

# Supply and demand, allocation and wage inequality: An international comparison

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# Supply and demand, allocation and wage inequality: an international comparison

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An allocation model of workers differentiated by their field of study is developed to test whether international differences in the wage structure can be explained by differences in labour demand and supply in each country. The model explicitly takes into account the effects of supply and demand shifts on the allocation structure to disentangle country specific differences in the recruitment for one occupation from real supply–demand effects. Empirical results based on data for nine countries show that cross-country differences in wage inequality explain at least two–third of the differences in labour demand and supply.

## I. Introduction

Relative wages of skill groups in the labour market can differ substantially between countries and between years. The main question is whether such differences in the wage structure reflect differences in supply of, and demand for workers in the educational groups distinguished, or whether institutional factors like wage-setting, pay norms and minimum wage are the main cause of these differences in the wage structure. In the first case, a balanced composition of supply and demand would be a main determinant of labour productivity, while in the second case the institutional setting would be the key determinant to explain productivity differentials.

The major difficulty to investigate the effect of supply and demand on wages is that workers' skills have to be compared over time or between countries. The intertemporal and international comparison of skills is problematic, since adequate standards to measure the *level* of skills do not exist. The challenge is to separate (i) the demand and supply explanation from (ii) the classification and the content of the study explanations. To contribute to the discussion

the effect of differences in supply and demand between different *types* of skills is investigated in this paper. By comparing types of skills (measured by field of study) the inherent problems of comparing skill levels between countries are avoided.

In the paper an explicit model of occupational allocation and wage formation of skill groups is developed. Since shifts in supply and demand should affect the allocation of an educational group in each occupation, it is possible to disentangle supply and demand effects from country-specific differences in classification or the contents of a study. Disaggregation by occupation enables the detection of occupation-specific differences in the allocation that are not caused by supply–demand factors. The remaining supply–demand differential can be compared statistically with wage differentials in each country. Using data about the labour market position of graduates from nine countries, it is estimated whether differences in the wage structure can be explained by differences in supply and demand. It is found that the differences in the wage structure are consistent with a supply–demand explanation and shown that with an elasticity of 2.14, reducing wage

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differentials across countries by 100% reduces demand and supply differentials by at least 64%.

The paper is related to literature about the growing wage inequality in the USA and literature about the differences in wage dispersion between the USA and countries in continental Europe (see Freeman and Katz, 1995), especially Germany. Katz and Murphy (1992) show that the increased wage inequality between skilled and unskilled workers in the USA can be explained from a supply–demand perspective if a constant exogenous growth in demand for skilled labour is assumed. Also Bound and Johnson (1992), Juhn *et al.* (1993), Levy and Murnane (1996), Machin and Van Reenen (1998) and Acemoglu (2002) argue that the rising wage inequality in the USA results from a skill biased technical change. Autor *et al.* (1998) and Krusell *et al.* (2000) demonstrate that computer investments could explain this increased demand for skilled labour. DiNardo *et al.* (1996), Lee (1999), Card and Lemieux (2001) and Card and DiNardo (2002) claim however that changes in wages do not reflect shifts in supply and demand. They argue that institutional changes rather than skill-biased technical change have caused the US increase in wage inequality during the 1980. Especially the reduction in the real minimum wage and deunionization are regarded as main determinants of increased wage inequality.

Related to this discussion, Blau and Kahn (1996) investigate international differences in the wage inequality between skill groups. Based on years of schooling and experience they construct a measure of skill to compare supply between countries and conclude that the supply of skilled labour is positively related to the skilled–unskilled wage differential. Blau and Kahn therefore argue that the international pattern cannot be explained by supply–demand differences and thus that institutional differences have to be responsible for the high income dispersion in the USA and the UK in comparison to European countries like Germany and France. Devroye and Freeman (2001) and Freeman and Schettkat (2001) raise questions about the validity of the skill measure used by Blau and Kahn, which is based on the assumption that each year of education and each year of experience lead to the same amount of skills in each country. International comparative studies in which students or workers in different countries

take a similar test, like the Third International Mathematics and Science Study (TIMSS)<sup>1</sup> or International Adult Literacy Survey (IALS) provide direct evidence on cross-country differences in the composition of skills by educational levels. These international tests focus however on a very specific set of skills, therefore maybe neglecting other skills that might be relevant for work. Using several techniques, especially based on the results of the IALS, Freeman and Schettkat show that the actual skill level of workers in Germany, especially with respect to the least skilled workers is much higher than was accounted for by Blau and Kahn.<sup>2</sup> According to Freeman and Schettkat this less dispersed ability distribution of Germans cannot explain the distribution of their wages completely, i.e. German workers in the lower segment of the labour market still earn relative more than their US counterparts with equal ability. Leuven *et al.* (2004) use the IALS for a comparison of seven countries in which they also take into account the effects of supply and demand on the wage structure. They find, in contrast to Blau and Kahn (1996), the wage structure to be consistent with a supply demand explanation. The findings of Leuven *et al.* (2004) show that analyses of the relationship between aggregate supply and demand and wages are very sensitive for the way in which skills are classified.<sup>3</sup> Blau and Kahn (2001) indeed find that performance on cognitive tests plays a role in explaining greater US wage inequality but that higher labour market prices and residual inequality still play important roles. However, they also acknowledge that higher labour market prices in the USA could be explained by either institutions or supply and demand. The present paper contributes to this discussion in two ways. First, the model developed enables not only the *sign* but also the *magnitude* of the effects of supply and demand on the wage structure to be evaluated. Second, by taking advantage of the information contained in the occupational allocation of workers, the model used is robust for the way in which skills are classified.

The allocation model developed in this paper is furthermore related to the literature on assignment models of heterogeneous workers to heterogeneous occupations developed in Roy (1951), Tinbergen (1956), Rosen (1978), Sattinger (1979) and Macdonald (1982). In this model wages are linked to the supply

<sup>1</sup> See also Nickell and Bell (1996) and OECD (2001).

<sup>2</sup> American workers with less than 12 years of schooling score on average less than their counterparts elsewhere whereas with more than 16 years of schooling the picture is reversed.

<sup>3</sup> Devroye and Freeman (2001) show in this respect that immigrants seem to have low IALS-scores compared to their wages, due to the relative importance of language ability in such tests.

of skills and to demand generated by the technology possibilities frontier of each economy. Education and occupation are distinguished between and the allocation of workers with different educational fields to the various occupations modelled. The total labour supply by educational fields is exogenous in the model, while the allocation to occupations is assumed perfectly elastic to wage rates. The demand for workers with different educational fields in each occupation depends on the technology possibilities and is derived using a production function. The production technology is such that educational groups of workers are imperfect substitutes. The focus in this paper is therefore on educational group wage inequality. If the skills content of a study is comparable across countries, differences in supply and demand should correspond to differences in wage rates between countries. However, when differences in the content of a study are observed, the optimal allocation of workers to the various occupations would differ across countries even at equivalent wage rates and supply and demand equilibrium. The allocation specification therefore enables supply and demand effects to be disentangled from country-specific differences in the employment of a group in a certain occupation either due to differences in classification or the content of a study.

The structure of this paper is as follows. In the next section, the theoretical model is presented. Therein, a method to identify the relationship between supply and demand and wages is subsequently derived, allowing differences across countries in the allocation structure. The third section covers the sources and description of the data. In addition, measures of wage inequality for all countries in the data are presented. The fourth section contains empirical results. Some final remarks and conclusions appear in Section V.

## II. Conceptual Framework

### Production function

The economy of each country is assumed to produce one output-good denoted  $H$ . The price of this good is used as numeraire. In each occupation  $i$  an intermediate good, denoted  $H_i$  is produced with workers from different fields of study as input.

The production function with  $n_o$  occupations and  $n_e$  educational groups, takes the two-level Constant Elasticity of Substitution (CES) form (see Sato, (1967):<sup>4</sup>

$$H = \min(\delta_i H_i) \quad (1)$$

where  $\delta_i$  is a technological parameter measuring the optimal proportion of output  $i$  in output.

Assuming that the intermediate outputs are inelastic (Leontief production function at the occupational level), substitution on the goods market is impossible and all adjustments come from educational substitution within the various occupational groups. Note that allowing for substitution on the goods market is just a matter of decomposing adjustments in the demand for workers into occupational and educational substitution. It would not affect substantially the magnitude of the adjustments in labour demand.<sup>5</sup> Within each occupation, educational groups of workers are imperfect substitutes and occupational technology is defined by:

$$H_i = \left( \sum_j a_{ij} L_{ij}^\beta \right)^{1/\beta} \quad (2)$$

where  $a_{ij}$  is the productivity parameter of workers with education  $j$  in occupation  $i$  and satisfies  $a_{ij} > 0 \forall i, j$  and  $\sum_j a_{ij} = 1$ .  $\beta$  is a production technology parameter<sup>6</sup> and  $\beta \leq 1$ .  $L_{ij}$  denotes the labour input with education  $j$  in occupation  $i$ .

<sup>4</sup>For the sake of convenience, the country index is skipped, i.e.  $c$  on both the parameters and the variables of the model.

<sup>5</sup>The analysis is reproduced with the general 2-level CES production function specification. We found similar results as those presented in this paper.

<sup>6</sup>The parameter of educational substitution elasticity within a single occupation equals  $\sigma = 1/1 - \beta$ . Three noteworthy special cases are: (i)  $\sigma \rightarrow 0$  (or  $\beta \rightarrow -\infty$ ) when educational groups are used in fixed proportions within occupations (Leontief production function), (ii)  $\sigma \rightarrow \infty$  (or  $\beta \rightarrow 1$ ) when educational groups are perfect substitutes within occupations (linear production function) and (iii)  $\sigma \rightarrow 1$  (or  $\beta \rightarrow 0$ ) when the elasticity of substitution between educational groups within occupations is unity (Cobb–Douglas production function). However, since fields of study compete in more than one occupation, the Allen partial elasticities of substitution (see Allen, 1938) between educational groups of workers need not to be equal to  $\sigma$  nor to be constant between all pairs of educational groups of workers.  $\sigma$  measures the partial elasticity of substitution between two educational groups of workers *within* an occupation. The Allen partial elasticities of substitution between two educational groups of workers equal:

$$A_{jk} = \frac{\eta_{jk}}{s_k} \quad \text{with} \quad \eta_{jk} \equiv \frac{\partial \ln L_j}{\partial \ln w_k} = \sigma \sum_i s_{k,i} \frac{L_{ij}}{L_j}$$

where  $\eta_{jk}$  is the corresponding cross-wage elasticity,  $s_k$  the cost-share of educational group  $k$  in total costs,  $s_{k,i} = (a_{ik}^\sigma w_k^{1-\sigma} / \sum_l a_{il}^\sigma w_l^{1-\sigma}) = (w_k L_{ik}) / \sum_l w_l L_{il}$  the cost-share of workers with education  $k$  in occupation  $i$  and  $L_j = \sum_i L_{ij}$  the demand for workers with education  $j$ .

**Table 1. Average number of workers by education and occupation expressed in the nine countries in promile**

Occupation	Education							Total
	Arts-Hum	Soci-Scie	Business	Law	Natur-Scie	Engineer	Health	
Arts-Hum	<b>17</b>	6	9	2	2	2	1	39
Social-Sciences	15	<b>24</b>	15	2	1	2	7	66
Business	14	18	<b>60</b>	11	8	10	2	123
Legal	3	2	1	<b>36</b>	1	1	1	45
Nat. Sciences	6	5	11	2	<b>59</b>	44	7	134
Engineering	3	2	7	1	14	<b>92</b>	1	120
Health	3	2	1	1	2	5	<b>64</b>	78
Managers	19	16	<b>39</b>	5	7	17	6	109
Teaching	<b>89</b>	12	10	2	21	11	5	150
Clerks	22	17	<b>24</b>	10	3	5	3	84
Other-lower	<b>12</b>	10	11	4	4	8	3	52
Total	203	114	188	76	122	197	100	1000

Note: For each occupation, the educational group with the largest frequency is represented in bold.

The allocation is characterized by the distribution of workers by educational fields to the (various) occupational fields. The distribution of workers by education within occupation needs not to be concentrated on one educational group only. Rather, several educational fields may be fairly represented within an occupation (see for example Table 1). There is an inherent dispersion due to the heterogeneous character of occupations and its impact on the assignment of tasks to educational groups of workers. Workers who find employment in the same occupation need not to perform exactly the same mix of tasks. Since educational fields differ in their skill content, workers with different educational backgrounds differ in their ability to perform the various tasks. Therefore, the optimal assignment of tasks to educational groups of workers leads to the presence of workers with different educational backgrounds in some (if not all) occupations. The optimal assignment of tasks changes as the wage rates by educational groups change through the supply and demand adjustment process. When comparing the allocation across countries, differences in supply and demand should correspond to differences in wage rates between countries. However, when differences in the contents of a study are observed, the optimal assignment of tasks to groups of workers would differ across countries generating differences in the allocation even at equivalent wage rates and

supply and demand situations.<sup>7</sup> The difficulty to compare educational systems between countries makes it necessary to take into account such differences.

Assuming that both the labour and commodity markets are perfectly competitive, the demand for workers with different fields of study in the various occupations is derived by equating marginal products to the respective wage rates.

$$\frac{\partial H}{\partial L_{ij}} = w_j \quad (3)$$

The demand for workers with education  $j$  in occupation  $i$ , expressed in logarithmic terms, reads as:

$$\ln L_{ij} = \ln H - \ln \delta_i + \sigma \ln a_{ij} - \sigma \ln w_j + \sigma \ln PC_i \quad (4)$$

with

$$PC_i = \left( \sum_k a_{ik}^\sigma w_k^{1-\sigma} \right)^{1/1-\sigma}$$

where  $w_j$  stands for the wage of workers with education  $j$ . The function  $PC_i$  represents the shadow price of producing one extra unit of intermediate output in occupation  $i$  (the unit cost function).

From Equation 4 changes in the demand for workers with education  $j$  in occupation  $i$  can be derived as a function of changes in wages, output and productivity parameters, i.e.  $a_{ij}$ . The demand

<sup>7</sup> Furthermore, differences in the classification of education might cause observed differences in the allocation of workers.

equation in infinitesimal form equals:

$$d \ln \frac{L_{ij}}{H} = \sum_k \frac{\partial \ln L_{ij}}{\partial \ln w_k} \times d \ln w_k + \sum_k \frac{\partial \ln L_{ij}}{\partial \ln a_{ik}} \times d \ln a_{ik} \quad (5)$$

Using workers with education  $l$  in occupation  $g$  as the reference group, changes in the relative allocation of workers with different educational backgrounds and occupations read as:

$$\begin{aligned} d \ln \frac{L_{ij}}{L_{gl}} &= \sum_k \frac{\partial \ln L_{ij}/L_{gl}}{\partial \ln w_k/w_l} \times d \ln \frac{w_k}{w_l} \\ &+ \sum_k \frac{\partial \ln L_{ij}/L_{gl}}{\partial \ln a_{ik}/a_{gl}} \times d \ln \frac{a_{ik}}{a_{gl}} \\ &= -\sigma \times d \ln \frac{w_j}{w_l} + \sigma \sum_k (s_{k,i} - s_{k,g}) \\ &\times d \ln \frac{w_k}{w_l} + \sigma \times d \ln \frac{a_{ij}}{a_{gl}} + \frac{\sigma^2}{1-\sigma} \\ &\times \sum_k (s_{k,i} - s_{k,g}) \times d \ln \frac{a_{ik}}{a_{gl}} = SD + AS \end{aligned} \quad (6)$$

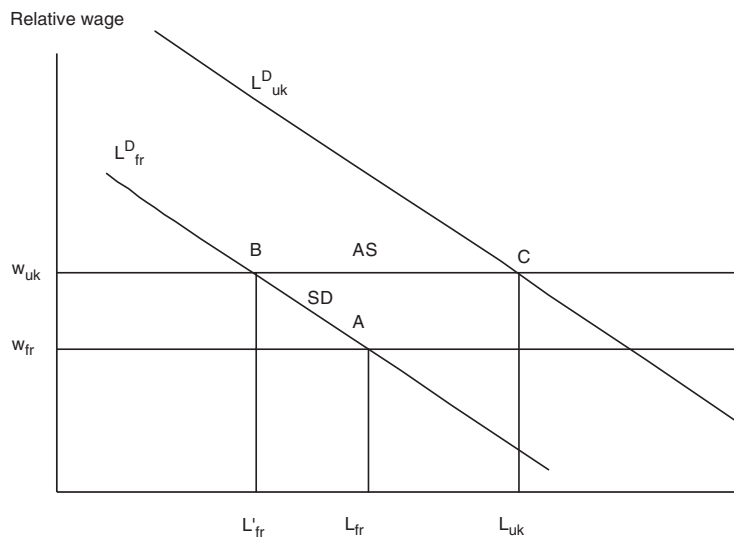
where  $s_{k,i} = a_{ik}^\sigma w_k^{1-\sigma} / \sum_l a_{il}^\sigma w_l^{1-\sigma} = w_k L_{ik} / \sum_l w_l L_{il}$  is the cost-share of workers with education  $k$  in occupation  $i$  and  $L_j = \sum_i L_{ij}$  the demand for workers with education  $j$ .

The change in the allocation of workers with education  $j$  in occupation  $i$  is decomposed into a

supply and demand effect (*denoted SD*), initiated by changes in the relative supply of the various educational segments and, allocation structure effect (*denoted AS*) characterized by differences in the production function parameters  $a_{ij}$ .

Changes in the demand for workers with the various educational backgrounds in the various occupations can be linked to (i) exogenous changes in wages, due to shifts in the composition of supply, and (ii) exogenous changes in the productivity parameters of the various types of workers.

In the context of cross-country analysis, exogenous changes in wage rates correspond to the distance between the relative wages observed in each country, and arbitrarily chosen new relative wages common to all countries. However, if the skill content of the graduates in the same field of study is not the same across countries, the relative productivity of workers in each field of study will vary across countries and so will wages. This will make it impossible to compare relative employment and wage equilibrium by educational groups of workers across countries even if the substitution process, linking differences in the relative supply of labour by fields of study with educational wage differentials, occurs freely. To illustrate the operation of the model the differences in the relative wage of engineering graduates to business graduates in France and the UK are compared. Great graphical simplification is achieved with only one occupation are considered. Therefore in the following example are considered only workers in managerial occupation. Figure 1 shows the relative



**Fig. 1.** An increase in the relative wage in France induces substitution between the two groups of workers and movements on the demand curve from point A to point B. The vector AB corresponds to the supply and demand effect (*SD*) captured in Equation 6. The relative demand in France however does not match the relative demand in the UK though the relative wages are equal. The distance between the relative demand in France and the relative demand in the UK corresponds to differences in productivity parameters. The vector BC corresponds to the allocation structure effect (*AS*) captured in Equation 6

demand for and relative supply of graduates in that particular occupation. In France, the log relative wage observed is  $-0.1$  and is accompanied by a log relative supply of  $-2.97$ . Intuitively, an increase in the relative wage rate from  $-0.1$  to  $0.08$  ( $w_{uk}$ , relative wage in the UK, is  $0.08$ ) induces substitution between both types of workers and reduces the relative demand from  $L_{fr}$  to  $L'_{fr}$  through the operation  $SD$  in Equation 6. The fact that the new equilibrium point in France, i.e. point  $B$  in Fig. 1, does not correspond with the equilibrium point in the UK ( $L'_{fr} < -2.97 < -1.03 = L_{uk}$ ), i.e. point  $C$ , implies differences in the productivity parameters between both countries. To match the UK equilibrium, the relative demand function in France has to shift from  $L_{fr}^D$  to  $L_{uk}^D$  through the operation of  $AS$  in Equation 6.

#### Isolating supply and demand from allocation structure effects

Since institutions in some countries may choose to compress wages for social cohesion purposes, relative wages observed may, in those countries, not correspond to competitive wage rates. It is therefore chosen to correct for supply and demand differences across countries *independently* from observed wage rates. This is done by equalizing labour supply and demand by educational group and occupation in the various countries. In other words, for each country, the total supply of workers in each educational segment and the total demand for workers in each occupation are set to the nine-country average. After controlling for demand and supply differences between countries, the allocation of workers with different educational backgrounds to the various occupations in each country  $c$ , say  $L_{ij,c}^t$ , satisfies thereby the following conditions:

$$\begin{cases} \sum_{i=1}^{n_o} L_{ij,c}^t = \bar{L}_{.j} \quad \forall c \\ \sum_{j=1}^{n_o} L_{ij,c}^t = \bar{L}_i \end{cases} \quad (7)$$

Equation 6 shows that changes in the allocation of workers as derived from the production function are biproportional and break down into an

occupation specific effect,  $R_{ig}$ , and an education specific effect,  $S_{jk}$ .

$$\begin{aligned} \ln \frac{L_{ij}^t}{L_{gk}^t} &= -\ln \frac{\delta_i}{\delta_g} + \sigma \ln \frac{a_{ij}}{a_{gk}} - \sigma \ln \frac{w_j^t}{w_k^t} \\ &\quad + \sigma \ln \frac{PC_i(w^t)}{PC_g(w^t)} \\ &\Leftrightarrow \\ \ln \frac{L_{ij}^t}{L_{gk}^t} - \ln \frac{L_{ij}^0}{L_{gk}^0} &= -\sigma \left( \ln \frac{w_j^t}{w_k^t} - \ln \frac{w_j^0}{w_k^0} \right) \\ &\quad + \sigma \left( \ln \frac{PC_i(w^t)}{PC_g(w^t)} - \ln \frac{PC_i(w^0)}{PC_g(w^0)} \right) \\ &\Leftrightarrow \\ \ln \frac{L_{ij}^t}{L_{gk}^t} &= \ln R_{ig} + \ln S_{jk} + \ln \frac{L_{ij}^0}{L_{gk}^0} \end{aligned} \quad (8)$$

Therefore, the new allocation of workers with education  $j$  in occupation  $i$  in each country,  $L_{ij,c}^t$ , can be derived by finding vectors  $R_g$  and  $S_k$  which satisfy the border conditions (same supply and demand vectors across countries) given the structure of allocation in country  $c$ , i.e. given the  $a_{ij,c}$  of country  $c$ .

Equation 8 is equivalent to the RAS method.<sup>8</sup> Using an iterative procedure in order to avoid approximation problems involved when inverting large matrices,<sup>9</sup> the demand and supply vectors  $R_{i,c}$  and  $S_{j,c}$  are derived for each country so that the border conditions (Equation 7) are satisfied, given the allocation observed in each country,  $L_{ij,c}^0$ .

This approach to derive changes in the allocation without taking wages explicitly into account is conceptually comparable to Tinbergen (1984). Tinbergen (1984) presents two structures related in the approach used here. The so-called Northwest-corner rule,  $t$ -method, that minimizes the *total tension* (in the case of diagonal matrix, when the demand vector equals the supply vector, i.e. 'educational equilibrium', only the main diagonal is non-empty) and, the independency solution met when the supply and demand probability distributions are independent.<sup>10</sup>

<sup>8</sup> See Stone and Brown (1964), Evans and Lindley (1973), Kadas and Klafzky (1976) and Van Eijs and Borghans (1996).

<sup>9</sup> For more details see Evans and Lindley (1973) and Van Eijs and Borghans (1996).

<sup>10</sup> Tinbergen notices that since the first solution *concentrates* all observations whereas the second solution spreads them evenly over the matrix, the actual allocation matrix may be somewhere in between. Our method minimizes the relative entropy,  $E_{L^0}(L^t) = \sum_{ij,c} L_{ij,c}^t \ln(L_{ij,c}^t/L_{ij,c}^0)$ , such that the new matrix  $\{L_{ij,c}^t\}$  satisfies the border conditions conditional on the reference matrix  $L^0$ . The relative entropy reaches a global minimum, i.e. 0, when the allocation  $L_{ij,c}^t$  is equal to the allocation  $L_{ij,c}^0$ . Therefore, this method can be seen as a minimization of *tension* given relative scarcity of certain workers' characteristics (border vectors) and initial allocation. It is comparable to Tinbergen's  $t$ -method. However, in contrast with Tinbergen, the present method uses a production function as underlying structure. Furthermore, when *educational equilibrium* is reached (supply vector equals demand vector) the resulting allocation would not necessarily lead to unimodal distribution of workers by education within each occupation and the new allocation satisfies the properties of Equation 6.

*Allocation structure*

Because the border conditions was imposed to all countries, if all countries would have the same production function, i.e. the same  $a_{ij}$ , the allocation after correction for supply and demand differences should be equal for all nine countries. Hence, the differences between the nine-country average allocation and these constructed allocation matrices provides information about the differences in the production functions across countries. The distance between the logarithm of the relative average allocation and the logarithm of the relative new allocation is used to proxy the differences in the production function parameters across countries:

$$\ln \frac{\overline{L}_{ij}}{\overline{L}_{gk}} - \ln \frac{L_{ij,c}^t}{L_{gk,c}^t} = \widehat{AS}_{ij,c} \quad (9)$$

Obviously, if one occupation only was observed, then  $\widehat{AS}$  would equal zero for all educational groups  $j$  and all countries even if the true production functions<sup>11</sup> are different across countries. In order to disentangle allocation structure differences across countries, at least two occupations are necessary. Intuitively, if one only knows that the relative employment of engineering graduates in France is twice the relative employment in the UK, one cannot conclude on whether the relative supply of engineering graduates in France is twice that of the UK or whether the engineering graduates in France are more productive in each occupation, compared to their UK counterparts. The proxy therefore only picks up differences in occupation specific productivity, assuming that the relative average productivity of workers with two different educational backgrounds is about the same in each country.

*Supply and demand*

Bearing in mind the possible differences in production function parameters between countries, observed relative wage rates to supply and demand across countries are confronted using the structural equation of the model, Equation 6. The equation relates the allocation of workers to on the one hand the supply and demand, and on the other hand the structure of allocation. If wages reflect supply and demand

they should explain allocation consistently after controlling for differences in production function. Comparing both the allocation structure and wages with the nine-country averages gives:

$$\begin{aligned} \ln \frac{\overline{L}_{ij}}{\overline{L}_{gl}} - \ln \frac{L_{ij,c}^0}{L_{gl,c}^0} &= -\sigma \left( \ln \frac{w_j^t}{w_l^t} - \ln \frac{w_{j,c}^0}{w_{l,c}^0} \right) \\ &\quad + \sigma \sum_k (s_{k,i,c} - s_{k,g,c}) \\ &\quad \times \left( \ln \frac{w_j^t}{w_l^t} - \ln \frac{w_{j,c}^0}{w_{l,c}^0} \right) + \widehat{AS}_{ij,c} \\ &= SD + \widehat{AS} \end{aligned} \quad (10)$$

*A supply and demand explanation*

The remaining question is how much of the observed differences in allocation across countries is due to observed differences in wage rates, allocation structures and other unobserved differences. To answer this question the allocation differences between countries is decomposed into three factors. To that aim three quantities are introduced.

Quantity  $A_c$  measures the distance between observed allocation and nine-country average allocation.<sup>12</sup>

$$A_c = \sum_{ij} |L_{ij,c}^0 - \overline{L}_{ij}|$$

Quantity  $B_c$  measures the distance between country-specific allocation at equalized wage rates by education and nine-country average allocation.

$$B_c = \sum_{ij} |L_{ij,c}^1 - \overline{L}_{ij}|$$

in which  $L_{ij,c}^1$  represents the allocation associated with equal wages for all educational fields for each country:

$$\begin{aligned} \ln \frac{\overline{L}_{ij}}{\overline{L}_{gl}} - \ln \frac{L_{ij,c}^1}{L_{gl,c}^1} &= -\sigma \left( \ln 1 - \ln \frac{w_{j,c}^0}{w_{l,c}^0} \right) \\ &\quad + \sigma \sum_k (s_{k,i,c} - s_{k,g,c}) \left( \ln 1 - \ln \frac{w_{j,c}^0}{w_{l,c}^0} \right) \\ &\quad + \widehat{AS}_{ij,c} \end{aligned}$$

<sup>11</sup> With one occupation, say  $i$ , even if the  $a_{ij}$  parameters are different in the various countries, imposing the border conditions,  $L_{ij,c}^t \equiv L_{j,c}^t = \overline{L}_j \equiv \overline{L}_{ij}$  implies  $\widehat{AS}_{ij,c} = \ln \overline{L}_{ij} / \overline{L}_{ik} - \ln L_{ij,c}^t / L_{ik,c}^t = 0$ .

<sup>12</sup> The unweighted absolute distances presented here may be driven by the distances observed where the allocation of workers is relatively large whereas the distances where the allocation of workers is relatively small are underestimated. Therefore absolute distances weighted by  $\overline{L}_{ij}$ , the world average allocation of workers will be computed to check the robustness of the results. The weighted absolute distances read as:  $\tilde{A}_c = \sum_{ij} |L_{ij,c}^0 - \overline{L}_{ij}| / \overline{L}_{ij}$ ,  $\tilde{B}_c = \sum_{ij} |L_{ij,c}^1 - \overline{L}_{ij}| / \overline{L}_{ij}$  and  $\tilde{C}_c = \sum_{ij} |\widehat{AS}_{ij,c}| / \overline{L}_{ij}$ .



Rearranged and taking the exponential:

$$\frac{L_{ij,c}^1}{L_{gl,c}^1} = \text{Exp} \left[ \begin{array}{c} \ln \frac{\bar{L}_{ij}}{L_{gl}} - \widehat{AS}_{ij,c} - \\ \sigma \left( \ln \frac{w_{j,c}^0}{w_{l,c}^0} - \ln 1 \right) \\ + \sigma \sum_k (s_{k,i,c} - s_{k,g,c}) \times \left( \ln \frac{w_{j,c}^0}{w_{l,c}^0} - \ln 1 \right) \end{array} \right]$$

with

$$L_c^1 = \sum_{ij} L_{ij,c}^1 = 1000$$

In 1 indicates that the new allocation matrix  $L_{ij,c}^1$  is associated to equal wage rates between educational groups of workers.

This measure of the distance between the allocation in different countries is corrected for country-specific wage-premia, that is those wages equilibrating country-specific supply and demand vectors<sup>13</sup> but includes country-specific allocation structure and unobserved country-specific effect.

Quantity  $C_c$  measures the distance between country-specific allocation given same supply and demand vectors across countries and nine-country average allocation matrix:

$$C_c = \sum_{ij} \left| \widehat{AS}_{ij} \right|$$

Therefore quantity  $C_c$  measures the distance between the allocation structure of each country with an average structure/yardstick structure.

### III. Data

The data used for empirical analysis are taken from the ‘Careers after Higher Education European Research Survey’ (CHEERS). Samples of graduates in higher education of the 1994/1995 academic year have been conducted three years after graduation (1998). The nine countries for which all necessary information were available are Italy, Spain, France, Austria, The Netherlands, The United Kingdom, Finland, Germany and Japan. The sample sizes are approximately 3500 for each country and are representative of the target population defined along field of study, the type of degree/institution, gender and the region.

<sup>13</sup> This would imply equalized supply and demand vectors across countries if and only if the allocation structures were equal across countries.

### The allocation of workers

Use is made of the information on the individuals’ educational and occupational fields provided by the International Standard Classification of Education (ISCED, 3 digits) and the International Standard Classification of Occupation (ISCO, 3 digits) respectively. These two classifications distinguish categories, with respect to both *levels* and *fields* of education and occupation. The first digit of the two codes give the educational and job *level*, respectively, while the two last digits characterize the vocational *fields*. The 3-digits ISCED and ISCO are recoded into seven educational fields and 11 occupational categories according to the classification reported in Table A1 of Appendix A. Since most of the graduates end up in higher level occupations, and ISCO makes hardly any distinction between very different occupations at the first digit level, the classification for high level jobs were refined and take together lower level jobs. Based on this classification, the number of workers per education and occupation for the nine countries considered are computed.

The average number of workers per education and occupation in the nine countries is reported in Table 1. The table shows that even though a large amount of workers are allocated to occupations for which their education is required, in each occupation the educational distribution of workers is fairly spread. The educational group with the largest frequency (Arts–Humanities field) accounts for 23% of the workers in Other-lower occupations. Health graduates account for up to 82% of the workers in Health occupations. Over all occupations, the number of workers having an education that differs from the educational field for which the largest frequency is observed adds up to about 48%. This figure indicates a fair dispersion in the distribution of workers by education within occupation.

Allocation turns out to be different between countries. To show this, the average absolute distances between the allocation of workers with different education to the various occupations of each country and the nine-country average allocation are computed and defined as:

$$\bar{A}_c = \frac{1}{7 \times 11} A_c = \frac{1}{7 \times 11} \sum_{ij} |L_{ij,c}^0 - \bar{L}_{ij}| \quad (11)$$

where  $\bar{L}_{ij}$  is the nine-country average number of workers with education  $j$  in occupation  $i$  and  $L_{ij,c}^0$  is the actual number of workers with education  $j$  in occupation  $i$  observed in country  $c$ . Both are expressed in promiles.

The absolute distances, reported in the bottom row of Table A2, indicate large differences in allocation matrices across countries. These differences may correspond with (i) cross-country differences in supply and demand situations, (ii) differences in the content of the various fields of study and/or (iii) differences across countries in the classifications of education and occupation. Though institutional factors might affect the *level* of employment, the *relative* allocation of workers with different education to the various occupations can reasonably be assumed unaffected by labour market institutional factors. The challenge is to separate (i) the demand and supply explanation from (ii) the classification and the content of the study explanations.

#### The educational wage rates by country

To derive the wage rates by educational category in each country, hourly earnings regressions are run independently for each country, including control for the effects of gender, age (quadratic form), job-tenure (quadratic form), hours weekly worked (log term), part-time, interaction of gender with age, job-tenure and part-time. Tenure is measured by means of workers' answers to the question: 'In which year did you start your current job?' It therefore refers to an occupation-related-tenure rather than a firm-tenure. Anyone earning less than 5 euros per hour or more than 150 euros per hour was excluded.

The following equation is estimated by OLS for each worker  $p$  in country  $c$ :

$$\ln W_{p,c} = \gamma_c + G'_c X_{pc} + \sum_j \alpha_{j,c} E_j + e_{p,c} \quad (12)$$

The variable  $\ln W$  is the log of hourly earnings;  $X_{pc}$  is a vector of explanatory variables including workers characteristics,<sup>14</sup>  $E_j$  are dummies for educational fields. The estimates for  $\alpha_{j,c}$  as reported in Table A2 of Appendix B, can be regarded as educational wage-premia for each country.

#### Wage inequality across countries

In several studies, wage inequality is found very different across countries with a larger wage inequality in the USA and the UK than in continental Europe and Japan.<sup>15</sup> In order to evaluate the extent to which

this stylized fact is reflected in the data on higher educated workers we compute some measures of wage inequality were computed.<sup>16</sup>

First is derived from the estimation of Equation 12 the total variance and the within and between educational categories variance in log hourly earnings. The total variance as well as the variance within and between educational categories in log hourly earnings are given by:

$$Within_c = \frac{1}{L_c} \sum_j L_{j,c} \times \sum_{p, E_j=1} (\ln W_{p,c} - \ln \widehat{W}_{p,c})^2$$

$$Between_c = \frac{1}{L_c} \sum_j L_{j,c} \times \sum_{p, E_j=1} (\ln \widehat{W}_{p,c} - \overline{\ln W}_c)^2$$

$$Total_c = \frac{1}{L_c} \sum_p (\ln W_{p,c} - \overline{\ln W}_c)^2$$

where  $L_{j,c}$  is the number of workers with education  $j$  in country  $c$ ,  $L_c$  is the number of workers in country  $c$ ,  $\ln \widehat{W}_{p,c}$  is the estimated log-earnings for workers  $p$  in country  $c$  and  $\overline{\ln W}_c$  is the average log-earnings in country  $c$ .

The analysis of wage inequality is completed by computing for each worker in each country,  $Y_{p,c}$ , the male, 40 hours per week, 30 years old, 2.8 years of tenure, etc.<sup>17</sup> ... equivalent hourly earnings using Equation 12 as follows:

$$\begin{aligned} Y_{p,c} &= \ln W_{p,c} - \gamma_c - G'_c (X_{p,c} - \overline{X}) \\ &= \sum_j \alpha_{j,c} E_j + G'_c \overline{X} + e_{p,c} \end{aligned} \quad (13)$$

For each country, the standard deviation and the 10, 50 and 90 percentiles of the corrected hourly earnings distribution are computed. The variance decomposition of the hourly earnings distribution as well as the 50–10, 90–50 and 90–10 percentiles gaps in the corrected hourly earnings distribution are reported for each country in Table 2. Whereas most studies that differentiate workers by their educational level find a significantly higher inequality in the UK, no such evidence among workers with the same educational level is found here. The total variance in hourly earnings and the variance within educational groups in the UK is of the same magnitude

<sup>14</sup> Age and its square, tenure and its square, a dummy variable for part-time work (less than 36 hours per week), gender and its interaction with age, tenure and part-time, and the log of weekly hours worked.

<sup>15</sup> See for instance Blau and Kahn (1996), Leuven *et al.* (2004), Devroye and Freeman (2001) and Freeman and Schettkat (2001).

<sup>16</sup> Notice that the measure of *between educational fields* wage inequality is part of the *within educational levels* wage inequality measured in most empirical analyses.

<sup>17</sup> The world-wide average age and tenure are 30 years of age and 2.8 years of tenure.

**Table 2. Variance decomposition of hourly earnings for each country**

	It	Sp	Fr	Au	Nl	UK	Fi	Ge	Jp
$\ln W_{p,c}$									
<i>Variance decomposition</i>									
<i>Between<sub>c</sub></i> ( $\times 10$ )	0.10	0.07	0.16	0.08	0.03	0.03	0.07	0.05	0.03
<i>Within<sub>c</sub></i>	0.14	0.16	0.11	0.12	0.05	0.12	0.08	0.10	0.08
<i>Total<sub>c</sub></i>	0.19	0.19	0.15	0.18	0.09	0.15	0.10	0.15	0.11
$Y_{p,c}$									
<i>Wage inequality</i>									
50–10	0.50	0.59	0.50	0.45	0.27	0.44	0.32	0.42	0.41
90–50	0.38	0.49	0.36	0.41	0.28	0.42	0.34	0.33	0.29
90–10	0.88	1.08	0.86	0.86	0.55	0.86	0.66	0.75	0.70
St dv	0.39	0.41	0.36	0.37	0.23	0.36	0.29	0.33	0.29

Note: The variance of hourly earnings is decomposed into between, within and total variance as obtained from estimation of separate regressions of Equation 12 for each country. The standard deviation and the 50–10, 90–50 and 90–10 percentile gaps of the distribution of corrected hourly earnings as obtained from Equation 13.

as that of France, Germany and to some extent Japan. These results are corroborated by those derived from the distribution of the corrected hourly earnings. The standard deviation of the distribution of the corrected hourly earnings for the UK is indeed roughly the same as that for France and Germany. Though, the 90–10 gap in earnings differential in the UK lies above that of Germany, no differences are found between the UK and France and Austria and even a slightly larger 90–10 gap for Italy. This result is consistent with the view that the large wage differentials in the UK reflect a wide distribution of skill levels among the workforce.

**IV. Empirical Results**

*The substitution elasticity and relative equilibrium wages*

From the model four nested specifications are derived.<sup>18</sup> First, assuming that all countries have the same allocation structure, i.e. there are no differences in the production functions, the model reduces to Specification (I).

$$\begin{aligned} \ln \frac{\bar{L}_{ij}}{L_{gl}} - \ln \frac{L_{ij,c}^0}{L_{gl,c}^0} &= -\sigma \left( \ln \frac{w_j^t}{w_l^t} - \ln \frac{w_{j,c}^0}{w_{l,c}^0} \right) \\ &+ \sigma \sum_k (s_{k,i,c} - s_{k,g,c}) \left( \ln \frac{w_j^t}{w_l^t} - \ln \frac{w_{j,c}^0}{w_{l,c}^0} \right) \\ &+ \varepsilon_{ij,c} = SD \end{aligned} \tag{14}$$

In the second Specification (II), the allocation changes are modelled against differences in the allocation structure only.

$$\ln \frac{\bar{L}_{ij}}{L_{gl}} - \ln \frac{L_{ij,c}^0}{L_{gl,c}^0} = \gamma \widehat{AS}_{ij,c} + \varepsilon_{ij,c} \tag{15}$$

In the third and fourth specifications, both changes in wages and differences in allocation structure are nested. Specification (III) corresponds to Equation 10 where the true allocation structure effect is replaced by its proxy  $\widehat{AS}$ .

$$\begin{aligned} \ln \frac{\bar{L}_{ij}}{L_{gl}} - \ln \frac{L_{ij,c}^0}{L_{gl,c}^0} &= -\sigma \left( \ln \frac{w_j^t}{w_l^t} - \ln \frac{w_{j,c}^0}{w_{l,c}^0} \right) \\ &+ \sigma \sum_k (s_{k,i,c} - s_{k,g,c}) \left( \ln \frac{w_j^t}{w_l^t} - \ln \frac{w_{j,c}^0}{w_{l,c}^0} \right) \\ &+ \widehat{AS}_{ij,c} + \varepsilon_{ij,c} \end{aligned} \tag{16}$$

To check the robustness of the  $AS$ -proxy in Specification (IV) the coefficient of the allocation structure effect is actually estimated rather than assuming unity. Comparing the results of both specifications enables the impact of using the proxy  $\widehat{AS}$  for the real allocation structure effect to be evaluated.

$$\begin{aligned} \ln \frac{\bar{L}_{ij}}{L_{gl}} - \ln \frac{L_{ij,c}^0}{L_{gl,c}^0} &= -\sigma \left( \ln \frac{w_j^t}{w_l^t} - \ln \frac{w_{j,c}^0}{w_{l,c}^0} \right) \\ &+ \sigma \sum_k (s_{k,i,c} - s_{k,g,c}) \left( \ln \frac{w_j^t}{w_l^t} - \ln \frac{w_{j,c}^0}{w_{l,c}^0} \right) \\ &+ \gamma \widehat{AS}_{ij,c} + \varepsilon_{ij,c} \end{aligned} \tag{17}$$

<sup>18</sup> The demand equations are estimated with wage on the right-hand side and employment on the left-hand for statistical reasons. Indeed, since employment is differentiated by education and occupation whereas wages are differentiated by education only, there is more measurement error in the employment variable than there is in the wage variable.

**Table 3. The relationship between allocation, wages and the allocation structure**

Specification	(I)	(II)	(III)	(IV)
Education				
Arts–Hum	–	–	–	–
Soci Scie	0.070 (0.221)	–	0.015 (0.090)	0.013 (0.090)
Business	–0.177 (0.312)	–	0.064 (0.091)	0.069 (0.091)
Law	–0.526 (0.470)	–	–0.053 (0.094)	–0.042 (0.094)
Natur Scie	–0.105 (0.271)	–	0.102 (0.089)	0.107 (0.090)
Engineer	–0.229 (0.343)	–	0.151 (0.089)	0.160 (0.090)
Health	–0.962 (0.765)	–	–0.109 (0.102)	–0.089 (0.100)
Const	0.252 (0.389)	0.077 (0.053)	0.002 (0.146)	0.007 (0.146)
$\sigma$	2.362 (1.695)	–	2.143 (0.623)**	2.138 (0.623)**
Control $\widehat{AS}$	No	Yes	Yes	Yes
$\gamma$	–	1.026 (0.015)**	–	1.020 (0.016)**
$T$	684	684	684	684
df	8	2	8	9
$R^2_{adj}$	0.097	0.876	0.878	0.878

Note: \*Significant at 10%. \*\*Significant at 5%.

Specifications (I), (III) and (IV) are estimated by non-linear least squares method and specification (II) by ordinary least squares. The results of the estimations are reported in Table 3. When no control for differences in the allocation structure are included, changes in wages across countries, through a production function specification, explain little of the changes in allocation as indicated by the very low adjusted  $R^2$  of specification (I). Though of a realistic magnitude,<sup>19</sup> the estimate of the substitution elasticity parameter obtained via specification (I) is found insignificant.

The results derived by estimating the model with specification (II) indicate that differences in allocation across countries are to a large extent due to differences in allocation structure. The adjusted  $R^2$  increases drastically compared to that of specification (I) indicating a large explicative power of allocation structure differences on differences in allocation observed across countries.

Therefore in specification (III) and (IV) the allocation structure differences are accounted for when estimating the production function. The results show that once the differences in allocation structures are controlled for, it is possible to explain a significantly

larger part of the variance in allocation,<sup>20</sup> and the elasticity of substitution parameter becomes significant (at 1%).

The estimated substitution elasticity within occupations equals 2.14. Table 4 reports the Allen elasticities of substitution between all pairs of educational groups to illustrate the substitution possibilities between educational groups. The elasticities have been evaluated for the nine-country average allocation and equal wage rates between educational groups. The own-wage elasticities indicate that countries usually have more difficulties to adjust changes in relative wages of Health graduates (–0.98) while they can more easily adjust changes in the wage rate of Social sciences graduates (–1.74).<sup>21</sup>

#### *A supply and demand explanation of wage differentials across countries*

The remaining question is how much of the observed differences in allocation across countries is due to observed differences in wage rates, allocation structures and other unobserved differences. To answer this question the estimates of specification (III) are used

<sup>19</sup> See Hamermesh (1992, 1993) for an exhaustive survey of empirical estimates of labour–labour substitution elasticities. Hamermesh's law, based on empirical regularities, indicates that labour–labour substitution elasticities lie around 1.4.

<sup>20</sup> A  $F$ -test reveals that Specification (IV) also fits the data significantly better than Specification (II), at the 1% level.

<sup>21</sup> All elasticities lie in the range of empirical regularities observed in Hamermesh (1992) and (1993) and Hamermesh and Grant (1979). Though obtained in a context of cross-country analysis of wage differentials, the magnitude of the elasticities is comparable to the magnitude of elasticities obtained from time-series analyses. Bound and Johnson (1992) find a parameter of substitution elasticity of 1.75 between skill-groups within sectors once accounting for skilled-biased technological change. Katz and Murphy (1992)'s estimate implies an elasticity of substitution between college and high school labour of 1.41. In the data, the largest elasticity of substitution is found between Engineering graduates and graduates in Natural Sciences which equals 3.07 while the lowest elasticity of substitution is found between Engineering graduates and graduates from Law school (0.78).

**Table 4. Own-wage elasticities and Allen partial elasticities of substitution evaluated for the world-wide allocation and equal wages across educational fields**

Educational Fields	Quantity of:						
	Arts–Human	Social Sciences	Busin	Law	Natural Sciences	Enging	Health
With respect to wage of:							
Arts–Humanities	−1.32	2.53	2.05	1.49	1.78	1.05	1.12
Social Sciences		−1.74	2.97	1.99	1.30	1.12	1.39
Business			−1.46	1.94	1.49	1.43	0.94
Law				−1.25	0.91	0.78	0.88
Natural Sciences					−1.58	3.07	1.15
Engineer						−1.15	1.04
Health							−0.98
Shares	0.203	0.114	0.188	0.076	0.122	0.197	0.100

**Table 5. Decomposition of international differences in allocation into supply and demand effects and allocation structure effects**

Countries	It	Sp	Fr	Au	Nl	UK	Fi	Jp	Ge	Total
Gap in allocation:										
<i>Observed</i>										
$A_c$	551	555	633	658	643	500	525	814	498	5377
<i>Control for SD</i>										
$B_c$	416	406	437	470	465	345	375	396	370	3680
<i>Structure</i>										
$C_c$	299	314	327	380	391	220	262	277	251	2721
<i>Control for AS</i>										
$A'_c = A_c - C_c$	252	241	306	278	252	280	263	537	247	2656
<i>Control for SD and AS</i>										
$B'_c = B_c - C_c$	117	92	110	90	74	125	113	119	119	959
% Change in Allocation										
<i>No control for AS</i>	24.4	26.8	31.0	28.6	27.8	31.0	28.6	51.3	25.7	31.6
<i>Control for AS</i>	53.4	61.6	64.2	67.7	70.9	55.4	57.1	77.8	51.9	63.9

and the allocation differences between countries are decomposed into quantity  $A_c$  which measures the distance between observed allocation and nine-country average allocation, quantity  $B_c$  which measures the distance between country-specific allocation at equalized wage rates by education and nine-country average allocation and quantity  $C_c$  which measures the distance between country-specific allocation given same supply and demand vectors across countries and nine-country average allocation matrix.

Table 5 reports the results for the unweighted distances. First, the total actual differences in allocation reduces from 5377 to 3680 when wage differentials across countries are eliminated. This result implies that the between-educational-group wage differentials across countries account for 31.6% of the *observed* allocation differences as indicated in the second a last row of the table. However, the differences in allocation structure already account for roughly 51% ( $2721/5377 = 0.506$ ) of the differences

in observed allocation across countries. The last row of the table indicates that, once the allocation structure differences across countries is substrated, the between-educational-group wage differentials across countries account for 63.9% of the *observed* allocation differences. To check the robustness of these results, the weighted absolute distances are computed. The weights are the world-wide average number of workers with education  $j$  in occupation  $i$  to control for the possibility that the absolute distances are driven by a few distances observed where the allocation of workers to occupation is large. The results, reported in Table 6, indicate that wage differentials across countries account for 93.3% of the observed weighted allocation differences.

These results imply that after correcting for differences in the production function between countries at least 2/3 of the differences in allocation can be explained by wage differentials while at most 1/3

**Table 6. Decomposition of international differences in allocation into supply and demand effects and allocation structure effects, using weighted absolute distances**

Countries	It	Sp	Fr	Au	Nl	UK	Fi	Jp	Ge	Total
Gap in allocation:										
<i>Observed</i>										
$\tilde{A}_c$	52	62	51	83	72	55	50	78	51	554
<i>Control for SD</i>										
$\tilde{B}_c$	42	45	44	44	62	36	42	66	43	423
<i>Structure</i>										
$\tilde{C}_c$	39	50	43	49	58	34	43	59	39	413
<i>Control for AS</i>										
$\tilde{A}'_c = \tilde{A}_c - \tilde{C}_c$	12	12	7	35	15	21	8	19	12	141
<i>Control for SD and AS</i>										
$\tilde{B}'_c = \tilde{B}_c - \tilde{C}_c$	3	-5	1	-5	4	2	-1	7	3	10
% Change in Allocation										
<i>No control for AS</i>	18.0	28.0	13.6	47.1	14.4	34.8	16.0	15.5	17.2	23.7
<i>Control for AS</i>	75.5	141.4	93.3	113.3	70.8	91.0	108.4	62.9	74.2	93.3

Note: The distances are weighted by the average number of workers by education and occupation.

remains unexplained and might be due to institutional factors.

## V. Conclusion

In this paper, an explicit model of occupational allocation and wage formation of skill groups is developed to test alternative hypotheses of wage differentials across countries. The main question is whether differences in the wage structure by skill groups across countries reflect differences in supply and demand of the groups distinguished or whether institutional factors like wage-setting, pay norms and minimum wage are the main cause for these differences in wage structure.

Since shifts in supply and demand should affect the allocation of a group in each occupation, this allocation model enables to disentangle supply and demand effects from country-specific differences in the employment of a group in a certain occupation either due to differences in education/occupation classifications or the contents of a study. Isolating occupation-specific differences in the allocation that are not caused by supply–demand factors, the remaining supply–demand differential is compared statistically with wage differentials in each country. Empirical results show that these allocation structure differences account for 50% of allocation differences across countries. Once correcting for these differences in allocation structure, it is found that with a labour–labour substitution elasticity parameter of 2.14, the shifts in demand and supply account for at least 64% of the allocation differences between countries. Reducing wage differentials across countries by 100%

reduces allocation differences by at least 64%. The remaining 36% can be imputed to unobserved factors, that may be related to labour market institutional factors like wage-setting, pay norms and minimum wage.

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**Appendix A: Cross-classification of Workers' Educational Backgrounds and the Various Jobs****Table A1. Classification of educational fields and occupational fields ('required education')**

Educational fields	ISCED <sup>22</sup> codes (3 digits)
Arts–Humanities	14, 20, 21, 22
Social Sciences	30–32
Business	34, 80–81, 84, 86
Law	38
Natural Sciences	40–48
Engineer	50–64, 85
Health	72–76
Occupations	ISCO <sup>23</sup> codes (3 digits)
Legislators–Managers	100–131
Natural Sciences	200–213, 220–221, 300–312, 314–321
Engineering	214
Health	222–225, 313, 322–323
Teaching	230–235, 331–334
Business	240–241, 341–343
Legal	242, 344–345
Social Sciences	243–244, 346
Arts–Humanities	245–271, 347–349
Clerks	400–490
Other lower	> 499

**Appendix B: Wage Premium by Educational Field and Country****Table A2. Wage-premium by educational field relative to Arts–Humanities graduates for each country and absolute distances in allocation**

$\ln w_{j1,c}^{obs} = \alpha_{j,c}$	It	Sp	Fr	Au	Nl	UK	Fi	Ge	Jp
Arts–Humanities (1)	–	–	–	–	–	–	–	–	–
Social Sciences (2)	0.10	0.03	–0.00	–0.01	0.12	0.05	–0.02	0.11	0.01
Business (3)	0.26	–0.02	0.23	0.19	0.10	0.09	0.21	0.12	0.00
Law (4)	0.17	–0.12	0.06	–0.07	0.19	0.12	0.15	–0.04	0.03
Natural Sciences (5)	0.13	0.09	0.30	0.11	0.13	0.10	0.05	0.04	0.14
Engineering (6)	0.28	0.14	0.13	0.08	0.06	0.17	0.16	0.15	0.09
Health (7)	0.15	–0.09	0.13	–0.00	0.02	0.14	0.11	–0.05	0.14
$\bar{A}_c$	7.16	7.21	8.22	8.55	8.35	6.49	6.82	6.47	10.57

Notes: The wage-premia by educational field relative to Arts–Humanities graduates for each country are derived from separate estimations of the earnings regression (Equation 12) for each country.

The average absolute distances between the allocation of each country and the nine-country average allocation are measured as specified in Equation 11.

<sup>22</sup> Since all individuals have a higher education, only the last two digits are reported. Individuals' ISCED first digits are 5, 6 or 7.

<sup>23</sup> The first nine occupational categories correspond to jobs for which a higher education is 'required' while for the last two, i.e. Clerks and other-lower, a lower educational level is 'required'.



**Appendix C: Derived Educational and Occupational Changes****Table A3. Education-specific changes in allocation after controlling for demand and supply differences**

$\ln(S_{j,c}/S_{7,c})$	It	Sp	Fr	Au	Nl	UK	No	Fi	Ge	Jp
Arts–Humanities	0.15	0.48	–2.98	–1.18	0.26	–1.05	2.09	–0.70	0.28	–0.98
Social Sciences	0.24	–0.20	–4.03	–0.69	0.73	–0.89	2.32	–0.36	0.86	–0.72
Business	0.48	0.32	–4.07	–1.06	0.17	–0.41	3.79	–0.37	–0.61	–0.17
Law	0.18	0.10	–3.87	–0.96	0.79	0.35	2.60	0.32	0.91	–0.65
Natural Sciences	0.30	–0.10	–3.82	–1.44	1.13	–1.00	2.22	–0.69	–0.37	0.10
Engineering	–0.13	–0.23	–2.94	–1.54	0.82	–0.13	1.84	–0.77	–0.27	–0.60
Health	–	–	–	–	–	–	–	–	–	–

**Table A4. Occupation-specific changes in allocation after controlling for demand and supply differences**

$\ln(R_{1,c}/R_{i,c})$	It	Sp	Fr	Au	Nl	UK	No	Fi	Ge	Jp
Leg manager	–	–	–	–	–	–	–	–	–	–
Sciences	1.15	0.22	0.66	0.88	–0.75	–0.79	0.45	0.10	0.46	1.04
Engineering	0.65	0.35	0.12	1.36	–0.40	–0.68	0.45	0.36	1.11	0.64
Health	–0.19	0.62	–0.28	2.82	–1.13	–0.06	–0.37	0.71	0.61	0.67
Teaching	0.91	0.52	–0.04	1.80	–1.94	–1.28	0.73	1.06	1.06	0.43
Business	2.10	–1.55	–0.75	1.79	–0.29	–0.93	0.72	0.65	0.91	–0.41
Legal	1.92	0.24	–0.15	2.67	–2.10	0.15	–1.09	0.87	2.18	–0.50
Social Sciences	0.47	–0.29	–0.35	2.93	–0.67	–1.71	–1.22	0.62	0.98	–1.16
Arts–Humanities	0.17	–2.15	–1.01	2.17	–1.59	–0.93	2.39	0.62	1.36	–1.33
Clerks	1.04	1.12	–0.80	0.44	–1.42	–1.19	–3.68	–1.35	0.12	2.16
Other lower occ	0.46	0.59	0.05	–0.28	–1.69	–0.91	–1.75	–0.97	–0.55	2.32