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Cultural diversity and plant-level productivity

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Abstract

Using comprehensive data for German establishments, we estimate plant-level production functions to analyze if "cultural diversity" affects total factor productivity. We distinguish diversity in the establishment's workforce and in the aggregate labor force of the region where the plant is located. We find that a larger share of foreign workers – either in the establishment or in the region – does not affect productivity. However, there are spillovers associated with the degree of fractionalization of the group of foreigners into different nationalities. The aggregate level is, quantitatively, at least as important for productivity as the workforce composition inside the establishment.

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Keywords: Cultural diversity, plant-level productivity, knowledge spillovers

JEL-class.: R23, J21, J31

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1. Introduction

What are the economic effects of "cultural diversity"? This question has recently attracted vast attention in the economics literature and in related disciplines, as the populations in modern advanced societies became substantially more heterogeneous along such dimensions as national origin, ethnicity, race, native languages, etc. Some of this research has been conducted at a very micro level. Those studies investigate, for example, if the overall performance of a team of individuals is fostered by the heterogeneity of the team members' cultural backgrounds.[1] Other studies look at aggregate units – cities, regions, or even countries – and address if growth and welfare are fostered by the cultural diversity in the respective populations.[2]

Surprisingly little is known, however, about the impact of diversity at a crucial level for economists: the firm. Using comprehensive and highly disaggregated German plant-level data, we analyze in this paper if a culturally more diverse mix of workers affects plant-level productivity. Furthermore, the current literature has so far only addressed the micro and the aggregate level impacts of diversity separately. We consider them jointly in order to study which level is more important. We explicitly distinguish cultural diversity within the establishment's workforce (the micro level) and in the labor force of the region where the respective plant is located (the aggregate level). This distinction matters a lot in the data: We observe heterogeneous plants, employing a diverse mix of foreign workers from different countries, which are located in regions with a rather homogeneous aggregate labor force; vice

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[1] A recent example is Kahane et al. (2012), who study the performance of hockey teams and focus on the impact of the team members' diversity. Further examples include Watson et al. (1993), Richard (2000), Hamilton et al. (2003, 2012), Ellison et al. (2010), Hoogendorn and van Prag (2012), and others. Horwitz and Horwitz (2007) provide a meta-study on the impact of diversity on team performance.

[2] Ottaviano and Peri (2005, 2006) have studied the impact of cultural diversity across US metropolitan areas. Related analyses at the regional or city level, also for other countries, have been conducted by Sparber (2009, 2010), Audretsch et al. (2010), Nathan (2011), or Suedekum et al. (2013). At an even higher level of aggregation, Spolaore and Wacziarg (2009) and Easterly and Levine (1997) address if diversified countries tend to grow faster, while Ortega and Peri (2013) show that the positive impact of diversity on income mainly stems from increasing TFP. Alesina and La Ferrara (2005) present a survey about the impact of ethnic diversity on economic outcomes at different aggregation levels.

versa, we observe rather homogeneous plants located in highly diverse regional environments. The main aim of this paper is then to shed light on two important questions: does cultural diversity matter for plant-level productivity, and in particular, at which level – the micro or the aggregate one – does cultural diversity matter more?

Theory makes ambiguous predictions about the direction of the impact. In the managerial literature, which traditionally emphasizes the micro level, diversity is sometimes called a "double-edged sword" (Horwitz and Horwitz 2007). On the one hand, diversity among a team of co-workers may raise productivity because of skill complementarities. When workers from different backgrounds interact at the workplace, they all bring along their various experiences and problem-solving abilities, which in turn can give rise to substantial synergies and innovative new ideas (Lazear 1999). On the other hand, diversity may also give rise to difficulties: Misunderstandings due to language problems may raise transaction costs, incompatible expectations or cultural traditions may reduce team performance, and so on.

The economic geography literature has traditionally emphasized effects at the metropolitan or regional level (Ottaviano and Peri, 2005, 2006). The key idea here is that the productivity of a firm may not only be affected by interactions within the own boundaries, but that other firms in the city or, more generally, the local business environment also matter via various forms of localized knowledge spillovers (Glaeser et al. 2011). In our context, this means that plant-level productivity may also depend on cultural diversity at the aggregate (regional) level, where both positive and negative impacts stem from different types of externalities.[3]

Ultimately, it is thus an empirical question if there are positive or negative spillover effects from cultural diversity on the establishments' productivity, and if these externalities arise

[3] See Ottaviano and Peri (2005, 2006) for a theoretical model that explicates different externalities from cultural diversity, some of which arise within the firm and others at the local level. Also see Alesina and La Ferrara (2005) and Alesina et al. (2013) for a review of various mechanisms why cultural diversity may affect productivity positively or negatively. These mechanisms may be due to technological or pecuniary externalities, and include communication spillovers (more frequent face-to-face interactions with a diverse set of people), deeper specialization if different cultural groups provide complimentary inputs, transaction costs if communication barriers hamper supplier relationships, and others.

mainly within the firm or at the regional level. To the best of our knowledge, this is the first paper to address these questions. We obtain two main findings: First, the total share of foreign employees in the plant's own workforce has no significant impact on productivity. For a given size of the group of foreign workers, however, we find that stronger fractionalization into different nationalities induces notable productivity gains, particularly strongly within larger manufacturing plants and less so in service establishments.[4] Second, a more diversified regional environment with foreigners from many different backgrounds (not with more foreigners per se) induces substantial productivity gains for the local firms, both in manufacturing and in services. This impact at the aggregate level is, quantitatively, at least as important as the micro level effects of diversity, and it turns out to be very robust across many different subsamples of firms. Summing up, although we cannot identify the precise mechanisms *why* cultural diversity affects productivity, we find that it *does* affect productivity in such a way that positive impacts outweigh possible negative ones on balance.

The main conceptual challenge for our empirical analysis is selectivity of firms and workers at both levels. First, if good firms and a diverse mix of foreign workers sort into particular cities for some other, unobserved reasons, this can lead to a spurious correlation and would not capture the causal effect of aggregate diversity on plant-level productivity. To address this endogeneity concern, we adopt an estimation strategy similar as in the seminal paper by Moretti (2004). He estimates plant-level production functions focusing on the external effect of aggregate human capital in the region on productivity at the disaggregate level. To address the sorting problem for high-skilled workers, he develops a fixed effects estimation approach and only exploits the variation across plants within industries and locations and years.

In contrast to Moretti (2004), we aim to identify also *within*-plant externalities, since we want to explore if plant-level productivity is affected mainly by cultural diversity at the micro or the

[4] Similar as in Alesina et al. (2013) and Suedekum et al. (2013) we distinguish size and fractionalization effects of diversity, where the former are captured by the total share of foreigners, and the latter by a Herfindahl-type index (see below). Notice that both other studies are conducted only at the aggregate level, while ours is the first paper to study the effects of diversity at the firm and at the regional level.

aggregate level. Within locations, however, a second endogeneity problem arises as there may also be selectivity in the matching of particular firms and foreign workers due to unobservable characteristics. Plant-fixed effects can partly address this concern, by capturing time-invariant omitted variables. Yet, results would still be biased if there are time-varying shocks simultaneously affecting productivity and diversity. The conventional instrumental variable solution to this problem is practically infeasible in our context, as we would need external instruments for diversity both at the plant and the regional level. We therefore adopt a dynamic estimation strategy using System GMM methods popularized by Blundell and Bond (2000) for the estimation of plant-level production functions. This approach takes into account unobserved productivity shocks in addition to plant-specific fixed effects and persistence in productivity, using internal instruments constructed from time lagged variables. Moreover, for the aggregate level of cultural diversity, we add widely used external instruments such as the "shift-share" index by Card (2005), and find that it gives rise to very similar results as in our baseline.

Our paper adds to the literature on the economic effects of cultural diversity in various respects. First, previous studies have either emphasized the micro level impacts of diversity in small teams (e.g., hockey teams), or the aggregate impacts at the country, regional or city level. Our results show that plant-level productivity is affected by cultural diversity on both levels: the workforce composition inside the establishment matters, but diversity also seems to have productivity enhancing effects via an aggregate effect on local business environments. Studies which focus only on the aggregate or on the micro level are thus likely to miss an important part of the overall picture.

Second, our paper is among the first to analyze the effects of cultural diversity on plant-level productivity. The related study by Parrotta et al. (2010) finds no productivity effects of ethnic workforce diversity among Danish firms. Boeheim et al. (2012) find, however, that Austrian firms seem to benefit from complementarities between workers from different birthplaces.

Our results on the mixed evidence for within-plant externalities are thus broadly in line with this literature. Importantly, both studies do not address whether spillovers from diversity arise mainly at the micro or at the aggregate level, whereas our results suggest that the latter dimension is quantitatively rather important. Other studies at the establishment or firm level mostly focus on other outcomes such as patenting activities (see Ozgen et al. 2011, Chellaraj et al. 2008), thereby contributing to the related discussion how diversity affects innovation (also see Niebuhr 2010 and Nathan 2011).

Finally, our study emphasizes that productivity spillovers come from the *diversification*, not from the *size* of the group of foreign workers. A larger share of foreign employees – either inside the establishment or in the region – does not spur productivity gains. What matters is the fractionalization of foreign workers into different nationalities. This finding, which is consistent with the aggregate-level results for birthplace diversity by Alesina et al. (2013), has important implications for the design of migration policies, as will be discussed below.

The rest of this paper is organized as follows. In section 2 we discuss our empirical strategy, and in section 3 we describe our data. Section 4 explains the specification of our variables, and section 5 gives a descriptive overview. Our main empirical results and several robustness checks are presented in Section 6. Section 7 concludes the paper.

2. Estimation approach

The starting point of our analysis is a log-linearized Cobb-Douglas specification of a plant-level production function, with plant i's value added in period t (denoted VA_{it}) as the output variable, and physical capital (K_{it}), high skilled labor (H_{it}) and less skilled labor (L_{it}) as standard inputs.

(1) $$\ln VA_{it} = \beta_1 \ln K_{it} + \beta_2 \ln H_{it} + \beta_3 \ln L_{it} + \ln A_{it}$$

Cultural diversity is then assumed to shift the plants' total factor productivity A_{it}:

(2) $\ln A_{it} = \theta_1 Div_{it} + \theta_2 Div_{(-i)rt} + u_{it}$

Notice that we explicitly allow for spillover effects from cultural diversity at the micro (plant) and at the aggregate (regional) level. The degree of cultural diversity of the plant's own workforce is denoted by Div_{it} , and $Div_{(-i)rt}$ captures the diversity of the labor force in the region where the respective plant is located. Below we discuss the precise measures for cultural diversity in greater detail. As the index (−i)rt in (2) indicates, when we calculate the diversity for region r we exclude the i^{th} plant's own contribution to the aggregate diversity in order to separate these two levels. The term u_{it} includes further plant-specific or regional characteristics: it may contain plant-specific fixed effects a_i, serial correlation over time, and an idiosyncratic error term ε_{it}.

The idea behind this specification is simple: if the diversity among the plants' own workforce has a positive (negative) external effect on productivity, we should observe that plants with a heterogeneous body of workers will produce more (less) output with the same amount of inputs – conditional on further characteristics – than firms where the workforce is more homogeneous in terms of cultural backgrounds. Similarly, if there are positive (negative) localized externalities from the composition of the regional workforce, we should observe a higher (lower) level of productivity of plants located in regions with a higher degree of diversity, again controlling for other characteristics.

The main challenge in the estimation of (1) and (2) is the potential bias from unobserved factors that simultaneously drive productivity and cultural diversity. This problem can arise on two levels. First, plants with high (low) productivity and a diverse body of foreign-born workers may be located in particular cities for reasons unrelated to spillovers from cultural diversity. If there is such sorting of firms and workers across space due to unobservable characteristics, we may end up with a spurious positive (negative) correlation between the region-specific diversity levels and the measured productivity levels of the plants in those locations. Second, within regions, a culturally heterogeneous workforce of foreign-born workers may match more frequently with good (bad) plants for some unrelated reasons, in which case we would obtain an upward (downward) biased coefficient for the plant's own diversity in the production function.

The former endogeneity issue is somewhat similar to the one discussed by Moretti (2004) in his seminal study on human capital externalities. He also estimates plant-level production functions and focuses on the external effect of aggregate human capital in the region on productivity at the disaggregate level. To address sorting of productive plants and skilled workers into particular cities, he develops a fixed effects estimation approach and exploits only the variation across plants within industries and locations and years. Our estimation framework is inspired by Moretti's (2004) approach.

In contrast to Moretti (2004), however, who focuses on aggregate spillover effects, we are also interested in within-plant externalities on productivity, which creates a second possible source of bias that refers to the workforce composition inside the establishment. Time-invariant omitted variables that affect the plants' productivity can be captured by plant-fixed effects a_i. Still, the endogeneity problem would not be resolved if plants adjust their inputs as a reaction to unobserved productivity shocks (Wooldridge 2009). One possible solution to tackle this problem would be to seek external instrumental variables that are correlated with cultural diversity but not with productivity, a strategy is frequently used in studies that focus on the aggregate level impacts of diversity only (Card 2005; Ottaviano and Peri 2005, 2006). However, one has to keep in mind that we are interested in the effects of diversity both at the micro and the regional level, and finding additional valid instruments for the different inputs at the plant levels is practically infeasible.[5] The use of local labor market variables as instruments for plant-level characteristics is also not possible in our context, as we model the effects of both regional and plant-level diversity, and thus regional diversity itself enters the

[5] See van Beveren (2012) for a general discussion on the estimation of plant-level production functions, showing that the use of external instrumental variables often proves to be difficult in this context.

regression as a potentially endogenous variable. As a solution to this multi-level endogeneity problem, we therefore use System GMM methods following Blundell and Bond (1998, 2000) and Bond (2002) that rely on internal instruments constructed from lagged variables.[6]

The final regression equation is given by eq. (3). In addition to the lagged dependent variable ($\ln VA_{i,t-1}$) that captures persistence in productivity,[7] we further include plant-specific control variables X_{it} and some regional characteristics $Z_{(-i)rt}$ that will be discussed further in Section 4. Time-specific dummy variables d_t capture common business cycle shocks, and the error term may include plant-specific effects a_{i}.

(3) $$\ln VA_{it} = \rho \ln VA_{i,t-1} + \beta_1 \ln K_{it} + \beta_2 \ln H_{it} + \beta_2 \ln L_{it} + \theta_1 Div_{it} + \theta_2 Div_{(-i)rt} + \gamma X_{it} + \delta Z_{(-i)rt} + d_t + a_{\mathrm{i}} + \varepsilon_{it}$$

The System GMM estimator estimates two equations simultaneously, eq. (3) in levels and in first differences, where endogenous explanatory variables are instrumented with their lagged first differences and levels, respectively. In addition to the lagged dependent variable and the plants' inputs, we treat all diversity measures at the plant and regional level as endogenous and instrument them accordingly.

This estimation strategy has at least three advantages compared to a static panel model with plant-fixed effects. First, while such a static approach would take into account the time-constant component of unobservable plant-specific effects, it would still be biased if there are time-varying and unobservable productivity shocks that are correlated with the diversity of the plant's workforce. Second, as the capital measure is not directly observed but computed from reported investments and industry-level approximations (see below), we expect it to contain some measurement error which fixed-effects methods tend to reinforce (van Biesebroeck 2007). Third and related to that, one variable to measure cultural diversity is the

[6] For the aggregate level of cultural diversity, we also add widely used external instruments such as the "shift-share" index by Card (2005), and find that it gives rise to very similar results as in our baseline, see section 6.3b.
[7] If we estimate eq. (3) without the lagged dependent variable, a test on autocorrelation shows that there is serial correlation in the value added function, while the test applied after estimating the dynamic model with the lagged value added shows that there is no autocorrelation in the error apart from plant-specific effects.

share of foreign workers in the respective workforce. Using shares in fixed effects estimations also introduces systematical measurement error (see Gerdes 2011).

System GMM estimation addresses these problems, since both the within- and the between-variation contribute to the identification of the parameters. As is well known, this estimation strategy generates more instruments than endogenous regressors, hence, we can perform tests for over-identifying restrictions with the null hypothesis of joint validity of all moment conditions. We report the Hansen J test statistic as it is robust to heteroscedastic standard errors (Roodman 2009a). Unfortunately, there is no reliable test for the problem of "too many instruments". To be able to judge the quality of the test statistic, we report it together with the number of instruments used and provide robustness checks reducing the number of time lags used to construct the instruments. Further, we test for the appropriate autocorrelation structure in the residuals of the first difference equation needed for the lagged variables to be valid instruments (Arellano and Bond, 1991). Finally, we implement Windmeijer's finite-sample correction for two-step covariance matrix estimation, and the standard errors in the regressions are adjusted for clustering at the region-industry level.

3. Data

We combine two data sets provided by the Institute for Employment Research (IAB) at the German Federal Employment Agency. The first one is the German Establishment History Panel (Betriebshistorik-Panel - BHP), which is generated from official German employment statistics. Second, we use the survey information from the IAB Establishment Panel (EP).

The EP data set is an annual survey of German plants collected in personnel interviews (see Kölling 2000 for further details). Drawn from the population of all German plants with at least one employee subject to social security, the sample is stratified across plant size and industries. The unit of observation is the individual establishment, as opposed to the concept of a firm that could comprise several plants. This level of observation is most suitable for our research question as the impact of regional characteristics would be diluted by firms with plants in more than one region. The EP provides a wide range of self-reported plant-specific variables, ranging from data on sales, investments, and employment to exporting behavior and organizational characteristics. All plant-level information come from the EP data, except for the details on the employed workforce. This information is taken from the more reliable administrative BHP data set which can be linked to the EP data via a unique common establishment identifier (see Hethey and Schmieder 2010 for details).

The BHP is a confidential administrative source based on process data from the German Federal Employment Agency. It is a comprehensive 100% sample of all German establishments employing at least one person subject to social security, thus excluding civil servants and self-employed individuals. The BHP data contain information on the plant's location (NUTS 3 regions) and the industry in which the establishment operates (three-digit NACE codes). Furthermore it includes various variables that describe the plant's workforce, including the nationality of the plants' employees. The classification of foreign nationalities is very detailed with around 180 different categories. Combining the BHP and the EP gives a unique data source to estimate plant-level productions functions and to address the micro and aggregate level impacts of diversity jointly. As the coverage of the BHP is universal, we also use it to compute the aggregate regional variables in (3), in particular the regional cultural diversity $Div_{(-i)rt}$ and the regional characteristics $Z_{(-i)rt}$. We focus on the period from 1999 to 2008, as from 1999 onwards the survey's definition of the plant population is consistent over time. The final estimation sample consists of 7,241 manufacturing and 4,102 service establishments for which all necessary information is available for at least three consecutive years, in order to ensure the availability of appropriate lagged instruments.[8]

4. Variables

In this section, we discuss the specification of all variables that we use for the estimation of equation (3). A list of all variables and information on the data can be found in Table 1.

TABLE 1 HERE

4.1. Production function variables

The dependent variable is the establishment's value added which is calculated from the plants reported sales minus intermediate inputs. To measure the plants' use of labor inputs, we calculate the average daily employment in full-time equivalents.[9] This variable approximates the necessary labor for the annual output far better than the alternative headcount of workers, as the latter would be sensitive to the number of part-time workers in the establishment. Seasonal variations in employment over the year are also smoothed out.

To account for human capital, we differentiate between high skilled and less skilled employees. To classify high-skilled labor, we use occupational data from the 1998/99 German Qualification and Career Survey conducted by the Federal Institute for Vocational Education and Training (BIBB). With this data, occupations are distinguished into a "high skilled" and a "less skilled" group using hierarchical cluster analysis based on the share of analytical work and the share of non-routine tasks relative to total working time, as well as on the average share of people holding a university degree for each occupation (see the online appendix for details). The so constructed skill variable is an appropriate proxy for human capital in our

[8] Non-profit organizations, the public sector as well as the financial sectors (NACE codes 11, 12, 13, 14, 20, 651, 652, 751, 752, 803, and 950) were excluded. For consistency, we further dropped the few plants that switched regions or changed their reported industry, and deleted plants that insource other plants.

[9] The BHP reports the number of employees in three categories: working full-time, part-time (large), and part-time (small). Full-time equivalents are then calculated using the weights 1, 0.6, and 0.3 for the different categories. The weighting is necessary, because no information on hours worked is provided.

context which focuses on foreign workers who may have been educated outside Germany, since university degrees are often not fully comparable across countries.

Turning to the measurement of physical capital, as many comparable establishment-level datasets, the EP does not contain a direct measure of the plant's capital stock. There is, however, information available on total investments, the share of net investments, and dummies for four categories of investment types (real estate, IT, production machinery, and transport equipment). We apply the modified perpetual inventory method that was developed by Müller (2008) explicitly for this dataset. Due to the rather short time dimension of our panel, we assign a starting value for the capital stock based on a proportionality assumption, using industry-specific information on average economic lives of different types of equipment and average investments in the first three observed years. Based on this proxy for the starting value, the perpetual inventory approach is then used to generate the capital stock for subsequent years.

4.2. Diversity measures

Our main focus is the level of cultural diversity at the plant and the regional level. As a proxy for the cultural background of a worker, we use the employee's nationality. One potential drawback of this approach is that only the recorded nationality is reported in the IAB data. Neither the country of birth, nor the naturalization of migrants is documented in the official statistics. When immigrants change their nationality to German, our measure would thus underestimate the true degree of cultural diversity. The same would be true for second-generation immigrants that have German citizenship but define themselves in terms of their parents' culture. However, we could also overestimate the effects of diversity, since cultural differences might diminish over time and language skills might improve the longer a foreign person is working in Germany. While one should keep these limitations in mind, it has to be clear that more detailed information about the self-perceived cultural origin of a worker would only be available in individual survey data. Such data is of substantially lower quality than administrative labor market statistics in other respects, however, especially for an analysis conducted at a highly disaggregated level.

To measure the within-plant diversity Div_{it}, we use two different variables: 1) the share of foreigners in plant i's total workforce s_{it}^{for}, and 2) the fractionalization index of the different foreign nationalities in the establishment's foreign employment, namely $HHI_{it}^{for} = 1 - \sum_{m=1}^{M_{it}} s_{m_{it}}^2$. Here, $s_{m_{it}}$ is the share of workers from nation m (with $m = 1, \dots, M_{it}$) among all foreign workers, and M_{it} is the total number of foreign nationalities within the respective plant i at time t. Analogously, the regional level of cultural diversity, $Div_{(-i)rt}$, is measured by 1) the overall employment share of foreigners in all other plants in the region, $s_{(-i)rt}^{for}$, and 2) the respective fractionalization index for the overall foreign employment in all other local plants, which can be written as $HHI_{(-i)rt}^{for} = 1 - \sum_{m=1}^{M_{(-i)rt}} s_{m_{(-i)rt}}^2$.

We choose this operationalization of cultural diversity, with two different variables at both aggregation levels, in order to separate size and fractionalization effects for the group of foreign workers, similar as in Alesina et al. (2013) and Suedekum et al. (2013). With the shares s_{it}^{for} and $s_{(-i)rt}^{for}$ we can investigate if there are productivity spillovers simply from having *more* foreign employees, irrespective of their nationality. The coefficient of the share of foreign workers also reflects average differences in productivity between native and foreign workers. Yet, conditional on the size of the group of foreigners, there can be additional productivity effects stemming from the fractionalization of this group into different cultural backgrounds (nationalities), which are captured by the two Herfindahl-type indices.[10]

[10] Alternatively, we could construct a single diversity variable that would also include the share of natives, similar as in Ottaviano and Peri (2005, 2006) or in Nathan (2011). However, the resulting index turns out to be completely dominated by the share of native German workers, and it is highly correlated with the overall foreign employment share. It therefore underemphasizes compositional differences within the group of foreigners. We return to this discussion below in Section 5, where we provide some descriptive evidence about the share of foreigners and the fractionalization index at the plant and the regional level.

Notice that the diversity index is equal to zero if all foreign workers in the plant (respectively, the region) come from the same foreign country. The index then rises with the total number of different nationalities in the respective workforce. For a given number of nationalities, it is higher the more uniformly the shares of the different foreign nationalities are distributed. The diversity index is also equal to zero by construction if there are no foreign workers at all. Controlling separately for the total share of foreigners helps to disentangle those two cases .

4.3. Other control variables

With regard to the other control variables included in the regression, we consider additional measures that characterize the plants' workforce, more specifically the share of female employees and the share of part-time work.[11] We also include some further characteristics for which other studies have found significant influences on plant-level productivity. In particular, exporting plants are typically found to be more productive than their domestic competitors. Similarly, foreign owned firms typically display a higher efficiency level (Conyon et al. 2002). We also include an age dummy for young firms[12], and we control both for the legal form and for the plant's affiliation in a larger corporate group. We further use self-reported information about the current state of the technology and machinery ("state-of-art" versus "out of date") to control for qualitative differences of the plants' technical equipment.

To capture the impact of regional workforce characteristics, we calculate further control variables at the NUTS 3 level, always excluding the individual plant under consideration. Here, we use size in terms of total regional employment to account for agglomeration effects á la Ciccone and Hall (1996). Additionally, we control for the regional stock of human capital in

[11] We do already control for part-time work in the full-time equivalents to define the volume of labor, but there might be a loss in overall productivity when the average proportion of part-time work increases. We have also experimented with the mean age and experience and also with the variation in age and experience of the workforce at the plant level. The coefficients turn out to be mostly insignificant and do not change the remaining coefficients, so that we have decided to leave out these variables.

[12] Including age in years instead of a dummy variable tends to be problematic in first differences or fixed effects with a set of year dummies.

the plant's location, similar as in Moretti (2004). Further regional control variables such as industrial diversity at the regional level, or the local own-industry employment share that captures localization economies in the spirit of Henderson (2003) are considered in the robustness checks.

5. Descriptive evidence

Before we turn to the regression results, we briefly present a descriptive overview in table 2. Overall, the average share of foreign employees across all plants in the sample is 3.6%, and it is similar for manufacturing and service plants. This share rises to 10.8% when focusing only on plants with at least one foreign worker.[13] The share of foreign workers is higher among less skilled workers in both sectors, but service plants employ relatively more high skilled migrants than manufacturing plants. The second dimension of cultural diversity is the fractionalization of the population of foreign workers within the establishment into different nationalities. The fractionalization index is on average 0.16 for all plants, and 0.41 for plants with at least one foreign employee. Manufacturing plants employ a more diverse mix of foreign workers than do service firms; the index is 0.18 in the former and 0.13 in the latter case. Furthermore, diversity among less skilled foreign workers is somewhat higher than among high skilled foreign workers.

TABLES 2 and 3 HERE ***FIGURE 1 HERE***

Turning to the regional level, the lower part of table 2 summarizes the variables used in the estimation averaged across the two samples of manufacturing and service establishments. The average share of foreigners in a region is 3.5% in the manufacturing sample and slightly higher in the sample of service plants. The proportion of foreign workers among the less skilled workforce is higher than among high skilled employees. The regions with the highest shares of foreigners are the metropolitan areas around Munich, Stuttgart and Frankfurt, as

[13] We also do observe a small number of plants that have a share of foreigners equal to one, which are typically very small plants mainly in restaurants and retail sale business.

well as in the Rhine-Ruhr area. The fractionalization index has a mean of 0.89 and 0.88 in the two subsamples, comparable to the value of birthplace diversity among migrants of 0.9 found by Alesina et al. (2013, table 3, page 28). It varies considerably and takes on values between 0.30 and 0.97, where typical university towns such as Trier or Jena tend to have the most diverse workforces. The traditional guest worker regions like the Rhine-Ruhr area, in contrast, display the lowest diversity due to the dominance of employees from former guest worker countries, such as Turkey or Greece.

One main focus of the following analysis is the separation of the effect of diversity at the plant and regional level. Table 3 shows that the correlation between the plant and the regional share of foreign workers is positive (0.627 and 0.386 for manufacturing and services plants, respectively), that is, plants in regions with more foreigners tend to employ more foreign workers themselves, not controlling for other characteristics. But it is interesting to note that the correlation between the fractionalization index at the plant and the regional level is negative (-0.301 and -0.055). That is, there are many homogeneous plants in heterogeneous regions, and vice versa. This emphasizes the importance of separating the within-plant externalities from spillover effects stemming from the regional workforce composition.

Furthermore, we find that the correlation between the share of foreigners and the fractionalization index is positive at the plant level (0.558 and 0.408 for manufacturing and services plants, respectively), but negative at the regional level (-0.530 and -0.448). Plants that employ more non-natives also tend to have a more diverse mix of foreigners. Regions where many foreign employees live, in contrast, are not necessarily more diverse with respect to the composition of nationalities. In fact, the two variables seem to capture distinct dimensions of the pool of migrants, which emphasizes the importance of distinguishing size and fractionalization effects in the empirical analysis.

Finally, the two panels of figure 1 show correlations with the (log) size of the region. As expected, the share of foreigners in the local labor force clearly rises with total regional size:

densely populated agglomerated regions tend to host more foreigners. The correlation between agglomeration and the fractionalization index is less clear, however. On the one hand, large regions may attract migrants from more countries, which would increase the mix of nationalities there. But the literature also describes a network effect, according to which new migrants tend to settle in regions where other members of their home country are already present (Bartel 1989). If, historically, a certain migrant group is more present in an agglomeration, this region further attracts immigrants from that country which, in turn, lowers diversity there. Descriptively, these opposite effects seem to offset each other.

6. Empirical results

6.1. Specification tests and results for background variables

We now discuss our estimation results. Table 4 presents the results for the production function estimation which is carried out separately for manufacturing and service establishments. Our preferred method is the System GMM estimator as explained above.

TABLE 4 HERE

As a reference, we also report the results for simple OLS and fixed effects (within) estimation of eq. (3), where lagged variables are not used as instruments. Focus at first on the coefficients for the lagged dependent variable, reported in the third row. Both for manufacturing and services, we find that OLS estimation yields the highest and fixed effects estimation the lowest coefficient, see the respective first and second column. The coefficient obtained in the System GMM estimation (see the respective third column) ranges in between the other two estimates. OLS estimates of the coefficient for the lagged dependent variable are upward biased in the presence of plant fixed effects, while the within estimator leads to a downward bias (see Roodman 2009a). Our findings are thus is in line with these theoretical considerations.

For our preferred dynamic panel estimator, the Hansen J test does not reject the null of joint validity of all instruments. The test on autocorrelation in the residuals of the equation in first differences cannot reject the null of no second order autocorrelation, which means that there is no first order autocorrelation in the level equation besides the plant fixed effect. As the test statistics support the dynamic specification and instrumentation of the endogenous variables, we are confident that we have a robust specification for the production function estimation.[14] Briefly looking at the other control variables, their coefficients turn out to have the expected signs: plants with newer technology produce more efficiently, single plants are less productive than plants that are part of a larger group, foreign ownership as well as exporting activity are both associated with higher productivity, at least in the manufacturing sample. In the service sector, plants with a higher share of part-time worker are more productive, probably because they are able to respond more flexibly to short-term demand variations. As for the regional control variables, we find that plants located in larger regions tend to be more productive, a result broadly in line with the large literature on agglomeration effects (Ciccone and Hall, 1996), even though regional size is no longer significant once we control for further region-specific characteristics. For the aggregate share of high skilled workers we find no clear effects on plant-level productivity in Germany.

6.2. Main empirical findings

Turning to our main variables, it can be seen in the first set of shaded rows in Table 4 that the effect of the share of foreigners in the establishment workforce has a negative sign both in manufacturing and in services, but is statistically not significant, however. We hence find no evidence for positive productivity spillovers simply from employing *more* foreign workers in the own establishment. However, for manufacturing plants, there are spillovers from diversity inside the establishment: Conditional on the overall size of the group of foreigners, plant

[14] A slightly disturbing issue is the barely significant and small coefficient estimate for the capital stock measure – an issue that has also shown up in other studies that used the EP data (see Zwick, 2004, for example). Recall, however, that the capital stock measure is an approximation calculated from investment figures and a constructed starting value (see Section 4). As such, it is likely to suffer from measurement error and the estimated coefficient is biased towards zero. Furthermore, GMM estimates of scale elasticities are known to be downward biased when plant-specific output prices are not observed (Ornaghi, 2006; Klette & Griliches, 1996).

productivity is higher the more fractionalized the group of foreign workers is in terms of cultural backgrounds.

As for the impact of aggregate cultural diversity, a similar picture emerges. Both in manufacturing and in services there are no productivity spillovers from the total share of foreign workers in the region. The estimated coefficients are now positive, but they are also insignificant. Yet, conditional on the overall size of the group of foreigners in all other local plants, there are strong and highly significant productivity effects of diversification. The more fractionalized the pool of foreign workers is in terms of nationalities, the higher is – on average – the total factor productivity of the establishments in the respective location, both in manufacturing and in services.

a) Quantitative benchmarking

To get a feeling for the economic significance of these effects, we first calculate the productivity change implied by a one standard deviation increase in the fractionalization index for the plant's own workforce, keeping the overall share of foreign workers in the establishment and everything else constant. The resulting productivity increase in the manufacturing sector is 9.7% (=(exp(0.310*0.300)-1)*100%), which ranges between the productivity advantage of having the newest technology (6.8%) and having a foreign owner (15.7%). Correspondingly, if the regional fractionalization index rises by one standard deviation in the manufacturing sample, holding constant the aggregate share of foreign workers, the observed productivity gain for the average plant would be 11.4% (=(exp(1.617*0.067)-1) *100%) given its own workforce composition.

The spillover effects from cultural diversity are, hence, economically quite sizable in the manufacturing sector, and our results suggest that diversity at the regional level is at least as important for plant-level productivity as the diversity of the establishment's own workforce. This is particularly true for service establishments, where neither the size nor the composition of the own foreign workforce seem to matter for productivity. These service plants still benefit, however, from aggregate diversity; the productivity gain from a one standard deviation increase in regional diversity, given the overall foreign employment share, is approximately 14.4% (=(exp(1.817*0.074)-1) *100%) for the average service plant.

We can also conduct a similar benchmarking exercise for the implied productivity effects of the change in observed diversity levels over time. In our estimation approach, both the differences between plants and the changes over time within plants contribute to the identification of the estimated effects of the workforce composition on productivity. Taking the average change of diversity within a plant per year as the basis for our calculations (0.001), our results suggest an increase in the manufacturing plants' output of 0.03%. If we look at the minimum (-0.831) and maximum (0.743) annual changes, the effect would range between -22.7% and +25.9% across firms, which suggests that the productivity effects of cultural diversity can be quite sizable at the establishment level. If we do an analogous calculation using annual changes of the regional diversity variable in the estimation sample, we get an effect of 0.4% looking at the average (0.002), and a range from -21.6% to 29.2% for the minimum and maximum observed annual change in regional diversity for service plants (and similar results for the manufacturing plants). Again, we thus find that diversity at the regional level has economic effects that are at least as important as the micro level effects.

b) Firms with and without foreign workers

Recall that there are two types of firms that have a diversity index equal to zero: plants that employ only foreign workers from one nationality, and firms that do not employ any foreigners at all. To check that the estimated diversity effect is not driven by pooling plants with and without foreign workers, we split the sample into plants with a positive share of foreigners and plants that only employ natives. As can be seen in Table 5, the diversity effect at the micro level indeed shows up for manufacturing plants with a positive share of foreign workers, and it has nearly the same magnitude as in the baseline specification. For service plants, the coefficient becomes larger, but it is still not significantly different from zero. Interestingly, the positive effect of a diverse regional environment shows up for service plants that do not employ any foreign workers themselves, and the estimated coefficient is even higher than in the pooled sample.

TABLES 5 and 6 HERE

Another way to look at this issue of threshold effects is to add a dummy variable that indicates whether at least one foreign worker is employed in the plant. Table 6 shows that in the manufacturing sample, this variable is significantly negative, while the diversity index still increases plant productivity. This result indicates that there are, in fact, costs associated with the employment of non-natives. However, independent of the amount of foreign workers, diversity among them increases productivity. In the service sector, there is again no significant impact at the micro level. Our results at the plant level are therefore not driven by the difference between plants with and without any foreign employee. This effect appears to be captured sufficiently by the share variable.

6.3. Robustness checks

We ran several robustness and specification tests. The corresponding result tables can be found in a supplementary online appendix for this paper.

First, one might be worried that the effect of the regional fractionalization index might capture correlated region-specific effects not related to cultural diversity. Though our dynamic estimation approach already addresses possible endogeneity concerns in various ways, the first set of robustness checks tries to exclude further confounding effects. To address industry-specific productivity shocks that vary over time and that are thus not absorbed by the plant fixed effects, we calculate the regional diversity measure excluding not only the plants' own contribution, but we also subtract the plants' own industry. The results turn out to be similar to the baseline results, although the level of significance decreases a bit for some coefficients.[15]

Another concern might be that the effect of the regional diversity index might stem from differences in the mix of occupations. Peri and Sparber (2009) and D'Amuri and Peri (2010) show that foreign migrants often tend to choose different occupations than natives, particularly such occupations where they have a comparative advantage. We include indices of occupational diversity among native and non-native employees. The coefficients are insignificant for these new variables, while our main results are basically unchanged. The sorting of migrants into specific occupations therefore also do not seem to drive our findings.

Next, we have experimented with the instrumental variables. As described above, our System GMM approach relies on internal instruments constructed from lagged variables. An alternative approach based only on external instruments is hard to imagine in our context, since we are interested in the effects of diversity both at the micro and the regional level. However, we have considered alternative instruments that have been used in the previous literature on the aggregate level impacts of cultural diversity. The first one is the "shift-share"-instrument popularized by Card (2005), which is a hypothetical local diversity index calculated by using regional employment shares of the different foreign nationalities in a base year (1987 in our case, which is well before the start of the observation period) which are then extrapolated with nationwide employment growth rates for those foreign nationalities.[16] Furthermore, Ottaviano and Peri (2005) used the geographical distance of metropolitan areas to major immigration hubs. We consider a similar variable for Germany, namely the minimum regional distance to an exterior border interacted with time fixed effects. Comparing the results with our baseline results, it turns out that there is again hardly any change. Furthermore, the number of instruments used in the estimation appears to be quite high,

[15] We have also tried to push this even a bit further, and to assess the effect of aggregate diversity only within the plants' own industry. However, there are often too few plants per industry .

[16] Eastern German regions are assigned with a value of zero here, as we do not observe their workforce compositions prior to the German reunification in 1990.

giving rise to concerns about weak instruments. Even in the main specification, where all available lags are used, we are far away from the problem that the number of instruments would be larger than the number of observations (Roodman, 2009b). If we restrict the instruments to t-4 or t-5, the results are quite stable across those specifications.

Finally, we have then included further region-specific control variables that are used in the urban agglomeration literature, more specifically the regional density, the number of plants in the region, the number of plants in the industry and region, the industrial diversity of the plants across industries, and the plants' own industry share in total regional employment. The inclusion of these variables does again not crucially affect our main findings.

6.4. Effect heterogeneity

In this last subsection, we provide additional estimations for subsamples of establishments in order to provide further insights of how and where the effects of diversity arise. The corresponding tables can also be found in the supplementary online appendix.

Our results from Table 4 suggest that diversity at the micro level matters more for manufacturing than for service establishments, even though both benefit from aggregate diversity. One possible explanation for this finding could be that the downsides of diversity, namely communication frictions, are more pervasive in the service sector that is overall more interactive and communication-intensive. In the manufacturing sector, on the other hand, it appears that the benefits of diversity, such as complementary skills and problem solving abilities, seem to dominate even within the establishment. In addition, manufacturing firms might have a different innovation behavior than service firms. There is evidence that service firms are more dependent on inter-firm co-operations, while manufacturing firms are often seen as "true innovators" that develop new ideas and products (see Tether 2005).

Another way to address this line of reasoning is to look at the effects of diversity separately for "high-tech and knowledge-intensive" industries, a sectoral aggregation defined by

EUROSTAT[17] that entails both manufacturing and service branches. Indeed we find that the positive impact of the aggregate diversity level stems from the part of the sample that belongs to these technology-intensive industries. In the low-tech and more basic sectors, we find no evidence for productivity spillovers from cultural diversity.

The spillover effects from regional diversity are also supposedly stronger for single plants than for plants which are part of a corporate group. For the latter type, their productivity may depend more on the organizational structure of the corporation while the impact of the regional environment may be of lesser importance. In fact, our baseline results are mainly driven by the subsamples of single plants. For these plants, we find again the positive productivity effects of aggregate diversity, both in manufacturing and in services. For the affiliated plants that are part of a corporate group, no such effects appear in the data.[18]

Previous research has found that large and small plants are often affected differently by external knowledge spillovers, see e.g. Rosenthal and Strange (2004). We therefore also investigate the impacts of cultural diversity separately for large and small plants. A plant is considered small if it employs less than 50 full-time equivalents. For the service sector, we find that productivity is stimulated by the aggregate diversity level particularly in small plants. There is a slightly negative effect of the plant-specific share of foreign workers on productivity in small service plants. Again, one reason could be that the communication costs in customer-oriented service plants are more pervasive, and this effect is likely to be most severe within small service plants with a leaner organizational structure.

Turning to the manufacturing sector, here we find that the positive overall impact of the within-plant diversity that we have found in Table 4 is actually driven by the large establishments. The coefficients for the impact of aggregate diversity is positive, both in large and small manufacturing plants, but the effects are now more imprecisely estimated.

[17] http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/Annexes/htec_esms_an7.pdf

[18] The results for these plants should be interpreted with caution, however. As the sample sizes are reduced by this additional sample split, we encounter some problems with the instrumentation of the endogenous variables (p-values of the Hansen J test is exactly 1).

Another relevant distinction refers to the plants' exporting behavior. Plants with employees from various countries might find it easier to enter foreign markets and to build up distribution networks in those countries (see Rauch and Trindade 2002, Peri and Requena-Silvente 2010). This is because the foreign employees may possess specific knowledge about the export destinations that are supposedly important for the success in these markets, and ultimately for the productivity of the plant. Interestingly, the share of foreign workers turns out to have a negative effect on productivity in non-exporting plants but a positive effect for exporters. A possible explanation might be that exporters interact more frequently with foreigners, so that the communication costs associated with intra-plant diversity are less relevant for them. The benefits from diversity inside the firm, on the other hand, is matters more for those firms as they may exploit their employees knowledge about different export markets. The impact of regional diversity is of similar magnitude for exporters and non-exporters, but the effect is statistically more robust for the latter group.

Finally, we address regional heterogeneity in the spillovers from diversity in separate estimations for agglomeration and non-agglomeration regions, defined according to a common classification scheme of the IAB. The effect of regional diversity on plant-level productivity across all establishments reveals an interesting pattern: there seem to be no effects in agglomerated regions, while the effect is much stronger and statistically more significant in less urbanized regions. This result is corroborated when splitting the sample into large and small regions (with above- or below-median absolute employment). Spillover effects from aggregate diversity appear to be concentrated among the small regions.

7. Conclusion

In this paper we have analyzed the impact of cultural diversity on plant-level productivity in a comprehensive sample of German establishments. We estimate plant-level production functions augmented with regional characteristics, while carefully addressing potential endogeneity concerns both at the plant and the regional level. We find that the size of the group of foreign employees in the plant has no significant impact on productivity. The diversification of the foreign employees with respect to their nationalities, however, increases the total factor productivity in German manufacturing plants. In addition, there are positive and economically significant spillover effects stemming from the regional diversification of the workforce. The positive impact of the regional workforce is mainly driven by small plants in the service sector, and shows up for plants in technology- or knowledge-intensive industries. The sheer number of foreign employees in a region again has no significant impact on plant productivity. These results are robust in a series of extended analyses in which we try to address alternative explanations for the productivity effect of cultural diversity.

The composition of the plants' own workforce and the composition of the working population of the region the plant is located in have thus a real positive effect on productivity across German establishments. The costs that are usually associated with a diverse workforce seem to be outweighed by the synergies that are created when different and new skills and abilities are combined. Interestingly, this productivity effect does not mainly arise from interactions at the micro level. Cultural diversity also seems to enfold its positive impacts at the aggregate level, by improving local business environments even to homogeneous establishments.

Our results have potentially important implications for migration policies. Currently, the public debate and also a large part of the academic literature on migration focuses on the number of migrants and their education level, while compositional effects like the cultural diversity within that group are often not taken into account. Our findings suggest that the diversification of this group in terms of cultural backgrounds is crucial when it comes to assessing the productivity effects spurred by immigration.

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Tables and Figures

Table 1 Variable Definitions

Variables		Source	Details
Production function variables			
VA_{it}	Value added	EP	Sales minus intermediates, in Euro
K_{it}	Physical capital	EP	Constructed from investments using a combination of proportionality approach and perpetual inventory method (Müller, 2008), in Euro
H_{it}	Human capital	BHP	Average daily employment in full-time equivalents
	High skilled labor input	BHP	Skilled labor according to the employee's occupation
	Less skilled input	BHP	Less skilled labor according to the employee's occupation
Diversity measures			
S_{it}^{for}	Share of foreigners	BHP	Share of labor input of non-native employees
	Share of high skilled foreigners	BHP	Share of high skilled labor input of non-native employees
	Share of less skilled foreigners	BHP	Share of less skilled labor input of non-native employees
HHI_{it}^{for}	Diversity among foreigners	BHP	HHI type diversity index $div_{it}^{for} = 1 - \sum_{m=1}^{M_{it}} s_{m_{it}}^2$, minimum zero, maximum at $div_{foreign}^{max} = 1 - 1/M_{it}$ with M_{it} number of different nations within the plant excluding natives
	Diversity among high skilled foreigners	BHP	HHI type diversity index calculated across all foreign nations of high skilled employees
	Diversity among less skilled foreigners	BHP	HHI type diversity index calculated across all foreign nations of less skilled employees
$S_{(-i)rt}^{for}$	Regional share of foreigners	BHP	Share of foreigners in the plant's region calculated excluding the plants' own workforce
$HHI_{(-i)rt}^{for}$	Regional diversity among foreigners	BHP	HHI type diversity index in the plant's region calculated excluding the plants' own workforce
Control variables			
	Share of females	BHP	Share of labor input of female employees
	Share of part time	BHP	Share of labor input of employees working part-time
	Exporter dummy	EP	Positive sales abroad = 1
	New technology dummy	EP	State-of-art equipment = 1
	Foreign owned dummy	EP	Establishment majority owner is foreign = 1
	Single plant dummy	EP	Establishment is single plant = 1
	GmbH dummy	EP	Establishment is a private limited company "GmbH" = 1
	AG dummy	EP	Establishment is a public limited company "AG" = 1
	Regional workforce	BHP	Sum of regional labor calculated excluding plants' own workforce
	Regional share of skilled labor	BHP	Share of skilled in the plant's region calculated excluding the plants' own workforce
d_t	Year specific effects	BHP	Dummy variable set for the years 2000 to 2007
a_i	Plant fixed effect		
ε_{it}	Idiosyncratic error term		

Table 2 Descriptive statistics of the estimation sample

	Manufacturing		Services	
	Sample mean	**Standard deviation**	**Sample mean**	**Standard deviation**
Plant specific variables				
Share foreigners	0.035	0.076	0.036	0.097
Diversity among foreigners	0.181	0.300	0.135	0.274
Share of high skilled foreigners	0.012	0.042	0.021	0.082
Share of less skilled foreigners	0.046	0.099	0.049	0.140
Diversity among high skilled foreigners	0.086	0.226	0.064	0.198
Diversity among less skilled foreigners	0.154	0.276	0.093	0.234
Log value added	14.551	1.901	14.051	1.687
Log labor	9.598	1.568	8.950	1.440
Log capital	14.337	2.250	14.087	2.481
Share of skilled labor	0.318	0.193	0.512	0.301
Share of female labor	0.273	0.220	0.392	0.271
Share of part-time labor	0.051	0.100	0.129	0.213
New Technology dummy	0.671	0.470	0.738	0.440
Single plant dummy	0.800	0.400	0.742	0.438
Foreign owner dummy	0.092	0.289	0.038	0.191
Exporter dummy	0.542	0.498	0.177	0.382
GmbH dummy	0.752	0.432	0.595	0.491
AG dummy	0.028	0.165	0.039	0.192
Region specific variables (excluding the plant's own contribution)				
Share foreigners	0.033	0.039	0.045	0.041
Diversity among foreigners	0.894	0.067	0.883	0.074
Share of high skilled foreigners	0.018	0.018	0.025	0.021
Share of less skilled foreigners	0.046	0.060	0.066	0.067
Diversity among high skilled foreigners	0.906	0.074	0.903	0.083
Diversity among less skilled foreigners	0.877	0.070	0.864	0.076
Share of skilled labor	0.093	0.039	0.101	0.042

Table 3 Pairwise correlation coefficients of the main variables

		Plant level		**Region level (excluding the plant's own contribution)**	
		Share of foreigners	Diversity among foreigners	Share of foreigners	Diversity among foreigners
Manufacturing					
Plant level	Share of foreigners	1.000			
	Diversity among foreigners	0.558	1.000		
Region level (excluding the plant's own contribution)	Share of foreigners	0.627	0.581	1.000	
	Diversity among foreigners	-0.324	-0.301	-0.530	1.000
Service					
Plant level	Share of foreigners	1.000			
	Diversity among foreigners	0.408	1.000		
Region level (excluding the plant's own contribution)	Share of foreigners	0.386	0.410	1.000	
	Diversity among foreigners	-0.199	-0.055	-0.448	1.000

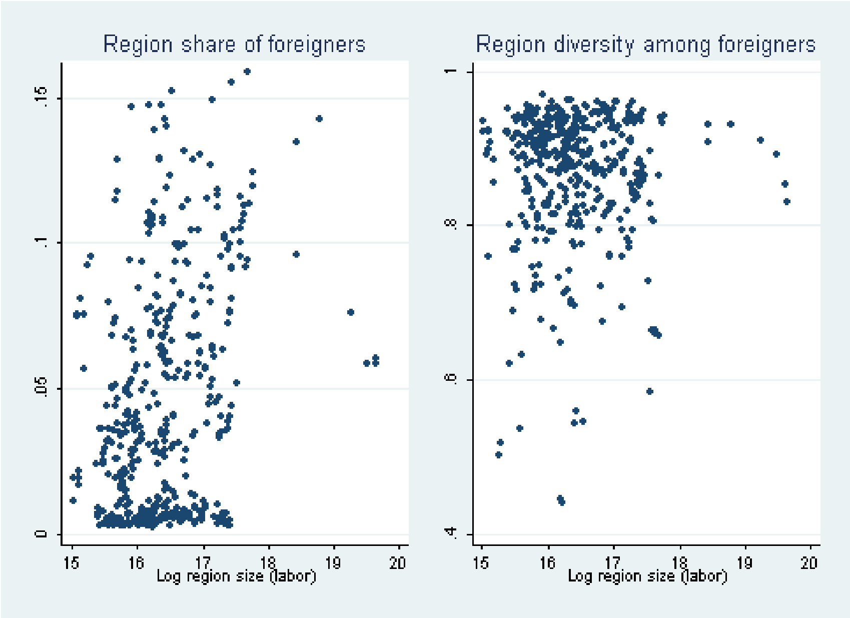

Figure 1: Region diversity and log region size
(One observation per region and year)

Table 4 Estimates of the plant-level production function using different estimation strategies

	Manufacturing						Services					
	OLS		FE		System GMM		OLS		FE		System GMM	
Plant-specific variables												
Share of foreigners	-0.204**	(0.090)	0.051	(0.328)	-0.041	(0.379)	0.147	(0.093)	0.354	(0.467)	-0.887	(0.573)
Diversity among foreigners	0.046*	(0.027)	0.109*	(0.058)	0.310**	(0.142)	0.090**	(0.042)	0.167	(0.121)	0.033	(0.280)
Lagged log value added	0.706***	(0.013)	0.155***	(0.025)	0.369***	(0.044)	0.738***	(0.017)	0.096***	(0.037)	0.377***	(0.043)
Log less skilled labor	0.123***	(0.010)	0.221***	(0.038)	0.288***	(0.053)	0.057***	(0.008)	0.095***	(0.031)	0.137***	(0.045)
Log high skilled labor	0.112***	(0.009)	0.107***	(0.029)	0.206***	(0.052)	0.107***	(0.011)	0.094**	(0.039)	0.245***	(0.060)
Log capital	0.046***	(0.005)	0.096***	(0.028)	0.016	(0.038)	0.052***	(0.006)	0.032	(0.064)	0.067*	(0.037)
Share female	-0.173***	(0.034)	0.045	(0.206)	-0.432***	(0.074)	-0.097**	(0.043)	-0.292	(0.230)	-0.197*	(0.117)
Share part-time	0.058	(0.054)	0.033	(0.191)	0.104	(0.116)	0.126***	(0.042)	-0.073	(0.117)	0.281***	(0.098)
New Technology dummy	0.022*	(0.012)	0.006	(0.017)	0.051**	(0.020)	0.057***	(0.020)	0.027	(0.033)	0.098***	(0.033)
Single plant dummy	-0.062***	(0.016)	-0.013	(0.034)	-0.160***	(0.032)	-0.053**	(0.022)	-0.119**	(0.055)	-0.186***	(0.066)
Foreign owner dummy	0.010	(0.021)	0.066	(0.049)	0.117***	(0.045)	0.019	(0.036)	-0.402**	(0.198)	0.047	(0.076)
Exporter dummy	0.063***	(0.015)	0.018	(0.026)	0.186***	(0.041)	0.048**	(0.022)	0.032	(0.053)	0.118***	(0.040)
GmbH dummy	0.040**	(0.015)	0.050	(0.045)	0.158***	(0.047)	0.051**	(0.020)	0.062	(0.070)	0.156**	(0.062)
AG dummy	-0.002	(0.035)	0.164	(0.131)	0.164**	(0.083)	0.124**	(0.052)	0.011	(0.155)	0.363**	(0.151)
Region-specific variables (excluding the plant's own contribution)												
Share of foreigners	-0.370	(0.414)	1.932	(3.847)	0.267	(3.000)	0.980	(0.698)	-5.983	(5.818)	4.248	(4.904)
Diversity among foreigners	0.193*	(0.101)	0.103	(0.383)	1.617**	(0.705)	0.613***	(0.168)	0.787	(0.680)	1.817**	(0.829)
Region size	0.035**	(0.015)	0.429	(0.365)	0.072	(0.048)	0.014	(0.022)	-0.048	(0.543)	0.027	(0.074)
Region share of skilled labor	0.227	(0.210)	-2.926	(2.173)	-0.387	(0.571)	-0.154	(0.275)	-5.140*	(2.773)	-0.177	(0.683)
Constant	0.843***	(0.257)	0.808	(6.071)	2.049**	(0.843)	0.850**	(0.417)	11.850	(9.261)	3.060**	(1.401)
Year dummies	Yes		Yes		Yes		Yes		Yes		Yes	
Industry and region dummies	Yes		No		Yes		Yes		No		Yes	
Statistics												
Number of observations	7,241		7,241		7,241		4,102		4,102		4,102	
Number of instruments					580						573	
Hansen J p-value					0.559						0.395	
AR(1) p-value					0.000						0.000	
AR(2) p-value					0.125						0.764	

Robust standard errors adjusted for clustering. * p<0.10, ** p<0.05, *** p<0.01. Firm controls: Lagged log value added, log less skilled labor, log high skilled labor, log capital stock, share women, share part-time workers, new technology dummy, single plant dummy, foreign owner dummy, exporter dummy, GmbH and AG dummy. Region controls: Log size of workforce, share of high skilled. Year dummies are included; in the untransformed equation we add region and industry dummies. For variables definitions see table 1. Manufacturing Industries: NACE codes 15-37. Service Sector: NACE codes 50-55, 60-67, 70-74, 85, 92-93. High-tech manufacturing: NACE codes 24, 29, 30-35, excluding 351. Low-tech manufacturing: NACE codes 15-23, 25-28, 351, 36, 37. Knowledge-intensive services: NACE codes 61, 62, 64, 66, 67, 70-74, 80, 85, 92. Other services: NACE codes 50-52, 55, 60, 63, 90, 91, 93. Source: Eurostat.

Table 5 Estimates for plants with and without foreign employees

	Manufacturing				Services			
	With foreign employees		Only native employees		With foreign employees		Only native employees	
Plant-specific variables								
Share of foreigners	-0.197	(0.331)			-0.185	(0.397)		
Diversity among foreigners	0.276**	(0.129)			0.158	(0.210)		
Region-specific variables (excluding the plant's own contribution)								
Share of foreigners	-1.553	(2.947)	1.051	(9.370)	-2.970	(5.211)	5.942	(5.978)
Diversity among foreigners	0.887	(1.059)	0.831	(0.740)	0.304	(0.747)	2.710***	(0.798)
Statistics								
Number of observations	3,036		4,205		1,479		2,623	
Number of instruments	580		454		541		446	
Hansen J p-value	0.993		0.626		1.000		0.440	
AR(1) p-value	0.000		0.000		0.000		0.000	
AR(2) p-value	0.201		0.856		0.338		0.675	

All comments and control variables as in Table 4.

Table 6 Estimates with foreign worker dummy

	Manufacturing		Services	
Plant-specific variables				
Foreign worker dummy	-0.131*	(0.071)	-0.444	(0.636)
Share of foreigners	0.327	(0.468)	0.052	(0.268)
Diversity among foreigners	0.257*	(0.144)	-0.110	(0.121)
Region-specific variables (excluding the plant's own contribution)				
Share of foreigners	-0.643	(3.069)	3.987	(4.592)
Diversity among foreigners	1.416**	(0.678)	1.905**	(0.801)
Statistics				
Number of observations	7,241		4,102	
Number of instruments	643		636	
Hansen J p-value	0.428		0.660	
AR(1) p-value	0.000		0.000	
AR(2) p-value	0.118		0.792	

All comments and control variables as in Table 4.

Cultural diversity and plant-level productivity

Michaela Trax Stephan Brunow Jens Suedekum

Supplementary online appendix
(not intended for publication)

Construction of the skill variable

To account for differences in the plants' human capital, we differentiate between highly skilled and less skilled employees. Skilled labor input is often approximated by employees holding a university degree. While this information is available in our data, we prefer to use a more comprehensive measure that takes into account assigned tasks of different occupations. For a practical reason, the traditional skill measure is frequently not reported and we would lose more than half of the final observations for which information on occupations would be available.

Further, high skilled people do not necessarily work in occupations that typically ask for a university degree and there are also many employees without higher education that work in occupations that typically do ask for a degree (Brunow and Hirte, 2009). This problem can be expected to be even more severe comparing native and foreign employees, as the different degrees might be less comparable across nations. Peri & Sparber (2009) and D'Amuri and Peri (2010) show that within education categories, natives and non-natives specialize in different tasks for which they have a comparative advantage.

We take the data on occupations from the 1998/99 German Qualification and Career Survey conducted by the Federal Institute for Vocational Education and Training (BIBB) and the Institute for Employment (IAB). Based on the share of analytical work and the share of non-routine tasks relative to total working time in addition to the average share of people holding a university degree that characterize each occupation, we classify occupations into a high skilled and less skilled group using hierarchical cluster analysis. The proportion of employees with a university degree is taken from the BHP data base. Given the identical continuous scale of the three variables we choose the Euclidean distance to measure similarities between occupations. The results used are based on a complete linkage, where the furthest distance of objects within two clusters is used to merge objects and clusters. Other methods lead to qualitatively similar clusters.

Additional empirical results: Robustness checks and effect heterogeneity

We present here the detailed results that are discussed in Section 6.3. and 6.4. in the main text. For brevity, we only report the coefficients for the main variables and the test statistics for the respective specification.

Table 7 Estimates excluding the plants' own industry

	Manufacturing		Service	
Plant-specific variables				
Share of foreigners	-0.047	(0.369)	-0.821	(0.569)
Diversity among foreigners	0.304**	(0.142)	0.013	(0.277)
Region-specific variables (excluding the plant's own contribution)				
Share of foreigners	0.265	(3.115)	3.648	(4.800)
Diversity among foreigners	1.268*	(0.671)	1.588*	(0.821)
Statistics				
Number of observations	7,241		4,102	
Number of instruments	580		573	
Hansen J p-value	0.528		0.389	
AR(1) p-value	0.000		0.000	
AR(2) p-value	0.118		0.773	

All comments and control variables as in Table 4.

Table 8 Estimates with hypothetical diversity index as alternative instrument

	Manufacturing		Services	
Plant-specific variables				
Share of foreigners	0.076	(0.364)	-0.397	(0.475)
Diversity among foreigners	0.285**	(0.136)	-0.064	(0.277)
Region-specific variables (excluding the plant's own contribution)				
Share of foreigners	5.666	(3.761)	7.038	(5.510)
Diversity among foreigners	0.527	(0.621)	1.676*	(1.001)
Statistics				
Number of observations	7,241		4,102	
Number of instruments	508		501	
Hansen J p-value	0.617		0.628	
AR(1) p-value	0.000		0.000	
AR(2) p-value	0.128		0.762	

All comments and control variables as in Table 4.

Table 9 Estimates with minimum distance to border x year as additional instrument

	Manufacturing		Services	
Plant-specific variables				
Share of foreigners	0.022	(0.383)	-0.806	(0.542)
Diversity among foreigners	0.308**	(0.142)	0.019	(0.238)
Region-specific variables (excluding the plant's own contribution)				
Share of foreigners	0.045	(3.291)	5.397	(6.311)
Diversity among foreigners	1.372*	(0.774)	1.694*	(0.952)
Statistics				
Number of observations	6,559		3,721	
Number of instruments	587		580	
Hansen J p-value	0.695		0.895	
AR(1) p-value	0.000		0.000	
AR(2) p-value	0.085		0.570	

All comments and control variables as in Table 4.

Table 10 Estimates imposing lag limits to instrument matrix

	Manufacturing				Services			
	t-2 to t-4		t-2 to t-5		t-2 to t-4		t-2 to t-5	
Plant-specific variables								
Share of foreigners	0.061	(0.531)	-0.071	(0.445)	-0.630	(0.653)	-0.850	(0.580)
Diversity among foreigners	0.390**	((0.160)	0.389***	(0.140)	0.049	(0.307)	-0.034	(0.297)
Region-specific variables (excluding the plant's own contribution)								
Share of foreigners	0.740	(3.520)	0.848	(3.366)	6.100	(4.263)	5.820	(4.289)
Diversity among foreigners	1.533**	(0.780)	1.590**	(0.729)	2.044**	(0.958)	1.856**	(0.921)
Statistics								
Number of observations	7,241		7,241		4,102		4,102	
Number of instruments	356		412		349		405	
Hansen J p-value	0.358		0.563		0.631		0.732	
AR(1) p-value	0.000		0.000		0.000		0.000	
AR(2) p-value	0.101		0.116		0.848		0.843	

All comments and control variables as in Table 4.

Table 11 Estimates for low- and high-tech industries

	Low tech manufacturing and other services plants		High tech manufacturing and knowledge-intensive plants	
Plant-specific variables				
Share of foreigners	0.074	(0.458)	-0.192	(0.452)
Diversity among foreigners	0.081	(0.191)	0.090	(0.169)
Region-specific variables (excluding the plant's own contribution)				
Share of foreigners	-1.391	(3.831)	4.860	(3.923)
Diversity among foreigners	0.531	(0.746)	2.858***	(0.934)
Statistics				
Number of observations	7,110		4,233	
Number of instruments	580		575	
Hansen J p-value	0.419		0.994	
AR(1) p-value	0.000		0.000	
AR(2) p-value	0.886		0.130	

All comments and control variables as in Table 4.

Table 12 Estimates for single plants and plants that are part of a corporate group

	Manufacturing				Services			
	Single plants		Part of group		Single plants		Part of group	
Plant-specific variables								
Share of foreigners	-0.158	(0.388)	-0.936	(0.839)	-0.685	(0.601)	-0.165	(0.688)
Diversity among foreigners	0.217	(0.141)	0.197	(0.162)	0.294	(0.313)	-0.109	(0.249)
Region-specific variables (excluding the plant's own contribution)								
Share of foreigners	1.813	(3.627)	-0.403	(3.829)	11.419*	(4.854)	-6.353	(5.924)
Diversity among foreigners	1.580**	(0.789)	-0.091	(0.857)	2.052**	(0.854)	-1.995*	(1.147)
Statistics								
Number of observations	5,794		1,447		3,043		1,059	
Number of instruments	570		570		563		530	
Hansen J p-value	0.521		1.000		0.835		1.000	
AR(1) p-value	0.000		0.000		0.000		0.000	
AR(2) p-value	0.216		0.101		0.689		0.177	

All comments and control variables as in Table 4.

Table 13 Estimates for large and small plants

	Manufacturing				Services			
	Large plants		Small plants		Large plants		Small plants	
Plant-specific variables								
Share of foreigners	-1.220	(0.923)	-0.073	(0.833)	0.655	(0.632)	-0.843*	(0.474)
Diversity among foreigners	0.286**	(0.137)	0.364	(0.546)	0.053	(0.285)	-0.015	(0.342)
Region-specific variables (excluding the plant's own contribution)								
Share of foreigners	3.986	(3.673)	-8.132	(28.486)	3.877	(9.071)	6.778	(4.592)
Diversity among foreigners	1.004	(0.782)	0.897	(1.905)	-0.943	(2.257)	2.340***	(0.756)
Statistics								
Number of observations	4,322		2,918		1,768		2,334	
Number of instruments	580		549		573		553	
Hansen J p-value	0.933		0.950		1.000		0.990	
AR(1) p-value	0.000		0.000		0.000		0.000	
AR(2) p-value	0.256		0.270		0.337		0.414	

All comments and control variables as in Table 4.

Table 14 Estimates for exporters and non-exporters

	Exporter		Non-exporter	
Plant-specific variables				
Share of foreigners	0.696**	(0.349)	-0.662**	(0.274)
Diversity among foreigners	-0.144	(0.167)	0.040	(0.253)
Region-specific variables (excluding the plant's own contribution)				
Share of foreigners	-2.014	(3.411)	3.117	(4.370)
Diversity among foreigners	1.551	(0.950)	1.429*	(0.750)
Statistics				
Number of observations	4,654		6,689	
Number of instruments	592		593	
Hansen J p-value	0.521		0.576	
AR(1) p-value	0.000		0.000	
AR(2) p-value	0.232		0.550	

All comments and control variables as in Table 4.

Table 15 Estimates for different regions

	Agglomerations		Other regions		Large region (Size above median)		Small region (Size below median)	
Plant-specific variables								
Share of foreigners	0.524	(0.430)	-0.239	(0.550)	0.333	(0.423)	-0.515	(0.689)
Diversity among foreigners	0.172	(0.205)	0.036	(0.207)	0.134	(0.156)	0.087	(0.231)
Region-specific variables (excluding the plant's own contribution)								
Share of foreigners	-4.353	(4.553)	2.113	(5.156)	-4.516	(3.573)	-1.723	(5.461)
Diversity among foreigners	0.449	(1.477)	1.401**	(0.601)	0.580	(1.305)	1.155**	(0.586)
Statistics								
Number of observations	3,930		7,413		5,672		5,671	
Number of instruments	578		586		590		589	
Hansen J p-value	1.000		0.564		0.715		0.467	
AR(1) p-value	0.000		0.000		0.000		0.000	
AR(2) p-value	0.125		0.738		0.223		0.535	

All comments and control variables as in Table 4.

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