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The Sources of Wage Variation: An Analysis Using Matched Employer-Employee Data

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Abstract
This paper estimates a wage equation that includes worker- and firm fixed effects simultaneously, using a longitudinal matched employer-employee dataset covering virtually all Portuguese employees over a little more than two-decades. The exercise is performed under optimal conditions by using (a) data covering the whole population of employees and (b) adequate econometric methods and algorithms. The variation in log real hourly wages is then decomposed into six different components related to worker and firm characteristics (either observed or unobserved) and a residual component. It is found that worker heterogeneity is the most important source of wage variation (46.2 percent), due in roughly equal parts to the unobserved component (24.2 percent) and the observed component (22 percent). Firm effects are less important overall (29.6%), although firms' observed characteristics do play an important role (14.8) in explaining wage differentials.

JEL Classification: J2, J41
Keywords: worker fixed effects, firm fixed effects, decomposition of wage variability, high-dimension matrices, wage policies, firm performance, labor force quality

I. Introduction

An important research theme in labor economics is why similar workers receive different remuneration and why similar firms pay different wages. There are two major approaches to explaining observed wage variability, one of which relies on the supply-side determinants of wages (viz. workers' characteristics) and the other on demand-side factors (their employers' characteristics). Empirically, the strength of each explanation can only be assessed if the characteristics of firms and workers, both observed and unobserved, are simultaneously accommodated in wage equation estimates.

However, the requirements of any such decomposition exercise are daunting; specifically, the availability of longitudinal datasets combining information on firms and their employees (namely, matched employer-employee datasets with unique identifiers for firms and workers) *and* the use of appropriate panel data econometric techniques to estimate two fixed effects – worker- and firm fixed effects – in wage equations. If either element is missing, it is impossible correctly to disentangle the effects of employers' decisions from the effects of choices made by workers in the explanation of wage variability. Fortunately, panel datasets have become available in recent years for many countries, while econometric tools (and computing capacity) have also improved greatly. Taken in conjunction, all these ingredients – data, econometric techniques, and computing facilities – have made it possible to bring new information to bear in the empirical debate on (many aspects of) wage determinants. In particular, in their pioneering work using a French longitudinal matched employer-employee dataset, Abowd, Kramarz, and Margolis (1999) were the first to propose an empirical framework for estimating worker and firm effects in wage equations. They reported that worker characteristics explained the major part of wage differentials, of inter-industry wage differentials, and of firm-size wage differentials.

In the present treatment, we use a longitudinal matched employer-employee dataset covering virtually all employees in Portugal. Our dataset contains a total of a little over 27 million observations, 1986-2006, drawn from 600,000 firms and 5.5 million workers. In estimating a wage equation that includes worker and firm effects, we use a routine that was especially developed in STATA providing an exact solution to the least squares problem that arises when dealing with very high dimension matrices. To our knowledge, this exercise is performed for the first time under optimal conditions; to repeat, universal coverage of the employed population and the use of adequate econometric tools.

The plan of the paper is as follows. By way of motivation for worker and firm fixed effects, respectively, some basic theoretical justifications for supply-side and demand-side determinants are first sketched in Section II. The general empirical framework necessary to estimate wage equations with worker and firm fixed effects is next established in Section III. A data description and barebones review of wage setting in Portugal is contained in Section IV. Wage variability is decomposed into its six components in Section V, the determinants of worker and firm fixed effects investigated, and correlations between the components of compensation addressed. Section VI assesses the relationship between firms' wage policies and their performance as well as labor force quality. Section VII concludes

II. Motivation

In a labor market operating under perfect competition, each worker should receive a wage that equals his or her marginal (revenue) product. Wage differentials should reflect differences in worker productivity and not depend on job or employer attributes (other than those affecting worker utility such as dangerous working conditions that will in normal circumstances attract a compensating differential). In turn, worker productivity has a basis in competence (whether observed or not), typically 'acquired' through investments in human capital. (Here we are abstract from unobserved intrinsic ability, and ignore related signaling models.) Workers are thus depicted as investing in their education – a process analogous to investments in physical capita – that subsequently yield a payoff in higher earnings. Earnings depend then upon absolute levels of education, where the latter will include post-school investments.

Familiarly, assessment of the overall effect of education on earnings is conducted via the estimation of Mincerian earnings functions. In general, the first wave of empirical research relied on supply-side explanations for wage differentials and used ordinary least squares estimators and cross-section data.[1] Despite the finding of positive well-determined associations between human capital variables and wages, such research was typically unable to explain more than 30 percent of the variance in wages, meaning that 70 percent was left unexplained.[2] And even the second wave of empirical research, using econometric techniques applied to panel data to deal with unobserved worker heterogeneity, still left much of the variance in wages unexplained.

There is no shortage of models seeking additional or alternative explanations for wage variability, but in each case the characteristics of firms rather than those of workers (i.e. worker competence or productivity differences) assume prime importance. Given the plethora of such treatments,[3] we choose to focus here on just two of them that pose perhaps the sharpest contrast with competitive market conditions. The first approach has a basis in rent sharing/insider-outsider considerations, while the second emphasizes labor market frictions.

Rent-sharing models predict that wages depend on employers' ability to pay. In particular, wages are predicted to have a positive correlation with firm profits, since firms may find it profitable to share their gains with their workers and pay above the going rate.[4] Recall that in the competitive framework of the standard neoclassical labor market model, wages do not depend on the firms' profits; rather, workers should simply be paid the market-determined opportunity cost of their time. Closely related to the notion of rent sharing is the insider-outsider model, in which there is a conflict of interest between the firm's insiders (viz. incumbent employees whose positions are safeguarded by labor turnover costs) and outsiders comprising the unemployed or employees working in the informal, competitive sectors of the labor market (see, for example, Blanchflower, Oswald, and Garret, 1990). Such models show how the different types of labor turnover costs borne by firms grant insiders market power and how they then use it to increase their wages. Among other things, these models explain why wages depend not only on external labor market conditions but also on the conditions inside the firm – including its productivity, profits, degree of competition, turnover costs and the bargaining strength of workers – and why the wages of workers from different groups of occupations, education and seniority are higher in some firms or industries than in others. In general, this family of models predicts that the firms' decisions also have an influence on wages, providing a justification for including firm characteristics alongside worker characteristics in wage equations.

The other explanation for wage differentials among workers with similar characteristics considered here derives from the job search and matching literature and emphasizes the role of labor market frictions in wage determination. Thus, the equilibrium job search model of Burdett and Mortensen (1998) predicts that firms may have incentives to offer higher wages than their competitors in order to guarantee a low quit rate and attract a large number of workers in a market characterized by the existence of frictions – even in circumstances of homogeneous workers and firms *ex-ante*. This model predicts that wages are increasing in firm size and workers' job seniority. Modifications of the Burdett and Mortensen model either permit firm heterogeneity or allow firms to make counter-offers to those employees who are offered better-paying jobs elsewhere in conjunction with firm (and worker) heterogeneity. Thus, allowing firms to differ in productivity, van den Berg and Ridder (1998) and Bontemps, Robin, and van den Berg (1999, 2000) show how the more productive firms offer higher wages. And in a model in which firms follow different wage policies and internal wage differentiation, Postel-Vinay and Robin (2002) demonstrate that allowing firms to make counter-offers wage to forestall turnover yields a predicted wage distribution that is close to that observed in practice. But in each case, firm characteristics assume critical importance.

For their part, matching models that also take into account the existence of frictions in the labor market provide an explanation for wage dispersion. In the models of Diamond (1982), Mortensen (1986), Pissarides (1985, 2000), and Mortensen and Pissarides (1994) the wage paid is set by the employer, but workers and firms bargain the share of the matching rent after they meet (*ex-post*). Differences in match productivity, then, explain why similar workers (firms) may receive (pay) different wages.[5]

In short, theoretical explanations for wage differentials have been posited not only on supply-side or worker characteristics but also on demand-side or firm characteristics. The bottom-line challenge is to include both in wage regressions, the task of the present treatment.

III. The General Empirical Framework to Measure Wage Differentials

The methodology applied in this paper parallels that initially developed by Abowd and Kramarz (1999) and Abowd, Kramarz, and Margolis (1999), who presented a statistical framework permitting worker and firm fixed effects to be estimated simultaneously in wage regressions. However, as noted earlier, and as elaborated upon below, we shall use a different algorithm to obtain an exact solution for the estimation problem.

The linear wage equation to be estimated has the form:

$$\ln w_{ijt} = X_{ijt}\beta + \theta_i + \varphi_j + \varepsilon_{ijt}, \qquad (1)$$

known in the statistical literature as a "two-factor analysis of covariance." In this equation, $\ln w_{ijt}$ is the natural logarithm of the real hourly wage of individual i ($i = 1,...,N$) working at firm j ($j = 1,...,J$) at date t ($t = 1,...,T_i$). There are T_i observations for each individual i and a total of N^* observations. X_{ijt} is a vector of k observed (measured) time-varying exogenous characteristics of individual i. θ_i is the person or worker fixed effect (capturing unobserved individual heterogeneity), and φ_j is the firm fixed effect (capturing unobserved firm heterogeneity) for the firm at which worker i is employed. Wage heterogeneity is related to both permanent unmeasured differences in employees and to permanent unmeasured differences in firms. According to this equation, there are four components that explain the wage variability:

1. the observed time-varying characteristics of workers ($X_{ijt}\beta$);
2. the workers' heterogeneity or worker fixed effects (θ_i);
3. the firms' heterogeneity or firm fixed effects (φ_j); and,
4. a residual component (ε_{ijt}) that we assume to follow the standard assumptions.

In matrix notation, the stacked system has the form:

$$\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{D}\boldsymbol{\theta} + \mathbf{F}\varphi + \boldsymbol{\varepsilon}. \qquad (2)$$

In this equation $\mathbf{Y}$ is a $(N^* \times 1)$ vector of real hourly wage (in logs), $\mathbf{X}$ is a $(N^* \times k)$ matrix with k observed time-varying characteristics of individuals, $\mathbf{D}$ is a $(N^* \times N)$ design matrix for the person effects, $\mathbf{F}$ is a $(N^* \times J)$ design matrix for the firm effects, $\boldsymbol{\theta}$ is a $(N \times 1)$ vector of person effects, φ is a $(J \times 1)$ vector of firm effects and $\boldsymbol{\varepsilon}$ is a $(N^* \times 1)$ vector of disturbances (we assume that mobility is exogenous, in order to make the design matrices orthogonal to the disturbances vector). All vectors/matrices ($\mathbf{Y}$, $\mathbf{X}$, $\mathbf{D}$, and $\mathbf{F}$) have row dimensionality equal to the total number of observations (N^*).

Equations (1) and (2) can be interpreted as the conditional expectation of real hourly wage given the observable characteristics of workers, the date of observation, and the identity of both individuals and employing firms. Thus, the total number of parameters to be estimated is $k + N + J$. However, it will not be possible to identify all firm and worker fixed effects. Abowd, Kramarz, and Margolis (1999) show that in order to identify the firm and worker fixed effects one needs to impose *G* restrictions on the parameters, where *G* is the number of "mobility groups," that is, the number of groups of connected firms and individuals.

The full least squares solution to estimate the parameters in (1) solves the following set of normal equations:

$$\begin{bmatrix} \mathbf{X'X} & \mathbf{X'D} & \mathbf{X'F} \\ \mathbf{D'X} & \mathbf{D'D} & \mathbf{D'F} \\ \mathbf{F'X} & \mathbf{F'D} & \mathbf{F'F} \end{bmatrix} \begin{bmatrix} \boldsymbol{\beta} \\ \boldsymbol{\theta} \\ \varphi \end{bmatrix} = \begin{bmatrix} \mathbf{X'Y} \\ \mathbf{D'Y} \\ \mathbf{F'Y} \end{bmatrix} \tag{3}$$

Application of the conventional least squares formula to estimate all parameters (worker fixed effects, firm fixed effects, and the coefficients of all observed time-varying worker characteristics) requires the inversion of a high dimension matrix. This is impossible to achieve using standard software and present-day computers. Accordingly, special algorithms are required to estimate the full model parameters.

Abowd and Kramarz (1999) and Abowd, Kramarz, and Margolis (1999) proposed an approximate statistical solution that corresponds to using conditional estimation methods (based on a conditioning effects matrix, *Z*) providing estimators that are as similar as possible to full least squares, but computationally tractable. More recently, Abowd, Creecy, and Kramarz (2003) have developed an algorithm that permits an exact solution of the least squares estimation of equations such as (1). The user-written command *a2reg* is the Stata implementation of this algorithm.

However, using this command to estimate our wage equation (3.1) with close to 27 million observations, 22 explanatory variables, and two high-dimensional fixed effects (c. 567,000 firms and 5.5 million workers) failed due to memory limitations (even in a computer with 8 Gigabytes of RAM and running *Stata* MP for Windows). We therefore followed an alternative methodology that was able to provide estimates for the regression coefficients and for both fixed effects. This procedure was developed by Guimarães and Portugal (2010) for the estimation of linear regression models with two high-dimensional fixed effects. In brief, this methodology is based on a partitioned algorithm strategy, follows an iterative procedure, and provides an exact solution to the least squares problem. While computationally intensive given its iterative nature, this approach nevertheless imposes minimum memory requirements. A detailed description of this methodology and how it can be implemented to estimate equation (1) is remitted to the Appendix. The publicly available user-written command *reg2hdfe* is a *Stata* implementation of the approach.

IV. The Data and the Institutional Wage Setting

Data

The Portuguese data used in this inquiry come from a longitudinal matched employer-employee dataset known as the Tables of Personnel (or *Quadros de Pessoal*) for the years 1986 to 2006 (excepting 1990 and 2001). This unique dataset was created by the Portuguese Ministry of Employment and is taken from a mandatory survey annual survey addressed to firms with wage earners. The survey covers various firm and establishment characteristics, as well as a set of characteristics of the workforce (see below). Being compulsory, it does not suffer from the non-response problems that often plague standard household and firm surveys. Further, as noted earlier, the survey covers almost all Portuguese employees, outside of Public Administration and domestic servants. Apart from the advantage of its comprehensive coverage, it is also generally recognized that dataset is reliable by virtue of its public availability.

Turning to specifics, the dataset includes information on the establishment (establishment identifier, location, industry, and employment), the firm (firm identifier, location, industry, legal form, ownership, year of formation, employment, sales, and capital), and its worker (social security identifier, gender, age, education, skills, occupation, employment status, professional level, seniority, earnings {base wage, seniority-related earnings, other regular and irregular benefits, and overtime pay}, normal and overtime hours, time elapsed since last promotion, and classification in the collective bargaining agreement).

For the purposes of this exercise, a subset of variables was selected, certain new variables created, and some observations removed. The final set of variables retained for analysis is given in Table A.1. Among the restrictions placed on the data were the excision of those individuals who were not working full time, who were aged less than 18 years and more than 60 years, who earned a nominal wage less than 80 percent of the legal minimum wage or above the 99.9 percent quantile in each year; and who recorded errors in admission/birth dates, duplicate social security codes or other errors in their social security codes.[6] The final dataset for the entire period (all 19 available years) comprises 26,960,952 observations drawn from 567,739 different firms and 5,492,332 individual workers. Descriptive statistics for the continuous (categorical) variables are provided in Table**s** A.2, A.3 and A4.

Institutional Setting

Over our sample period, the wage bargaining system in Portugal is conventionally characterized as having displayed a high degree of centralization and a moderate degree of coordination (OECD, 1997). Insofar as wages are concerned, the greater centralization that occurred since the mid-1980s via the agency of social pacts has involved indicative wage guidelines for the national average wage increase. Although these shape the ensuing collective bargaining, the latter still reflects the backdrop of decentralized employers' and workers' organization within their confederate bodies.

That said, collective bargaining in Portugal mainly takes place at sectoral level. Voluntary and mandatory extensions are commonplace. The former occur when one side subscribes to an agreement to which was not a party (and gains the approval of the other side), or more typically when employers extend the coverage of an agreement they have signed with a particular union to the entire workforce. Mandatory extension by state fiat is also widespread and applies in circumstances where workers are unorganized or where bargaining for some reason fails. Note, however, that sectoral agreements may only have an occupational scope within the industry so that there is often more than one contract within a sector, reflecting occupation, region, trade union affiliations or some combinations of these alternatives.

Firms can of course negotiate their own collective agreements with either one or a number of unions or several companies can come together to bargain with the trade unions. But such formally decentralized wage bargaining is the exception rather than the rule. Such single-firm and multi-firm bargains as opposed to sectoral contracts are largely restricted to public enterprises. Note that the recent increase in multi-firm bargaining among joint stock companies is purely the result of a privatization/reorganization process occurring in such enterprises.

Sectoral bargaining in Portugal differs from that in other nations because Portuguese industrial relations are characterized by fragmentation and multiple unionism. The corollary is that contents of collective agreements at once extensive and general. They are extensive in covering a large number of categories of worker but general in setting only minimum conditions for each – in particular, mean monthly wages – while dealing with few other terms and conditions. In a bargaining framework that sets wage levels and does not cover projected wage growth, employers have a margin to adjust their wage policies to the prevailing economic conditions (see Cardoso and Portugal, 2005, for a discussion of the ramifications of this ***de facto*** decentralization).

IV. The Role of Individual and Firm Heterogeneity in Wage Differentials

In order to decompose wages variability into the six components identified earlier, we first estimated equation (1), where our explanatory variables (or observed time-varying characteristics) are firm size, age, age squared, seniority, and seniority squared. We also included 18 year dummies. The dependent variable is the natural logarithm of the real hourly wage. The results are reported in Table 1.

(Table 1 near here)

Observe that the R^2 of this equation is higher than in standard wage regressions. The worker fixed effects, firm fixed effects, and worker time-varying characteristics together explain 91.4 percent of the variability in real wages. Wages increase with age and seniority at a decreasing rate, as expected. Larger firms pay higher wages.

In this framework, the worker fixed effects (θ_i) include both the workers' unobserved and observed but non-time-varying characteristics (such as gender and education; see note 7 below). Similarly, the firm fixed effects (φ_j) include both the firms' unobserved and observed but non-time-varying characteristics (such as region, size, industry, etc.).

We next decomposed the two estimated effects (θ_i and φ_j) into their respective observed and unobserved components, by estimating the following two regression equations:

$$\hat{\theta}_i = const. + W_i\eta + \varepsilon_i \,, \qquad (4)$$

where W_i is a vector of non-time-varying worker characteristics (gender and five education dummies), η is the associated vector of coefficients, and $W_i\eta$ is the worker non-time-varying observed characteristics effect. Note that α_i, the worker-specific intercept – which captures the worker unobserved characteristics effect and can be interpreted as the opportunity cost or the market valuation of worker heterogeneity – is obtained residually by $\hat{\alpha}_i = \hat{\theta}_i - W_i\hat{\eta}$;

and,

$$\hat{\varphi}_j = const. + Z_j\lambda + \varepsilon_j, \tag{5}$$

where Z_j is a vector of non-time-varying firm characteristics (four region dummies, capital ownership {viz. share of domestic capital and share of public capital}, and 28 industry dummies), λ is the associated vector of coefficients, and $Z_i\lambda$ is the firm non-time-varying observed characteristics effect.[7] ϕ_j, the firm-specific intercept (which captures the firm unobserved characteristics effect), is obtained residually, by $\hat{\phi}_j = \hat{\varphi}_j - Z_j\hat{\lambda}$.

We have now the following compensation components (besides the residual):

- $X_{it}\hat{\beta}$: observed firm and worker time-varying characteristics.
- $\hat{\theta}_i$: worker effects (include the observed worker non-time-varying characteristics and the unobserved worker characteristics).
  - $W_i\hat{\eta}$: observed worker non-time-varying characteristics.
  - $\hat{\alpha}_i$: unobserved worker characteristics.
- $\hat{\varphi}_j$: firm effects (include the observed firm non-time-varying characteristics and the unobserved firm characteristics).
  - $Z_j\hat{\lambda}$: observed firm non-time-varying characteristics.
  - $\hat{\phi}_j$: unobserved firm characteristics.

Tables 2 and 3 report the estimation results for the worker fixed effects and the firm fixed effects regressions, respectively, while Table 4 reports descriptive statistics for the components of real compensation by gender.

(Table 2 near here)

Beginning with Table 2, we observe that the worker fixed effect for females is, on average, 17.8 percent ($=1-\exp(-0.19647)$) smaller than for men, and that there is an increasing *premium* associated with the education level: a worker who has completed the second stage of tertiary education shows a fixed effect that is, on average, more than twice (1.3 times or $1-\exp(0.84417)$) that for a worker with pre-primary or without any level of completed education (the reference category). Overall, these non-time-varying worker characteristics explain 38.4 percent of the variability in worker fixed effects.

(Table 3 near here)

Similarly, we observe that the geographic location of the firm, its capital ownership, its size (number of employees), and the industry it belongs to play important roles in explaining the differences in the firm fixed effects. Specifically, the firm fixed effects are on average larger in all NUTS II regions than in *Norte* (the reference category). Further, we observe that the firm fixed effects tend to be higher among firms with larger shares of non-domestic or non-public capital. Finally, there is also strong evidence of material differences in firm fixed effects across different industries.

(Table 4 near here)

Descriptive statistics for the components of real compensation by gender are provided in Table 4. For all the components of real compensation, the averages for males are higher than those for females (other than the predicted effect of individual time-varying characteristics, such as age and seniority). The gender differences are greater for the worker fixed effects component than for the firm fixed effects component (18.8 percent and 5.7 percent, respectively). Within each of these two components, gender differences are greater for the observed sub-components: 18.8 percent for the gender and education sub-component of worker fixed effects component; and 4 percent for the firm sub-component of firm fixed effects related to the observed characteristics (viz. region, ownership as measured by share of domestic and of public capital, and industry). And in general, the variability of worker fixed effects is greater than the variability of firm fixed effects. Male workers exhibit higher variability in all wage components (except for the education and gender sub-component of worker fixed effects).

In Table 5, we report the correlations among the components of real hourly wages. Of the three main components – time-varying characteristics, worker fixed effects, and firm fixed effects – the worker fixed effects component shows the highest correlation with log of real total compensation (0.76), followed by the firm fixed effects component (0.67), and by the individual and firm time-varying characteristics component (0.48). Considering the components within the firm fixed effects, the observable part of the firm fixed effects is the most highly correlated with log of real total compensation (0.54). The unobserved part of the firm component is less important in determining total compensation. Both observed and unobserved components of worker fixed effects are highly correlated with the log of real total compensation (0.58 and 0.51, respectively). Therefore, the observable part of each component is more highly correlated with the log of real total compensation than the unobservable part.

(Table 5 near here)

For comparison purposes, abstracting from differences in estimation method and explanatory variables included in regressions (1) and (2), we note that Abowd, Kramarz, and Margolis (1999) found that the unobserved part of the worker fixed effect was that component most highly correlated with the log of real total compensation (0.80 or 0.73, depending on the method), and that the firm components (either observed or unobserved) were much less important (0.21 or 0.26, depending on the estimation method).

We also find that the correlation between the firms' wage policies (as proxied by the firm fixed effects) and the quality of their workforce (captured by the worker fixed effects) is positive but not very large (0.27). However, it is much larger than that found in the literature. For example, using the 'persons first' method, Abowd, Kramarz, and Margolis (1999), report a correlation of 0.11 (see also the lower estimates of Goux and Maurin, 1999, using Cab or Force Survey (LFS) data).

The correlations in Table 5 also suggest an interpretation in terms of sorting. The matching and assignment literature includes models that predict complementarity between worker and firm levels of productivity, suggesting that good workers tend to be found in good firms.[8] Our results are partly consistent with this literature (see |Barth and Olsen, 2003). In terms of the *observable* characteristics, there is some evidence of positive assortative matching between workers and firms, the correlation coefficient between the corresponding components being 0.32. By the same token, we do not find any evidence of assortative matching in terms of the unobservable characteristics (the correlation is -0.04).[9]

On the whole, these results indicate that the relationship between firms' wage policies and the quality of the workers they select is positive but weak and that there are certainly factors other than wage policies that explain the distribution of high-ability workers across firms.

Finally, to measure the contribution of worker and firms characteristics, both observed and unobserved, to wage variability, we used the following equation:

$$ln\, w_{it} = X_{it}\beta + \alpha_i + W_i\eta + \phi_j + Z_j\lambda + \varepsilon_{it} = \sum_{p=1}^{6} C_{it}^{p} , \qquad (6)$$

where C_{it}^{p} is the p[th] component ($p = 1,...,6$) that contributes to explaining wage variability. The contribution of each component, C_{it}^{p} , is calculated by:

$$Cov(ln\, w_{it}, C_{it}^{p}) / Var(ln\, w_{it}), \qquad (7)$$

where $\sum_{p=1}^{6} Cov(ln\, w_{it}, C_{it}^{p}) / Var(ln\, w_{it}) = 1$.

The largest contribution to wage variability comes from worker fixed effects (46.2 percent), followed next by firm fixed effects (29.2 percent), and then by the firm and individual time-varying characteristics component (16.0 percent). There is therefore a residual contribution of 8.6 percent. Among the worker fixed effects, both subcomponents make a similar contribution (24.2 percent from the unobserved worker characteristics and 22.0 percent from the gender and education component). Among the firm fixed effects, the observed subcomponent contributes more (14.8 percent) than the unobserved subcomponent (14.4 percent).

V. The Relationship between Firms' Wage Policies, Labor Force Quality, and Performance

In this section, we seek to determine if the compensation policies followed by firms are related to their performance. As firms differ not only in the wage policies they follow, but also in the average quality of their labor force, we also attempt to ascertain whether employing high-wage workers has any relation with firm performance.

To these ends, we estimated an equation in which the dependent variable is the log of sales per employee – a measure of productivity that gives some indication of firm performance – and where the explanatory variables are the averages, across firms, of the wage components estimated in the previous section, namely firms' compensation policy components ($\hat{\phi}_j$ and $Z_j\hat{\gamma}$) and firms' labor force quality components, $\overline{(X_{it}\hat{\beta})}_j$, $\overline{(\hat{\alpha}_i)}_j$, and $\overline{(W_{it}\hat{\eta})}_j$. The results of this exercise are shown in Table 6.

(Table 6 near here)

It would appear that productivity is positively affected by all compensation policy components, principally by the worker observed characteristics component (gender and education), by the worker unobserved characteristics component, and by the firm observed characteristics component (region, capital ownership, size, and industry). Accordingly, high-wage workers (those with above-average worker fixed effects) tend to work in firms with higher productivity, as predicted by the rent-sharing model, inter al., and high-wage firms (those with above-average firm fixed effects) tend to be the most productive ones.

Following a similar procedure for France, Abowd, Kramarz, and Margolis (1999) have concluded that the major impact on firms' productivity stems from the time-varying observed characteristics of their workers, followed next by the unobserved component of the worker fixed effects, and then by the firm fixed effects (again selecting the results from the "persons first" method).

VI. Conclusion

In this exercise we have used a large longitudinal matched employer-employee dataset with close to 27 million observations to estimate a wage equation with both worker and firm fixed effects. Our approach was motivated by supply-side and demand-side arguments taken from alternative wage determination models and it sought at a theoretical level to overcome major empirical frailties that arise when estimating wage equations using data limited on at least one dimension – either firm/worker characteristics or the longitudinal dimension.

We deployed an econometric technique that provides an exact solution to the least squares estimation problem arising when estimating simultaneously worker and firm fixed effects in wage equations with high-dimension datasets. We decomposed the log of real hourly wages into several components: observed worker time-varying characteristics, worker heterogeneity (to include observed non-time-varying characteristics and unobserved characteristics), firms heterogeneity (again both observed and unobserved), and a residual component. We reported that worker heterogeneity is the most important source of wages variability in Portugal (contributing 46.2 percent) due in roughly equal parts to the unobserved component (24.2 percent) and to observed non-time-varying characteristics such as gender and education (22.0 percent). On the whole, firm effects were found to be less important (contributing 29.2 percent), although observed characteristics such as location, capital ownership, and industry play an important role in explaining wage differentials (14.8 percent).

We also reported that firms hiring 'high-wage' workers and paying higher wages ('high-wage' firms) tend to be more productive firms. On the other hand, the the connection between the firms' compensation policies and the quality of their workforces, in contrast with previous evidence, was shown to be positive.

These results suggest that both worker characteristics (observed or unobserved, and which correspond to the wage component that is transferable from job to job) and firm characteristics (observed or unobserved, which reflect the systematic differences in wages paid to similar individuals) each play important roles in explaining wage differentials in Portugal. The latter result provides some impetus for theories that rely on the firm-side determinants of wages.

Endnotes

1. Our maintained hypothesis is that returns to firm-specific training recouped through the tenure coefficient overstate the role of such investments.

2. Mortensen (2003) refers to this degree of unexplained variability as "wage dispersion."

3. The reader is directed toward implicit contract theory, principal-agent models, and efficiency wage theories.

4. The earliest rent-sharing studies used industry data (see, for example, Dickens and Katz, 1986). Firm studies constituted the next phase (e.g. Hildreth and Oswald, 1997; Arai, 2003). The most recent treatments have used matched employer-employee data to control for unobserved worker abilities (see, for example, Guertzgen, 2008; and, for an alternative approach, Card et al., 2009).

5. For treatments combining both approaches – equilibrium job search and matching – see Quercioli (1998), Robin and Roux (1998), and Mortensen (2000). Recent extensions include Rosholm and Svarer (2004), and Cahuc, Postel-Vinay, and Robin (2005).

6. Individuals employed outside of mainland Portugal and those in agriculture, hunting, forestry and fishing (as well as misclassified industries) were also excluded.

7. We assume that the variables included in Z are structural characteristics of firms. Their changes over time are either nonexistent or too small to be considered time-varying and to be included as explanatory variables directly in equation (1). The same reasoning applies to the education variable for workers in equation (4). Note further that the industry classification in Portugal changed in 1995. Because of this and given that the regression comprises the entire period, we constructed an aggregated common classification that comprises 29 different industries (see Table A.6).

8. The idea is developed in Becker (1973), and a literature review is provided by Sattinger (1993).

9. In their Norwegian study, Barth and Dale-Olsen (2003, Table 1) report a positive and significant correlation between the observables in the case of low-skilled workers and a negative and significant correlation between the unobservables for both low- and high-skilled workers.

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Annex: Implementing Estimation of the Parameters of the Wage Equation

Here we describe how the algorithm developed by Guimarães and Portugal (2010) can be implemented to estimate the parameters of our wage equation defined in Section III, which has the following specification:

$$\mathbf{Y} = \mathbf{X\beta} + \mathbf{D\theta} + \mathbf{F}\varphi + \boldsymbol{\varepsilon}\,. \tag{A.1}$$

As stated previously, $\mathbf{Y}$ is a $(N^{*}\times 1)$ vector of real hourly wage, $\mathbf{X}$ is a $(N^{*}\times k)$ matrix with k observed time-varying characteristics of individuals, $\mathbf{D}$ is a high-dimensional $(N^{*}\times N)$ design matrix for the worker effects, $\mathbf{F}$ is a $(N^{*}\times J)$ high-dimensional design matrix for the firm effects, and $\boldsymbol{\varepsilon}$ is a $(N^{*}\times 1)$ vector of disturbances.

Our goal is to estimate the k effects of the time-varying characteristics (vector $\boldsymbol{\beta}$), as well as the N worker fixed effects (vector $\boldsymbol{\theta}$) and the J firm fixed effects (vector φ).

The one high-dimension fixed effect case

As a starting point, consider equation (A.1) without firm fixed effects:

$$\mathbf{Y} = \mathbf{X\beta} + \mathbf{D\theta} + \boldsymbol{\varepsilon}\,. \tag{A.2}$$

The normal equations can be written as:

$$\begin{bmatrix} \mathbf{X'X} & \mathbf{X'D} \\ \mathbf{D'X} & \mathbf{D'D} \end{bmatrix} \begin{bmatrix} \boldsymbol{\beta} \\ \boldsymbol{\theta} \end{bmatrix} = \begin{bmatrix} \mathbf{X'Y} \\ \mathbf{D'X} \end{bmatrix}, \tag{A.3}$$

which can be arranged into:

$$\begin{bmatrix} \mathbf{X'X\beta} + \mathbf{X'D\theta} = \mathbf{X'Y} \\ \mathbf{D'X\beta} + \mathbf{D'D\theta} = \mathbf{D'Y} \end{bmatrix}. \tag{A.4}$$

Solving each set of equations independently leads to the following solutions for $\boldsymbol{\beta}$ and for $\boldsymbol{\theta}$:

$$\begin{bmatrix} \hat{\boldsymbol{\beta}} = (\mathbf{X'X})^{-1}\mathbf{X'}(\mathbf{Y} - \mathbf{D\theta}) \\ \hat{\boldsymbol{\theta}} = (\mathbf{D'D})^{-1}\mathbf{D'}(\mathbf{Y} - \mathbf{X\beta}) \end{bmatrix}. \tag{A.5}$$

This suggests an iterative estimation procedure. If $\boldsymbol{\theta}$ were known, the least squares estimates of $\boldsymbol{\beta}$ would be obtained simply by regressing the variable $\mathbf{Y} - \mathbf{D}\widehat{\boldsymbol{\theta}}$ on $\mathbf{X}$. If, in turn, $\boldsymbol{\beta}$ were known, the least squares estimates of $\boldsymbol{\theta}$ would correspond to the group means (across workers) of the elements of $\mathbf{u} = \mathbf{Y} - \mathbf{X}\widehat{\boldsymbol{\beta}}$. Therefore, the strategy for estimating $\boldsymbol{\beta}$ and $\boldsymbol{\theta}$ can be implemented in the following steps:

1) Run a regression of $\mathbf{Y}$ on $\mathbf{X}$ to obtain starting values for $\boldsymbol{\beta}$;
2) Compute the residuals $\mathbf{u}$ using the last estimate of $\boldsymbol{\beta}$;
3) Estimate $\boldsymbol{\theta}$ as the group (worker) means of $\mathbf{u}$;
4) Estimate $\boldsymbol{\beta}$ by running a regression of $\mathbf{Y}$ on $\mathbf{X}$ and an additional variable, $\mathbf{D}\boldsymbol{\theta}$, computed using the last estimates of $\boldsymbol{\theta}$; **and,**
5) Return to step 2 and iterate until convergence.

Following this approach all that is required is the estimation of successive linear regressions, by least squares, with $k+1$ explanatory variables, and the computation of group means of the elements of $\mathbf{u}$ in each iteration. We do not need to be concerned about the dimension of $\mathbf{D}$, since the transformation $\mathbf{(D'D)}^{-1}\mathbf{D'}$ used to estimate $\boldsymbol{\theta}$ corresponds to a group average and the expression $\mathbf{D}\boldsymbol{\theta}$ used to estimate β is a column vector containing all the elements of $\boldsymbol{\theta}$. With this strategy, we avoided the inversion of a large matrix that would be required if we had simply added $\mathbf{D}$ to the set of regressors.

The two high-dimension fixed effects case

Turn now to the entire equation (A.1), including both worker and firm fixed effects. In this case, solving each set of normal equations independently yields:

$$\begin{bmatrix} \hat{\boldsymbol{\beta}} = (\mathbf{X'X})^{-1}\mathbf{X'}(\mathbf{Y}-\mathbf{D}\boldsymbol{\theta}-\mathbf{F}\varphi) \\ \hat{\boldsymbol{\theta}} = (\mathbf{D'D})^{-1}\mathbf{D'}(\mathbf{Y}-\mathbf{X}\boldsymbol{\beta}-\mathbf{F}\varphi) \\ \hat{\varphi} = (\mathbf{F'F})^{-1}\mathbf{F'}(\mathbf{Y}-\mathbf{X}\boldsymbol{\beta}-\mathbf{D}\boldsymbol{\theta}) \end{bmatrix}. \qquad \text{(A.6)}$$

The partitioned algorithm can be easily extended to accommodate this case, by iterating between the estimation of $\boldsymbol{\beta}$, $\boldsymbol{\theta}$ and φ. The algorithm will converge to the least squares solution but at a slow rate of convergence.

In practice there are several steps that can be taken to speed up convergence. First, we can avoid estimation of one of the fixed effects by sweeping it out using the within transformation (fixed effects transformation). Second, we can use a standard acceleration technique by adjusting the trajectory of the estimates for the fixed effects. Finally, we can implement the regression in two steps using the Frisch-Waugh-Lovell theorem. In the first step we expurgate the two fixed effects from $\mathbf{Y}$ and $\mathbf{X}$ while in the second step we run a regression of the transformed $\mathbf{Y}$ on the transformed $\mathbf{X}$. This regression will provide the correct least squares estimates for $\boldsymbol{\beta}$ as well as the correct standard errors (whether or not clustered) as long as we correct the degrees of freedom associated with the estimate of the variance of the error term. For more details see Guimarães and Portugal (2010).

Table 1: Fitted Wage Equation with Worker and Firm Fixed Effects

	Coeficient	**t-statistic**
Age (years)	0.02635	38.80
Age squared	-0.00028	- 32.24
Seniority (years)	0.00928	23.66
Seniority squared	-0.00021	- 16.69
Size (ln employees)	0.03477	19.44
Year 1987	0.05101	81.37
Year 1988	0.06704	81.59
Year 1989	0.08361	88.29
Year 1991	0.19075	141.31
Year 1992	0.23867	146.06
Year 1993	0.24625	123.10
Year 1994	0.27142	113.93
Year 1995	0.28178	102.01
Year 1996	0.29323	96.11
Year 1997	0.34041	94.92
Year 1998	0.38492	102.24
Year 1999	0.42510	106.56
Year 2000	0.43414	103.35
Year 2002	0.44985	88.91
Year 2003	0.45249	82.61
Year 2004	0.47934	83.70
Year 2005	0.48591	85.31
Year 2006	0.48225	86.76
Observations	26.960.952	
R-squared	0.91360	

Table 2: Regression Estimates of Worker Fixed Effects on Non-Time-Varying Worker Characteristics

	Coeficient	t-statistic
Constant	-0.12966	-419.80
Female	-0.19647	-1.877.17
First stage of basic education	0.09963	317.65
Second stage of basic education	0.23714	712.96
Secondary or post-secondary education	0.34360	1.035.55
First stage of tertiary education	0.73128	1.537.64
Second stage of tertiary education	0.84417	2.210.16
Observations	26.959.500	
R-squared	0.38400	

Table 3: Regression Estimates of Fixed Effects on Firm Characteristics

	Coeficient	t-statistic
Constant	-0.39302	-156.49
Centro	0.00861	77.46
Lisboa	0.10548	1.092.68
Alentejo	0.03990	202.13
Algarve	0.08685	373.79
Share of domestic capital	-0.00023	-236.92
Share of public capital	0.00043	210.52
Industry 2	-0.33036	-129.30
Industry 3	-0.46087	-183.08
Industry 4	-0.52404	-208.54
Industry 5	-0.52659	-208.90
Industry 6	-0.50678	-200.93
Industry 7	-0.35288	-139.87
Industry 8	0.13338	49.71
Industry 9	-0.23734	-93.87
Industry 10	-0.33906	-133.17
Industry 11	-0.35489	-140.80
Industry 12	-0.44184	-175.52
Industry 13	-0.38226	-151.45
Industry 14	-0.34407	-136.16
Industry 15	-0.36173	-143.27
Industry 16	-0.56387	-222.92
Industry 17	-0.14406	-56.81
Industry 18	-0.50326	-200.20
Industry 19	-0.45728	-181.99
Industry 20	-0.59757	-237.48
Industry 21	-0.33380	-132.89
Industry 22	-0.00190	-0.76
Industry 23	-0.41258	-163.98
Industry 24	-0.33207	-127.72
Industry 25	-0.39339	-155.55
Industry 26	-0.55098	-218.75
Industry 27	-0.41722	-165.39
Industry 28	-0.64545	-243.73
Industry 29	-0.34199	-24.64
Observations	26.844.678	
R-squared	0.36960	

Note:
The legend for Industries is provided in Table A.6.

Table 4: Means and Standard Deviations of Compensation Components, by Gender

	Male		Female		Total	
	Mean	**Standard deviation**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
Log of real hourly wage (1986 prices)	0.37274	0.56410	0.14178	0.51165	0.28058	0.55541
Predicted effects of X variables (a)	1.07816	0.18522	1.07589	0.18349	1.07725	0.18453
Time	0.32302	0.14954	0.34119	0.14161	0.33027	0.14670
Time-varying observable characteristics of workers	0.59956	0.08133	0.58766	0.08218	0.59481	0.08188
Time-varying observable characteristics of firms	0.15554	0.07897	0.14704	0.07514	0.15215	0.07758
Worker fixed effects	0.06847	0.33445	-0.10352	0.31659	-0.00016	0.33810
Worker fixed effects: unobserved component	0.00000	0.27700	0.00000	0.24677	0.00000	0.26535
Worker fixed effects: observed component (b)	0.06847	0.18519	-0.10352	0.20147	-0.00016	0.20952
Firm fixed effects	-0.77436	0.24559	-0.82987	0.23310	-0.79651	0.24221
Firm fixed effects: unobserved component	0.00637	0.19567	-0.00960	0.18745	0.00000	0.19259
Firm fixed effects: observed component (c)	-0.78078	0.15009	-0.82022	0.14014	-0.79651	0.14747
Number of observations	16.202.276		10.757.224		26.959.500	

Notes:

(a): Time-varying observable characteristics of workers (age, age squared, seniority and seniority squared), time-varying observable characteristics of firms (size) and years.

(b): Gender and education.

(c): Region, ownership and industry.

Table 5: Correlations between the Compensation Components

		1	2	2.1	2.2	2.3	3	3.1	3.2	4	4.1	4.2	5
Log of real hourly wage (1986 prices)	**1**	1											
Predicted effects of X variables (a)	**2**	0.48	1										
Time	**2.1**	0.22	0.74	1									
Time-varying observable characteristics of workers	**2.2**	0.32	0.55	0.02	1								
Time-varying observable characteristics of firms	**2.3**	0.38	0.40	-0.15	0.21	1							
Worker fixed effects	**3**	0.76	0.10	-0.02	0.12	0.15	1						
Worker fixed effects: unobserved component	**3.1**	0.51	0.01	-0.07	0.18	0.11	0.78	1					
Worker fixed effects: observed component (b)	**3.2**	0.58	0.15	0.06	-0.04	0.11	0.62	0.00	1				
Firm fixed effects	**4**	0.67	0.20	-0.02	0.16	0.37	0.27	0.07	0.35	1			
Firm fixed effects: unobserved component	**4.1**	0.43	0.07	0.00	0.06	0.13	0.09	-0.04	0.20	0.79	1		
Firm fixed effects: observed component (c)	**4.2**	0.54	0.24	-0.03	0.18	0.43	0.33	0.16	0.32	0.61	0.00	1	
Residual	**5**	0.29	0.00	0.00	0.00	0.00	0.00	-0.02	0.02	0.00	0.00	0.00	1

Notes:
(a): Time-varying observable characteristics of workers (age, age squared, seniority and seniority squared), time-varying observable characteristics of firms (size) and years.
(b): Gender and education.
(c): Region, ownership and industry.

Table 6: Performance Equation Results

	Dependent variable: Log of productivity (sales per employee)	
	Coeficient	**t-statistic**
Constant	10.20949	3.145.79
Predicted effects of X variables (a)	0.31185	141.63
Time	0.66059	241.59
Time-varying observable characteristics of workers	1.52996	228.26
Time-varying observable characteristics of firms	-0.60517	-163.27
Worker fixed effects: unobserved component	1.56513	775.57
Worker fixed effects: observed component (b)	2.19575	868.52
Firm fixed effects: unobserved component	1.44622	1.050.23
Firm fixed effects: observed component (c)	1.04209	492.83
Observations	24.707.576	
R-squared	0.19	

(a): Time-varying observable characteristics of workers (age, age squared, seniority and seniority squared), time-varying observable characteristics of firms (size) and years.
(b): Gender and education.
(c): Region, ownership and industry.

Table A.1: Variables Used and their Definition/Construction

Variable	Description	
Year	Year of reference (from 1986 to 2006, except 1990 and 2001)	
Firm	Firm identification number	
Ss	Worker identification number (Social Security code)	
Workers' characteristics:		
Gender	Gender (male and female)	
Age	Age in years	
Educ	Education level (ISCED)*	No formal education or below ISCED 1
		Primary education or first stage of basic education (ISCED 1)
		Lower secondary education or second stage of basic education (ISCED 2)
		(Upper) secondary education and post-secondary non-tertiary education (ISCED 3 and 4)
		Tertiary level of education 1 (ISCED 5b)
		Tertiary level of education 2 (ISCED 5a and 6)
Tenure	Tenure or seniority (number of months since admission)	
Compensation and hours:		
w1	Base wage (Euros per month)	
w2	Seniority payments (Euros per month)	
w3	Regular benefits (Euros per month)	
w4	Irregular benefits (Euros per month)	
w5	Overtime pay (Euros per month)	
hours1	Number of normal hours per month	
hours2	Number of extra hours per month	
Hw	Hourly wage (Euros). Computed as (w1+w2+w3+w5)/(hours1+hours2)	
real_hw	Real hourly wage (Euros). Deflator: Consumer Price Index (prices of 1986)	
ln_real_hw	Logarithm of real hourly wage	
Firms' characteristics:		
employees	Number of employees in the firm	
ln_employees	Logarithm of the number of employees in the firm	
inds	Firm industry	
inds6	Firm industry (6 sectors) – common classification from 1986 to 2006	Mining and quarrying (NACE Rev.1 activities 10 to 14)
		Manufacturing (NACE Rev.1 activities 15 to 37)
		Electricity, gas, and water supply (NACE Rev.1 activities 40 to 41)
		Construction (NACE Rev.1 activities 45)
		Market services (NACE Rev.1 activities 50 to 74)
		Social services (NACE Rev.1 activities 80 to 99)

inds29	Firm industry (29 sectors) – common classification from 1986 to 2006	
region	Firm NUTS II region	Norte
		Centro
		Lisboa
		Alentejo
		Algarve
sales	Firm sales (Euros)	
real_sales	Real firm sales (Euros). Deflator: Consumer Price Index (prices of 1986)	
real_sales_employee	Real firm sales (Euros) per employee	
share_n	Firm percentage of domestic capital (0 – 100)	
share_p	Firm percentage of public capital (0 – 100)	

Note: * ISCED (International Standard Classification of Education.), 1997.

Table A.2: Means and standard deviations of continuous variables

Year	*real_hw*		*ln_real_hw*		*age*		*seniority*		*employees*		*ln_employees*		*share_n*		*share_p*		*real_*
	Euro; prices of 1986				**Years**		**Months**		**Number**				**%**				
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**
1986	1.1414	0.7204	0.0071	0.4606	35	11	113.4	95.0	1.686	4.583	5.1217	2.2447	65.9	46.1	15.4	35.1	31.9
1987	1.1935	0.7590	0.0478	0.4676	35	11	112.9	97.0	1.605	4.458	5.0666	2.2361	69.5	44.8	13.9	33.7	39.1
1988	1.1845	0.7705	0.0391	0.4685	35	11	108.6	98.6	1.502	4.351	4.9162	2.2336	69.6	44.9	12.5	32.2	39.0
1989	1.1989	0.8308	0.0411	0.4819	35	11	104.3	99.8	1.119	3.591	4.7820	2.1371	72.2	43.6	9.8	28.8	27.0
1991	1.4132	1.1025	0.1716	0.5349	35	11	101.8	103.0	1.307	4.045	4.8003	2.2117	70.7	44.3	11.3	30.9	39.0
1992	1.4897	1.2020	0.2148	0.5489	35	11	98.9	101.6	1.202	3.796	4.7138	2.1931	75.0	42.3	8.4	27.3	44.0
1993	1.5141	1.2643	0.2224	0.5595	35	11	98.6	100.7	951	2.784	4.6087	2.1621	72.9	43.3	7.6	25.9	49.4
1994	1.5584	1.3385	0.2428	0.5720	35	11	99.1	100.3	870	2.637	4.4600	2.1857	71.5	43.8	8.0	26.6	27.0
1995	1.5566	1.3193	0.2456	0.5648	35	11	100.6	101.7	845	2.573	4.4367	2.1822	73.5	42.8	5.5	22.0	35.7
1996	1.5754	1.3306	0.2588	0.5636	35	11	101.0	102.3	800	2.348	4.4278	2.1863	72.5	43.4	6.2	23.4	34.1
1997	1.5981	1.3146	0.2843	0.5462	36	11	96.5	101.1	762	2.281	4.3227	2.1822	71.3	44.1	5.2	21.4	32.2
1998	1.6922	1.3817	0.3397	0.5497	36	11	97.2	102.9	802	2.339	4.3480	2.2211	71.5	43.9	5.0	20.8	48.8
1999	1.7384	1.4277	0.3662	0.5489	36	10	96.1	102.2	777	2.290	4.2810	2.2160	71.5	44.0	4.6	20.2	36.2
2000	1.7274	1.3993	0.3655	0.5406	36	10	91.6	100.7	793	2.338	4.1969	2.2233	71.2	44.1	4.1	19.2	32.5
2002	1.7497	1.4174	0.3772	0.5430	36	10	86.8	98.0	728	2.204	4.0565	2.2293	71.9	44.0	4.0	19.0	40.1
2003	1.7574	1.4505	0.3780	0.5471	37	10	88.2	96.6	656	1.998	4.0082	2.2141	72.8	43.6	3.5	17.8	39.7
2004	1.8183	1.5302	0.4045	0.5575	37	10	90.0	96.2	626	1.873	4.0074	2.2089	73.2	43.4	3.3	17.2	36.6
2005	1.8177	1.5430	0.4029	0.5589	37	10	89.0	95.3	623	1.905	3.9701	2.2130	72.3	43.9	3.1	16.7	32.0
2006	1.8157	1.5261	0.4022	0.5593	37	10	89.7	95.3	690	2.094	4.0062	2.2400	71.7	44.1	3.5	17.7	50.8
1986-2006	1.6012	1.3356	0.2806	0.5557	36	11	96.6	99.6	902	2.834	4.3733	2.2342	71.8	43.9	6.4	23.7	37.9

Table A.3: Distribution across categories of categorical variables (%)

	1986	1987	1988	1989	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2002	2003	2004	2005	2006	1986-
gender	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Male	66.9	66.8	65.8	64.5	63.4	62.3	62.2	60.6	60.1	60.3	59.0	58.7	58.1	57.8	58.4	57.9	57.8	57.3	56.7	60.1
Female	33.1	33.2	34.2	35.5	36.6	37.7	37.8	39.4	39.9	39.7	41.0	41.3	41.9	42.2	41.6	42.1	42.2	42.7	43.3	39.9
educ	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Pre-primary or no education	7.7	7.1	6.2	5.6	4.3	4.0	3.6	2.8	2.4	2.3	2.0	1.8	1.6	1.5	1.7	1.6	1.6	1.3	1.2	2.8
First stage of basic education	71.7	71.9	72.7	71.7	68.3	67.1	66.2	64.6	64.0	62.1	61.2	58.8	57.8	55.9	50.7	48.7	46.7	44.6	42.0	58.3
Second stage of basic education	6.9	7.3	7.7	8.4	10.5	11.1	11.6	15.0	14.9	15.3	15.3	16.1	16.3	17.0	19.1	20.0	21.0	21.7	22.4	15.6
Secondary or post-secondary education	10.8	10.8	10.5	11.3	13.1	13.7	14.2	13.0	13.7	14.8	15.6	16.6	17.3	17.9	19.1	19.5	20.1	20.6	21.7	16.2
First stage of tertiary education	1.3	1.2	1.2	1.2	1.5	1.6	1.7	1.6	1.7	1.8	1.9	2.1	2.1	1.9	2.4	2.5	2.6	2.7	2.6	2.0
Second stage of tertiary education	1.6	1.6	1.7	1.8	2.3	2.6	2.8	3.1	3.3	3.6	3.9	4.6	4.9	5.7	7.0	7.6	8.1	9.1	10.2	5.0
inds6	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Mining and quarrying	0.9	0.8	0.7	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.6
Manufacturing	52.7	53.1	52.5	52.4	47.9	46.4	45.2	42.0	42.6	41.9	40.1	38.4	37.9	35.6	30.9	29.6	29.0	27.4	26.2	38.8
Electricity, gas, and water supply	1.8	1.7	1.7	0.7	1.3	1.3	1.2	1.1	1.1	1.1	1.0	1.0	0.9	0.8	0.6	0.6	0.6	0.6	0.6	1.0
Construction	7.7	7.9	8.0	8.6	8.8	8.8	9.0	9.0	9.1	9.4	9.7	9.6	9.6	10.6	12.1	11.5	11.5	11.6	11.3	9.9
Market services	31.3	31.2	31.5	31.6	34.8	35.9	36.8	38.9	40.7	41.1	41.2	42.8	42.9	43.8	45.6	46.9	47.1	46.9	47.5	41.1
Social services	5.6	5.4	5.5	5.9	6.3	6.8	7.2	8.2	5.8	5.9	7.3	7.6	8.0	8.6	10.3	10.9	11.4	13.0	13.9	8.6
size	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
< 5 employees	4.0	4.2	4.7	4.9	5.3	5.6	6.1	7.4	7.7	8.0	8.6	8.9	9.2	9.8	10.7	11.6	11.9	12.3	12.3	8.7
5-9 employees	6.3	6.4	7.1	7.4	7.5	7.8	8.3	9.4	9.6	9.7	10.3	10.4	10.7	11.2	12.5	12.7	12.6	12.6	12.3	10.2
10-49 employees	21.8	22.4	23.9	24.7	24.6	25.4	26.1	27.2	26.7	26.4	27.3	27.0	27.6	28.4	30.7	29.2	28.6	29.0	28.8	27.1
50-99 employees	10.9	11.2	11.6	11.9	12.1	12.1	12.3	12.0	12.1	11.7	12.1	11.5	11.5	11.7	10.0	10.8	10.8	10.7	10.6	11.4
100-249 employees	15.0	14.9	15.3	15.1	14.6	15.1	14.9	13.7	13.9	14.0	13.7	13.6	13.3	12.9	11.6	11.6	12.0	11.6	11.9	13.3
250-499 employees	11.0	10.5	10.1	10.7	9.9	9.7	9.4	9.1	9.1	8.5	8.2	7.9	7.7	7.4	6.8	6.8	6.9	6.8	6.7	8.3
500-999 employees	10.0	10.4	9.1	8.7	8.7	7.5	6.9	5.7	6.1	6.3	5.9	5.7	5.4	4.9	4.5	4.6	4.8	5.0	5.0	6.2
1,000-1,999 employees	6.9	6.4	5.7	6.0	4.8	5.3	4.9	5.1	5.1	4.8	3.9	4.3	4.9	4.7	4.6	4.6	4.5	4.0	4.1	4.8
2,000-4,999 employees	5.9	5.6	5.0	5.2	6.6	6.1	6.0	6.1	6.0	7.3	6.2	6.5	5.1	3.3	3.8	4.0	4.4	4.1	3.4	5.2
≥ 5,000 employees	8.2	7.9	7.6	5.3	5.9	5.4	5.1	4.3	3.8	3.2	3.8	4.3	4.6	5.6	4.9	4.1	3.6	3.9	4.8	4.9
region	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Norte	38.8	38.8	39.5	40.0	38.7	38.4	37.5	38.1	38.9	38.2	38.6	36.8	37.7	36.7	35.3	34.8	34.8	35.0	35.1	37.1
Centro	13.5	14.3	15.3	16.0	16.1	16.3	17.4	17.3	17.4	17.9	17.9	18.4	18.3	18.6	19.1	19.0	19.0	19.1	19.0	17.7
Lisboa	43.0	42.1	39.9	38.6	39.5	39.4	39.1	38.3	37.4	37.3	36.5	37.5	36.7	37.1	37.5	37.7	37.6	37.3	37.3	38.1
Alentejo	2.9	3.0	3.3	3.4	3.5	3.6	3.6	3.8	3.8	3.9	4.3	4.4	4.4	4.5	4.6	4.8	4.8	4.8	4.7	4.1
Algarve	1.8	1.8	2.0	2.1	2.3	2.3	2.4	2.6	2.5	2.7	2.8	2.9	2.9	3.1	3.5	3.8	3.8	3.9	3.9	2.9

Table A.4: Further descriptive statistics on real hourly wages (real_hw)

	1986	1987	1988	1989	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2002	2003	2004	2005	2006	1986-2006
Mean	1.1414	1.1935	1.1845	1.1989	1.4132	1.4897	1.5141	1.5584	1.5566	1.5754	1.5981	1.6922	1.7384	1.7274	1.7497	1.7574	1.8183	1.8177	1.8157	1.6012
Stdandard deviation	0.7204	0.7590	0.7705	0.8308	1.1025	1.2020	1.2643	1.3385	1.3193	1.3306	1.3146	1.3817	1.4277	1.3993	1.4174	1.4505	1.5302	1.5430	1.5261	1.3356
Variance	0.5189	0.5760	0.5937	0.6903	1.2155	1.4449	1.5985	1.7916	1.7406	1.7705	1.7282	1.9092	2.0384	1.9580	2.0089	2.1039	2.3414	2.3807	2.3289	1.7838
Coefficient of variation	0.6311	0.6359	0.6505	0.6930	0.7801	0.8069	0.8350	0.8589	0.8476	0.8446	0.8226	0.8165	0.8213	0.8101	0.8100	0.8254	0.8415	0.8488	0.8405	0.8341
Skewness	3.9	3.3	3.9	4.1	3.8	3.9	3.9	5.2	4.1	4.0	4.2	3.8	3.8	3.9	3.7	4.0	3.8	4.7	3.7	4.2
Kurtosis	53.4	28.6	41.1	38.8	28.2	30.4	27.8	120.3	34.0	32.7	38.8	29.6	29.2	29.8	25.0	30.2	25.8	148.4	24.5	51.1
Percentiles																				
1	0.5164	0.5475	0.5391	0.5401	0.5919	0.5805	0.5877	0.5960	0.6149	0.6155	0.6462	0.7040	0.7252	0.7289	0.7364	0.7329	0.7358	0.7348	0.7371	0.5925
5	0.5870	0.6065	0.5912	0.5887	0.6381	0.6522	0.6443	0.6458	0.6598	0.6626	0.7060	0.7313	0.7629	0.7575	0.7576	0.7542	0.7889	0.7844	0.7641	0.6788
10	0.6235	0.6438	0.6393	0.6333	0.6802	0.6962	0.6890	0.6938	0.7055	0.7125	0.7498	0.7910	0.8254	0.8288	0.8374	0.8297	0.8423	0.8384	0.8399	0.7358
25	0.7046	0.7326	0.7295	0.7213	0.7860	0.8141	0.8169	0.8269	0.8342	0.8472	0.8868	0.9357	0.9610	0.9649	0.9713	0.9728	0.9912	0.9846	0.9836	0.8840
50	0.9034	0.9331	0.9273	0.9296	1.0383	1.0824	1.0951	1.1096	1.1118	1.1297	1.1562	1.2058	1.2385	1.2453	1.2667	1.2648	1.2981	1.2934	1.2931	1.1619
75	1.2927	1.3561	1.3475	1.3422	1.5744	1.6560	1.6803	1.7245	1.7128	1.7352	1.7589	1.8660	1.8929	1.8852	1.9214	1.9170	1.9816	1.9739	1.9783	1.7560
90	1.9460	2.0676	2.0388	2.0743	2.6268	2.7810	2.7970	2.9481	2.9451	2.9545	2.9622	3.1732	3.2758	3.1991	3.2035	3.2356	3.3774	3.3765	3.3882	2.9549
95	2.5560	2.6992	2.6382	2.7455	3.4043	3.6363	3.7412	3.9152	3.9140	3.9651	3.9337	4.2292	4.3947	4.3393	4.3708	4.4387	4.6786	4.6931	4.6970	4.0104
99	3.9747	4.2277	4.2957	4.6106	6.0351	6.5558	6.9905	7.2697	7.1583	7.2361	7.1608	7.5327	7.7271	7.5760	7.7910	7.8670	8.3439	8.3873	8.2635	7.2615
Range ratios																				
95/5	4.3545	4.4505	4.4621	4.6641	5.3352	5.5756	5.8067	6.0629	5.9324	5.9838	5.5717	5.7828	5.7609	5.7285	5.7696	5.8851	5.9303	5.9832	6.1474	5.9079
90/10	3.1211	3.2115	3.1894	3.2751	3.8621	3.9945	4.0596	4.2492	4.1747	4.1465	3.9507	4.0117	3.9688	3.8597	3.8255	3.8996	4.0099	4.0272	4.0341	4.0159
75/25	1.8348	1.8512	1.8472	1.8608	2.0031	2.0342	2.0569	2.0855	2.0532	2.0482	1.9834	1.9943	1.9696	1.9538	1.9782	1.9705	1.9992	2.0046	2.0112	1.9865

Table A.5: Real hourly wage (real_hw) variability between firms and within firms, 1986-2006

	Mean sum of squares		B / W
	Between firms (B)	Within firms (W)	
Total	38.2165	1.0018	38.15
Workers' characteristics:			
gender			
Male	36.3965	1.2137	29.99
Female	16.1452	0.5894	27.39
educ			
Pre-primary or no education	1.5865	0.1705	9.30
First stage of basic education	7.7111	0.2791	27.63
Second stage of basic education	10.6261	0.7390	14.38
Secondary or post-secondary education	17.4963	1.2608	13.88
First stage of tertiary education	19.4688	2.6975	7.22
Second stage of tertiary education	41.6678	4.6934	8.88
Firms' characteristics:			
inds6			
Mining and quarrying	25.6579	0.7421	34.57
Manufacturing	36.7146	0.7019	52.31
Electricity, gas, and water supply	316.6787	1.5856	199.72
Construction	7.7563	0.7682	10.10
Market services	38.9309	1.2761	30.51
Social services	31.4632	1.2372	25.43
size			
< 5 employees	1.4303	0.2021	7.08
5-9 employees	4.5583	0.3251	14.02
10-49 employees	31.0635	0.6080	51.09
50-99 employees	137.1016	0.9308	147.29
100-249 employees	456.0715	1.2467	365.81
250-499 employees	995.9859	1.3978	712.52
500-999 employees	2.060.9589	1.3775	1.496.19
1,000-1,999 employees	5.437.2047	1.7777	3.058.65
2,000-4,999 employees	12.437.6790	1.7423	7.138.49
≥ 5,000 employees	35.673.6580	1.8885	18.889.65
region			
Norte	21.2746	0.6693	31.79
Centro	9.9644	0.5259	18.95
Lisboa	73.9201	1.6121	45.85
Alentejo	11.1877	0.6304	17.75
Algarve	5.5049	0.5255	10.48

Table A.6: Legend for the 29 common industries classification from 1986 to 2006

Industry	Description
Industry 1	Mining of coal and lignite; extraction of peat; extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction, excluding surveying; mining of uranium and thorium ores
Industry 2	Mining of metal ores; other mining and quarrying
Industry 3	Manufacture of food products and beverages; manufacture of tobacco products
Industry 4	Manufacture of textiles; manufacture of wearing apparel; dressing and dyeing of fur
Industry 5	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
Industry 6	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
Industry 7	Manufacture of pulp, paper and paper products; publishing printing and reproduction of recorded media
Industry 8	Manufacture of coke, refined petroleum products and nuclear fuel
Industry 9	Manufacture of chemicals and chemical products
Industry 10	Manufacture of rubber and plastic products
Industry 11	Manufacture of other non-metallic mineral products
Industry 12	Manufacture of basic metals; manufacture of fabricated metal products, except machinery and equipment
Industry 13	Manufacture of machinery and equipment n.e.c.
Industry 14	Manufacture of office machinery and computers; manufacture of electrical machinery and apparatus n.e.c.; manufacture of radio, television and communication equipment and apparatus; manufacture of medical, precision and optical instruments, watches and clocks
Industry 15	Manufacture of motor vehicles, trailers and semi-trailers; manufacture of other transport equipment
Industry 16	Manufacture of furniture; manufacturing n.e.c.; recycling
Industry 17	Electricity, gas, steam and hot water supply; collection, purification and distribution of water
Industry 18	Construction
Industry 19	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel; wholesale trade and commission trade, except of motor vehicles and motorcycles; retail trade, except of motor vehicles and motorcycles; repair of personal and household goods
Industry 20	Hotels and restaurants
Industry 21	Land transport; transport via pipelines; water transport; air transport; supporting and auxiliary transport activities; activities of travel agencies; post and telecommunications
Industry 22	Financial intermediation, except insurance and pension funding; insurance and pension funding, except compulsory social security; activities auxiliary to financial intermediation
Industry 23	Real estate activities; renting of machinery and equipment without operator and of personal and household goods; computer and related activities; research and development; other business activities
Industry 24	Public administration and defence; compulsory social security
Industry 25	Education
Industry 26	Health and social work
Industry 27	Sewage and refuse disposal, sanitation and similar activities; activities of membership organizations n.e.c.; recreational, cultural and sporting activities; other service activities
Industry 28	Private households with employed persons
Industry 29	Extra-territorial organizations and bodies

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