omega_{it}^j \lambda_{it}^j.$$

The first order conditions for this problem are:

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

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

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

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[7]See section 5 for further discussion on this issue.

Equations (3), (4) and (5) equalize marginal productivity to the marginal cost of retained workers, poached workers and young workers, respectively. Notice that we already introduce the equilibrium result on wages, $\omega_{it}^j = \omega_{jt} + m$. 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 poach workers from all the other firms in the industry to access the whole range of knowledge.[8] Moreover, firms always want to retain some of their own workers because the marginal productivity of retained workers when the industry retains zero workers is infinite (see equation 3).[9]

Since individual labor supply is inelastic, individuals only care about maximizing their life-time income, which depends on which firm they start working. In equilibrium it must happen that all workers within an industry have the same life-time income in present value, where β is the consumer discount rate.

$$w_{it} + \frac{\omega_{i,t+1}}{1+\beta} = w_{jt} + \frac{\omega_{j,t+1}}{1+\beta}, \quad \forall i \neq j. \tag{6}$$

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 disposable income reduces to ω_{it}. Thus, equation (6) refers to both stayers and movers.

Next we present the market clearing conditions for the labor market. Equation (7) refers to the market for young workers and equation (8) to the experienced workers' market.

$$\sum_{i=1}^{F} L_{it} = N_t, \tag{7}$$

$$\sum_{j \neq i} \lambda_{jt}^i + \eta_{it} = L_{i,t-1} \; \forall i = 1, ...F, \tag{8}$$

In the left-hand side of equations (7) and (8) 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. Equations (3) to (8) determine the equilibrium of this economy.

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[8]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.

[9]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 larger 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

In a symmetric equilibrium all levels of knowledge are the same across firms, although the type of knowledge keeps being different for each firm. In such a case $A_{it} = A_t \ \forall i$. We also assume that there is no population growth neither technological growth (N_t, F_t, B_t and A_t are constant overtime). Thus, hereinafter we suppress the time subscripts.

In a symmetric equilibrium 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 ($L_i = \frac{N}{F} \ \forall i$). Moreover, also due to symmetry, wages are the same for all types of experienced worker.

Definition 1 *The symmetric equilibrium is characterized by the vector of variables (η, λ, L) and the prices (w,ω) that solve the following system of equations:*

$$\alpha \eta^{\sigma-1} A^\alpha (BL)^{1-\alpha} (\eta^\sigma + p(F-1)\lambda^\sigma)^{\frac{\alpha}{\sigma}-1} = \omega, \qquad (9)$$

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

$$(1-\alpha)(\eta^\sigma + p(F-1)\lambda^\sigma)^{\frac{\alpha}{\sigma}} A^\alpha B^{1-\alpha} L^{-\alpha} = w, \qquad (11)$$

$$L = \frac{N}{F}, \qquad (12)$$

$$(F-1)\lambda + \eta = L. \qquad (13)$$

Equations (9) to (11) come from the firm's problem and equations (12) and (13) are the labor market clearing conditions. Note that equation (6) becomes an identity in a symmetric equilibrium. We prove in the appendix that the symmetric equilibrium for this economy exists. Moreover, we show that under some conditions it is unique.

In the symmetric case we can rewrite the firm production function as:

$$Y = \left(\frac{A}{B}\right)^\alpha B \left(\left(\frac{\eta}{L_E}\right)^\sigma + p(F-1)\left(\frac{\lambda}{L_E}\right)^\sigma\right)^{\frac{\alpha}{\sigma}} L_E^\alpha L^{1-\alpha}, \qquad (14)$$

where L_E is the total amount of experienced workers in the firm. We obtain a standard Cobb-Douglass production function with two inputs: experienced labor (L_E) and young labor (L). The non-standard result is that the total factor productivity (TFP) is composed of three elements: the learning-by-doing, the technological level and the labor composition within the firm. $(\frac{A}{B})^\alpha$ denotes the *learning-by-doing* component of the TFP, B denotes the *technological level* and finally $((\frac{\eta}{L_E})^\sigma + p(F-1)(\frac{\lambda}{L_E})^\sigma)^{\frac{\alpha}{\sigma}}$ describes the effect of the *firm composition of experienced labor* on the TFP. Notice that when

$\frac{A}{B} > 1$ there is learning-by-doing in the industry. Moreover, when A and B grow in the same proportion, then the learning-by-doing component is not affected and the technological level increases.

We refer to the industry-specific experience premium as the real wage growth a worker experiences in his life. Using equations (9) and (11) we obtain that

$$\frac{\omega}{w} = \frac{\alpha L}{(1-\alpha)\eta \left(1 + p(F-1)\left(\frac{\lambda}{\eta}\right)^{\sigma}\right)}. \tag{15}$$

The previous equation reveals that all the parameters of the model affect the industry experience premium through changes in the composition of the labor force within the firm.

Let us explain at this point why extending the model to more than one industry would not affect our results on wage premium. Basically, the introduction of several industries would endogenize the supply of young workers per industry. In equilibrium the discounted sum of wages (which should also include the cost of acquiring the required education level of the industry) must be the same in each industry. This condition determines the supply of young workers per industry. Notice also that the supply of young workers determine the supply of experienced workers next period. Since the firm production function has constant returns to scale, the marginal productivity of each input is homogeneous of degree zero on both inputs. Moreover, we know that under perfect competition wages equal the value of the marginal productivity of the worker. Notice that by computing the experience premium of an industry we eliminate the price component. Therefore, although the level of wages within an industry will be affected by the general equilibrium forces, the results on experience premium within an industry remain unaffected. This result can also be seen on the expression above. The experience premium is homogeneous of degree zero in young and experienced workers.

4 Results

Next, we 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 experience premia. We first solve analytically for the case of zero mobility costs. Then we simulate the model with positive mobility costs and pursue a comparative static analysis on the symmetric equilibrium.

4.1   The case of zero mobility costs

It is useful to obtain the solution of the model for the case of zero mobility costs ($m = 0$). In such a case, it is possible to obtain an explicit solution for the equilibrium. Using equations (9), (10), (12) and (13) we derive an expression for λ, η and $\frac{\lambda}{\eta}$.

$$\lambda = \frac{p^{\frac{1}{1-\sigma}} N/F}{1 + (F-1)p^{\frac{1}{1-\sigma}}}, \tag{16}$$

$$\eta = \frac{N/F}{1 + (F-1)p^{\frac{1}{1-\sigma}}}, \tag{17}$$

$$\frac{\lambda}{\eta} = p^{\frac{1}{1-\sigma}}. \tag{18}$$

We can observe that in absence of mobility costs labor mobility only depends on the ability of learning-by-hiring (p), the substitutability between different types of workers (σ) and the size of the industry (N and F). Notice that technological variables (A and B) do not affect labor mobility in this case. Labor mobility is increasing with the learning-by-hiring and decreasing with the elasticity of substitution and the variety of knowledge. Obviously, with positive mobility costs, the rate of poached workers over retained workers is always lower than the value obtained in this section.

It can be proved that in the case of zero mobility costs, the equilibrium amount of labor mobility coincides with the amount of labor mobility that maximizes the human capital measure (H). In contrast, with positive mobility costs, the equilibrium labor mobility is below this level, so the human capital measure could be increased by increasing labor mobility. It would not be efficient, however, since larger labor mobility would also increase the total mobility costs.

To obtain the industry experience premium in the case of zero mobility costs, we take equation (15) and substitute η and λ by their equilibrium value (equations (16) and (17)).

$$\frac{\omega}{w} = \frac{\alpha}{1-\alpha}. \tag{19}$$

In the equilibrium with zero mobility costs the experience premium only depends on the input share of experienced and young workers. Positive mobility costs are therefore essential to have an impact of labor mobility on wage growth.

4.2 The comparative static analysis with mobility costs

When mobility costs are positive it is not possible to solve explicitly for the equilibrium. We resort to simulation exercises to examine the factors that determine experience premium in our model. We provide a formal proof of the results for the case $\alpha > \sigma$ in the appendix.[10]

For the simulation we take standard values of the basic parameters. We assume each period has 25 years. We need $\alpha > 0.5$ in order to have positive returns to experience (see equation 19), therefore we take the value $\alpha = 0.6$. Since there is no previous literature for σ, we take an arbitrary value for the baseline parametrization, 0.5, which corresponds to an elasticity of substitution among different types of experienced workers of 2. We give arbitrary numbers to the rest of the parameters in order to have interior solutions: $A = 100$, $B = 1$, $p = 0.4$, $m = 2$, $N = 100$ and $F = 10$. Under this specification mobility costs represent around 11.5% of the total wage of the poached worker ($\omega + m$). Results are robust to changes in the parametrization baseline.[11]

Figures 1 and 2 show the relationships between the parameters of the model and the two main variables: labor mobility and experience premium. As expected, all the parameters that affect positively the productivity of poached workers induce larger labor mobility. The learning-by-doing, the technological level, the variety of knowledge and the learning-by-hiring are in this group. In contrast, mobility costs and the elasticity of substitution have a negative relationship with labor mobility.

Insert here figure 1.

More surprising are the results on industry experience premium. The dashed lines in figure 2 correspond to the experience premium in absence of mobility costs. The first thing to be noticed is that the experience premium with positive mobility costs is lower than the experience premium with no mobility costs. The intuition behind is that larger mobility costs reduce the total demand for experienced workers, and thus the experience premium.

Insert here figure 2.

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[10]We obtain the same qualitative results in all simulations, regardless of having $\alpha > \sigma$ or $\alpha < \sigma$. However, the analytical proof for the latter case is weaker since it requires additional assumptions. It is available upon request.

[11]Simulation was run for several values of the parameters with no major changes in the qualitative results. Check appendix B2 for more details. Particular attention was given to check robustness in two cases: when $\alpha > \sigma$ and $\alpha < \sigma$. Values for α and σ ranged from 0.6 to 0.8 and from 0.3 to 0.8, respectively.

While the learning-by-doing, the technological level and the mobility costs have a monotonic relationship with the experience premium, the other parameters under study reveal a non-monotonic relationship. We observe that experience premium presents a U-shape relationship with the variety of knowledge, the learning-by-hiring and the elasticity of substitution between different types of workers.

Equation (15) reveals that most of the effects of the parameters on experience premium go through the amount of retained workers (η) and the relative amount of labor mobility ($\frac{\lambda}{\eta}$). Both channels are a measure of the mobility of workers in the industry, which is the main determinant of the industry experience premium. An increase in the mobility of workers has two effects on the firm: a larger productivity level[12] and a larger bill for mobility costs. This creates a trade-off on the net productivity of experienced workers. Results on experience premium depend on which of these two effects dominates.

To analyze the effect of mobility costs on experience premium recall that an increase in mobility costs reduces the amount of labor mobility. This in turn provokes a decrease in the human capital measure of the firm and an ambiguous effect on the total mobility costs bill. It turns out that the former effect dominates and the industry experience premium is decreasing in mobility costs.[13]

The learning-by-doing and the technological level, both affect positively labor mobility. This means that an increase in these parameters translates into larger productivity (larger H) and a larger bill of mobility costs. We observe, however, that the former force dominates.[14] Hence, the experience premium is increasing with the learning-by-doing and the technological level. The result that experience premium is increasing with the learning-by-doing is consistent with the human capital theory, which relates wages to productivity. With regard to our parameter on the technological level, Connolly and Gottschalk (2006) show that wage growth is more important for more-educated workers. This is consistent with our result that experience premium is increasing with B if we interpret B as the education level of young workers.

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[12]Recall that with positive mobility costs the optimal amount of labor mobility is below the one that maximizes human capital (H). Thus, increasing the equilibrium level of labor mobility always increases H.

[13]Actually, if we allow mobility costs to get to huge levels (above 20-50% of total wage ($\omega + m$)), we would observe a U-shape relationship between mobility costs and experience premium. In such a case, assumption 3 in the appendix B2 does not hold. We consider that such cost levels are unreasonable since one period is 25 years, so we do not report them in our results.

[14]In rare occasions we found that too low values of technological level and learning-by-doing reverse the results.

In contrast to the previous results, we obtain a non-monotonous relationship when we analyze the variety of knowledge, the learning-by-hiring and the elasticity of substitution among different types of experienced workers. An increase in learning-by-hiring (p) affects positively the amount of labor mobility. This implies an increase in the effective measure of human capital and a larger mobility costs bill. For low levels of learning-by-hiring the latter force dominates and experience premium is decreasing in p. However, as learning-by-hiring becomes more important, the productivity gain of the increased labor mobility compensates for the increase in mobility costs and then experience premium is increasing in p.

Similarly, the intuition for a U-shape relationship between variety of knowledge and experience premium can be understood by analyzing this trade-off between productivity and mobility costs. Recall that we find that variety of knowledge increases labor mobility. We obtain that for low values of F, increasing this parameter raises mobility costs more than productivity. However, as F is large enough, any increase in mobility costs is more than compensated by the increase in productivity. This explains the U-shape relationship between experience premium and variety of knowledge.

A similar intuition is behind the effect of the elasticity of substitution among different types of experienced workers. As different types of workers become more substitutable, there is a reduction in labor mobility in equilibrium and consequently there is a loss in productivity and a decrease in total mobility costs. When complementarieties are very strong, the former effect is larger, thus experience premium decreases. However, when the degree of substitutability of workers becomes sufficiently large, the loss in productivity is more than compensated by the decrease in mobility costs. As a result, the elasticity of substitution has a U-shape relationship with the experience premium.

5 Discussion

Let us briefly discuss in this section the two main shortcomings of the model.[15] First of all, we assume that all knowledge is industry-specific. This strong assumption ensures that no worker will find it worthwhile to change industry. Therefore, we do not allow for inter-industry labor mobility in our model. This assumption allows us to analyze in a partial analysis (one industry only) the relationship between labor mobility and experience premium. We acknowledge that this constitutes an important limitation of the model. A more complete analysis should include both, general and industry-specific

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[15]I thank an anonimous referee for pointing out them to me.

knowledge, what would give rise to possibly different combinations of inter- and intra-industry labor mobility. Our results on experience premium should therefore be seen as partial equilibrium results.[16]

Secondly, we set up the problem of the firm to be a static one. For that, we assume that firms cannot write long-term contracts to prevent workers from leaving the firm in the next period. Moreover, firms do not take into account that their hiring decision in period t determines the supply of experienced workers in period $t + 1$. However, being each firm the only provider of each type of experienced workers, a dynamic maximization problem of the firm would be more realistic. When choosing today how many young workers to hire, firms are determining how many experience workers they can hire tomorrow. In a dynamic setting firms would take this into account. Moreover, in a model where labor mobility implies at the same time knowledge diffusion, a dynamic setting would introduce a second dimension to the problem. Firms may want to control the diffusion of knowledge by affecting the supply of experienced workers and deciding to retain them. We believe this would be especially important in the case of imperfect product market competition, where prevention of knowledge diffusion could become an entry barrier and/or a new mechanism of market competition. Actually, there are several papers dealing with this issue in a two-period model with two firms (Combes and Duranton, 2006; Fosfuri et al., 2001; Fosfuri and Ronde, 2004; Gersbach and Schmutzler, 2003). Although we gain simplicity by setting a static problem for the firm, the drawback is that we cannot explain any strategic behavior of the firm.

6   Conclusion

Why do some industries give larger returns to industry experience than others? We propose a model where labor mobility across firms affects wage growth in an industry. The determinants of labor mobility within an industry explain then the differences in experience premium across industries. We find that experience premium is decreasing in mobility costs, while increasing in the learning-by-doing and the technological level of the industry. Interestingly, wage growth presents a U-shape relationship with the learning-by-hiring, the substitutability between different types of workers and the variety

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[16]In a general equilibrium framework, when a worker decides to change industry, the loss of productivity (wage) due to unusable industry-specific knowledge must be compensated by a greater productivity of his/her general knowledge in the new industry. Depending on how industry-specific and general knowledge enter in the production function we should obtain different patterns of inter-industry labor mobility.

of knowledge in the industry.

Additionally to the results on industry experience premium, in the symmetric equilibrium we obtain an extended TFP specification. Our extended TFP adds two variables to the traditional technological level of the firm. On the one hand, the learning-by-doing capability that a firm offers to their workers affects the TFP. On the other hand, the firm composition of experienced labor also determines firms' TFP. This result suggests that labor mobility may partially explain the differences in TFP across countries.

A Proof of the existence and uniqueness of the symmetric equilibrium.

We first rewrite equations (9)-(13) by introducing one new variable: $x = \frac{\lambda}{\eta}$.

$$\alpha A^\alpha B^{1-\alpha} \left(\frac{\eta}{L}\right)^{\alpha-1} (1 + p(F-1)x^\sigma)^{\frac{\alpha}{\sigma}-1} = \omega, \tag{20}$$

$$p\alpha A^\alpha B^{1-\alpha} x^{\sigma-1} \left(\frac{\eta}{L}\right)^{\alpha-1} (1 + p(F-1)x^\sigma)^{\frac{\alpha}{\sigma}-1} = \omega + m, \tag{21}$$

$$(1-\alpha) A^\alpha B^{1-\alpha} \left(\frac{\eta}{L}\right)^\alpha (1 + p(F-1)x^\sigma)^{\frac{\alpha}{\sigma}} = w, \tag{22}$$

$$L = \frac{N}{F}, \tag{23}$$

$$(F-1)x + 1 = \frac{L}{\eta}. \tag{24}$$

Using equations (20) and (21) we equalize ω, and substitute η/L using equation (24). Then we obtain one equation depending only on x, which can be written as:

$$px^{\sigma-1} = 1 + \frac{m(1 + p(F-1)x^\sigma)^{\frac{\sigma-\alpha}{\sigma}}}{\alpha A^\alpha B^{1-\alpha}(1 + (F-1)x)^{1-\alpha}}. \tag{25}$$

Next, we show that such equation has a solution, so the symmetric equilibrium exists. Let us denote any solution of equation (25) by x^*. Recall that we know from solving the model with zero mobility costs that if the equilibrium exists, x^* must be smaller than $p^{\frac{1}{1-\sigma}}$, and given that $p \in [0, 1]$ and $\sigma < 1$, we know that $x^* \in [0, 1]$. Thus, we focus on this region to find the equilibrium.

Since the functions are continuous, to prove that the equilibrium exists it is enough to show that in equation (25) $LHS(x = 0) > RHS(x = 0)$ and $LHS(x = 1) < RHS(x = 1)$. This means that they must cross at least once, so the equilibrium exists. At $x = 0$ the LHS has a vertical asymptote and the RHS is finite. At $x = 1$ the $LHS = p < 1$ and it is trivial to check that the RHS is larger than 1. Therefore, the equilibrium exists.

Next, we prove uniqueness of equilibrium. The LHS of equation (25) is always positive, decreasing in x and convex.

$$\frac{\partial LHS}{\partial x} = p(\sigma - 1)x^{\sigma-2} < 0.$$

$$\frac{\partial^2 LHS}{\partial x^2} = p(1-\sigma)(2-\sigma)x^{\sigma-3} > 0.$$

Moreover, it is straight forward to check that the limit of the LHS when x goes to zero is infinity and the limit of the LHS when x goes to infinity is zero.

The RHS of equation (25) is always positive and the first derivative is the following:

$$\frac{\partial RHS}{\partial x} = -\frac{(F-1)m(1+(F-1)px^{\sigma})^{-\frac{\alpha}{\sigma}}\Psi(x)}{A^{\alpha}B^{1-\alpha}\alpha x(1+(F-1)x)^{2-\alpha}},$$

where

$$\Psi(x) = px^{\sigma}(\alpha - \sigma + (F-1)(1-\sigma)x) + x(1-\alpha).$$

The slope of the RHS depends on the sign of $\Psi(x)$. Notice that $\Psi(x)$ is always positive when $\alpha \geq \sigma$. On the other hand, when $\alpha < \sigma$, it is easy to check that $\Psi(x)$ is negative for all $x < \overline{x}$ and positive for $x > \overline{x}$, where $\overline{x}$ is the solution to $\Psi(\overline{x}) = 0$.

Assumption 1 $\Psi(x^*) = px^{*\sigma}(\alpha - \sigma + (F-1)(1-\sigma)x^*) + x^*(1-\alpha) > 0$ *for all x^* that solve equation (25).*

Under assumption 1 the RHS is decreasing in equilibrium. Moreover, the LHS is steeper than the RHS in the first equilibrium. For both functions to cross a second time it must happen that the RHS is now steeper than the LHS. Hence, if the equilibrium is to be unique it can not happen that the $\left|\frac{\partial RHS}{\partial x}\right| > \left|\frac{\partial LHS}{\partial x}\right|$ at any x^* that solves equation (25). Assumption 2 guarantees that $\left|\frac{\partial RHS}{\partial x}\right| < \left|\frac{\partial LHS}{\partial x}\right|$ at all x^*. Thus, when assumption 2 holds, the symmetric equilibrium is unique.

Assumption 2 $\Psi(x^*) < \frac{A^{\alpha}B^{1-\alpha}\alpha(1-\sigma)(1+(F-1)x^*)^{2-\alpha}px^{*\sigma-1}}{(F-1)m(1+(F-1)px^{*\sigma})^{-\frac{\alpha}{\sigma}}}$ *for all x^* that solve equation (25).*

To sum up, we proved that the equilibrium always exists. When $\alpha > \sigma$, we need assumption 2 to prove that the equilibrium is unique. When $\alpha < \sigma$, we need assumptions 1 and 2 to prove uniqueness of equilibrium. These assumptions were satisfied for all the simulation exercises performed.

B   Comparative analysis with mobility costs. Analytical proofs for the case $\alpha > \sigma$.

In this section we provide the analytical proofs of the results of the comparative analysis in the case of $\alpha > \sigma$ and positive mobility costs. We study how parameter changes affects labor mobility and experience premium in equilibrium. Some of the results require some assumptions to hold.

B.1   Results on labor mobility

We rewrite equation (25) to have $G = LHS - RHS = 0$ and differentiate with respect to the parameter. The sign of this derivative indicates how the parameter affects x^*.

Let Δ be the following expression:

$$\Delta = \frac{(1 + (F - 1)px^\sigma)^{\frac{-\alpha}{\sigma}}}{A^\alpha B^{1-\alpha}(1 + (F - 1)x)^{1-\alpha}}.$$

Notice that given the restrictions assumed on the parameters of the model Δ is always positive.

Variation of p

$$\frac{\partial G}{\partial p} = x^{\sigma-1} + \frac{x^\sigma(F - 1)m(\alpha - \sigma)}{\alpha\sigma}\Delta.$$

Since we consider the case of $\alpha > \sigma$, it is trivial to check that this derivative is positive. This implies that learning-by-hiring affects positively the labor mobility in equilibrium.

Variation of m

$$\frac{\partial G}{\partial m} = -\frac{1}{\alpha}(1 + (F - 1)px^\sigma)\Delta < 0.$$

This derivative is negative, so an increase in mobility costs always results in a decrease in labor mobility.

Variation of A

$$\frac{\partial G}{\partial A} = \frac{m(1 + (F - 1)px^\sigma)}{A}\Delta > 0.$$

This derivative is positive, so an increase in the learning-by-doing always results in larger labor mobility in equilibrium.

Variation of B

$$\frac{\partial G}{\partial B} = \frac{(1-\alpha)m(1+(F-1)px^\sigma)}{\alpha B}\Delta > 0.$$

This derivative is positive, so an increase in the technological level always results in larger labor mobility in equilibrium.

Variation of F

$$\frac{\partial G}{\partial F} = -\frac{m(px^\sigma(\sigma - \alpha(1+(F-1)(1-\sigma)x) - (1-\alpha)\sigma x)}{\alpha\sigma(1+(F-1)x)}\Delta.$$

Since $\alpha > \sigma$, it is trivial to check that this derivative is positive. Notice additionally that the effect on total mobility $(F\lambda)$ is also positive.

Variation of σ

$$\frac{\partial G}{\partial \sigma} = px^{\sigma-1}Log[x] + \frac{m(1+(F-1)px^\sigma)}{\alpha\sigma^2}\Delta*$$
$$* ((F-1)p\sigma(\alpha-\sigma)x^\sigma Log[x] - \alpha(1+(F-1)px^\sigma)Log[1+(F-1)px^\sigma]).$$

Notice that since in equilibrium $0 < x^* < 1$, then $Log[x^*] < 0$ and $Log[1+(F-1)px^{*\sigma}] > 0$. Then, it is easy to check that since $\alpha > \sigma$ the derivative has a negative sign. This means that the more substitutable are the different types of experienced workers, the less labor mobility there will be in equilibrium.

B.2   Results on experience premium

From equations (20) and (22) we obtain:

$$\frac{\omega}{w} = \frac{\alpha(1+(F-1)x)}{(1-\alpha)(1+p(F-1)x^\sigma)}. \tag{26}$$

We use this expression together with the results on labor mobility to check how the experience premium depends on each parameter.

Let us define $\Gamma = 1 - px^{\sigma-1}(\sigma - (F-1)(1-\sigma)x)$. Hereinafter we assume that Γ is positive in equilibrium.

Assumption 3 $\Gamma = 1 - px^{*\sigma-1}(\sigma - (F-1)(1-\sigma)x^*) > 0$ *for all x^* that solve equation (25).*

This assumption is always satisfied except for really low levels of labor mobility. During the simulation exercises, violation of assumption 3 occurred only in the following cases:

- with large mobility costs. They must represent above 20% of the total wage of a poached worker $(\omega + m)$ in order to change the results. Since each period represents 25 year span, we do not consider this violation of assumption 3 problematic.

- with strong substitutability between types of experienced workers. Although Γ becomes slightly negative for cases with strong substitutability between types of experienced workers, all results on experience premium hold.

- with small technological parameters (A and B). In rare cases, too small values of A and B violate assumption 3 and then the relationship between these parameters and wage premium becomes negative.

Variation of p

$$\frac{\partial \frac{\omega}{w}}{\partial p} = \frac{\alpha(F-1)(\frac{\partial x}{\partial p}\Gamma - (1 + (F-1)x)x^\sigma)}{(1-\alpha)(1 + p(F-1)x^\sigma)^2}.$$

We showed in appendix B.1 that $\frac{\partial x}{\partial p}$ is positive. Then the effect of learning-by-hiring on experience premium is ambiguous. When $\frac{\partial x}{\partial p}\Gamma > (1 + (F-1)x)x^\sigma$, then the learning-by-hiring affects positively the equilibrium experience premium. Otherwise, the effect is negative.

Variation of m

$$\frac{\partial \frac{\omega}{w}}{\partial m} = \frac{\alpha(F-1)\Gamma}{(1-\alpha)(1 + (F-1)px^\sigma)^2}\frac{\partial x}{\partial m} < 0.$$

This derivative is negative. Therefore, experience premium is decreasing in mobility costs.

Variation of A

$$\frac{\partial \frac{\omega}{w}}{\partial A} = \frac{\alpha(F-1)\Gamma}{(1-\alpha)(1 + (F-1)px^\sigma)^2}\frac{\partial x}{\partial A} > 0.$$

We obtain a positive impact of learning-by-doing on experience premium.

Variation of B

$$\frac{\partial \frac{\omega}{w}}{\partial B} = \frac{\alpha(F-1)\Gamma}{(1-\alpha)(1 + (F-1)px^\sigma)^2}\frac{\partial x}{\partial B} > 0.$$

We obtain a positive impact of technological level on experience premium.

Variation of F

$$\frac{\partial \frac{\omega}{w}}{\partial F} = \frac{\alpha[(F-1)\frac{\partial x}{\partial F}\Gamma - x(px^{\sigma-1}-1)]}{(1-\alpha)(1+p(F-1)x^\sigma)^2}.$$

We showed in appendix B.1 that $\frac{\partial x}{\partial F} > 0$. Then the effect of F on experience premium is ambiguous. Notice that the first term in the numerator is positive. Recall that in equilibrium $x < p^{\frac{1}{1-\sigma}}$. Then the last term in the numerator is negative. For low levels of F the negative effect dominates and variety of knowledge affects negatively the equilibrium experience premium, while for high levels of F the total effect of variety of knowledge on experience premium is positive.

Variation of σ

$$\frac{\partial \frac{\omega}{w}}{\partial \sigma} = \frac{\alpha(F-1)(\frac{\partial x}{\partial \sigma}\Gamma - px^\sigma(1+(F-1)x)Log[x])}{(1-\alpha)(1+p(F-1)x^\sigma)^2}.$$

We showed in appendix B.1 that $\frac{\partial x}{\partial \sigma} < 0$. Then the sign of this derivative is ambiguous. If $|px^\sigma(1+(F-1)x)Log[x]| > \left|\frac{\partial x}{\partial \sigma}\Gamma\right|$, the elasticity of substitution affects positively the equilibrium experience premium. Otherwise the effect is negative.

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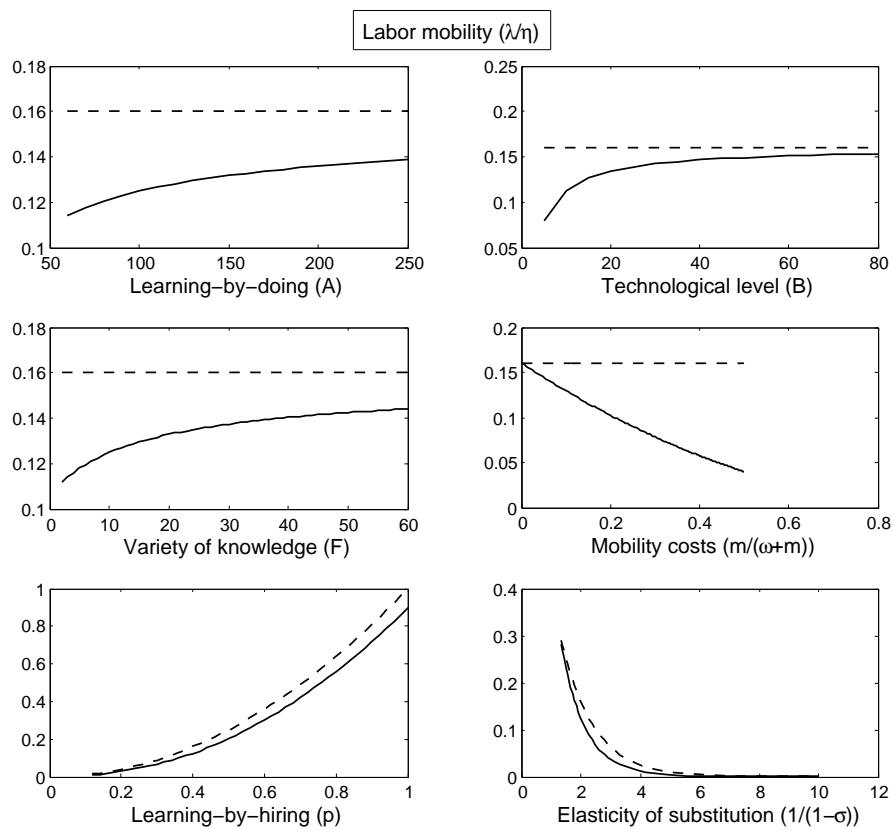
Figure 1: $\frac{\lambda}{\eta}$ as a function of the industry characteristics. Simulation results. Dashed lines show the equilibrium with zero mobility costs.
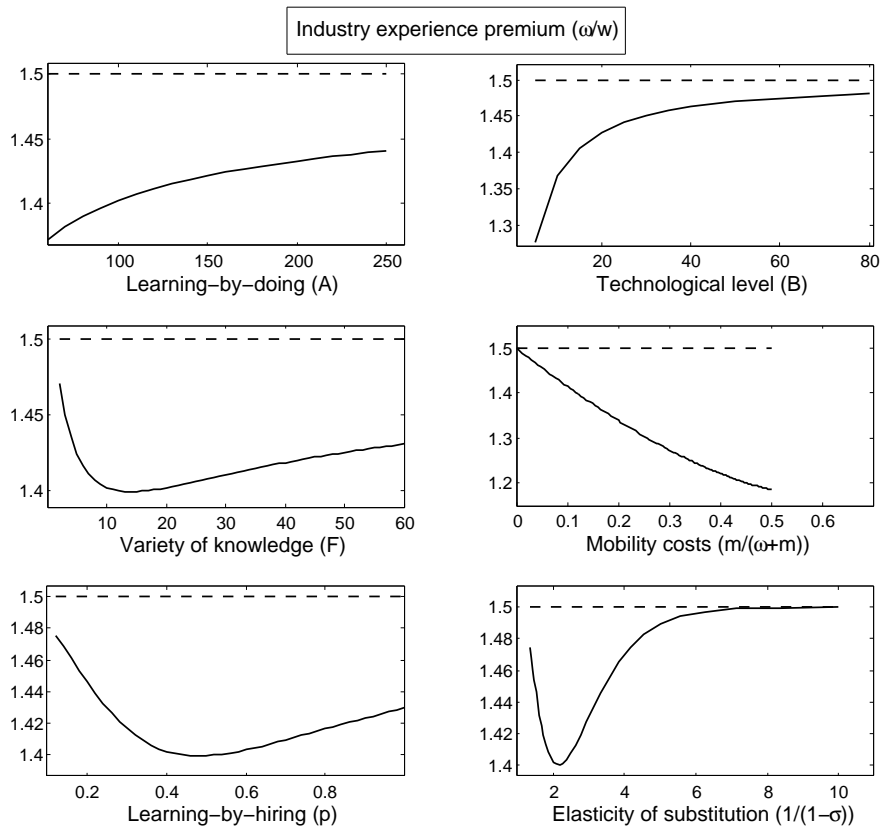
Figure 2: Experience premium $\left(\frac{\omega}{w}\right)$ as a function of the industry characteristics. Simulation results. Dashed lines show the equilibrium with zero mobility costs.