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1 Introduction

In the course of technological progress, industrialised countries have been undergoing a severe structural change, from largely service-based to increasingly knowledge-based societies and economies. This coincides with the continued globalisation of markets and production processes. In this context, the European Union (EU) has liberalised labour mobility sequentially, as one of several means "become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth" (European Council, 2000). Immigration is thus supposed to foster economic growth and prosperity.

Therefore, the impact of immigration on the economy has become an important research field, the so-called migrant impact analysis (MIA, see Nijkamp et al. 2012). MIA aims to identify positive and negative effects of immigration and can be categorized in a wide range of fields. One of these is the impact of immigration on economic performance and innovation. Private firms' innovation is the source of sustained growth (Romer, 1990) and an important indicator of economic performance in a knowledge-based economy. Empirical evidence on innovation in the U.S. provides evidence of a positive impact from the specific characteristics of immigrants (Hunt and Gauthier-Loiselle, 2010; Kerr and Lincoln, 2010).

Albeit not a "classical" immigration country such as the United States, Germany has one of the largest migrant shares in Europe[1]. However, immigrants in Germany are relatively low-qualified, which is only starting to change more recently (Bruecker and Ringer, 2008; Bruecker, 2013).[2] Given this pessimistic outlook regarding the quantity and quality of immigrants to Germany, we assess whether the composition of migrants, i.e. their cultural diversity, can partly compensate for their low number and average skill level. We add to the MIA literature by investigating the relationship between establishments' cultural diversity and innovation outcomes in German business establishments. For this purpose we use a linked employer-employee data set that covers detailed workforce characteristics. Also, in the light of the literature on knowledge spillovers, there could be a spillover effect from diversity at the regional level to the outcome of an individual establishment, which we consider as well.

The paper is structured as follows. Section 2 derives a theoretical framework. Section 3 provides an overview of related previous evidence. Sections 4 and 5 describe the data and present the strategy and interpretation of our multivariate analysis. Section 6 concludes.

[1] 8.5 percent of the resident population are non-German citizens, the population with a "migration background" amounts to 19.5 percent (Federal Statistical Office, 2012).

[2] This is despite the problem that immigrants' qualifications might not be acknowledged in Germany.

2 Theoretical framework

Broadly, there are two economic rationales of what stimulates firms' innovation. On the one hand, innovation is costly and innovators set prices as close as possible to the monopoly price level (Romer, 1990, S78; Grossman and Helpman, 1991, 90sq). The incentive to innovate thus is to capture the monopoly rent. On the other hand, firms may face stronger pressure to innovate if competition is tougher (and so expected monopoly rents are lower; cf. Bodvarsson and van den Berg, 2009, 233sq). One may then argue that strong competition leads to prices that are far from monopoly rents. Irrespective of the debate on competition effects and price setting behaviour, innovation is an important prerequisite for maintaining competitiveness which may also secure monopoly rents. Specifically, we distinguish four different kinds of innovation:

- Product introductions, the most "radical" (and least frequent) kind of innovation, require a large amount of creativity and originality. Product introductions aim to enter new markets.
- Product imitations are the case where a firm adopts a product introduced by another firm. While a firm may not possess the resource to develop and introduce an entirely new product, it can still imitate others' innovative products, provided its workers are able to adapt and implement the knowledge required to produce the good (which is the more difficult, the more recent and technologically sophisticated the copied product).
- Product improvements are primarily a matter of quality and productivity increases within a neatly defined product. This kind of innovation may therefore be called "incremental," as opposed to "radical." Product improvements can be seen as a quality-ladder competition model which goes back to the idea of Schumpeter's creative destruction.
- Process innovations are about increasing productivity, as the aim is to increase production efficiency (which is reflected in the question used in the innovation survey we use). An important representation of process innovation is problem solving, which Hong and Page (2008) have shown to benefit from workforce diversity.

The basic inputs into the innovation process have been identified by Griliches (1979), who models innovation as a "knowledge production" process, incurring all the peculiarities of knowledge as a factor of production (first and foremost, its public-good characteristics)[3]. Applying Griliches' (1979) knowl-

[3]Romer (1990) proposed that innovation, i.e. the productive utilisation of knowledge, is the main driver of technological progress and thus, economic growth. His model also improves Griliches' (1979) knowledge production function by interpreting knowledge creation by learning as an endogenous mechanism of technological progress, and thus growth. The importance of learning in this context had already been discussed by Lucas (1988).

edge production framework, our hypothesis can be formulated in slightly different notation as follows. Innovation of a firm i to time t that is located in region r requires conventional inputs (X_{it}) and public knowledge (K_{rt}), and is furthermore determined by other unobserved factors (u_{it}):

$$I_{it}^{r} = f_I(X_{it}, K_{rt}, u_{it}) \tag{1}$$

Conventional inputs (such as R&D capital) can be thought of as physical capital C_{it} and labour L_{it}. In addition to these inputs firms use knowledge, which can be proxied by material R&D inputs and by human capital input (HK_{it}). The latter also captures part of the effect of external knowledge, since a more qualified workforce is more able to exploit public knowledge. There is also a productivity parameter A_{it} which captures other sources of factor productivity in the innovation process. The firm-internal inputs can be represented by a function $f_X(\cdot)$:

$$X_{it} = f_X\left(A_{it}, C_{it}, HK_{it}, L_{it}\right), \tag{2}$$

where labour L_{it} is additively separable with respect to nationalities. This makes the workforce employed culturally diverse. According to Ottaviano and Peri (2005), due to the complementarity effect of cultural diversity (DIV_{it}), labour gets more productive (innovative) as the number of different nationalities increases *and,* possibly, as workers are spread more evenly across nationalities (the different dimensions of cultural diversity are discussed below). Following Ottaviano and Peri (2005), define $0 \leq \tau_{it} \leq 1$ as a function which increases with the degree of cultural diversity as is the case for DIV_{it}. Then $(1 - \tau_{it})$ represents a negative effect of cultural diversity on knowledge production and innovation. Such negative effects and thus costs arise if cultural barriers give rise to frictions in communication or even conflict, distorting any productive process. However, it is theoretically open whether the positive or negative effects of diversity prevail. Collecting terms and substituting equation (2) into (1), the augmented knowledge production function becomes

$$I_{it} = f(A_{it}, C_{it}, HK_{it}, L_{it}, (1 - \tau_{it})DIV_{it}, u_{it}). \tag{3}$$

Broadly speaking, there are two different rationales as to why workforce diversity should stimulate innovation. First, as Hong and Page (2004) argue in a formal model, a diverse group of problem-solvers can reach better outcomes the most qualified problem-solvers under certain conditions, due to a broader variety of aggregate knowledge. The importance of "soft" aspects such as diversity in cultures is emphasised, inter alia, by Lazear (1999). This is because cultural heritage, as well as distinct skills

acquired in the home culture, may lead to more fertile problem-solving and decision-making.

The second rationale why diversity should foster innovation rests on the importance of public knowledge and its exploitation, which has been prominently debated theoretically (Griliches, 1979; Romer, 1990; and others) as well as empirically (Audretsch and Feldman, 2004). Firms are better prepared to exploit public knowledge if their workforce has a high "absorptive capacity," i.e. the ability to understand, interpret, and implement new (external) knowledge to the existing production process. This capacity will be the larger, the broader the existing knowledge base in the workforce. We suppose that cultural diversity, given the size and qualification structure of the workforce, extends this knowledge base, and thus increases absorptive capacity. Thus, both the utilisation and production of knowledge (the central mechanisms of the "knowledge production" process) should be fostered by workers' cultural diversity.

Considering the public-good nature and "tacitness" of knowledge (K_{rt}), furthermore, we consider innovation potentials external, but close to the establishment. Various regional factors such as industrial agglomeration or industrial variety are typically suggested as sources of productive knowledge exchange. There is a large body of literature arguing that knowledge spillovers occur largely locally (Jaffe et al., 1993; Keely, 2003; Howells, 2012). Furthermore, firms' productivity and innovation effort gain from the presence of a (local) industrial variety (Jacobs externalities).

In the literature on skill complementarities (e.g. Frenken et al., 2007) it is argued that at the regional level, radical innovation benefits most from the availability of diverse skills, whereas incremental innovation (product improvement, process innovation) benefits from relatively homogenous, but high-level productive capacities (i.e. skills). However, it is unclear whether these considerations are transferable to the establishment level, since Frenken et al. (2007) consider variety of industries within a region, an aspect of variety that cannot be observed upon an establishment's workforce. Furthermore, the occurrence of cultural diversity at the plant level is likely to vary across industries, as is the occurrence of different kinds innovation. Therefore, we cannot expect any specific structure of diversity effects across categories of innovation.

We apply the following three-dimensional concept of cultural diversity. The dimensions are: (1) the proportions of different subgroups (nationalities) within a group, (2) the number of different subgroups, and (3) the evenness of the distribution of these subgroups within the aggregate. Its formal representation is the Fractionalizsation Index,

$$DIV_H = 1 - \sum_{n=1}^{N} (\frac{L_n}{L})^2 \in (0, 1), \tag{4}$$

where $\frac{L_n}{L}$ is the proportion of a cultural (national) group out of N groups in a firm's workforce. The measure equals one minus the Herfindahl index and represents the probability of drawing two different nationalities if two individuals are drawn at random from a workforce. This probability increases in each of its three dimensions. The Fractionalization index is most frequently used in the literature, so it is our preferred measure of cultural diversity. However, it is critisized that it assigns too much weight to the largest cultural groups (Niebuhr, 2010, 568sq; Trax et al., 2012, 20sq). In our case, the issue of weighting the largest cultural group is most critical with respect to the native group, the Germans. For this reason we exclude natives from the diversity index, and use

$$DIV_H^{migr} = 1 - \sum_{m=1}^{M} (\frac{L_m^*}{L^*})^2 \in (0,1), \tag{5}$$

to identify diversity effects while controlling for the proportion of migrants employed (FOR= L^*/L). L_m^*/L^* is the proportion of migrant workers of the $m-$th nationality with M foreign nationalities employed.

Our specification disentangles the dimensions of cultural diversity: FOR identifies the effect of the proportion of *all* migrants with respect to the firm's entire workforce, whereas DIV_x^{migr} captures the effect of the number of *distinct* foreign nationalities (cultural variety) and the evenness of their distribution. The underlying rationale is that changes in DIV_x^{migr} most likely coincide with changes in FOR, but as previous research suggests, the effect of such changes on firm performance may differ in signs and magnitude; in particular, FOR may be driven by one large group, which may contribute to workforce polarisation but not diversity.

Besides disentangling the FOR and DIV_x^{migr} dimensions of cultural diversity, we separate migrants by skill groups, as the causes and effects of diversity should be quite distinct between skill groups:

- High-skilled migrants may be culturally diverse because they are internationally sought-after experts of some kind. These are knowledge-intensive workers, as identified by our high-skilled definition. It is in this group that we expect positive diversity effects, since this is where learning and knowledge exchange occur primarily. Part of this effect may arise from complementarities in educational background (as long as education has been acquired abroad); the rest of the effect should be due to complementarities between cultural backgrounds (e.g. attitudes, work ethics, informal methods of problem-solving).

- Low-skilled migrants typically work in jobs that require less analytical thinking and communication, and are thus less likely to generate new knowledge. However, their share in an establishment's

employment may be high. Their diversity might also be high, but this is due to the indifference of cultural backgrounds—their specific knowledge is not sought after, but is in fact irrelevant in the job they perform.

We define highly-skilled workers by the task content of their occupation, following the seminal idea of Autor et al. (2003), who suggested that what is typically referred to as "skill-biased technological change" is in fact a structural change of the productive tasks performed in a job. This concept has risen particular attention in the labour immigration literature, where recent studies have found that immigrants sort themselves into less communication- and interaction-intensive jobs (Peri and Sparber, 2009; D'Amuri and Peri, 2011).

Since we are interested in the influence of external workforce structure as well as at the internal level, we account for the regional workforce structure by considering the quantity and high-skilled share of workers within the same region and industry.

3 Previous evidence

Niebuhr (2010) finds that regional cultural diversity has positive effects on innovation as measured by patent applications, but so do regional R&D expenditure and regional industrial structure, as manufacturing is stronger in patenting than the service sector. Separate regressions for high-skilled R&D employment indicate that these effects occur not only among the highest-qualified researchers who may be some kind of international elite, suggesting that innovation is not merely driven by human capital, but also by cultural diversity. Such a finding is supported by Lee and Nathan (2010) at the firm level considering a sample of 2,300 firms located in London. They provide evidence that there is a significant positive relationship between cultural diversity and process and product innovation. Focussing on the effect of diversity among management teams, Lee and Nathan (2013) find again a small but significant impact of cultural diversity within teams on innovation outcomes for London firms while controlling for endogeneity issues.

There exist other work at the establishment level which does not directly focus on innovation outcomes. Cultural diversity has been studied by Brunow and Blien (2011), who estimate establishments' employment and find it decreasing in cultural diversity if output is held constant. This is interpreted as a positive productivity effect. To estimate the effect of the migrant share and the evenness of the nationality distribution, the specifications hold constant the number of nationalities in an establishment. The relationship between diversity and employment varies in the number of nationalities (Brunow and Blien, 2011, 9). Migrants' employment share and cultural diversity seem to have positive productivity

effects for given numbers of employed nationalities, but the number of nationalities is estimated with a negative sign. This can be seen as evidence of the "Babel effect."In contrast, cultural diversity seems to improve productivity for a given number of nationalities.

Trax et al. (2012) study German establishments productivity and investigate spillovers (with respect to productivity) from cultural diversity within and between firms (within regions). Cultural diversity is found to have a distinct positive productivity effect, as opposed to an establishment's share of migrants. However, diversity effects are found to be rather heterogeneous between firms with respect to sectors, industries, and other establishment characteristics. At the regional level, spillovers from diverse workers are more found to be stronger in knowledge-intensive sectors. Also, the positive diversity effects are more pronounced in manufacturing than in services. Furthermore, exporting firms reach higher productivity levels if they employ higher shares of migrants, contrary to non-exporters (Trax et al., 2012, 21sq). Another work by Brunow and Nijkamp (2012) supports the evidence of productivity gains and these are due to highly-skilled foreign employees. They cannot find any evidence of a positive coherence between low-skilled diversity and establishment productivity.

In contrast, Parrotta et al. (2011a) investigate cultural diversity in Danish firms and its effects on productivity, and find negative effects. Separating the observations by two occupational groups (blue v. white collar) reveals that the effect is less pronounced in white-collar occupations, where communication and high formal qualification are more important. Some of Parrotta et al.'s (2011a) findings may be due to peculiarities of the Danish labour market. In particular, due to the small domestic market, a lot of Danish firms conduct a large part of communication in English. This should be found all the more in higher-skilled sectors, and this is where the study indeed finds, at least, neutral diversity effects.

The above studies indicate that diversity may be most beneficial, or least harmful, in knowledge-intensive production. Further "success factors" of cultural diversity include exporting and manufacturing, i.e. (possibly) capital intensity, which may coincide with knowledge intensity. This suggests that diversity's benefits in fact come from knowledge exchange and knowledge production. Accordingly, a number of studies have also explicitly related establishments' innovation to cultural diversity. Ozgen et al. (2011) investigate the diversity-innovation relationship in Dutch establishments. The regressions include the number of nationalities (including Dutch) and a diversity index (excluding Dutch). The former is mostly insignificant. Migrant diversity, on the other hand, is significantly positively related to product innovation.

Parrotta et al. (2011b) relate cultural diversity in Danish firms to their propensity to innovate (apply for a patent), the number of patents applied for, and the variety of technological fields in which they applied for patents. It is found that for all three success measures, cultural diversity seems to have a

positive effect. Finally, a study by Ostergaard et al. (2011) investigates diversity's effect on several categories of firms' innovation, but does not find any significant effects. In contrast, the study finds significantly positive coefficients on gender diversity (a balanced gender structure), suggesting that other aspects of workforce diversity should be controlled for when analyzing cultural diversity.

Lee and Drever (2012) consider firm innovation capability in creative occupations and creative industries located in London/UK. They provide evidence that employing creative people enhances product innovation abilities. However, firms operating in creative industries are not more innovative than firms in other industries. The results are supported by Lee and Rodríguez-Pose (2013), who support the robust result of creative occupations. They find weak evidence that creative industries firms are more innovative in contrast to Lee and Drever (2012).

To summarise the previous evidence, most authors find that different dimensions of diversity have opposing effects: Whereas the sheer presence (share) of migrants is often negatively related to (knowledge) productivity, the diversity of migrants is mostly found positively related to innovation and productivity. Another central finding is that diversity effects vary across different skill groups, encouraging us to separate workers by a broad but meaningful distinction of skill levels. Finally, the literature highlights other aspects of diversity such as age, experience and gender, that should be controlled for. The following section describes the data we use to tackle all these issues.

4 Data

The central source of data is the Institute for Employment Research's (IAB) Establishment Panel (EP). It is a representative survey of German establishments which is conducted on an annual basis. We use survey responses on innovation behaviour from 2001, 2004, and 2007 through 2009, which are coded as binary variables indicating whether an establishment has performed a particular kind of innovation (product introduction, product imitation, product improvement, process innovation[4]) or not in the previous year. To focus on establishments which conduct innovation as a for-profit business activity, public-sector establishments are excluded from the sample (as identified by legal form). Importantly, this also excludes the public higher education sector. On the basis of a unique identifier it is possible to connect the EP with other administrative data collected by the German social security system, administered by the Federal Employment Agency (BA).

The establishment's employment data used is a special draw originating from the German social security system, and include all employees subject to social security contribution. This excludes civil

[4]Process innovations have only been surveyed 2007 through 2010.

servants and the self-employed, however. As a 100% sample of regular employment in Germany, the employee data contain vast information on Germany's workforce, including detailed sociodemographic characteristics such as formal education and nationality, but also delivers characteristics of the job such as the occupation and information on full-time or part-time employment. Cultural diversity measures are constructed from these data, for each establishment's workforce, as well as each NUTS 3 region's regular employees (out of the 100% sample).

Cultural identity is usually defined by either nationality or country of birth. Bellini et al. (2008) discuss advantages and disadvantages of both concepts. In our context, the nationality concept denies the innovative potential in naturalised citizens, while the country-of-birth concept denies that by assimilation (e.g., if a migrant received her education and training within the host country), migrants should not differ strongly from natives. Another critical remark is in order regarding nationality as an identifier of cultural identity: Treating each nationality equally as a distinct "culture" ignores differences in "cultural distance" between nationalities. Failing to account for the variation in cultural distance may introduce measurement error, resulting in attenuation bias. Since the country of birth is not available in our data, we consider the nationality and take the disadvantages of the method as given. Concerning cultural distance, we argue that aggregating nationalities to cultural groups results in a loss of information, and therefore, potentially, a loss of precision in the estimates of cultural diversity especially if smaller establishments are concerned. Those establishments may have several nationalities employed but only one foreign culture group, which implies low cultural diversity.

Because we are interested in the migrants' effect additionally to the native workforce (we regard migrants as potentially complementary workers), we exclude all establishments from the analysis which solely employ foreigners. This exclusion rules out a potential bias from very small establishments such as family-owned groceries, who may typically not innovate despite a high "cultural potential" for knowledge production.

To generate the above-mentioned high-skilled definition, we relate reported occupations to task performance (cf. Autor et al., 2003) and classify occupations into high- and low-skilled. For this purpose we use the following characteristics of the occupation: the average time spent on analytical tasks relative to the sum of time spent on analytical and manual tasks; the average time spent on non-routine tasks relative to the sum of time spent on non-routine and routine tasks; and the share of university degree holders in the occupation. The reclassification of high- and low-skilled people not just on the basis of formal qualification also overcomes the problem of under- and overeducation (Duncan and Hofmann 1981) which has been shown to be present in the German labour market (Brunow and Hirte 2009). Data on time spent in analytical, manual, non-routine and routine work was obtained from the German Qualification

and Career Survey 1998/1999 which is jointly collected by the Federal Institute for Vocational Education and Training (BIBB) and the Institute for Employment Research (IAB). Occupations are classified as high-skilled if the proportions of analytical and non-routine tasks and the occupation's share of university degree holders are high. For this classification we perform a hierarchical cluster analysis using the average linkage method. We carefully went through the list of occupations of the cluster analysis and manually reclassified workers of the retail sector, delivery men and unskilled office workers into the low-skilled group.

Additional employee data (workers' age and tenure) were merged to the establishment data from the IAB's main linked employer-employee data set LIAB, which does not cover all establishments we observe. On the regional level, we have data on population and population density. These were obtained from the GENESIS data base of the Federal Statistical Office (StBA).

5 Econometric specification and description of variables

After data preparation, the final data set comprises an unbalanced panel with a median number of observations per establishment of about 4. It comprises up to 69,000 observations. Table 1 provides an overview of the relative percentages for each innovation type and number of observations available. About 40 % of all establishments report product improvement, whereas only about 10% of all establishments introduce new products. Adoption of technologies or products takes place in about every fourth and process innovation takes place in every fifth establishment.

Table 1: Proportion of establishments doing innovation in one of the fields

in %	improvement	adoption	introduction	process innov.	Average No. of obs.[1]
2000	41.0	24.1	9.6		11,673
2003	37.9	18.5	7.2		11,503
2006	45.5	30.5	13.9	25.3	11,537
2007	41.9	24.9	9.7	19.9	11,350
2008	43.9	27.0	10.4	19.6	11,323
2009	40.6	25.0	9.9	18.4	11,422
Total No. of obs.	68,820	68,829	68,802	45,604	

[1]Note: No. of obs. between innovation types varies slightly each year

Our empirical model on firm's innovation is derived from the theoretical specification given in equation (3). It is a reduced form model and is given by:

$$
\begin{aligned}
I_{it}^{jr} &= \beta_0 + \beta_1 HK_{it} + \beta_2 FOR_{it} + \beta_3 DIV_{it} + \sum_{k=1}^{K} \beta_k EMPL_{kit} + \sum_{l=1}^{L} \beta_l EST_{lit} \\
&\quad + \sum_{p=1}^{P} \beta_p (REG - IND)_{prjt} + \sum_{n}^{N} \beta_n REG_{nrt} + \gamma_j + \delta_r + \zeta_t + \epsilon_{it}, \qquad (6)
\end{aligned}
$$

where I_{it}^{jr} relates to one of the four binary innovation outcomes of the ith firm to time t that is located in region r and which operates in industry j. In equation (6) the variable DIV_{it} henceforth denotes DIV_H^{migr}. Human capital input (HK_{it}) is proxied by the share of high-skilled workers by the above definition (occupations with a amount of analytical tasks). The Parameter β_2 identifies whether the presence of Non-Germans affects innovation in general. Given FOR_{it}, β_3 measures the effect of migrant diversity. As discussed above, we include both FOR_{it} and DIV_{it} separately for high- and low-skilled migrants. Because most of the migrants in Germany are rather low-qualified by means of formal qualification (Bruecker and Ringer, 2008; Bruecker, 2013), the distinction in task-related skill groups seems more appropriate. The generally lower qualification level of the migrant workforce suggests that while a high share of foreigners may be negatively related to innovation, diversity within FOR_{it} may have a positive effect. However, since FOR_{it} and DIV_{it} are positively correlated (corr=0.249), failing to control for FOR_{it} might imply a biased estimate of β_3.

In the variable vector $EMPL$, we include information describing other kinds of workforce diversity in the firm, i.e. the mean and SD of workers' age, as well as the share of women employed (measured in FTE person-days) as controls of demographic workforce diversity. $EMPL$ furthermore controls for the mean and SD of workers' tenure, as a proxy of establishment specific human capital. EST includes a number of other relevant establishment-level characteristics, such as an indicator whether the establishment is foreign-owned, whether it is a single-site firm, and its legal form, i.e. whether it is (part of) a privately owned firm (with unlimited personal liability, as opposed to corporations with limited personal liability). The reason behind controlling for legal form is that the propensity to innovate may differ across types of liability, as innovation always entails risk.

One innovation-related advantage of "diverse" firms with respect to exporting is the staff's better awareness of foreign customers' preferences and generally, international consumption and technology trends. Therefore, we control for an interaction of migrant diversity and the establishment's export share in total sales, as we want to identify DIV's potential effects solely through the channels skill complementarity and absorptive capacity. Since coefficients on interaction terms in binary models cannot be interpreted without ambiguity in terms of either significance or sign (cf. Ai and Norton 2003: 124),

the DIV-exports interaction must not be interpreted itself, but is only included as a control variable.

To control for unobserved time-invariant effects of industrial affiliation and location, we include two-digit industry[5] (γ_j) and NUTS 3 region fixed effects (δ_r). Specifically, this accounts for the obvious selectivity of innovativeness with respect to industries and for the selectivity of establishments' location. However, some regional variables are part of our research interest rather than just control variables, notably cultural diversity. As on the establishment level, we include regional high- and low-skilled migrants' employment share and diversity to control for potential spillover effects from the regional workforce, which (according to our hypothesis) are more likely to occur if the regional (high-skilled) migrant workforce is more culturally diverse. Regional cultural diversity is part of the variable set REG, which also includes population density within the region and spatially weighted population density in all surrounding regions, as a proxy for market size (which influences the chances of successful innovation for the reasons discussed in the theoretical section). REG also includes regional R&D expenditures, proxying the physical capital invested in R&D (unfortunately, we have no such measure at the establishment level).

The set of variables denoted $REG-IND$ includes the volume (full-time equivalent person-days) and high-skilled shares of the regional (NUTS 3) workforce employed in the same 2-digit industry, controlling for Marshall-Arrow-Romer agglomeration economies that might foster innovation. Finally, ζ_t is a set of year dummies, and ϵ_{it} is the IID error term. To account for the likely clustered structure of the error term, we cluster standard errors at the establishment level.

Our dependent variable indicates whether the establishment reports any product introduction, imitation, improvement, or process innovation, respectively. The binary outcomes require discrete choice models such as Logit and Probit to obtain consistent estimates. Because the Probit model works under the more general assumption of a standard normally distributed error, in principle, Probit should be the preferred model. In the Logit specification, there is more probability mass in the tails of the error distribution. This allows a slightly better identification of radical innovations (which are rare). The estimated coefficients indicate the direction and significance of the influence of each variable but do not allow an interpretation of its magnitude because of the nonlinearity. Therefore average marginal effects are computed. It turns out that the results between Logit and Probit do not differ much, so we report only the Probit results.

Given our longitudinal data, using a panel model should be considered to control for unobserved heterogeneity at the establishment level. However, for two reasons, a fixed-effects (FE) specification is inappropriate. First, it leaves unused any information from establishments which do not change their innovation status between the survey periods. This concerns a large part of the establishments in our

[5] Industries are defined by the German Classification of Industries of 2003 (WZ03).

sample, and is due to the relatively short length of the panel. Second, FE precludes the identification of effects from between-firm variation. As all variables of interest have substantially higher between- than within-firm variation, this simply means that the bulk of information in our data would go unused.

A fundamental problem in the analysis of innovation is reverse causality, running from the propensity to innovate to regressors such as human capital. In most cases, even time lags of the explanatory variables are likely to be endogenous, since the decision to be innovative (in the future) requires the employment of qualified workers well in advance, and if establishments see migrant diversity as another requirement for being innovative, this variable is also affected by simultaneity bias. Concerning the interpretation of results, this means that the estimated marginal effects cannot be interpreted as causal relationships.

6 Results

Before the results obtained by Probit regression are presented, some robustness checks and estimation issues are discussed. To provide a picture of the significance of the variables included we first estimate an 'only-constant-and-fixed-effects-model' and compare the results with those when additional explanatory variables are included. Likelihood ratio tests support that the additionally included variables jointly improve the explanatory power of the model. We estimate several models for each type of innovation that include different of explanatory variables. It turns out that neither the estimates nor the significance levels of the explanatory variables included change seriously between the models. We therefore only present the full model. The estimates are robust within each type of innovation but vary between different types of innovation. Because only marginal effects provide a magnitude of the effects on the probability to innovate, we present only the average marginal effects in the main regression tables.

For all types of innovation, our results suggest that larger companies in terms of employment levels are those who are more innovative. Because the industry fixed effect controls for the general probability of being innovative or not, the estimated effect of establishment size is not biased by the sectoral differences in firm size. A similar point can be made for the employment of high-qualified workers. Establishments operating in a specific industry and region are more innovative, the more highly-skilled workers they employ. This highly supports the knowledge-production function theory of Griliches (1979). Also, establishments with a higher proportion of exports in total sales are those who are more innovative. According to the theory of Melitz (2003), firms tend to be more export-oriented the higher firms own productivity is. In the abstract modelling framework productivity is a result of an innovation process taking place in a research sector. Our finding is in line when the assumption of an external research sector is not taken too literally. Exporting establishments are more likely to be innovative for the following reasons: first in

Table 2: Average marginal effects of the entire sample

	improvement	adoption	introduction	process innov.
ln FTE	0.059***	0.030***	0.017***	0.047***
	(0.00)	(0.00)	(0.00)	(0.00)
prop. high-skilled workers	0.144***	0.055***	0.057***	0.078***
	(0.01)	(0.01)	(0.01)	(0.01)
prop. exports	0.252***	0.125***	0.097***	0.125***
	(0.02)	(0.02)	(0.01)	(0.02)
DIV * prop. exports	0.039	-0.083**	-0.049**	-0.027
	(0.05)	(0.03)	(0.02)	(0.03)
d. single est.	-0.028***	-0.023***	-0.012***	-0.030***
	(0.01)	(0.01)	(0.00)	(0.01)
d. private partnership	-0.019*	-0.007	-0.002	-0.025**
	(0.01)	(0.01)	(0.01)	(0.01)
d. foreign owner	0.015	-0.023**	-0.009	-0.004
	(0.01)	(0.01)	(0.01)	(0.01)
mean tenure	-0.005***	-0.005***	-0.004***	-0.003***
	(0.00)	(0.00)	(0.00)	(0.00)
s.d. tenure	0.001	0.001	0.001	-0.001
	(0.00)	(0.00)	(0.00)	(0.00)
mean age	-0.003***	-0.002***	-0.001***	-0.002***
	(0.00)	(0.00)	(0.00)	(0.00)
s.d. age	-0.001	0.001	-0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
prop. female	0.031***	0.047***	0.017***	0.041***
	(0.01)	(0.01)	(0.01)	(0.01)
prop. high-skilled foreigners	-0.075**	-0.029	-0.039*	-0.013
	(0.03)	(0.03)	(0.02)	(0.03)
prop. low-skilled foreigners	-0.063***	-0.052**	-0.043***	-0.028
	(0.02)	(0.02)	(0.02)	(0.02)
diversity high-sk. foreingers	0.093***	0.040**	0.043***	0.053***
	(0.02)	(0.02)	(0.01)	(0.02)
diversity low-sk. foreigners	-0.021	-0.023*	0.004	-0.011
	(0.01)	(0.01)	(0.01)	(0.01)
ln FTE reg.-ind.	0.004	0.001	-0.001	0.005*
	(0.00)	(0.00)	(0.00)	(0.00)
ln prop. HK reg.-ind.	0.037	0.003	0.058***	0.069**
	(0.04)	(0.03)	(0.02)	(0.03)
ln pop. density	0.062	-0.049	-0.115	-0.628**
	(0.10)	(0.10)	(0.07)	(0.30)
W ln pop. density	0.106***	0.061***	0.021	0.031
	(0.02)	(0.02)	(0.01)	(0.05)
regional prop. high-skilled foreigners	-0.222	0.616	0.131	-1.791
	(0.94)	(0.86)	(0.58)	(1.31)
regional prop. low-skilled foreigners	0.410	-0.200	-0.500	-0.222
	(0.72)	(0.68)	(0.47)	(1.14)
regional diversity high-sk. foreingers	-0.019	0.137	0.070	-0.241
	(0.10)	(0.09)	(0.06)	(0.18)
regional diversity low-sk. foreigners	-0.168	-0.026	-0.111	-0.123
	(0.12)	(0.11)	(0.09)	(0.20)

the field of process innovation to be relatively more productive to compete in global markets. Second, in product improvement to secure export success and competitiveness with 'state-of-the-art' products. Third, they are innovative in terms of product introduction to enter new, global markets. Exporting also matters for the probability of product imitation, which we view as evidence that establishments engaged in exporting are more aware of relatively (but not radically) innovative products that promise success, as they might have been introduced successfully in some foreign markets but not in others, or not in Germany.

Concerning international structures, one might expect that foreign ownership relates to a higher degree of innovation because foreign owners might have an interest in higher dividends and therefore establishments should be more innovative. However, after controlling for export behaviour and the legal form, the estimate is insignificant with the exception of product imitation. In that case the estimate is significant and negative. This may be because imitation is an relatively unlikely to yield large profits, as opposed to product introduction and product improvement.

We now turn to the effects of the workforce related variables. If the average age of employees and average tenure increase, the likelihood of innovation decreases for all innovation types. Given this result, one could argue that innovative capability decreases in age and tenure due to "cognitive lock-in." Interestingly, demographic diversity (the standard deviations of employees' age and tenure) is insignificant, suggesting that a mixture of young and old employees with respect to age and job tenure does not yield gains in terms of innovation.

Focussing on cultural diversity and thus, the employment of migrants, replicates previous studies' findings. Whereas the migrant share among the high-skilled is negative or insignificant, high-skilled migrant diversity is positively related to innovation. Because the definition of highly skilled employees rests upon formal qualification but also job characteristics, it is not biased towards the likely over-qualification by migrants which may work in jobs that do not require a university degree. Interestingly, the negative effect of the high-skilled migrant share is only significant for product improvement and introduction, and stronger for the former innovation type. These both kinds of innovation are the most direct indicators of product market success (be it by quality improvement or an extension of the product portfolio). Our result suggests that these realms, which require detailed knowledge of the product market, actually profit from a relatively low share of migrants among the high-skilled. This indicates that, despite the importance of exporting for innovation, an important fraction of innovations also aims at the domestic market.

Contrary to their share, the diversity of high-skilled migrants is positive and significant. An argument frequently found in the literature is that people from various countries have distinct approaches of problem

solving and, if they interact, the outcome might be more efficient. Our estimations support this claim. In contrast, the migrant share among the low-skilled employees, and partly also their diversity, is significantly negative. This does not necessarily imply that lower-skilled migrants are harmful to innovation. The problem here is that we do not observe which tasks are performed by which employees. However, the labour immigration literature (e.g., Peri and Sparber, 2009; D'Amuri and Peri, 2011) suggests that less skilled migrants self-select into jobs characterized by manual and routine tasks, i.e. relatively well-established production processes. Such jobs, and potentially, the establishments where they are located, do not aim at innovation.

As a control variable concerning cultural diversity, we consider the interaction term with the proportion of exports. Here we find a negative significant effect on product introduction and imitation. The interpretation is as follows: For a given intensity of exports, a more culturally diverse migrant workforce (including all skill levels) reduces the likelihood of being innovative. One might have expected that the presence of different nationalities increases the probability of innovation success in exporting firms because the variety of country-specific knowledge is larger, concerning e.g. foreign consumers' preferences and product market regulations. The opposite is suggested by our estimate, however. This might be due to the difficult interpretation of the interaction term of our non-linear model. Possibly, the negative estimate captures only part of the true effect. For instance, the true effect could be such that once a given level of cultural diversity is achieved, it does not improve the likelihood to be innovative anymore, while below a certain threshold, cultural diversity contributes to exporters' innovation success.

The last set of variables concerns establishments' regional environment variables. These covariates are mainly insignificant, which is partly explained by the inclusion of regional and industry fixed effects and the high degree of time consistency of these variables. However, if within a region and industry the proportion of high-skilled workers increases, the likelihood of product introduction and process innovation increases. Thus, our results suggest a spillover effect from the human capital embodied in workers within a region and industry, which supports the existence of MAR (specialization) externalities. Also, if the establishment is located in a region with high employment density, the likelihood of being innovative increases for product imitation and improvement, suggesting the presence of agglomeration externalities in the form of knowledge spillovers. Contrary to our expectations, we do not find any significant effects of regional cultural diversity in line with our hypotheses.

To ensure the robustness of the results, it is common in the analysis of the German labour market to focus on either East or West Germany. In our case, as we are interested in the effects of cultural diversity, West Germany (which has much higher migrant population shares and diversity) appears more interesting. Furthermore, establishments in East Germany are partly production units of larger companies

Table 3: Average marginal effects considering West German establishments only

	improvement	adoption	introduction	process innov.
ln FTE	0.062***	0.031***	0.018***	0.052***
	(0.00)	(0.00)	(0.00)	(0.00)
prop. high-skilled workers	0.126***	0.052***	0.046***	0.074***
	(0.02)	(0.01)	(0.01)	(0.02)
prop. exports	0.201***	0.119***	0.084***	0.139***
	(0.03)	(0.02)	(0.01)	(0.03)
DIV * prop. exports	0.121**	-0.043	-0.009	-0.039
	(0.05)	(0.04)	(0.03)	(0.05)
d. single est.	-0.037***	-0.028***	-0.016***	-0.032***
	(0.01)	(0.01)	(0.01)	(0.01)
d. private partnership	-0.023*	-0.011	-0.004	-0.030**
	(0.01)	(0.01)	(0.01)	(0.01)
d. foreign owner	0.020	-0.019	-0.011	-0.003
	(0.01)	(0.01)	(0.01)	(0.01)
mean tenure	-0.004***	-0.003**	-0.003***	-0.003**
	(0.00)	(0.00)	(0.00)	(0.00)
s.d. tenure	-0.002	-0.002	0.000	-0.002
	(0.00)	(0.00)	(0.00)	(0.00)
mean age	-0.003***	-0.003***	-0.002***	-0.001**
	(0.00)	(0.00)	(0.00)	(0.00)
s.d. age	-0.000	0.001*	-0.001	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
prop. female	0.020	0.038***	0.010	0.037***
	(0.01)	(0.01)	(0.01)	(0.01)
prop. high-skilled foreigners	-0.086**	-0.040	-0.054**	-0.054
	(0.04)	(0.03)	(0.02)	(0.04)
prop. low-skilled foreigners	-0.043*	-0.042*	-0.044**	-0.025
	(0.02)	(0.02)	(0.02)	(0.03)
diversity high-sk. foreingers	0.102***	0.046**	0.047***	0.073***
	(0.02)	(0.02)	(0.01)	(0.02)
diversity low-sk. foreigners	-0.034**	-0.022	0.001	-0.012
	(0.02)	(0.01)	(0.01)	(0.02)
ln FTE reg.-ind.	0.010***	0.003	0.001	0.007*
	(0.00)	(0.00)	(0.00)	(0.00)
ln prop. HK reg.-ind.	0.052	0.084*	0.082***	0.140***
	(0.05)	(0.04)	(0.03)	(0.05)
ln pop. density	-0.369	-0.541**	-0.580***	-1.279**
	(0.26)	(0.25)	(0.17)	(0.64)
W ln pop. density	0.079*	0.091**	0.026	0.153
	(0.04)	(0.04)	(0.03)	(0.10)
regional prop. high-skilled foreigners	-0.896	-0.134	0.189	-2.248
	(1.16)	(1.08)	(0.73)	(1.61)
regional prop. low-skilled foreigners	0.652	-0.159	-0.292	-0.608
	(0.80)	(0.77)	(0.51)	(1.36)
regional diversity high-sk. foreingers	-0.180	-0.020	0.157	-0.077
	(0.23)	(0.21)	(0.14)	(0.32)
regional diversity low-sk. foreigners	-0.659***	-0.190	-0.303*	-0.369
	(0.23)	(0.23)	(0.16)	(0.35)

with headquarters in West Germany, reducing the likelihood of innovation in East German establishments. These differences may yield biased results due to effect heterogeneity, which cannot be controlled by means of region fixed effects. We therefore restrict the sample to West German establishments. The marginal effects are presented in Table 3 and the estimated parameters for the probit model are shown in Table 8 in the Appendix.

The emerging from the full sample is confirmed by the sub-sample of West German establishments. Some region and industry related variables become more significant, which is especially the case for the intra-industrial regional employment and its proportion of high-qualified workers. Population density has a negative coefficient, indicating that in densely populated areas establishments are less likely to innovate. Focussing on cultural diversity yields strong negative and significant effects of the diversity of low-skilled migrants in the region. The reason may be that traditionally, immigrants to West Germany are less qualified and work in rather manual-routine oriented jobs. Then, establishments located in regions that possess high low-skilled migrant employment shares are those which do not innovate. However, considering the interaction term of establishment's own cultural diversity and the export proportion on revenues now has a positive and highly significant effect on the probability of product improvement, which seems more plausible than the above findings for the full sample.

Another robustness check is in order concerning the potential distinctness of establishments that employ migrants. The negative effects of migrant shares might be driven by a selectivity problem: establishments employing migrants may differ systematically from those who do not, and the reasons for the decision whether to employ migrants or not are unobserved. This is another potential source of bias. We therefore consider a sub-sample of establishments with at least one Non-German employee. The marginal effects are presented in Table 4 and the estimated parameters of in Table 9 in the Appendix. The results obtained largely resemble the already presented evidence. So we only discuss the main differences. First, the effects of low-skilled and high-skilled migrant shares is now mostly insignificant, while it was negative in the other models. The only exception concerns product introduction. This is due to the selection of natives and foreigners into different tasks and jobs, which is not fully captured by the distinction of skill groups. Migrants select into jobs demanding routine or manual tasks, which are less related to innovation. This selection effect is captured by the proportion of foreigners variables in the full sample, but disappears in the current sample. Regarding migrant diversity, however, this robustness check confirms our previous findings: whereas diversity among the low-skilled is negative, diversity of high-skilled employees is positively related to innovation. An increase of the presence of high-skilled workers increases the likelihood to be innovative more than in the other models. Thus, we conclude that firms employing migrants are those who do not innovate frequently. However, if additional human capital

Table 4: Average marginal effects considering establishments only which employ foreigners

	improvement	adoption	introduction	process innov.
ln FTE	0.072***	0.032***	0.020***	0.073***
	(0.00)	(0.00)	(0.00)	(0.01)
prop. high-skilled workers	0.227***	0.082***	0.106***	0.165***
	(0.02)	(0.02)	(0.02)	(0.03)
prop. exports	0.178***	0.110***	0.091***	0.087**
	(0.03)	(0.03)	(0.02)	(0.04)
DIV * prop. exports	0.071	-0.065	-0.025	0.006
	(0.06)	(0.05)	(0.03)	(0.06)
d. single est.	-0.021	-0.037**	-0.008	-0.021
	(0.01)	(0.01)	(0.01)	(0.02)
d. private partnership	-0.012	-0.003	0.010	-0.032
	(0.02)	(0.02)	(0.01)	(0.02)
d. foreign owner	-0.006	-0.034***	-0.018**	-0.013
	(0.01)	(0.01)	(0.01)	(0.01)
mean tenure	-0.002	-0.006***	-0.003**	-0.002
	(0.00)	(0.00)	(0.00)	(0.00)
s.d. tenure	0.001	0.006**	0.003	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)
mean age	-0.006***	-0.005***	-0.004***	-0.006***
	(0.00)	(0.00)	(0.00)	(0.00)
s.d. age	-0.001	0.002	-0.001	0.002
	(0.00)	(0.00)	(0.00)	(0.00)
prop. female	0.049**	0.087***	0.053***	0.028
	(0.02)	(0.02)	(0.02)	(0.02)
prop. high-skilled foreigners	-0.045	-0.020	-0.046*	0.012
	(0.03)	(0.04)	(0.03)	(0.04)
prop. low-skilled foreigners	-0.021	-0.036	-0.057**	-0.004
	(0.03)	(0.03)	(0.02)	(0.04)
diversity high-sk. foreingers	0.045**	0.044**	0.057***	0.025
	(0.02)	(0.02)	(0.01)	(0.02)
diversity low-sk. foreigners	-0.048***	-0.026	0.014	-0.043**
	(0.02)	(0.02)	(0.01)	(0.02)
ln FTE reg.-ind.	-0.001	0.004	-0.002	-0.001
	(0.00)	(0.00)	(0.00)	(0.00)
ln prop. HK reg.-ind.	0.028	0.067	0.073*	0.185***
	(0.06)	(0.06)	(0.04)	(0.06)
ln pop. density	-0.018	-0.273	-0.364*	-0.050
	(0.22)	(0.22)	(0.21)	(0.72)
W ln pop. density	0.043	0.059	0.006	-0.032
	(0.04)	(0.04)	(0.03)	(0.12)
regional prop. high-skilled foreigners	0.276	1.690	0.150	-2.443
	(1.48)	(1.47)	(1.08)	(2.41)
regional prop. low-skilled foreigners	0.541	0.757	-1.273	-0.191
	(1.06)	(1.04)	(0.81)	(1.98)
regional diversity high-sk. foreingers	-0.052	0.031	0.188	-0.534
	(0.22)	(0.22)	(0.15)	(0.41)
regional diversity low-sk. foreigners	-0.749***	-0.237	-0.052	-0.681
	(0.26)	(0.27)	(0.21)	(0.47)

is employed, then the effect of a marginal change in the human capital composition is stronger than for the entire sample.

Following the suggestions in the literature, foreigners offer other ways of problem solving and therefore improve innovation capacity of a firm. The interaction of different kind of knowledge is then a promoter of innovation. Therefore one may argue that establishments in knowledge intensive industries[6] gain particularly from employing (high-skilled) migrants. We therefore restrict the sample to establishments in knowledge intensive industries. The marginal effects are presented in Table 5 and the parameter estimates can be found in Table 10 in the Appendix.

The results show a similar pattern as before. The marginal effect of the proportion of human capital employed on innovation is now smaller, but this was to be expected given the definition of the establishments included. Focussing on the employment of migrants reveals that there is a weakly significant negative impact of the export-diversity interaction term. It was argued that low-skilled migrants select into manual and routine jobs and therefore, into non-innovative establishments. Among knowledge-intensive establishments, for a given level of exports, a higher degree of diversity still relates negatively to innovation, meaning that establishments with a more diverse migrant workforce, at a given level of exports, are less likely to innovate, working against the positive effect of high-skilled migrants' diversity as such. This might indicate that exposure to international competition in knowledge-intensive sectors requires more cultural homogeneity because the "Babel effect"is more strongly felt by these establishments under global market pressure, but given the rather low robustness of the interaction term's significance across sub-samples, the result should be interpreted cautiously.

The proportion of low-skilled foreigners is insignificant and that of high-skilled foreigners only for product imitation and introduction. As was the case for the entire sample, the diversity of the high-skilled matters significantly in all types of innovation. This supports the hypothesis that the interaction of different cultures yields a gain in innovation processes. The effect is stronger than in the full sample and the other sub-samples, showing the importance of cultural diversity in knowledge-intensive industries. Establishments in these industries may also benefit relatively more from spillovers of knowledge emerging in other establishments. There is a significant and positive impact of the proportion of human capital employed in the other establishments in the region on the probability of innovation. The remaining regional variables are insignificant or provide the same pattern as discussed earlier.

To summarise our main results, we aim at verifying an augmented knowledge production function with particular emphasis on the cultural diversity of workers. By and large, our results support the idea that cultural diversity contributes to a productive exchange of productive knowledge. However, this

[6] Knowledge-intensive services: NACE Rev. 1.1 codes 61, 62, 64, 66, 67, 70-74, 80, 85, 92.

Table 5: Average marginal effects for establishments in knowledge-intensive industries

	improvement	adoption	introduction	process innov.
ln FTE	0.040***	0.022***	0.004	0.033***
	(0.00)	(0.00)	(0.00)	(0.00)
prop. high-skilled workers	0.090***	0.030*	0.030***	0.039**
	(0.02)	(0.02)	(0.01)	(0.02)
prop. exports	0.294***	0.139***	0.148***	0.186***
	(0.06)	(0.04)	(0.03)	(0.04)
DIV * prop. exports	-0.297**	-0.198*	-0.012	-0.166*
	(0.13)	(0.10)	(0.06)	(0.10)
d. single est.	-0.081***	-0.033**	-0.037***	-0.069***
	(0.02)	(0.01)	(0.01)	(0.02)
d. private partnership	-0.069***	-0.023	-0.017	-0.042**
	(0.02)	(0.02)	(0.01)	(0.02)
d. foreign owner	0.028	0.018	-0.017	-0.017
	(0.03)	(0.03)	(0.02)	(0.03)
mean tenure	-0.001	-0.004*	-0.002	-0.003
	(0.00)	(0.00)	(0.00)	(0.00)
s.d. tenure	-0.004	-0.002	-0.001	0.001
	(0.00)	(0.00)	(0.00)	(0.00)
mean age	-0.004***	-0.003***	-0.002***	-0.002**
	(0.00)	(0.00)	(0.00)	(0.00)
s.d. age	0.000	-0.001	0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)
prop. female	-0.002	0.010	-0.013	0.031
	(0.02)	(0.02)	(0.01)	(0.02)
prop. high-skilled foreigners	-0.074	-0.093*	-0.087**	0.044
	(0.06)	(0.06)	(0.04)	(0.06)
prop. low-skilled foreigners	-0.031	-0.025	-0.009	-0.037
	(0.05)	(0.04)	(0.03)	(0.05)
diversity high-sk. foreingers	0.149***	0.086***	0.077***	0.070**
	(0.04)	(0.03)	(0.02)	(0.03)
diversity low-sk. foreigners	-0.080***	-0.025	0.020	-0.025
	(0.03)	(0.02)	(0.02)	(0.03)
ln FTE reg.-ind.	0.005	-0.032***	-0.023***	0.009
	(0.01)	(0.01)	(0.01)	(0.01)
ln prop. HK reg.-ind.	-0.023	0.025	0.086**	0.087
	(0.08)	(0.06)	(0.04)	(0.07)
ln pop. density	0.019	-0.526**	0.038	-0.993
	(0.23)	(0.20)	(0.16)	(0.68)
W ln pop. density	0.076*	0.008	0.027	0.145
	(0.05)	(0.04)	(0.03)	(0.12)
regional prop. high-skilled foreigners	-2.378	-0.042	-0.357	-4.678
	(2.08)	(1.90)	(1.31)	(2.91)
regional prop. low-skilled foreigners	1.284	-1.096	0.645	2.425
	(1.65)	(1.57)	(1.05)	(2.60)
regional diversity high-sk. foreingers	-0.033	-0.222	0.143	-0.328
	(0.27)	(0.23)	(0.17)	(0.41)
regional diversity low-sk. foreigners	0.454	0.318	0.014	-0.480
	(0.29)	(0.28)	(0.21)	(0.48)

effect would go unnoticed if one did not distinguish the backgrounds of differences in cultural diversity carefully. For instance, low-skilled migrants, as well as skilled migrants whose formal qualification is not officially acknowledged in Germany typically work in less innovative establishments. Therefore, high- and low-skilled migrants, as well as their proportion in the respective skill group and their diversity in terms of nationality must be distinguished in order to find evidence of a positive cultural diversity effect on innovation. In contrast, spillover effects of migrant diversity from the regional level are mostly insignificant. Partly, however, there is a positive effect of the regional proportion of high-skilled workers on establishments' innovation outcome, supporting Griliches' (1979) knowledge-production function approach.

The positive effect of high-skilled migrant diversity is robust across the (sub-)samples used in this paper. Because of missing data on the functional type of establishments (whether an establishment performs R&D or takes strategic decisions on innovation, or is only an operative unit performing only production steps), it is argued that the mainly negative effects of low-skilled migrants on innovation captures establishments' orientation towards operative tasks, rather than real aspects of cultural diversity. This is so because migrants work more frequently in manual and routine-intensive jobs. Although our definition of high- and low-skilled workers is based on characteristics of jobs, this differentiation does not entirely capture all aspects of the production process.

7 Conclusions

We investigate the relationship between cultural diversity and innovation in German business establishments. Earlier empirical studies, as well as theoretical approaches mostly from the organisation science literature, have identified innovation as a promising realm of diversity advantages. The diversity-innovation link in Germany hitherto has only been studied from a regional perspective by Niebuhr (2010).

The empirical results suggest that human capital and establishments' resources are the most important determinants of innovation. Our hypothesis that cultural diversity fosters innovation can only be confirmed partially, and the interpretation depends on the precise definition of cultural diversity as a multi-dimensional concept. We only find that establishments get more innovative as their high-skilled migrant workforce gets more culturally diverse, supposedly because migrants complement each other's skills and increase the establishment's absorptive capacity. Contrarily, all kinds of innovation relate significantly negatively to migrant shares, even among the high-skilled. These results imply that a diverse mix of skilled migrants can generate productive ideas, but the mere presence of *many* migrants will not suffice. This trade-off between the "scope" (migrant share) and "scale" of migrant diversity complicates

the interpretation, since normally, high migrant shares and migrant diversity coincide.

Our results also suggest that higher employment shares of low-skilled migrants reduces the innovation potentials of establishments. Other empirical work suggests that migrants, and especially those with lower educational levels, self-select in occupations with a relatively high proportion of manual and routine work. Although our definition of high- and low-skilled is based on this insight, there is still variation within occupations in terms of manual and routine work. Therefore, the negative estimate of the share of low-skilled migrants probably captures the kind of work tasks performed in an establishment, as low-skilled migrants typically work in production units that carry out routinised tasks rather than creative or innovative tasks. Unfortunately, there are no data available on the task structure of the establishment and thus, the estimate of the share of low-skilled migrants probably suffers from omitted variable bias.

Thus, restrictions to the quantitative interpretation of results arise from various sources of bias and imprecision. In particular, migrant diversity may be measured with error, and could be endogenous because of reverse causality and omitted variables. Since these sources of error imply different directions of bias, the results—albeit quantitatively hard to interpret—cannot be taken as either upper or lower bounds of the real effect.

Given these limitations, our results suggest that workforce diversity can be beneficial for establishments' innovation at least among the high-skilled. Thus, cultural diversity seems to foster establishments' knowledge production more than diversity in age and tenure. Importantly, we find that the effect of high-skilled migrants' diversity is larger and more significantly robust than gender diversity, which we proxy by the share of female employees (in full-time equivalents). Cultural diversity within NUTS 3 regions, however, does not seem to foster individual establishments' innovation. While our panel is too short, and variance in establishments' innovation data is too low to identify effects with a fixed effects model, we use a large set of important control variables and ensure the robustness of our results by considering different subsamples. These variations suggest that the effects of cultural diversity are sensitive with respect to the heterogeneity of industries (and their respective production processes) and establishments, e.g., in terms of dependence on exporting. Therefore, besides the positive effect of high-skilled migrant diversity, we conclude that the effect of cultural diversity (which comprises several dimensions) on innovation cannot be generalized.

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Appendix

Table 6: Summary statistics

Variable	N	Mean	SD	Min	Max
Improvement	69,335	.419	.493	0	1
Imitation	69,344	.250	.433	0	1
Introduction	69,318	.101	.302	0	1
Process I.	45,917	.209	.407	0	1
ln FTE	431,669	8.740	2.088	-.510	16.684
share hsk	431,669	.200	.288	0	1
share fem	431,669	.445	.339	0	1
share exports	157,161	.073	.184	0	1
d. single est.	189,952	.315	.464	0	1
d. non-inc.	189,952	.066	.249	0	1
d. for.own.	189,952	.059	.237	0	1
ln FTE reg ind	430,893	13.634	1.742	-11.090	17.670
share hsk reg ind	430,775	.203	.188	0	5.942
ln pop. dens.	431,669	6.083	1.302	3.613	8.380
ln pop. dens. SW	431,669	72.245	32.230	17.472	150.090
mean tenure	165,861	6.790	4.284	.005	34.961
SD tenure	388,670	1.816	2.919	0	23.410
mean age	165,861	41.423	6.387	16	76
SD age	388,670	4.396	5.737	0	38.890
FOR hsk	431,669	.015	.074	0	1
FOR lsk	431,669	.048	.130	0	1
DIV hsk	431,669	.062	.200	0	.970
DIV lsk	431,669	.159	.290	0	.967
FOR hsk ext	431,669	.027	.017	.000	.143
FOR lsk ext	431,669	.061	.048	.001	.219
DIV hsk ext	431,669	.909	.080	.110	.969
DIV lsk ext	431,669	.852	.085	.273	.967

Table 7: Probit estimates of the entire sample

	improvement	adoption	introduction	process innov.
ln FTE	0.188***	0.107***	0.117***	0.207***
	(0.01)	(0.01)	(0.01)	(0.01)
prop. high-skilled workers	0.462***	0.193***	0.390***	0.345***
	(0.04)	(0.04)	(0.05)	(0.05)
prop. exports	0.808***	0.444***	0.662***	0.554***
	(0.07)	(0.06)	(0.07)	(0.08)
DIV * prop. exports	0.126	-0.295**	-0.334**	-0.120
	(0.15)	(0.12)	(0.13)	(0.15)
d. single est.	-0.090***	-0.081***	-0.082***	-0.134***
	(0.02)	(0.02)	(0.03)	(0.03)
d. private partnership	-0.059*	-0.023	-0.015	-0.111**
	(0.03)	(0.03)	(0.04)	(0.05)
d. foreign owner	0.048	-0.082**	-0.065	-0.018
	(0.04)	(0.04)	(0.04)	(0.04)
ln FTE reg.-ind.	0.014	0.003	-0.007	0.021*
	(0.01)	(0.01)	(0.01)	(0.01)
ln prop. HK reg.-ind.	0.119	0.012	0.397***	0.304**
	(0.13)	(0.12)	(0.14)	(0.15)
ln pop. density	0.199	-0.172	-0.789	-2.786**
	(0.32)	(0.34)	(0.50)	(1.34)
W ln pop. density	0.340***	0.216***	0.146	0.136
	(0.07)	(0.07)	(0.09)	(0.24)
mean tenure	-0.017***	-0.018***	-0.024***	-0.014***
	(0.00)	(0.00)	(0.00)	(0.00)
s.d. tenure	0.002	0.003	0.007	-0.004
	(0.00)	(0.00)	(0.01)	(0.01)
mean age	-0.009***	-0.009***	-0.009***	-0.010***
	(0.00)	(0.00)	(0.00)	(0.00)
s.d. age	-0.003	0.002	-0.000	0.001
	(0.00)	(0.00)	(0.00)	(0.00)
prop. female	0.099***	0.168***	0.117***	0.181***
	(0.03)	(0.03)	(0.04)	(0.05)
prop. high-skilled foreigners	-0.240**	-0.104	-0.268*	-0.056
	(0.11)	(0.11)	(0.14)	(0.14)
prop. low-skilled foreigners	-0.203***	-0.185**	-0.296***	-0.126
	(0.07)	(0.07)	(0.10)	(0.10)
diversity high-sk. foreingers	0.298***	0.141**	0.297***	0.234***
	(0.07)	(0.06)	(0.07)	(0.08)
diversity low-sk. foreigners	-0.069	-0.082*	0.024	-0.049
	(0.04)	(0.04)	(0.05)	(0.06)
regional prop. high-skilled foreigners	-0.710	2.186	0.897	-7.949
	(3.00)	(3.05)	(4.01)	(5.80)
regional prop. low-skilled foreigners	1.313	-0.710	-3.427	-0.986
	(2.31)	(2.40)	(3.19)	(5.06)
regional diversity high-sk. foreingers	-0.061	0.485	0.478	-1.070
	(0.31)	(0.33)	(0.44)	(0.79)
regional diversity low-sk. foreigners	-0.539	-0.093	-0.760	-0.546
	(0.39)	(0.41)	(0.60)	(0.88)
Constant	-25.480***	-15.353***	-6.452	3.602
	(4.16)	(4.44)	(5.75)	(14.86)
Fixed Effects	NUTS3 Region, 2-digit industry, Time FE included			
Pseudo R2	0.185	0.090	0.147	0.197
log-likelihood	-28070	-25516	-13591	-13695
No. obs	50945	50929	50517	33839
No. establ.	20207	20190	20015	13121

Note: Estimates obtained by Probit; cluster robust s.e. in (); * p<0.1; ** p<0.05; *** p<0.01;

Table 8: Probit estimates considering West German establishments only

	improvement	adoption	introduction	process innov.
ln FTE	0.197***	0.107***	0.119***	0.216***
	(0.01)	(0.01)	(0.01)	(0.01)
prop. high-skilled workers	0.401***	0.180***	0.308***	0.309***
	(0.05)	(0.05)	(0.06)	(0.07)
prop. exports	0.642***	0.416***	0.564***	0.580***
	(0.09)	(0.08)	(0.10)	(0.11)
DIV * prop. exports	0.385**	-0.151	-0.061	-0.160
	(0.18)	(0.15)	(0.17)	(0.19)
d. single est.	-0.117***	-0.098***	-0.108***	-0.134***
	(0.03)	(0.03)	(0.04)	(0.04)
d. private partnership	-0.072*	-0.039	-0.029	-0.124**
	(0.04)	(0.04)	(0.05)	(0.06)
d. foreign owner	0.062	-0.066	-0.070	-0.013
	(0.05)	(0.04)	(0.05)	(0.05)
ln FTE reg.-ind.	0.032***	0.011	0.004	0.030*
	(0.01)	(0.01)	(0.01)	(0.02)
ln prop. HK reg.-ind.	0.165	0.293*	0.550***	0.583***
	(0.17)	(0.15)	(0.19)	(0.20)
ln pop. density	-1.178	-1.893**	-3.875***	-5.325**
	(0.83)	(0.87)	(1.16)	(2.66)
W ln pop. density	0.251*	0.318**	0.175	0.636
	(0.14)	(0.14)	(0.18)	(0.41)
mean tenure	-0.014***	-0.011**	-0.019***	-0.013**
	(0.00)	(0.00)	(0.01)	(0.01)
s.d. tenure	-0.005	-0.006	0.003	-0.008
	(0.01)	(0.01)	(0.01)	(0.01)
mean age	-0.011***	-0.010***	-0.012***	-0.006**
	(0.00)	(0.00)	(0.00)	(0.00)
s.d. age	-0.001	0.005*	-0.004	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
prop. female	0.063	0.135***	0.069	0.154***
	(0.04)	(0.04)	(0.06)	(0.06)
prop. high-skilled foreigners	-0.274**	-0.141	-0.359**	-0.225
	(0.12)	(0.12)	(0.16)	(0.15)
prop. low-skilled foreigners	-0.136*	-0.146*	-0.295**	-0.104
	(0.07)	(0.08)	(0.12)	(0.11)
diversity high-sk. foreingers	0.326***	0.163**	0.311***	0.305***
	(0.07)	(0.06)	(0.07)	(0.08)
diversity low-sk. foreigners	-0.109**	-0.078	0.007	-0.049
	(0.05)	(0.05)	(0.06)	(0.07)
regional prop. high-skilled foreigners	-2.858	-0.469	1.262	-9.362
	(3.71)	(3.78)	(4.85)	(6.70)
regional prop. low-skilled foreigners	2.078	-0.558	-1.949	-2.530
	(2.56)	(2.69)	(3.42)	(5.65)
regional diversity high-sk. foreingers	-0.575	-0.070	1.046	-0.322
	(0.74)	(0.74)	(0.90)	(1.33)
regional diversity low-sk. foreigners	-2.101***	-0.666	-2.024*	-1.535
	(0.74)	(0.81)	(1.04)	(1.46)
Constant	-15.811	-19.514*	4.522	-30.693
	(11.03)	(11.07)	(14.19)	(32.76)
Fixed Effects	NUTS3 Region, 2-digit industry, Time FE included			
Pseudo R2	0.193	0.094	0.148	0.206
log-likelihood	-16556	-15140	-8128	-8600
No. obs	29929	29853	29489	20007
No. establ.	12498	12459	12305	8049

Table 9: Probit estimates for establishments employing foreigners

	improvement	adoption	introduction	process innov.
ln FTE	0.235***	0.103***	0.107***	0.257***
	(0.01)	(0.01)	(0.02)	(0.02)
prop. high-skilled workers	0.740***	0.267***	0.573***	0.584***
	(0.08)	(0.08)	(0.09)	(0.10)
prop. exports	0.578***	0.361***	0.493***	0.309**
	(0.11)	(0.10)	(0.11)	(0.13)
DIV * prop. exports	0.231	-0.212	-0.135	0.021
	(0.19)	(0.16)	(0.18)	(0.20)
d. single est.	-0.069	-0.121**	-0.044	-0.073
	(0.05)	(0.05)	(0.06)	(0.06)
d. private partnership	-0.038	-0.009	0.053	-0.112
	(0.05)	(0.05)	(0.06)	(0.09)
d. foreign owner	-0.020	-0.111***	-0.096**	-0.045
	(0.05)	(0.04)	(0.05)	(0.05)
ln FTE reg.-ind.	-0.002	0.013	-0.013	-0.002
	(0.01)	(0.01)	(0.01)	(0.02)
ln prop. HK reg.-ind.	0.091	0.220	0.394*	0.655***
	(0.21)	(0.18)	(0.21)	(0.23)
ln pop. density	-0.058	-0.892	-1.967*	-0.177
	(0.72)	(0.72)	(1.13)	(2.53)
W ln pop. density	0.141	0.193	0.035	-0.114
	(0.12)	(0.12)	(0.16)	(0.43)
mean tenure	-0.008	-0.019***	-0.017**	-0.006
	(0.01)	(0.01)	(0.01)	(0.01)
s.d. tenure	0.003	0.019**	0.018	-0.002
	(0.01)	(0.01)	(0.01)	(0.01)
mean age	-0.019***	-0.017***	-0.020***	-0.021***
	(0.00)	(0.00)	(0.00)	(0.00)
s.d. age	-0.002	0.005	-0.007	0.005
	(0.01)	(0.01)	(0.01)	(0.01)
prop. female	0.160**	0.286***	0.287***	0.098
	(0.07)	(0.07)	(0.08)	(0.09)
prop. high-skilled foreigners	-0.145	-0.064	-0.246*	0.042
	(0.11)	(0.12)	(0.14)	(0.14)
prop. low-skilled foreigners	-0.067	-0.117	-0.307**	-0.014
	(0.09)	(0.09)	(0.12)	(0.13)
diversity high-sk. foreingers	0.145**	0.146**	0.307***	0.087
	(0.07)	(0.07)	(0.08)	(0.09)
diversity low-sk. foreigners	-0.157***	-0.084	0.076	-0.153**
	(0.06)	(0.05)	(0.07)	(0.07)
regional prop. high-skilled foreigners	0.899	5.536	0.810	-8.640
	(4.82)	(4.81)	(5.84)	(8.54)
regional prop. low-skilled foreigners	1.761	2.478	-6.878	-0.675
	(3.45)	(3.39)	(4.40)	(7.02)
regional diversity high-sk. foreingers	-0.170	0.101	1.018	-1.890
	(0.71)	(0.74)	(0.82)	(1.45)
regional diversity low-sk. foreigners	-2.438***	-0.775	-0.283	-2.409
	(0.85)	(0.89)	(1.15)	(1.65)
Constant	-7.782	-9.170	6.525	9.767
	(7.46)	(7.34)	(9.14)	(25.30)
Fixed Effects	NUTS3 Region, 2-digit industry, Time FE included			
Pseudo R2	0.214	0.102	0.156	0.196
log-likelihood	-10130	-10030	-6052	-6144
No. obs	18689	18581	17999	12258
No. establ.	8649	8588	8292	5376

Table 10: Probit estimates for establishments in knowledge-intensive industries

	improvement	adoption	introduction	process innov.
ln FTE	0.122***	0.083***	0.027	0.139***
	(0.01)	(0.01)	(0.02)	(0.02)
prop. high-skilled workers	0.274***	0.112*	0.205***	0.163**
	(0.06)	(0.06)	(0.07)	(0.08)
prop. exports	0.898***	0.523***	1.006***	0.781***
	(0.18)	(0.16)	(0.19)	(0.18)
DIV * prop. exports	-0.906**	-0.741*	-0.083	-0.695*
	(0.41)	(0.39)	(0.40)	(0.42)
d. single est.	-0.247***	-0.124**	-0.252***	-0.291***
	(0.05)	(0.05)	(0.06)	(0.07)
d. private partnership	-0.209***	-0.087	-0.119	-0.176**
	(0.07)	(0.06)	(0.09)	(0.09)
d. foreign owner	0.087	0.066	-0.117	-0.071
	(0.10)	(0.09)	(0.12)	(0.11)
ln FTE reg.-ind.	0.014	-0.122***	-0.159***	0.040
	(0.04)	(0.04)	(0.05)	(0.05)
ln prop. HK reg.-ind.	-0.071	0.095	0.588**	0.364
	(0.24)	(0.23)	(0.28)	(0.31)
ln pop. density	0.058	-1.971**	0.257	-4.163
	(0.71)	(0.77)	(1.10)	(2.87)
W ln pop. density	0.232*	0.031	0.182	0.608
	(0.14)	(0.15)	(0.21)	(0.52)
mean tenure	-0.004	-0.013*	-0.015	-0.012
	(0.01)	(0.01)	(0.01)	(0.01)
s.d. tenure	-0.013	-0.007	-0.006	0.005
	(0.01)	(0.01)	(0.01)	(0.01)
mean age	-0.011***	-0.013***	-0.014***	-0.008**
	(0.00)	(0.00)	(0.00)	(0.00)
s.d. age	0.000	-0.002	0.001	-0.002
	(0.00)	(0.00)	(0.01)	(0.01)
prop. female	-0.005	0.037	-0.089	0.131
	(0.06)	(0.06)	(0.08)	(0.08)
prop. high-skilled foreigners	-0.225	-0.349*	-0.596**	0.183
	(0.20)	(0.21)	(0.28)	(0.24)
prop. low-skilled foreigners	-0.093	-0.094	-0.062	-0.157
	(0.15)	(0.16)	(0.19)	(0.20)
diversity high-sk. foreingers	0.454***	0.321***	0.523***	0.295**
	(0.12)	(0.11)	(0.13)	(0.13)
diversity low-sk. foreigners	-0.245***	-0.092	0.136	-0.105
	(0.08)	(0.09)	(0.11)	(0.11)
regional prop. high-skilled foreigners	-7.257	-0.159	-2.432	-19.613
	(6.36)	(7.12)	(8.95)	(12.21)
regional prop. low-skilled foreigners	3.917	-4.110	4.395	10.169
	(5.05)	(5.90)	(7.16)	(10.92)
regional diversity high-sk. foreingers	-0.102	-0.834	0.977	-1.374
	(0.84)	(0.88)	(1.18)	(1.74)
regional diversity low-sk. foreigners	1.385	1.193	0.094	-2.014
	(0.89)	(1.04)	(1.44)	(2.02)
Constant	-18.387**	7.811	-15.381	-19.806
	(9.28)	(10.12)	(15.14)	(32.56)
Fixed Effects	NUTS3 Region, 2-digit industry, Time FE included			
Pseudo R2	0.155	0.106	0.161	0.163
log-likelihood	-6772	-5419	-2776	-3322
No. obs	11749	11398	10272	7765
No. establ.	4896	4748	4307	3144