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Birthplace diversity and productivity spill-overs in firms*

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Abstract

We determine workforce composition and wages in firms in the presence of productivity spill-overs between co-workers. In equilibrium, workers' wages depend on the production structure of firms, own group size, and aggregate workforce composition in the firm. We estimate the wage effects of workforce diversity and own group size by birthplace and the implied production structure in Austrian firms using a comprehensive matched employer-employee data set. In our data, we identify a positive effect of workforce diversity and a negative effect of own group size on wages, which suggest that workers of different birthplaces are complements in production on average.

JEL Codes: D21, D22, F22, J31.

Key words: workforce composition, productivity spill-overs, worker group size.

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1 Introduction

The labor force in industrialized countries is changing in the course of large and increasing inflows of immigrant workers. As of 2009, the overall stock of migrant workers in OECD countries represented 14 per cent of the total labor force.[1] This has potentially important effects on workforce composition and workers' wages. Indeed, a growing empirical literature documents that the composition of co-workers matters for workers' wages.[2] Existing empirical findings regarding the signs of effects are, however, inconclusive: increases in the share of immigrant co-workers, for example, decrease wages in some studies (e.g. Aslund and Skans (2010)) but increase wages in other studies (e.g. Dustmann et al. (2011)). At the same time, little is known about the underlying nature of this relationship.

In this paper, we provide a potential explanation for the variety of existing empirical findings based on a theory of optimal worker assignment and productivity spill-overs in firms. According to this theory, workforce composition is chosen optimally depending on the production structure of firms and the complementarity between workers from the same (or a different) group. We distinguish between workers by birthplace and allow for productivity spill-overs between workers of a given birthplace. Our structural model characterizes the equilibrium size of worker groups by birthplace, and group-specific wages. It predicts the effects of workforce diversity and own group size (the share of workers with the same birthplace in the firm) depending on the production structure of firms. In particular, if there are complementarities between workers of different birthplace in the firm, we expect wages to increase in diversity and decrease in own group size. If there are complementarities between workers of the same birthplace, we expect wages to decrease in diversity and increase in own group size.

Our model builds on the model of optimal worker allocation in the presence of intra-firm spill-overs by Saint-Paul (2001). We adapt the analysis to consider productivity spill-overs related to the birthplace diversity of the workforce. We measure workforce diversity in firms using an index of fractionalization by birthplace at the firm level.[3] The model predicts that wages increase (decrease) in this index, if there are positive spill-overs between workers of different (the same) birthplace. Of course, it is possible that spill-overs of both kinds exist at the same time and the resulting wage

[1] OECD (2011).

[2] See, for example, Carrington and Troske (1998a,b), Bayard, Hellerstein, Neumark and Troske (1999), Elliott and Lindley (2008), Hellerstein and Neumark (2008), Aslund and Skans (2010), Dustmann, Glitz and Schönberg (2011).

[3] This index reflects the probability that two randomly selected workers from a firm are from a different birthplace. It has been used as a measure of ethnic fractionalization in, for example, Alesina, Devleeschauwer, Easterly, Kurlat and Wacziarg (2003).

depends on the dominating effect.

The model implies further that wages decrease in own group size, conditional on workforce fractionalization, if there are positive spill-overs between workers of different birthplace (for example due to complementary culture-specific skills). Conversely, wages are predicted to increase in own group size, if there are positive spill-overs between workers of the same birthplace, for example due to common language or customs. In short, this is because workers in bigger groups have a smaller marginal effect on workforce diversity, ceteris paribus, and, therefore, receive a greater wage discount (premium) in compensation for any positive (negative) productivity spill-overs between workers from different groups.

We test for the predictions of our model, deriving the production structure of firms implicitly from the data. Our data provide comprehensive employer-employee information for the universe of workers in Austria. Austria is an ideal country to study wage effects of workforce composition by birthplace, because immigrants represent a large share of the workforce and differ considerably in birthplace. Our estimating sample consists of approximately 1,400,000 observations for 199,000 workers and 15,300 firms during the period 1990-2005.

We find evidence for a wage premium for diversity in our sample: greater workforce fractionalization is associated with greater wages on average. Accordingly, we find that the effect of group size on wages is negative on average. Our baseline finding indicates that a 10 percentage point increase in the share of workers from the same birthplace decreases wages by 0.2%. We also find that the effect of workforce fractionalization is non-linear: greater workforce fractionalization is associated with greater wages at low levels of fractionalization, but it is associated with smaller wages at higher levels of fractionalization. Our findings show that the effect of worker group size on wages may depend on the production structure in firms; this can account for important heterogeneity in the way in which co-worker characteristics affect wages. Moreover, if firms choose group size optimally, group size may be endogenous to the nature of productivity spill-overs between co-workers. Then, empirical estimates of group size effects that do not control for the production structure of firms may suffer from endogeneity bias.

Our paper is related to three broad strands of the literature. First, it is related to the empirical literature that estimates wage effects of worker group size in firms. An important part of this literature is the literature on segregation at the firm level, which documents systematic relationships between wages and the share of minority workers (by race, sex or birthplace) in firms. For example, Carrington and Troske (1998a) analyze the distribution of black and white workers across large manufacturing firms in the U.S. and find that the wages of black workers decrease, but the wages of white workers increase, in the share of their black co-workers. Using the same data set, Carrington and Troske (1998b) find that women's wages decrease in the share of their female co-workers. Bayard et al. (1999) find that the wages of black and hispanic male workers decrease in the shares of black and hispanic workers in U.S. firms, respectively. More recently, several European studies have investigated the wage effect of workforce composition by birthplace. Elliott and Lindley (2008) show that the wages of immigrants compared to natives decrease in the shares of immigrant co-workers in the UK. Aslund and Skans (2010) find that the wages of immigrants and natives decrease in the share of immigrant co-workers in Sweden.

This literature typically focuses on the links between the clustering of minority workers in firms and average wage gaps between minority and majority workers. It does not, however, address directly the potential reasons for such clustering. For example, as pointed out by Hellerstein and Neumark (2008), the matching of workers with specific co-workers may in part be determined by previously unobserved complementary worker characteristics such as English-language proficiency. Using longitudinal employer-employee data, we can analyze how wages change in response to changes in own group size for given individuals (i.e., conditional on worker fixed effects). This allows us to control much more precisely than previous studies for unobserved worker characteristics that may affect both co-worker composition and wages. In addition, we extend the literature in providing a theoretical framework that allows us to determine workforce composition endogenously in the presence of productivity spill-overs across workers and derive structural wage equations with testable hypotheses for group size effects on wages.

Dustmann et al. (2011) provide, like us, both a theoretical and an empirical analysis of group size effects on wages at the firm level. They, however, focus on an alternative mechanism through which co-worker characteristics may affect wages, via job networks. In their model, a firm is more likely to hire a minority worker from a particular group, if the share of existing minority workers from that group in the firm is larger. They find that the wage of an immigrant worker increases in the share of immigrant co-workers with the same nationality. While job networks may certainly play a role, they do not, however, suggest any systematic relationship between workforce diversity and wages. Our wage effect via workforce diversity and productivity spill-overs is, therefore, likely to exist independently of any potential effects via job networks.

Second, we contribute to the empirical literature that estimates wage or productivity effects of diversity based on the theory of productivity spill-overs by Lazear (1999). This literature started with cross-country studies on the effect of ethnic, linguistic and religious diversity on per capita GDP (Easterly and Levine (1997), Alesina et al. (2003)). Ottaviano and Peri (2005, 2006) analyze diversity effects at the metropolitan level; they find a positive effect of cultural diversity on the wages of natives in US cities. Nathan (2011) and Südekum, Wolf and Blien (2014) reach similar conclusions for the UK and western Germany at the metropolitan and regional level, respectively. Brunow and Brenzel (2012) and Bellini, Ottaviano, Pinelli and Prarolo (2013) find a positive effect of cultural diversity on GDP per capita and productivity at the regional level in European countries. Finally, in a recent paper at a more aggregate level, Alesina, Harnoss and Rapoport (2013) find a positive effect of birthplace diversity on GDP per capita for a large sample of OECD and non-OECD countries.

These papers do not analyze the impact of diversity at the firm level but at more aggregate levels, i.e. the metropolitan, regional or country level. At those levels it is, however, difficult to distinguish between spill-overs that arise within the firm and other potential spill-overs from outside the firm.[4] A few recent papers estimate the effect of workforce diversity also at the firm level, but they focus on firm outcomes such as productivity or innovation, and not on wages. For example, Parrotta, Pozzoli and Pytlikova (2014a) find a negative effect of ethnic diversity on productivity in Denmark, and Ozgen, Nijkamp and Poot (2013) and Parrotta, Pozzoli and Pytlikova (2014b) find a positive effect of cultural or ethnic diversity on innovation in the Netherlands and in Denmark. In a slightly different context, Kahane, Longley and Simmons (2013) provide evidence for a positive effect of cultural diversity among hockey team members on team performance (measured by the team winning percentage). Our paper is the first, to the best of our knowledge, to analyze the effects of diversity on wages at the firm level. For this purpose, we use two-way fixed effects estimation to account for the fact that high- or low-productivity firms may not only employ a more or less diverse workforce, but that high- or low-productivity workers may also sort endogenously into more or less diverse firms. Moreover, we consider a non-linear functional form of diversity spill-overs and find that spill-overs are positive at low levels of diversity, but may become negative at high levels of diversity.

Third, our paper is related to the theoretical literature on optimal worker assignment, which explains workforce composition and wages as a function of the production structure of firms. Kremer (1993) analyses a production function in which production consists of different complementary tasks ('o-ring' production function). He shows that firms will match together workers of similar skill, and

[4] For example in the form of 'localized knowledge spill-overs', see Glaeser, Ponzetto and Tobio (2011).

derives equilibrium wages as a function of worker skill under this production function. Kremer and Maskin (1996) derive the equilibrium wage distribution and the pattern of skill levels within firms under a slightly different production function to account for increases in segregation. Lazear (1999) analyses optimal workforce composition in 'global firms' that may employ multi-cultural teams in order to diversify the firm's portfolio' of skills, if the skill complementary between workers more than compensates for the costs of cross-cultural communication. In his model, similar to ours, the optimal allocation of workers, and the effect of workforce composition on wages, will depend on the production structure of firms.[5] The model of Saint-Paul (2001) is most closely related to our model. It postulates a production function according to which firm output is a (general) function of average skill in the firm. In consequence, wages increase in average skill in the firm. In our case, output is a general function of an aggregate index of workforce diversity (fractionalization) in the firm. We find that, depending on whether spill-overs across different groups of workers are positive or negative, wages will increase or decrease in this index. Similar to Saint-Paul (2001), the exact pattern of workforce compositions and — in our case — the effect of own group size on wages will depend on the specific functional form of the production function. We then test for the wage effects of workforce diversity and own group size and derive the nature of productivity spill-overs across worker groups implicitly from our data.

In sum, our paper provides several important contributions to the growing literature on workforce composition and wages. We, first, present a structural model of workforce composition to explain why workers of different groups may not be distributed randomly across firms. This model, second, provides a rationale for the differences in existing empirical findings regarding the links between worker group size and wages, which, as we argue, may be due to differences in the production structure of firms. We, finally, test for the wage effects of workforce composition (workforce diversity and own group size) that we propose in our model using comprehensive matched employer-employee data that allow us to identify the causal effect of workforce composition on wages.

The paper is structured as follows. In Section 2, we derive an expression for equilibrium wages in the presence of intra-firm spill-overs that depend on the degree of workforce heterogeneity in the firm. Section 3 describes the data and provides descriptive statistics for the composition of the workforce in Austrian firms. Section 4 introduces the empirical model that we use to test for the wage effects of workforce composition and presents our empirical results. Section 5 concludes.

[5] See Kremer (1993), Kremer and Maskin (1996), or Saint-Paul (2001), who derive labor market implications for specific production functions.

2 The Model

We develop a model of workforce composition in firms when there are productivity spill-overs between workers in the firm. Our model builds on the model of intra-firm spill-overs by Saint-Paul (2001), where a firm's total output is a function of an aggregate index for the workforce. In our case, this is an index for workforce composition by birthplace.[6] This allows us to formalize potential productivity spill-overs across workers within firms in a way that is quite general and does not require specific assumptions about the production function of firms. We use this model to derive testable hypotheses on the nature of productivity spill-overs between different groups of workers, and the effect of workforce composition on wages.

2.1 Intra-Firm Spill-Overs and Wages in Firms

We consider an economy with a given total number of workers who differ in their birthplace n, b_n, $n \in \{1, ..., N\}$. Workers are distributed across firms that each employ a total number of workers, which is normalized to 1. Firms can enter the market freely and choose optimally (skill-specific) group shares, g_{nk}, taking the total number of workers in the firm as given.[7][8] In each firm, we consider workers of birthplace n and a given skill (individual productivity) $y_k \geq 0$.

Each worker's total productivity is given by the sum of his skill y_k and a spill-over effect that depends on the birthplace composition of his co-workers. This spill-over effect is captured in a function of workforce heterogeneity, $f(F)$, where F is equal to the probability that a co-worker (of the same or a different skill) has a different birthplace $m \neq n$. Total output is given by $a = \sum_n \sum_k g_{nk} y_k + f(F)$, with $\sum_n \sum_k g_{nk} = \sum_n g_n = 1$. We assume that $f(F)$ is continuous and twice differentiable.

To measure worker heterogeneity, we use an index of fractionalization (Alesina et al. (2003)) equal to 1 minus the Herfindahl index of workers by birthplace:

$$F = \sum_n g_n (1 - g_n) = 1 - \sum_n g_n^2. \tag{1}$$

[6] In Saint-Paul (2001), the index equals the average skill level of workers in the firm.

[7] The assumption of a fixed number of workers per firm allows for the existence of an equilibrium even in the presence of increasing returns in production. This assumption is common in models of optimal worker assignment in the presence of spill-overs (see, for example, Kremer (1993) or Saint-Paul (2001)). It can be relaxed by introducing a cost for increasing the firm size (compare Saint-Paul (2001), section V.C).

[8] This implies that there will be a total number $\sum_n b_n$ of firms in equilibrium.

This index is equal to the probability that two randomly selected workers in a firm are from different birthplaces. It varies between zero (all workers are from the same birthplace) and $1-(1/N)$ (workers are uniformly distributed across groups).[9] Furthermore, it decreases in the average group share (for a given variance of group shares) and in the variance of group shares (for given average group share). This can be seen by rewriting (1) as a function of the statistical mean and variance of group shares, $1/N$ and v:

$$F = 1 - \left[\frac{1}{N} + Nv\right], \text{ where } v = \frac{\sum_n \left(g_n - \frac{1}{N}\right)^2}{N}. \tag{2}$$

Differentiating $F(\mathbf{g})$ with respect to g_n, holding the average group share $1/N$ constant, results in:

$$\frac{\partial F}{\partial g_n} = -2\left(g_n - \frac{1}{N}\right), \; g_n \neq \frac{1}{N}. \tag{3}$$

Equation (3) shows that the fractionalization index increases in the share of a minority group (with a group share smaller than the average group share) and decreases in the share of a majority group (with a group share greater than the average group share). The marginal effect of group share on fractionalization decreases linearly in group share (for given average group share).

The spill-over function $f(F)$ measures the effect of workforce composition on worker productivity. It can be increasing or decreasing, depending on the nature of spill-overs across workers of different birthplace (henceforth also called worker types). For example, workers of the same type may generate positive spill-overs because they work in teams (Kremer, 1993) or because they share the same language (Lazear, 1999). Alternatively, they may generate negative spill-overs because they are competing for a complementary fixed factor in the firm such as capital or workers of complementary skill types. (For example, administrative workers could be complementary to manual workers). In the presence of complementarities between workers of different (the same) birthplace, each worker's productivity depends positively (negatively) on the degree of fractionalization and $f(F)$ will be increasing (decreasing). In the absence of spill-overs, we assume $f(F) = 0$ such that firm output is equal to the sum of individual worker productivities $\sum_n \sum_k g_{nk} y_k$.

Total output in firm i is then a function of the group size of workers in the firm:

$$a_i = \sum_n \sum_k g_{nki} y_k + f(F_i(\mathbf{g_i})).$$

Note that this output function exhibits constant returns to group size, g_{nki}, if there are no spill-

[9] Note that the maximum of the fractionalization index approaches one, as the number of worker groups approaches infinity.

overs and $f(F_i) = 0$. However, it can also exhibit increasing or decreasing returns, depending on whether (i) there are positive or negative spill-overs across workers from different birthplaces, and (ii) an increase in group size g_{nki} serves to increase or decrease workforce fractionalization by birthplace.

Firms decide on optimal group shares of workers with birthplace n and skill k, g_{nki}, to maximize profits. The optimal employment structure of a firm is the solution to the following maximization problem:

$$\max_{g_{nki}} \sum_n \sum_k g_{nki} y_k + f(F_i(\mathbf{g_i})) - \sum_n \sum_k g_{nki} w_{nki},$$

subject to

$$g_{nki} \geq 0 \quad \forall\ n \in \{1, ..., N\},\ k \in \{1, ..., K\},$$

and

$$\sum_n g_{ni} = 1. \tag{4}$$

Firms, therefore, decide how many workers of each type to hire, g_{nki}, subject to the constraint that the total number of workers in the firm is fixed.[10] The market wage for a worker of birthplace n and skill k, w_{nk}, is exogenous to the firm and is determined by aggregate demand and supply of workers of type n, b_n, as described in the next section. If $g_{nki} = 0$, then that type is not employed in the firm. Using (3), the maximization problem for a firm i results in the following first-order condition:[11]

$$y_k - f'(F_i) 2 \left(g_{ni} - \frac{1}{N_i} \right) - w_{nki} - \lambda_i \leq 0, \tag{5}$$

where λ_i is the Lagrange multiplier from (4), which can be interpreted as the opportunity cost of an increase of group size g_{nki} that comes at the expense of a decrease in the size of another group g_{mli}, $m \neq n$. It can be derived from the condition that $y_k - f'(F_i)2\left(g_{ni} - \frac{1}{N_i}\right) - w_{nki}$ must be the same for all workers in the firm in optimum (i.e., firm profits cannot be increased by a marginal replacement of one worker by another worker). Integrating (5) over all employees of the firm and taking into account the zero-profit condition, $\sum_n \sum_k w_{nki} g_{nki} = \sum_n \sum_k y_k g_{nki} + f(F_i)$ shows that the opportunity cost of a job in the firm, λ, is equal to $f'(F_i)F_i - f(F_i)$.

According to equation (5), an increase in group size g_{nki} marginally affects output in four ways:

[10]This means that firms cannot increase output by hiring more workers but only by hiring a different mix of worker types. Compare, for example, Saint-Paul (2001).

[11]Equation(5) holds with equality, if $g_{nki} > 0$.

first, via an increase in output equal to the skill k of a worker, y_k; second, via an increase in the productivity of all workers due to the change in workforce fractionalization F caused by an increase in group size g_{ni}, $-f'(F_i)2\left(g_{ni}-\frac{1}{N_i}\right)$; third, via the wage cost of employing a worker of birthplace n and skill k, w_{nki}; and fourth, via the opportunity cost of employing that worker instead of a different one, $f'(F_i)F_i - f(F_i)$.

We can now characterize the equilibrium wages of workers of skill k and birthplace n as follows.

Proposition 1. *Consider a firm i with given workforce heterogeneity F_i and number of groups employed N_i. The equilibrium group-specific wage of workers of skill k and birthplace n is such that*

$$w_{nki}(g_{ni}) \geq y_k + f(F_i) - f'(F_i)F_i - f'(F_i)2\left(g_{ni} - \frac{1}{N_i}\right),$$

for all firms i;

$$w_{nki}(g_{ni}) = y_k + f(F_i) - f'(F_i)F_i - f'(F_i)2\left(g_{ni} - \frac{1}{N_i}\right),$$

if firm i employs worker type n.

Wages depend not only on individual worker characteristics as described by y_k but also on how a worker's own characteristics compare with those of his co-workers. If there are positive spill-overs from working with workers of a different birthplace, $f'(F_i) > 0$, then the wage decreases in own group size, g_{ni}, given F_i.[12] If there are positive spill-overs from working with workers of the same type, $f'(F_i) < 0$, then the wage increases in own group size.

Wages of workers with birthplace n and skill k are equal to their individual productivity, y_k, plus the average spill-over, $f(F_i)$ and an additional wage component, which equals the difference between a type-n worker's marginal effect on fractionalization and output, and the average marginal effect in the firm, $\left[-f'(F_i)2\left(g_{ni}-\frac{1}{N_i}\right) - f'(F_i)F_i\right]$. This component is positive or negative depending on whether the marginal effect of workers on the productivity of their co-workers is greater or smaller than the average marginal spill-over.[13] It is more likely to be positive, the smaller the size of a worker's group, g_{ni}, relative to the average group size, $1/N_i$, if $f(F_i)$ is increasing, i.e., if there are complementarities between workers of different birthplaces (and vice versa). This is because the smaller group size is, the greater is the marginal effect of group size on workforce fractionalization.

[12]Note that, since $g_{ni} = \sum_k g_{nki}$, we have $\frac{\partial g_{ni}}{\partial g_{nki}} = 1$.

[13]Notice that the willingness of a firm to pay for a worker can be negative, for example, if productivity spill-overs are positive and the marginal effect of a worker on spill-overs in the firm is sufficiently small. In turn, the willingness to pay for a worker can be positive, even if individual skill is zero.

In consequence, smaller worker groups are more likely to get a wage premium, while larger worker groups are more likely to get a wage discount, if spill-overs across different worker types are positive (and vice versa, if spill-overs are negative). On average, the deviation of marginal spill-over effects from the average marginal effect is zero and the sum of wages equals total output, as required by the zero profit condition.

2.2 Workforce Composition and Wages Across Firms

The wages of worker types according to proposition 1 depend on the decision of firms as to how many workers of each type to employ. In the following, we characterize the allocation of workers to firms and the resulting firms' workforce fractionalization F in equilibrium, defined as follows.

Equilibrium. *An equilibrium is an allocation of workers to firms such that (i) firms maximize profits, (ii) no potential entrant firm could make strictly positive profits, and (iii) all workers are allocated.*

In equilibrium, existing firms make zero profits and potential entrants cannot make positive profits due to free entry. The overall demand for workers of birthplace n and skill k as implied by the number of firms and the size of worker groups g_{nk} employed in each firm needs to be equal to the overall supply of workers of birthplace n and skill k, $\forall\ n, k$.

Proposition 2. *The equilibrium distribution of worker types and wages across firms can be characterized as follows.*

i. Firms of type i with greater productivity spillovers than firms of type j, $f'(F_i) > f'(F_j)$, employ workers in smaller group shares compared to firms of type j, and vice versa;

ii. wages decrease (increase) linearly in the group share g_n, given $f'(F)$, if productivity spillovers across different worker types are positive (negative);

iii. the overall wage schedule $w_{nk}(g_n)$ is convex and decreasing, if $f'(F) > 0$, and it is convex and increasing, if $f'(F) < 0$;

iv. the total supply of workers with a given birthplace n and skill k, b_{nk}, equals total demand for those workers in the economy.

Proof. Consider two existing firms, i and j, with different production structures $f'(F_i) > f'(F_j)$. Then, the largest group employed in firm i is smaller than the smallest group employed in firm j. To see this, note that proposition 1 implies that

$$y_k + f(F_i) - f'(F_i)F_i - f'(F_i)2\left(g_{ni} - \frac{1}{N_i}\right) \geq y_k + f(F_j) - f'(F_j)F_j - f'(F_j)2\left(g_{ni} - \frac{1}{N_j}\right) \quad (6)$$

and, vice versa,

$$y_k + f(F_j) - f'(F_j)F_j - f'(F_j)2\left(g_{nj} - \frac{1}{N_j}\right) \geq y_k + f(F_i) - f'(F_i)F_i - f'(F_i)2\left(g_{nj} - \frac{1}{N_i}\right). \quad (7)$$

Comparing the difference between the left-hand side of (6) and the right-hand side of (7) with the difference between the right-hand side of (6) and the left-hand side of (7), we find that

$$\left[f'(F_j) - f'(F_i)\right](g_{ni} - g_{nj}) \geq 0. \quad (8)$$

The wages of workers of type n internalize the effect that workers have on the productivity of their co-workers via their contribution to the size of group g_n and, in turn, to workforce fractionalization. If the fractionalization of the workforce has a large positive effect on productivity in the firm ($f'(F)$ is large), then larger groups, which have a smaller effect on workforce fractionalization, get penalized more.[14] As a result, larger groups of type n are employed in firms where $f'(F)$ is smaller, and vice versa. This proves i.

If a group of size n is employed in different firms i and j, then the wage of a worker from that group is the same in both firms, since according to proposition 1 we have

$$w_{nki} = y_k + f(F_i) - f'(F_i)F_i - f'(F_i)2\left(g_n - \frac{1}{N_i}\right) \geq y_k + f(F_j) - f'(F_j)F_j - f'(F_j)2\left(g_n - \frac{1}{N_j}\right)$$

and

$$w_{nkj} = y_k + f(F_j) - f'(F_j)F_j - f'(F_j)2\left(g_n - \frac{1}{N_j}\right) \geq y_k + f(F_i) - f'(F_i)F_i - f'(F_i)2\left(g_n - \frac{1}{N_i}\right).$$

and, therefore,

$$w_{nki} = w_{nkj}.$$

[14] In fact, they have a negative effect, if they are larger than average.

Furthermore, the slope of the wage function is constant for given $f'(F)$ according to proposition 1. This proves ii. The slope increases as $f'(F)$ becomes smaller (and group shares become larger) according to (8). This proves iii. iv is the condition for the labor market equilibrium for all types of workers.

■

Corollary. *The equilibrium wage of a worker with birthplace n who belongs to a firm-specific worker group of size g_{ni} can be characterized as follows.*

The wage of a worker with birthplace n is linear in own group size within a given range, and, for firms i that hire within range ρ, given by:

$$w_{nki}(g_{ni}) = y_k + \phi_\rho - \psi_\rho g_{ni},$$

where

$$\phi_\rho = f(F_i) - f'(F_i)F_i + \psi_\rho \frac{1}{N_i},$$

$$\psi_\rho = 2f'(F_i).$$

Proof. Follows from proposition 1 and (8).

■

Figure 1 illustrates how firms are organized in equilibrium.[15] According to proposition 2, firms with greater productivity spill-overs employ smaller groups. Wages are linear in own group size within a given cluster, as shown for two firms i and j in two different clusters, with different productivity spillovers, $f'(F_i) > f'(F_j)$.

Panel a depicts the case of positive returns to workforce fractionalization, $f'(F) > 0$. In this case, wages for workers of skill k decrease linearly with increasing worker group size, given F. This is because, as group size increases, the marginal effect of group size on aggregate workforce fractionalization decreases. In consequence, the wage premium, which compensates workers for

[15] The equilibrium number of clusters, the number of firms per cluster and the distribution of workers across firms is not necessarily unique. It is determined by the shape of the spill-over function, f(F), the supply of workers of type n, b_n, and the number of worker types, N, in the economy.

their effect on the positive productivity spill-overs within the firm, decreases. The wage function $w_{nk}(g_n)$ becomes increasingly flat as group size increases, if there are different clusters of firms with $f'(F_i) \neq f'(F_j)$ in the economy.[16]

In panel b, which depicts the case of negative returns to workforce fractionalization, $f'(F) < 0$, effects go in the opposite direction. Wages for workers of type n now increase linearly with increasing worker group size, given F, because the marginal effect of group size on aggregate workforce fractionalization and, therefore, on the negative productivity spill-overs within the firm, decreases. The wage function $w_{nk}(g_n)$ becomes increasingly steep with increasing group size, if $f'(F_i) \neq f'(F_j)$. In both panels, the overall wage schedule across firms is convex.[17]

Average wages in firms equal average firm output, $a_i = \sum_n \sum_k g_{nki} y_k + f(F_i)$. $f(F)$ may have convex parts and concave parts.[18] In the concave parts, there are local decreasing returns to workforce fractionalization, which create a force for agglomeration of different group sizes within the same firm. In the convex parts, there are local increasing returns, which create a force for a separation of workers by group size, that is, the employment of workers with different group sizes in different firms. If $f(F)$ is convex over some interval, and there is a separation of worker groups into different clusters, then the (positive or negative) slope of the wage function increases. If $f(F)$ is globally concave, then there is only one cluster of firms ($f'(F_i) = f'(F_j)$), the wage function $w_{nk}(g_n)$ is linear, and firms may employ workers in all group sizes.

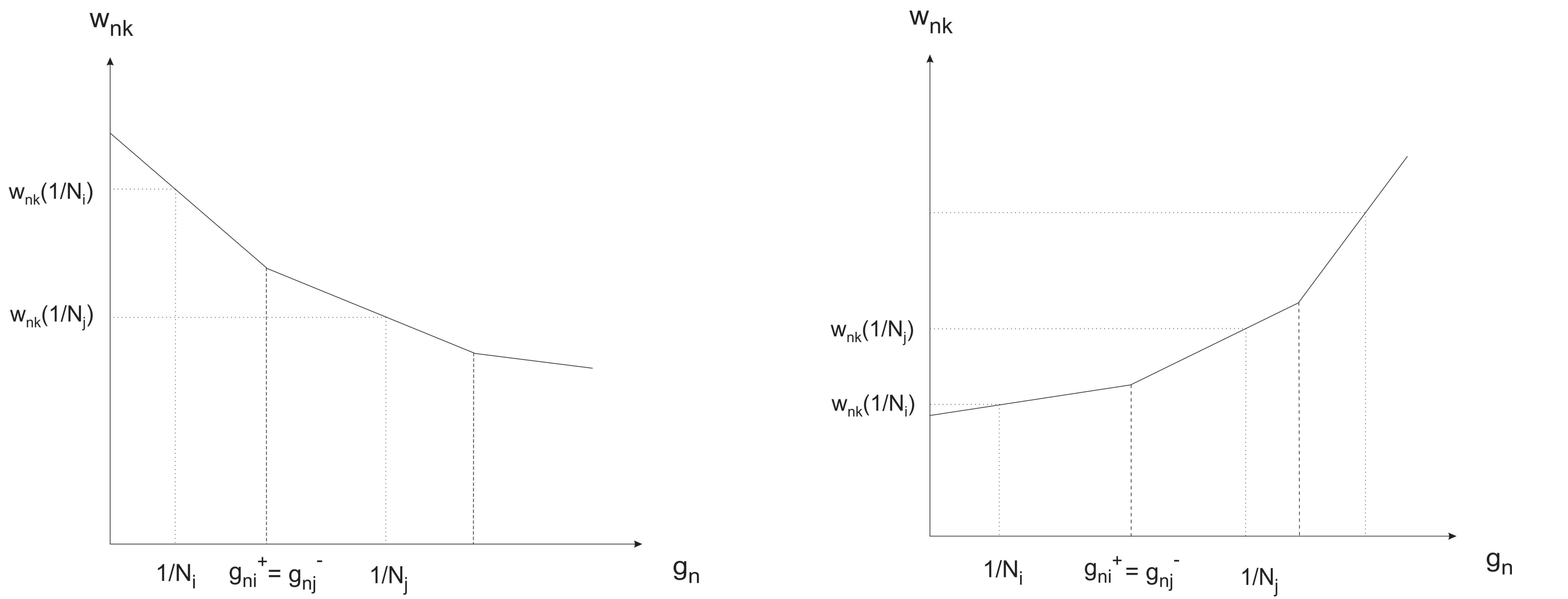
Summing up, our model shows that the effect of own group share on wages depends on the nature of productivity spill-overs across worker groups. For given workforce fractionalization and average group share at the firm, we expect that own group share has a negative (positive) wage effect, if $f'(F_i)$ is positive (negative) (proposition 1). However, group shares and workforce fractionalization in firms may be endogenous and vary systematically with firm-specific productivity spill-overs, such that larger groups (and, therefore, more homogeneous workforces) are employed in firms where the benefit from fractionalization ($f'(F)$) is smaller (proposition 2). Note that in this case empirical estimates of group size effects on wages may be biased, unless they control for potential endogeneity of group size due to differences in the production structure of firms ($f'(F)$).

[16]Note that, unlike in the figure, the wage function will not be continuous, unless the distribution of group shares has full support. However, single values of that function will correspond to the wages of workers of those groups that have positive support.

[17]Note that, whereas we have assumed here that $f(F)$ is the same in all firms, results also hold in the case where $f(F)$ is firm-specific.

[18]Compare Figure 1 in Saint-Paul (2001).

Figure 1: Workforce composition and wages in equilibrium when spillovers across workers of different type n are positive (panel a) and negative (panel b).



NOTE: The figure illustrates the wage schedule for workers of type n and skill k in an example with three clusters of firms. In panel a, the spill-over function is assumed to be increasing, $f'(F) > 0$; in panel b, it is assumed to be decreasing, $f'(F) < 0$. Consider firms in clusters i and j. Firms in cluster i employ worker groups with a maximum group size of g_{ni}^{+}. Firms in cluster j employ workers in greater groups with a minimum group size of g_{nj}^{-}. See proposition 2. Since the group size of all workers is smaller in cluster i compared to j, workforce fractionalization is greater in i than in j.
If spillovers across workers of different type are positive ($f'(F) > 0$, panel a), then wages are greater in cluster i than in cluster j; this follows from (8) and proposition 1. Furthermore, wages decrease with increasing group size within firms. This is because, as group size increases, the marginal effect of group size on aggregate workforce fractionalization and, therefore, on the positive productivity spill-overs within the firm decreases. If a group of a given size is employed in both clusters i and j, then the wage of a worker from that group has to be the same in both clusters, $g_{ni}^{+} = g_{nj}^{-}$, which follows from proposition 1. If spillovers across workers of different type are negative ($f'(F) < 0$, panel b), wages are smaller in cluster i than in cluster j. Wages increase with increasing group size within firms, because the marginal effect of group size on aggregate workforce fractionalization and, therefore, on the negative productivity spill-overs within the firm decreases.

3 Data and Descriptives

3.1 Data

We estimate wage regressions using data from the Austrian Social Security Database (ASSD).[19] From the ASSD, we obtain detailed information on the workers' earnings and employment histories, in particular, their work experience and tenures in firms. We construct firm-level information, such as firm size or the firm's composition of the workforce, in addition to available indicators for industry classification (NACE) and location. We obtain the workers' country of origin from the Austrian Public Employment Service (AMS) and their Labor Market Database ("Arbeitsmarktdatenbank"), which we match to our data. For each firm, we calculate the fractionalization index F_{jt} equal to 1 minus the Herfindahl index by birthplace, $1 - \sum_n g_n^2$, where g_n is the share of group n in the firm.

Our dependent variable, log daily wages, is derived from gross wages as well as the number of days employed at each firm. Since we do not observe the number of hours worked, we restrict the sample to men as women are more likely to work part-time than men.[20] We exclude workers from seasonal industries (tourism, construction, and farming) and drop firms with fewer than 10 employees. We draw a 15 percent random sample of all male private employees, aged 20 to 60 between 1990 and 2005. The final sample consists of approximately 199,000 workers in 15,300 firms. In total, this results in more than 1,400,000 observations.

We use the country of birth rather than citizenship as the indicator for an immigrant worker, because ethnic background may be more relevant for productivity spill-overs than citizenship. Table 1 compares the distribution of the countries of origin in our sample with official census data and demonstrates that our data capture well the distribution of the overall population. The table also shows that while there are differences between citizenship and country of birth, these differences tend to be minor.[21]

[19] See Zweimüller, Winter-Ebmer, Lalive, Kuhn, Wuellrich, Ruf and Buchi (2009) for details on these data.

[20] In 1994, about 1.4 percent of male and 26 percent of female employees worked part-time (Statistik Austria, 2011). These numbers increased steadily over time, reaching 4.8 percent and 37.8 percent, respectively, in 2004.

[21] Citizenship matters for the employment of workers, because employment regulations differ for workers from EU member states and other immigrants. Workers from the EU are free to settle and work in Austria, while workers from non-EU member states are required to obtain a work permit. However, changes in citizenship occurred rarely during our sample period.

3.2 Workforce Composition in Austrian Firms

The employment of foreign workers in Austria is concentrated in few firms. Figure 2 shows the distribution of immigrant workers over firms for the year 2000: about 30 percent of firms employ less than 5 percent of immigrant workers, and 1 percent of firms employ more than 60 percent of immigrant workers. Hardly any firms employ only immigrant workers. However, there is considerable variation in the share of immigrant workers across firms. Figure 3 shows that about 20 percent of firms employ a workforce with a degree of fractionalization that is smaller than 0.05, and the distribution at intermediate levels of workforce fractionalization is approximately uniform. According to our model, fractionalization may be greater in one firm than another, if marginal productivity spill-overs from fractionalization are greater in this firm compared to the other, or if marginal spill-overs are the same. Workforce fractionalization may also differ across firms, if firms' labor supply constraints differ, for example, by region or industry.

Table 2 provides descriptive statistics for firms with below and above average fractionalization. Firms with a low fractionalization index pay on average higher wages, some €74 per day, compared to those with a more heterogeneous workforce, which pay on average €67 per day. Low-fractionalization firms employ a lower share of immigrant workers than firms with a high fractionalization index. They have a lower share of blue-collar workers than low-fractionalization firms, 48 vs. 74 percent, but a greater share of female workers, 36 vs. 32. Low-fractionalization firms are slightly larger, by about 10%.

Table 3 shows descriptive worker statistics for native Austrians and four groups of immigrant workers. These groups are the three largest groups of immigrants in our sample, Germans, workers from former Yugoslavia, and Turkey, and a residual group consisting of all other immigrant workers. Average wages are greatest for Austrians and Germans and about 20% less for the other groups. The average share of immigrant workers in the firm is about 12 percent for Austrians, almost 24 percent for Germans, about 33 percent for workers from ex-Yugoslavia, about 39 percent for Turkish workers, and about 32 percent for workers in the residual group of "other". This indicates that immigrants are more likely than natives to work together with other immigrant workers. The average fractionalization index, which is about 0.19 for natives and on average about 0.47 for immigrants, confirms this.[22]

Table 4 tabulates the average share of co-workers with whom workers of different origin work. The

[22] Fractionalization and the relative sizes of different groups are calculated for the entire firm, i.e., also including workers who are not sampled, in particular, women.

pattern shows that workers from the same country of origin tend to work together. The workforce of firms in which Austrians work consists on average of 92 percent of Austrian workers, 1 percent of German workers, 4 percent workers from ex-Yugoslavia, and roughly 2 percent Turkish and workers from other countries. In contrast, the average workforce in a firm of a Turkish worker consists only to about 47 percent of Austrians and some 39 percent of Turkish workers; the share of German workers is comparable to that for the typical Austrian worker, around 1 percent, and the share of workers from ex-Yugoslavia is greater at 11 percent. Workers from the same origin may tend to work together, if productivity spill-overs between them are positive. However, they may also tend to share common regions of residence, or industries, and may therefore be more likely to work with each other.

We can see from Table 4 that worker from different origin differ along other characteristics, too. For example, tenures for Austrians are about 8 years in comparison to about 6 years for immigrants; their labor market experience in Austria is with about 16 years almost twice as long as those of immigrants. Austrians, and Germans, are less likely to be blue-collar workers than immigrants. There are only minor differences between Austrians and immigrants in age, which is between 35-39 years on average across all groups, and the share of women in the firm, on average about 25%.

4 Empirical Evidence

4.1 Specification

We estimate the following empirical specification of wages to test our model:

$$w_{ijt} = \alpha + \beta S^{own}_{ijt} + F'_{jt}\gamma + X'_{ijt}\delta + \upsilon_{ijt}, \tag{9}$$

where w_{ijt} is the logarithm of the daily wage of worker i in firm j at time t. S^{own}_{ijt} is the share of co-workers in the firm with the same country of origin as worker i.[23] The coefficient, β, is a measure of productivity spill-overs across worker types. According to proposition 1, we expect that the wages of workers with a greater group share g_n are smaller compared to the wages of workers in smaller groups — conditional on birthplace heterogeneity in the firm and individual worker skills

[23] As firms' sectoral affiliation do not change over time, differences in sectors will be absorbed in the firms' fixed-effects. In order to consider differences between sectors more explicitly, we subtract from each wage the year's sectoral mean wage. Our results are virtually identical to the result obtained from undemeaned values, but for the magnitude of the fixed-effects. Those results are available at request.

— if spill-overs between workers from a different birthplace are positive ($\beta < 0$ if $f'(F) > 0$). In turn, we expect wages to be greater for workers in greater groups, if spill-overs between workers from a different birthplace are negative ($\beta > 0$ if $f'(F) < 0$). In the absence of spill-overs by birthplace ($f'(F) = 0$), we expect that wages do not depend on group size by birthplace.

F_{jt} is a vector that represents the spill-over function $f(F)$ as a function of workforce fractionalization in firm j at time t. We do not specify the functional form of $f(F)$ a priori but approximate the spill-over function by a polynomial of F. Note that $E(w_{ijt}|F_{jt}) = f(F_{jt})$, since the average wage in the firm is $\sum_n \sum_k w_{nk} g_{nk} = \sum_n \sum_k y_k g_{nk} + f(F)$ according to our model. We assume that the spill-over function is the same in all firms in the sample. However, we will allow for differences in the production structure of firms by also estimating effects separately for different subsamples of firms.

X_{ijt} is a vector of worker-, firm-, and time-specific characteristics. We include the worker characteristics of age and age squared, tenure at the firm and tenure squared, and overall labor market experience to control for individual observable skill (y_k). We also control for the size of the firm and the number of different birthplace groups employed at the firm. In addition, we include the composition of the workforce according to characteristics other than birthplace that could generate productivity spill-overs between workers for reasons unrelated to birthplace. (For example, if workers of different occupation or experience are complements or substitutes in production, independently of their birthplaces, and occupation or experience is correlated with birthplace.) We control for the share of blue collar workers, the share of female workers, the share of workers in four different age groups (aged 20-30, 30-40, 40-50, and 50-60), the share of workers with short tenure at the firm (fewer than 500 days), and the share of workers with short labor market experience (fewer than 1500 days). Finally, we also control for year indicators.

The error term takes the form $\upsilon_{ijt} = \pi_i + \phi_j + \epsilon_{ijt}$, the sum of a worker fixed-effect, π_i, a firm fixed-effect, ϕ_j, and a white noise residual ϵ_{ijt}. Worker fixed-effects serve to control for unobserved differences in individual productivity. Firm fixed-effects serve to control for unobserved differences in the production structure of firms and firm productivity, for example, due to differences in managerial ability. The estimation of equation (9) is based on Abowd, Kramarz and Margolis (1999) and identification is obtained by mobility of workers across firms.[24,25] As a robustness

[24]Due to the large number of workers and firms the estimation of firm and worker effects is computationally intensive. Estimation is based on a Stata module by Ouazad (2008) and standard errors are obtained from bootstrapping with 20 repetitions.

[25]The necessary assumption that permits identification of the unobserved fixed-effects requires that the error term ϵ_{ijt} is uncorrelated with any observable characteristic as well as with the worker and the firm fixed-effects

check, we also use instrumental variable estimates, which provide similar results.

4.2 Results

Table 6 presents the results from estimating equation (9). The dependent variable in all specifications is the deviation of the (daily) wage from the sector's average wage (in logs). All specifications control for the (log) of the number of workers employed, the number of different groups in the firm, the share of foreign workers in the firm, the share of female workers, the share of workers with less than 1500 days tenure, the share of workers who have been with the firm for less than 500 days, the share of blue-collar workers, shares of workers in different age groups (between 30 and 40, between 40 and 50, older than 50), the worker's tenure and tenure squared, his labor market experience, his age and age squared, and worker, firm, and year fixed-effects. We estimate standard errors by bootstrapping using 20 repetitions clustered on workers.

Our preferred specification is presented in column 6, where we use a quartic polynomial in fractionalization and the size of a worker's own group to model the effect of birthplace heterogeneity in the firm. (We do not obtain significant results for higher-oder polynomials.) The results of column 6 indicate that a quartic relation between fractionalization and wages is supported by our data and we plot the corresponding function in Figure 4. The results show that the wage effect of workforce fractionalization is positive for all values of fractionalization that we observe in our data (the maximum is 0.78). The estimates suggest that for values greater than 0.85 the relationship might be negative.

By including time-varying firm characteristics we account for the fact that workforce fractionalization by birthplace may correlate with other time-varying characteristics of the workforce that might also generate productivity spill-overs and may, therefore, affect wages. For example, it could be that workforces that are more heterogeneous with respect to birthplace are also more heterogeneous with respect to work experience or tenure. Then, if there are positive productivity spillovers between workers with little and more work experiences, or between workers with short and long tenures, the estimated wage effect of fractionalization will be biased upwardly. To address this concern, we include the share of blue collar workers, the share of female workers, the share of workers with little labor market experience, the share of workers with short tenure, and the shares of work-

(assumption of exogenous matching). However, the firm fixed-effects are only identified up to a normalizing constant (Abowd, Creecy and Kramarz (2002)). The correlation between the workers' fixed-effects and the firms' fixed effects, -0.12, and the correlation between a worker's fixed-effect and the mean of the co-workers' fixed components (De Melo, 2008), 0.25, are at the lower end of correlations typically found in empirical work.

ers in four age groups (20-30, 30-40, 40-50, 50-60) in the firm in our set of control variables. We find that our estimated coefficients hardly change with the inclusion of these additional workforce characteristics.[26] Hence, the estimated effects of workforce composition on wages extend beyond the changes in these other characteristics.

We additionally present different specifications to illustrate the sensitivity of results to changes in the specification of the estimating equation. The specification presented in column 1 models wages as a function of fractionalization, ignoring any effects that might arise from the size of own group. The estimated linear effect of fractionalization on wages is positive. In column 2, we estimate wages as a function of own group size only and find that group size impacts negatively on wages. Both findings suggest that in terms of our model, workers from different birthplaces are on average complements. In column 3, we include both group size and fractionalization in the set of controls and obtain qualitatively the same results. In the next three columns, we present the results from including higher-order polynomial terms of fractionalization. The non-linear wage effect of fractionalization implies that the effect of own group size may be non-linear as well, because smaller (larger) groups tend to work in firms with higher (lower) levels of fractionalization.[27] In particular, it implies that the effect of own group share may be decreasing in the group share. We therefore include the squared own group share in column 7. We find that the coefficient of the squared group share is negative as expected, but insignificant, and the coefficient of the group share now becomes insignificant, too. We therefore choose the specification in column 6 as our preferred specification.

In sum, we estimate that wages increase in the degree of workforce fractionalization and decrease in own group size on average; the effects of fractionalization are, however, non-linear. The estimated coefficients are stable across all specifications. We find that, on average, an increase in own group share by 0.1 index points decreases wages by about 0.2%.[28]

Our empirical estimates are based on the assumption that correlations between w_n and g_n are driven by exogenous changes in (aggregate) labor supply. However, if there is endogenous sorting of minority workers into high-productivity firms, the estimated effects will be biased. Endogenous sorting might arise, for example, because immigrant workers are more mobile than native workers and are therefore more likely to work in high-productivity firms, or because high-productivity firms demand more workers and are therefore more likely to employ immigrants if the labor supply of

[26] Results are available at request.

[27] The correlation coefficient between workforce fractionalization and worker group share is -0.7.

[28] This effect is comparable in size to other estimates of wage effects from changes in own group size, for example in Dustmann et al. (2011).

same-skill natives is scarce.[29] Moreover, according to our theory, smaller groups of workers may be employed more in firms where the productivity spill-overs from heterogeneity are greater. We address any such (time-invariant) issues by controlling for worker and firm fixed-effects in our estimations.[30]

In the Appendix in Table A.1, we demonstrate the sensitivity of our estimates to the inclusion of worker and firm fixed-effects. The estimates indicate a strong association of fractionalization with wages, which decreases with the inclusion of worker and firm fixed-effects. This indicates that there exists a considerable amount of unobserved heterogeneity which, if uncontrolled for, results in overestimated effects from workforce fractionalization. We also find a positive correlation between own group share and wages in the absence of worker fixed effects, which becomes negative once worker-fixed effects are controlled for. This indicates that there is substantial endogenous sorting of workers by group share. This may be because workers who belong to larger groups are better informed and move more into high-productivity firms, but it is also consistent with a theory of job search networks according to which workers with larger group shares are more likely to have been referred to the job and, if job referral is more efficient than other methods of job search, are also more likely to earn higher wages.[31] The coefficient of own group share remains negative and significant but becomes smaller when we additionally include firm fixed effects. This implies that a specific demand of high-productivity firms for minority workers may explain part but not all of our wage effect of own group size. We interpret our results as evidence that workers of different birthplace exert positive productivity spill-overs on each other, conditional on observable and time-invariant unobservable worker and firm characteristics.

However, omitted time-variant firm-specific characteristics that affect wages may be correlated with workforce composition at the firm. This could be the case, for example, if firms with positive labor demand shocks pay higher wages and, at the same time, employ more foreign workers, for whom group size is smaller on average. In this case, the OLS estimates for group size, for example, would be biased downwards. To address this concern, we include the share of foreign workers in the firm in all our specifications. If time-variant shocks do not systematically vary at the firm-group size level for given shares of foreign workers or are not related to wages, including this variable helps to identify the causal effect of workforce composition on wages. We find that the coefficient for the share of foreign workers is negative and significant, but the coefficients of the other explanatory

[29] In Austria, firms need to document a specific need for non-EU immigrant workers before they can be employed.

[30] Alternatively, we also use instrumental variable estimation, see section 4.3.

[31] See, for example, Dustmann et al. (2011).

variables hardly change when we include the share of foreigners in our set of controls (results available at request). This indicates that our results are not driven by systematic changes over time in the shares of foreign workers employed in firms.

Firms may systematically hire foreign workers in expansive periods who are a minority among the foreign worker population at the firm, or fire such workers in recessions. If growing firms pay higher wages and also hire their additional workers from the minority groups among a given share of foreign workers, then this may result in a negative correlation between wages and group size that is unrelated to productivity spill-overs. Dustmann et al. (2011) demonstrate the robustness of their results to the inclusion of firm-year fixed effects (in their Table 5), which suggests that a bias arising from this channel is not likely. We estimate the effects of workforce composition separately for stable, growing, and declining firm to address this concern. Stable firms are firms where the number of workers changed by not more than 10% between the first and the last year in the sample; growing firms are firms where the number of workers increased by more than 10%; and declining firms are firms where the number of workers decreased by more than 10%.[32]

Columns 1-3 in Table 7 show the results for stable, growing, and declining firms. We find that the coefficients of fractionalization are statistically significant in each subsample. Figure 5 plots the estimated spill-overs which are similar to the one obtained for all firms, but smaller in growing and declining firms compared to stable firms. Table 7 also shows that the effect of own group size is negative in each subsample. This suggests that effects do not result from a systematic hiring or firing of workers from small groups in growing or declining firms.

In our econometric model, we assume that the spill-over function $f(F)$ is the same across firms and productivity-relevant differences between firms are captured by firms' fixed-effects. However, the degree of complementarity between workers of different birthplace (as measured via $f(F)$) may be different in firms, if production structures are different. For example, if positive productivity spill-overs arise from complementarities in the performed tasks of workers, we expect that the effects of fractionalization are smaller in firms where workers perform more homogeneous tasks such as in, for example, firms with a large share of factory workers. Similarly, if positive spill-overs arise from sharing a common language or business culture, the effects of fractionalization may be smaller in firms where communication within the firm is important such as, for example, firms in the service sector.

[32] Ideally, we would include an additional term in our econometric specification where we interact the firm's indicator variable with the time indicator, $\eta_{jt} = \phi_j \times \delta_t$, similar to Dustmann et al. (2011). However, since we only measure workforce fractionalization once per firm and year in our data, we cannot control for this interaction term directly.

Table 7 reports results from stratifying our sample into subsamples of firms by the share of blue-collar workers (columns 4 and 5), and by sector (columns 6 and 7). Figures 6-7 plot the corresponding spill-over functions. They show that the pattern is similar to the pattern for the full sample of firms. However, the wage effects of fractionalization are greater, at least at low levels of fractionalization, in firms with a low share of blue-collar workers compared to firms with a large share of blue-collar workers (Figure 6). They are very similar in firms that operate in the service sector and in the manufacturing sector (Figure 7). The marginal effect of own group share is negative in all subsamples.

4.3 Instrumental variable estimation

Since the assumption of exogenous sorting might be violated, we also estimate the effect of fractionalization on wages with instrumental variables. The use of an appropriate instrument would allow to correct for the endogeneity of fractionalization. Following the literature on the wage effects of immigration, we use the deviation of actual versus predicted shares of immigrants ('shift-share') (Card, 1999; Cutler, Glaeser and Vigdor, 2008). In addition, we also instrument the period's number of immigrant workers by past values, a strategy employed by e.g., Dustmann et al. (2011).

The shift-share instrument is constructed from the nation-wide share of each birthplace group in 1980. We calculate, for each birthplace-firm-group, the growth that this group experienced nationally in the ten years prior to the year under consideration. The instrument uses the change in birthplace diversity that does not depend on the actual flow of workers into a firm but is based on the overall change in the population. Because fractionalization is highly correlated with firm fixed-effects (we only have annual observations), we cannot use both instrumental variables and firm fixed-effects in the first stage specifications.

The estimation results for both instruments are tabulated in Table A.2. Sectoral indicator variables are defined according to the Statistical Classification of Economic Activities in the European Community (NACE). This classification system consists of a 6 digit code that summarizes economic activity at different levels and our sectoral indicators uses the classification at the group level.

Our first stage statistics (Cragg-Donald F-statistics) indicate that there is substantial correlation between the instrument and the instrumented variables (fractionalization and the share of own group). The estimated coefficients remain qualitatively the same but are (in absolute terms) greater compared to those obtained from the two-way fixed effects estimates.[33] Given the large standard

[33] For example, estimates suggest that already fractionalization values above 0.2 result in lower wages.

errors and the low correlation between the workers' fixed-effects and the firms' fixed effects, we prefer the two-way fixed approach results to the instrumental variables approaches.

5 Conclusion

Co-worker characteristics matter for wage outcomes, if productivity spill-overs exist between different types of workers. We develop a structural framework, based on a theoretical model of optimal worker assignment, which provides a unified theory for wage effects of workforce diversity and own group size, and contributes to existing empirical findings, which have focused on reduced-form estimates for either workforce diversity or own group size but have not considered potential links between the two.

We argue that workforce composition may be endogenous and vary systematically with the degree of productivity spill-overs depending on the production structure of firms. Wages are predicted to decrease (increase) in own group size in the presence of positive (negative) spill-overs, ceteris paribus. In our data, we find that greater workforce diversity and smaller own group shares result in higher wages on average. This suggests that workers of different birthplace are complements in production, consistent with our theoretical model.

Regarding the wage effects of workers' own group size, the literature suggests two other explanations apart from effects on productivity: discrimination and networks used in the job finding process. They predict a correlation between own group size and wages that is due to common driving factors, such as preferences of employers for workers from certain groups (discrimination), or the probability of workers to be referred to the job (job networks). While such links may very well exist, they do not, however, suggest any systematic relationship between workforce fractionalization and wages. Our wage effect, therefore, seems to exist independently of those other possible effects. Our findings suggest that accounting for the production structure of firms may be important when estimating effects of co-worker characteristics on worker productivity.

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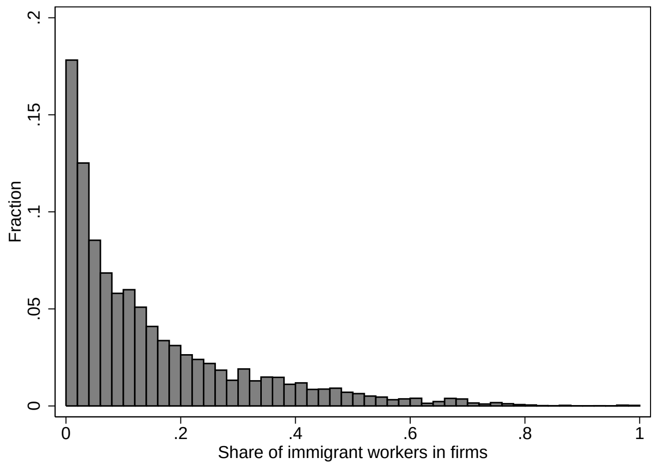
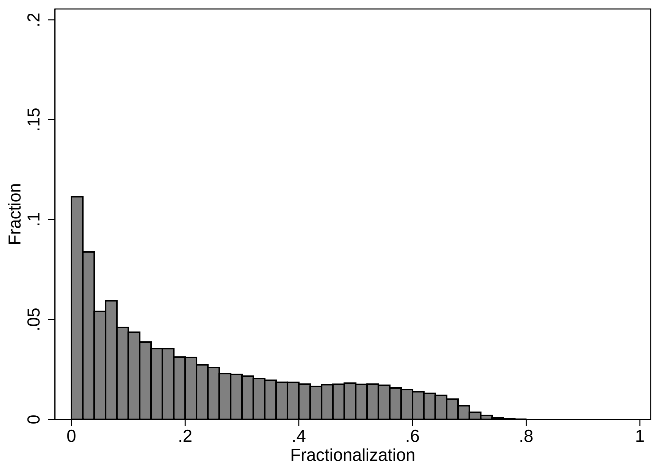
6 Graphs and Tables

Figure 2: Distribution of the share of immigrant workers in firms.



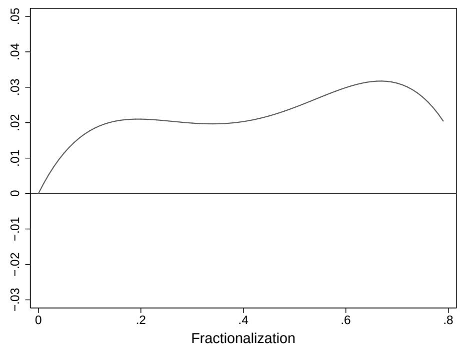
NOTES: Shares of immigrant workers in Austrian firms in 2000. Firms with fewer than 10 employees excluded. N=79,944 firms.

Figure 3: Distribution of the degree of fractionalization in firms.



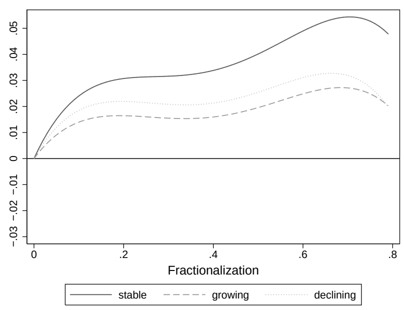
NOTES: Degree of workforce fractionalization in Austrian firms in 2000. Firms with fewer than 10 employees excluded. N=79,944 firms.

Figure 4: Estimated spill-over function $f(F)$.



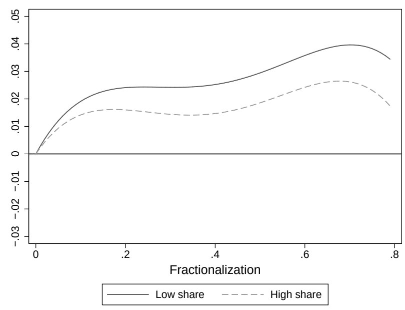
Note: Estimated wages based on polynomial specification of $f(F)$. The specification is as shown in Table 6, column 6. Note that the maximum value of the fractionalization index in our sample is 0.78.

Figure 5: Stable, growing and declining firms.



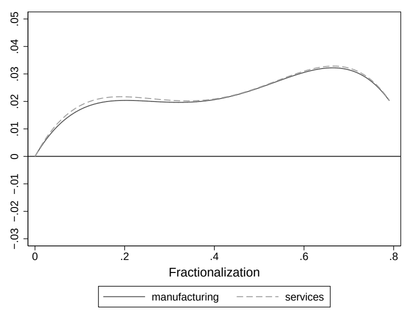
Note: Fractionalization as a function of coefficients in Table 7, columns (1)-(3).

Figure 6: Low and high share of blue-collar workers.



Note: Fractionalization as a function of coefficients in Table 7, columns (4) and (5).

Figure 7: Manufacturing and service sector.



Note: Fractionalization as a function of coefficients in Table 7, columns (6) and (7).

Table 1: Workers' migration background (% of working population).

	Official statistics		Sample
	citizenship	country of birth	
Native	89.69	85.41	85.61
Immigrant	10.31	14.59	14.39
Europe:	9.36	12.79	13.13
former Yugoslavia	4.71	5.43	6.05
EU-27-States:	2.86	4.96	4.34
Germany	1.01	1.70	1.32
Poland	0.37	0.68	0.63
former Czechoslovakia	0.27	0.62	0.56
Hungary	0.22	0.40	0.56
Turkey	1.61	2.07	2.40
America	0.16	0.28	0.18
Africa:	0.21	0.42	0.31
Nigeria	0.04	0.05	0.04
Oceania	0.02	0.03	0.02

NOTES: Working population by citizenship/country of birth in 2001. Census 2001 data, Statistics Austria, selected countries.

Table 2: Firm characteristics, by low and high fractionalization.

	wage	share female	share blue	share foreign	firmsize	number of firms
low fractionalization	64.9	0.36	0.50	0.04	144.9	8516
	(26.1)	(0.26)	(0.35)	(0.06)	(159.5)	
high fractionalization	63.4	0.32	0.75	0.30	121.2	6829
	(26.6)	(0.26)	(0.25)	(0.17)	(126.9)	

NOTES: Mean values of the years 1990-2005. Standard errors in parentheses. Wages are daily wages in €.

Table 3: Worker characteristics, by workers' country of birth.

	wage	fraction-alization	share own	share foreign	age	exper-ience	tenure	share blue	share female	number of observations
Austrian	72.2	0.18	0.89	0.11	35.7	14.9	7.6	0.60	0.26	1,273,924
	(27.1)	(0.17)	(0.13)	(0.13)	(11.6)	(8.7)	(7.6)	(0.31)	(0.20)	
Germany	82.1	0.34	0.08	0.24	37.6	7.5	4.2	0.58	0.32	12,618
	(29.7)	(0.21)	(0.13)	(0.20)	(10.9)	(8.0)	(6.0)	(0.34)	(0.21)	
Yugoslavia	60.0	0.42	0.20	0.32	37.5	10.7	4.7	0.77	0.23	97,925
	(18.9)	(0.17)	(0.15)	(0.19)	(10.9)	(8.0)	(6.0)	(0.19)	(0.21)	
Turkey	58.5	0.48	0.19	0.37	34.4	10.3	4.2	0.77	0.23	52,267
	(17.9)	(0.16)	(0.15)	(0.19)	(10.6)	(7.4)	(5.6)	(0.17)	(0.20)	
Other	64.8	0.41	0.15	0.32	38.3	7.6	3.7	0.70	0.28	34,380
	(24.4)	(0.19)	(0.16)	(0.21)	(9.5)	(5.5)	(4.4)	(0.27)	(0.21)	
Total	70.8	0.22	0.79	0.14	35.8	14.3	7.2	0.62	0.25	1,471,114
	(26.7)	(0.19)	(0.27)	(0.16)	(11.5)	(8.7)	(7.4)	(0.31)	(0.20)	

NOTES: Mean values of the years 1990-2005. Standard deviation in parentheses.

Table 4: Share of co-workers, by birthplace.

	Share of co-workers from					Mean
	Austria	Germany	Yugoslavia	Turkey	Other	Fractionalization
Austrians	0.89	0.01	0.05	0.02	0.03	0.18
Germans	0.76	0.08	0.07	0.04	0.05	0.34
Yugoslavians	0.68	0.01	0.2	0.06	0.04	0.42
Turks	0.63	0.01	0.13	0.19	0.05	0.48
Other	0.68	0.02	0.1	0.05	0.15	0.41
Overall	0.86	0.01	0.07	0.03	0.03	0.22

NOTES: Workers' background in Austrian firms between 1990 and 2005. Firms with less than 50 employees excluded. N=1,471,114.

Table 5: Descriptive statistics: main sample and subsamples.

Variables	Definition	Total	Stable	Firmsize Grow.	Decl.	Share blue collar Low	High	Sector Serv.	Manuf.
daily wage	gross yearly wage divided by number of days employed	70.8	69.5	71.8	70.6	75.6	66.3	68.7	74.1
		(26.7)	(25.8)	(26.9)	(26.6)	(29.1)	(23.3)	(26.8)	(26.4)
fractionalization	Herfindahl div. index by workers' birthplace (16 cat.)	0.22	0.20	0.24	0.21	0.15	0.28	0.22	0.21
		(0.19)	(0.19)	(0.19)	(0.19)	(0.15)	(0.21)	(0.19)	(0.18)
share own	share of workers with the same birthplace in the firm	0.79	0.82	0.77	0.80	0.85	0.73	0.79	0.80
		(0.27)	(0.26)	(0.28)	(0.27)	(0.24)	(0.29)	(0.27)	(0.27)
share foreign	non-Austrian workers as a share of all workers in the firm	0.14	0.13	0.16	0.14	0.09	0.19	0.15	0.13
		(0.16)	(0.16)	(0.16)	(0.15)	(0.1)	(0.18)	(0.16)	(0.14)
number of groups	number of groups with different birthplace in the firm	5.7	4.7	5.8	5.7	5.6	5.8	5.6	6.0
		(2.9)	(2.6)	(2.9)	(2.9)	(3)	(2.8)	(3)	(2.7)
age	age of worker	35.8	36.3	34.8	36.1	36.3	35.4	35.6	35.9
		(11.5)	(11.6)	(11.2)	(11.6)	(11.6)	(11.5)	(11.5)	(11.5)
tenure	worker's tenure in firm (in years)	7.2	7.1	5.6	7.7	7.7	6.7	6.4	8.4
		(7.4)	(7.3)	(6.4)	(7.7)	(7.6)	(7.2)	(7.1)	(7.8)
experience	worker's labour market experience (in years)	14.3	14.7	13.5	14.5	14.8	13.8	13.7	15.1
		(8.7)	(8.7)	(8.6)	(8.8)	(8.9)	(8.6)	(8.6)	(8.8)
share female	share of female workers in firm	0.25	0.23	0.24	0.26	0.33	0.18	0.27	0.22
		(0.2)	(0.2)	(0.2)	(0.2)	(0.19)	(0.19)	(0.22)	(0.16)
share experienced	share of workers more than 1500 days of work experience	0.20	0.19	0.22	0.20	0.20	0.21	0.22	0.18
		(0.12)	(0.12)	(0.12)	(0.12)	(0.11)	(0.13)	(0.14)	(0.08)
share blue	share of blue collar workers in firm	0.62	0.63	0.61	0.62	0.38	0.85	0.56	0.70
		(0.3)	(0.32)	(0.31)	(0.3)	(0.26)	(0.07)	(0.34)	(0.22)
share short	share of of workers with less than 500 days of tenure in firm	0.28	0.29	0.33	0.27	0.26	0.30	0.32	0.22
		(0.18)	(0.19)	(0.19)	(0.17)	(0.16)	(0.19)	(0.19)	(0.12)
firmsize	number of workers in firm	300.5	208.0	256.8	316.3	313.5	288.2	271.8	354.1
		(240.3)	(171.9)	(217.2)	(246.2)	(246.2)	(233.8)	(229.2)	(255.1)
share age 16-29	share of workers aged 16-29 in firm	0.37	0.36	0.41	0.36	0.37	0.38	0.38	0.36
		(0.15)	(0.15)	(0.15)	(0.14)	(0.15)	(0.14)	(0.16)	(0.12)
share age 30-39	share of workers aged 30-39 in firm	0.27	0.26	0.28	0.27	0.27	0.27	0.27	0.27
		(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
share age 40-49	share of workers aged 40-49 in firm	0.21	0.22	0.20	0.22	0.21	0.22	0.21	0.22
		(0.07)	(0.08)	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)	(0.07)

NOTES: Sample period 1990-2005. Firms with less than 50 employees and more than 1000 employees excluded. N=1,471,114 (full sample). Stable/growing/declining firms are firms with employment changes between -10% and +10%/more than 10%/less than 10% between 1995 and 2005 (or the first and last year in the sample, respectively). Firms with a low/high share of blue collar workers are firms with a share of blue collar workers that is lower/higher than the median share (median share of blue collar in our sample is 0.7). Manufacturing/service firms are firms in NACE-sections 5-19/20-25.

Table 6: Effect of workforce heterogeneity on workers' wages.

	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)
Fractionalization	0.042***		0.031**	0.050***	0.152***	0.292***	0.300***
	(0.013)		(0.013)	(0.017)	(0.018)	(0.028)	(0.041)
Fractionalization^2				-0.055***	-0.433***	-1.399***	-1.540***
				(0.017)	(0.054)	(0.152)	(0.175)
Fractionalization^3					0.385***	2.652***	2.915***
					(0.053)	(0.317)	(0.358)
Fractionalization^4						-1.655***	-1.805***
						(0.216)	(0.246)
Share own group		-0.024***	-0.020***	-0.020***	-0.020***	-0.020***	0.023
		(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.035)
Share own group^2							-0.046
							(0.035)
R-squared	0.854	0.837	0.854	0.854	0.854	0.854	0.854

NOTES: N=1,471,114; sample restricted to firms of 50-1000 workers. The dependent variable is the logarithm of daily wages, deflated to 2000 prices, as deviations from the sectoral mean. ***, **, and * indicate significance at the 1, 5, and 10% level. All specifications control for firm-fixed and person-fixed effects. All estimations control for the number of different groups, the (log) of the number of workers employed, the share of foreign workers in the firm, the share of female workers, the share of workers with less than 1500 days overall employment, the share of workers who have been with the firm for less than 500 days, the share of blue-collar workers, shares of workers aged less than 30, between 30 and 40, and between 40 and 50, the worker's tenure and tenure squared, his labor market experience, age and age squared, and year indicators. Standard errors are obtained by bootstrapping (20 repetitions).

Table 7: Effect of workforce heterogeneity on workers' wages: subsamples.

				Share of blue-collar workers			
	Stable	Growing	Declining	Low	High	Services	Manufacturing
Fractionalization	0.376***	0.232***	0.305***	0.301***	0.242***	0.305***	0.279***
	(0.057)	(0.026)	(0.013)	(0.020)	(0.015)	(0.014)	(0.022)
Fractionalizationˆ2	-1.641***	-1.123***	-1.463***	-1.325***	-1.226***	-1.474***	-1.332***
	(0.337)	(0.150)	(0.075)	(0.112)	(0.089)	(0.082)	(0.133)
Fractionalizationˆ3	3.008***	2.136***	2.782***	2.400***	2.379***	2.809***	2.553***
	(0.734)	(0.325)	(0.163)	(0.271)	(0.187)	(0.177)	(0.306)
Fractionalizationˆ4	-1.818***	-1.323***	-1.745***	-1.437***	-1.493***	-1.760***	-1.611***
	(0.516)	(0.228)	(0.115)	(0.210)	(0.127)	(0.122)	(0.228)
Share own group	-0.013***	-0.020***	-0.021***	-0.015***	-0.025***	-0.020***	-0.019***
	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	63,362	290,551	1,117,201	716,727	754,387	865,614	518,295
R-squared	0.852	0.851	0.855	0.876	0.825	0.857	0.850

NOTES: Sample restricted to firms of 50-1000 workers. The dependent variable is the logarithm of daily wages, deflated to 2000 prices. ***, **, and * indicate significance at the 1, 5, and 10% level. All estimations control for person- and firm fixed effects, the number of different groups, the (log) of the number of workers employed, the share of foreign workers in the firm, the share of female workers, the share of workers with less than 1500 days overall employment, the share of workers who have been with the firm for less than 500 days, the share of blue-collar workers, shares of workers aged less than 30, between 30 and 40, and between 40 and 50, the worker's tenure and tenure squared, his labor market experience, age and age squared, and year indicators. Standard errors are obtained by bootstrapping (20 repetitions). Change in firmsize between first and last year in sample, stable: less than 10 percent change, growing: firmsize increased by more than 10 percent, declining: firmsize decreased by more than 10 percent.

A Appendix

A.1 Additional Tables

Table A.1: Unobserved worker and firm characteristics.

	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)
Fractionalization	1.298***	0.796***	0.379***	0.292***
	(0.042)	(0.038)	(0.043)	(0.016)
Fractionalizationˆ2	-4.239***	-3.207***	-1.126***	-1.399***
	(0.239)	(0.206)	(0.236)	(0.141)
Fractionalizationˆ3	8.465***	5.947***	2.345***	2.652***
	(0.520)	(0.441)	(0.514)	(0.311)
Fractionalizationˆ4	-5.287***	-3.607***	-1.456***	-1.655***
	(0.369)	(0.310)	(0.367)	(0.212)
Share own group	0.153***	-0.041***	0.153***	-0.020***
	(0.003)	(0.008)	(0.003)	(0.007)
Person fixed-effects	no	yes	no	yes
Firm fixed-effects	no	no	yes	yes
R-squared	0.428	0.503	0.565	0.854

NOTES: N=1,471,114; sample restricted to firms of 50-1000 workers. The dependent variable is the logarithm of daily wages, deflated to 2000 prices, relative to sectoral mean. ***, **, and * indicate significance at the 1, 5, and 10% level. All estimations control for the number of different groups, the (log) of the number of workers employed, the share of foreign workers in the firm, the share of female workers, the share of workers with less than 1500 days overall employment, the share of workers who have been with the firm for less than 500 days, the share of blue-collar workers, shares of workers aged less than 30, between 30 and 40, and between 40 and 50, the worker's tenure and tenure squared, his labor market experience, age and age squared, and year indicators. Standard errors in models (1)-(3) are clustered on workers; standard errors of model (4) are obtained by bootstrapping (20 repetitions).

Table A.2: IV estimates.

	IV predict	IV lagged
Fractionalization	0.671***	0.571**
	(0.249)	(0.239)
Fractionalizationˆ2	-4.863***	-10.800***
	(1.473)	(1.409)
Fractionalizationˆ3	11.438***	25.246***
	(3.401)	(3.254)
Fractionalizationˆ4	-8.626***	-20.811***
	(2.532)	(2.459)
Share own group	-0.065***	-0.269***
	(0.021)	(0.021)
Observations	1,469,798	1,469,798
R-squared	0.512	0.486
Number of sectoral indicators	240	240
Person fixed effects	yes	yes
Firm fixed effects	no	no
First stage F-Statistics		
Fractionalization	2197.85	3691.59
Fractionalizationˆ2	986.16	1534.32
Fractionalizationˆ3	1920.88	2990.32
Fractionalizationˆ4	2148.49	3448.73
Share own group	2859.58	4304.88
Weak-identification test		
Cragg-Donald F-statistic	129.33	121.83

NOTES: N=1,471,114; sample restricted to firms of 50-1000 workers. The dependent variable is the logarithm of daily wages, deflated to 2000 prices. ***, **, and * indicate significance at the 1, 5, and 10% level. All specifications control for person-fixed effects. All estimations control for the number of different groups, the (log) of the number of workers employed, the share of foreign workers in the firm, the share of female workers, the share of workers with less than 1500 days overall employment, the share of workers who have been with the firm for less than 500 days, the share of blue-collar workers, shares of workers aged less than 30, between 30 and 40, and between 40 and 50, the worker's tenure and tenure squared, his labor market experience, age and age squared, and year indicators. Standard errors are obtained by bootstrapping (20 repetitions).

A.2 Undemeaned estimation results

This appendix provides additional material for the editors and referees. It is available on request or for an online appendix but not intended for a printed copy.

Table A.3: Effect of workforce heterogeneity on workers' wages (OLS-estimates).

	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	
Fractionalization	0.044***		0.032**	0.051***	0.150***	0.294***	0.304***
	(0.013)		(0.013)	(0.017)	(0.017)	(0.028)	(0.041)
Fractionalizationˆ2				-0.054***	-0.423***	-1.410***	-1.554***
				(0.017)	(0.054)	(0.151)	(0.175)
Fractionalizationˆ3					0.376***	2.691***	2.960***
					(0.053)	(0.317)	(0.358)
Fractionalizationˆ4						-1.690***	-1.844***
						(0.216)	(0.247)
Share own group		-0.024***	-0.020***	-0.020***	-0.020***	-0.020***	0.021
		(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.035)
Share own groupˆ2							-0.044
							(0.035)

NOTES: N=1,471,114; sample restricted to firms of 50-1000 workers. The dependent variable is the logarithm of daily wages, deflated to 2000 prices. ***, **, and * indicate significance at the 1, 5, and 10% level. All specifications control for firm-fixed and person-fixed effects. All estimations control for the number of different groups, the (log) of the number of workers employed, the share of foreign workers in the firm, the share of female workers, the share of workers with less than 1500 days overall employment, the share of workers who have been with the firm for less than 500 days, the share of blue-collar workers, shares of workers aged less than 30, between 30 and 40, and between 40 and 50, the worker's tenure and tenure squared, his labor market experience, age and age squared, and year indicators. Standard errors are obtained by bootstrapping (20 repetitions).