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Immigrants' contribution to innovativeness:
Evidence from a non-selective immigration country

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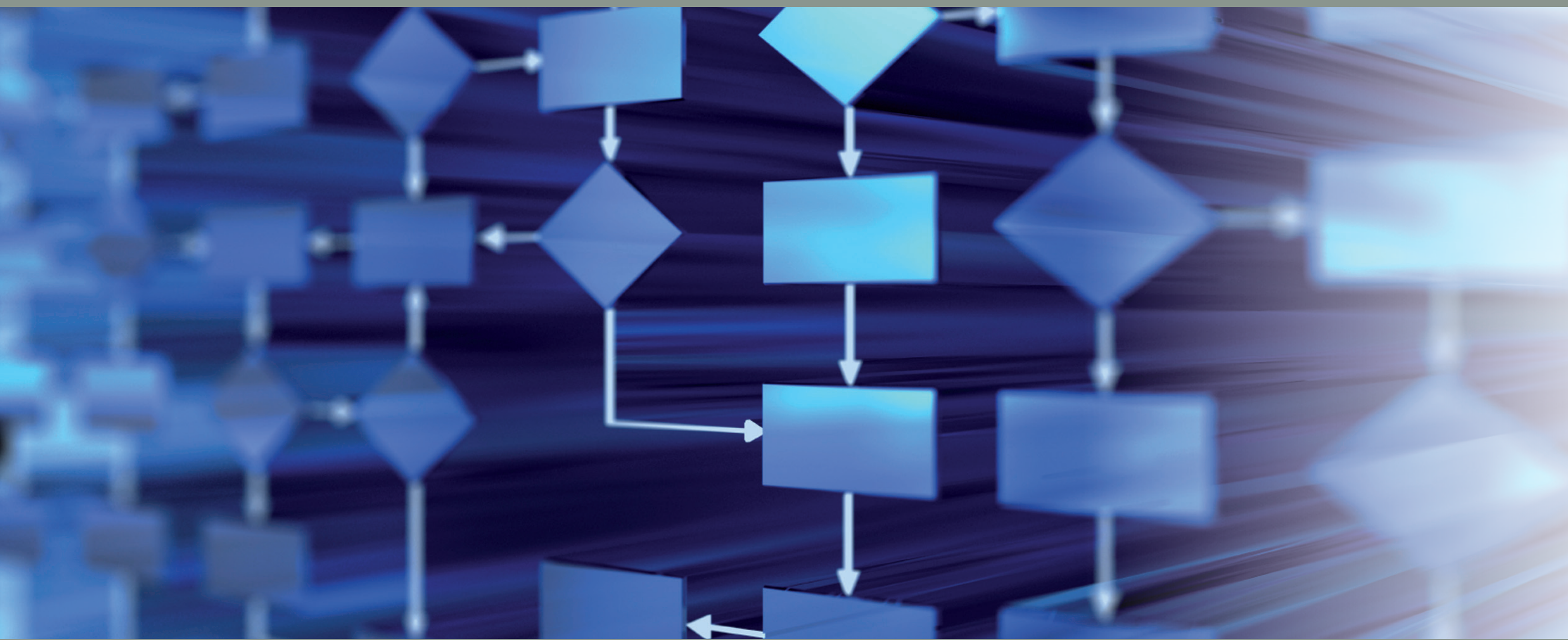

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ABSTRACT

The economic consequences of migration are hotly debated and a main topic of recent political movements across Europe. We analyze Polish immigration in the context of the 2004 enlargement of the European Union and find a positive and significant spillover effect of the immigrants on the number of local inventors in German counties in 2001-2010. For causal identification, we exploit a historical episode in the Polish migration history to Germany before the fall of the Iron Curtain and construct a shift-share instrument. Our results differ from findings for high-skilled migration to the United States, which is particularly interesting as Polish immigration to Germany was not based on selection by qualification in our period of analysis.

KEY WORDS: Migration, Innovation.

JEL CLASSIFICATION: J61, O31

DISCLAIMER

The views expressed in this paper are those of the authors, and do not necessarily reflect the views of the World Intellectual Property Organization, its member states or the Federal Commission of Experts for Innovation and Research.

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Immigrants' Contribution to Innovativeness: Evidence from a Non-Selective Immigration Country

Katharina Candel-Haug, Alexander Cuntz, Oliver Falck*

Abstract

The economic consequences of migration are hotly debated and a main topic of recent populist movements across Europe. We analyze Polish immigration in the context of the 2004 enlargement of the European Union and find a positive and significant spillover effect of the immigrants on the number of local inventors in German counties in 2001–2010. For causal identification, we exploit a historical episode in the Polish migration history to Germany before the fall of the Iron Curtain and construct a shift-share instrument. Our results differ from findings for high-skilled migration to the United States, which is particularly interesting as Polish immigration to Germany was not based on selection by qualification in our period of analysis.

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1 Introduction

Integration of migrants into the labor market and their contribution to economic growth is an important topic of public debate. Economic research has largely been analyzing the impact of immigration on natives' wages and employment opportunities and is increasingly interested in the impact of migration on innovation and growth in the host country. We add to this literature by studying how the number of inventors of German nationality was impacted by the arrival of Polish immigrants in the time period around the Eastern enlargement of the European Union. A particularity of this immigration wave is that entry and the permission to work were not conditional on a university degree.

Several studies, like Kerr and Lincoln (2010) or Moser et al. (2014) look at high-skilled immigration and its impact on patenting. Other work analyzes the effects of immigrant shares or ethnic diversity on innovation (Hunt and Gauthier-Loiselle, 2010; Ozgen et al., 2013; Bosetti et al., 2015). This paper uses historical migration patterns in a shift-share instrumental variable approach to quantify the contribution of migration, both high- and low-skilled, to innovativeness by incumbent inventors in Germany in 2001–2010. The expansion of the European Union by 10 countries, mostly from Eastern Europe, in 2004, generated one of the greatest migration waves in Europe in the first decade of the millennium and was accompanied by a great amount of uncertainty concerning labor market integration and growth potential in the destination countries.

One of the central empirical papers on high-skilled immigration and innovation in the United States is Kerr and Lincoln (2010). In contrast to that US case, migration from Eastern Europe to Germany around the enlargement was not regulated based on immigrants' qualifications. We therefore apply the Kerr and Lincoln (2010)-approach to the German case so as to directly compare the effects of a skill-based immigration system to an immigration policy that is not based on qualifications.

From a unique dataset developed by Miguelez and Fink (2013), we obtain disaggregated information on patenting inventors in Germany, such as their nationality and place of residence. We count the inventors indicated in patent applications by nationality, aggregate these counts to the county (*Kreis*) level, and add information on the local Polish immigrant group as well as county characteristics. In our two baseline estimations at the county level, we relate the number of Polish immigrants to the number of inventors of, first, Polish and, second, German nationality. We control for migrants' endogenous location choice by employing a shift-share prediction of the number of Polish immigrants to the county. Among the immigrants from new EU member states to Germany, Polish citizens comprise by far the largest group and their particular migration history to Germany after the Solidarnosc movement in the 1980s allows the construction of our instrument. They came as political refugees and were allocated to German municipalities based on a quasi-random distribution system. We therefore focus on Polish immigration to Germany and, rather than referring to the year before our period of analysis, our shift-share instrument is backed by a conclusive historical immigration story in the 1980s. We set the period of our analysis around the enlargement, that is from 2001 to 2010.

Our results suggest a positive and statistically significant impact of Polish immigration on the number of inventors in Germany. Some of these migrants became inventors themselves: Counties that received 10 percent more Polish immigrants than other counties experienced a 0.28 percent higher number of Polish inventors. This effect size is quite small but still one-tenth of what was found for high-skilled immigration in the United States. The spillovers from Polish migrants to inventors of German nationality have a slightly higher point estimate ($\beta = 0.032$) and, in contrast to the results for the United States, are statistically significant. We conclude that some Polish immigrants are inventors, but that a greater number of them are – independent of their qualification level – complements to incumbent inventors in Germany.

More in detail, Kerr and Lincoln (2010) build a shift-share instrument exploiting regional variation in the count of noncitizen immigrant scientists and engineers at an earlier point in time and estimate a reduced-form IV specification. They find that more high-skilled immigration leads to more science and engineering employment as well as more patents by Indian or Chinese inventors. The point estimates for Anglo-Saxon inventors and total patenting are also positive but not statistically significant. Hunt and Gauthier-Loiselle (2010) use a similar identification strategy and find positive effects of skilled immigrant shares on total patents per capita. These results confirm that skilled immigrants make a positive contribution to local innovativeness in total. Spillovers on incumbent inventors cannot be tested directly with their data. However, Hunt and Gauthier-Loiselle (2010) conclude from the difference between their individual- and state-level results, that there are positive spillovers from immigrants in this domain. Moser et al. (2014) find that the arrival of German Jewish emigrants to the United States in the 1930s significantly increased the number of patents in the immigrants' specialized fields. This result, however, is neither driven by the immigrants' contribution to patenting nor by an increase in the patent productivity of incumbent researchers; rather the arrival of German Jewish researchers attracted new domestic inventors to the particular research fields in which the immigrants were successful. We learn from Moser et al. (2014) that migrants can also have an indirect innovation effect by changing a firm's or a field's specialization.

Turning to Europe, Bosetti et al. (2015) conduct a macro-level analysis for a panel of 20 European countries and find that the share of foreign workers in the skilled labor force explains increases in patent counts. According to Ozgen et al. (2013)'s study using Dutch firm-level data, the share of foreigners in a firm has a negative effect and cultural diversity (variance of ethnicities) among employees has a positive effect on firm innovativeness. In contrast to the US-papers and in line with our study, Bratti and Conti (2018) analyze the impact of immigrants of all skill-levels on innovation in Italy. They do not find any significant effects in various specifications. Finally, we are aware of a single study for Germany on this topic: Jahn and Steinhardt (2016) exploit the immigration of ethnic Germans from Eastern Europe to Germany and find that their presence has a positive impact on total patenting at the regional level. These studies on Europe provide interesting insight into the total effect of immigration on patent counts. However, the data do not allow disentangling migrant and resident contributions to patenting. Our paper, in contrast, gives more information on the mechanism of the effect and on whether immigrants are substitutes or complements to incumbents in the host country. Furthermore, we do not limit our analysis to high-skilled immigrants.

In the following section, we explain our identification strategy in more detail. We present our data set in Section 3 and our results in Section 4. Section 5 concludes.

2 Identification and Empirical Specification

We are interested in the impact of Polish immigration on innovativeness in Germany over a 10-year-period around the Eastern enlargement of the European Union (2001-2010).[1] For our empirical model, we follow the literature by exploiting regional variation and choose the county (*Kreis*) level for analysis. Furthermore, innovativeness is proxied by (patenting) inventor counts. The effect of immigrants on the number of inventors is subject to different potential mechanisms: On the one hand, Polish immigrants can be inventors and patent in Germany without impacting incumbent patentees. On the other hand, when immigrants are complements, they push patenting activities of German inventors and have a positive impact on total patenting whether they patent themselves or not. But immigrants can also be substitutes to incumbent inventors and crowd them out if the new arrivals are more successful. We shed light on these mechanisms by separately analyzing the impact of Polish immigrants on inventors of Polish nationality and on inventors of German nationality.

[1]Choosing this time frame also avoids confusion in the context of the reform of the German nationality law in 2000.

2.1 Empirical Model

We estimate the following equation:

$$log(\text{Num of inv})_i = \beta_0 + \beta_1 * \widehat{Mig}_i^{POL} + \beta_2 * \boldsymbol{x}_i + \beta_3 * (\text{Agglo FE}) + \beta_4 * (\text{State FE}) + \varepsilon_i \quad (1)$$

where i indicates the county level and *log(Num of inv)* denotes, in separate regressions, the logged number of inventors of Polish or German nationality aggregated across the ten years of our period of analysis 2001–2010. $\mathbf{x}$ is a set of county-specific controls relating to the distance to Poland, the industry structure of the county and the presence of a university. *Agglo FE* represents the agglomeration type or settlement structure of the county, *State FE* the federal state the county is located in, and ε_i the error term. The key coefficient of interest is β_1. It gives us the effect of Polish immigration to German counties on the number of inventors in the counties. In an estimation with the actual Polish immigration numbers at the county level, the coefficient would most likely be biased because we expect the distribution of Polish immigrants across German counties to be endogenous in our setting. We therefore implement a shift-share type approach.

The Shift-Share Instrument

Relating regional immigration to regional innovativeness would suffer from a serious selection problem: Polish inventors, that is, immigrants with the relevant qualifications, are likely to choose their residence according to the structure of innovative (i.e., research and patenting intensive) industries in Germany. The development of the number of Polish migrants and inventors in county i are therefore both potentially driven by the density of innovative industries. To overcome this problem, we employ a shift-share type of instrument, such as can be found in earlier work of Card (2001), Hunt and Gauthier-Loiselle (2010), and Lewis (2011), in order to use exogenous variation of the number of migrants.[2] The instrument consists of two parts: A regional distribution

[2]This instrument is also known as a *Bartik*-type instrument because it was first applied in Bartik (1991).

and a macro trend. The macro trend is then disaggregated to the regional level based on an exogenous migrant share of an earlier point in time. In this analysis, we use Polish emigration flows around the EU enlargement ($Mig_{t=2001-2010}$) and disaggregate them to the regional level in Germany based on each county's share of Polish citizens in 1989 ($(\frac{Mig_i^{POL}}{Mig_D^{POL}})_{t=1989}$). In fact, the instrument is a prediction of the migration flows to the respective county in the period of analysis and looks as follows:

$$\widehat{Mig}_i^{POL} = ln(Mig_{t=2001-2010}^{POL \rightarrow World}) * (\frac{Mig_i^{POL}}{Mig_D^{POL}})_{t=1989}^{norm} \quad (2)$$

The idea underlying this approach is that immigrants tend to live in locations with a higher share of people of similar background. This phenomenon is partly due to the presence of cultural or religious institutions such as, in our case, Polish cultural centers, Polish-speaking Catholic masses, and restaurants or supermarkets with Polish cuisine and products. Social ties also play a big role in immigrants' location choice. Burchardi and Hassan (2013) and Hoisl et al. (2016) show that social ties are persistent over a long time period. There is extensive empirical evidence of the advantages of being integrated in this kind of network, especially for job search (e.g., Edin et al., 2003 for Sweden; Damm, 2009 for Denmark; Hoisl et al., 2016 for Germany). The shift-share instrument structure is widely used and acknowledged in the economic literature on migration and has also been applied in research on trade (e.g., Autor et al., 2013) and technological change (e.g., Acemoglu and Restrepo, 2017).

Among all 10 new EU member states of 2004, we limit the analysis to migrants from Poland. Restricting our analysis to a particular group is motivated by the idea of our instrument that allocates migrants based on their ethnic and cultural network: as the new member states are culturally and language-wise very heterogeneous, we do not expect immigrants from these countries to form "new member states networks" but to join existing networks of migrants with the same country of origin. We are aware, that other papers use the aggregate of predicted immigration from all source countries, hence avoiding a restriction to a particular migrant group. However, it has recently been pointed out by Goldsmith-Pinkham et al. (2018) that the shifts in the Bartik-type instrument affect an instrument's relevance but do not automatically solve the endogeneity problem. Consequently, authors need to explain why the earlier shares are exogenous.[3] The particular immigration history of Poles to Germany in the 1980s allows us to use an earlier distribution that we argue is exogenous in our setting. In Section 2.2 we explain why this is the case. Furthermore, Poles are and have been one of the largest group of foreigners living in Germany and they also were the largest group of immigrants after the EU Eastern enlargement, which makes them an economically relevant group.

For the macro trend we use the total emigration flow from Poland ($Mig_{t=2001-2010}^{POL \rightarrow World}$) instead of Polish migration to Germany. The presence of innovative industries in Germany might be a pull factor impacting Polish migrants' destination decisions. By using total emigration to all countries in the world, we account for push factors of migration from Poland, such as unfavorable labor market conditions, which we consider to be exogenous in our setting. Furthermore, in contrast to most existing studies, we measure the total migration flow and do not restrict the analysis to high-skilled individuals or occupations demanding high qualifications.

In addition, for the computation of the instrument, we follow Kerr and Lincoln (2010) and take the log of the macro trend and normalize the 1989-share. It is a reduced-form instrumental variable approach.

Controlling for Confounding Factors

The distribution of Poles across Germany in 1989, which is the relevant share for our instrument, is not entirely unrelated to the number of inhabitants of a county (see Figures 1 and A1). Besides, big agglomerations with their concentration of highly qualified workforce and excellent infrastructure could be more likely to host innovative

[3] A summary of the recent discussion on shift-share instruments can be found at `http://blogs.worldbank.org/impactevaluations` (last viewed on July 16, 2018).

firms than rural counties. We therefore add fixed effects for the settlement structure of the respective county (*Agglo FE*), distinguishing between agglomerations, urbanized zones, rural counties with some more densely populated spots, and rural areas. With this approach, we avoid our results to be confounded by county population or population density. As a result of the settlement structure fixed effects, we identify our effect only within these groups, which means we compare, for example, densely populated counties with other densely populated counties.

Furthermore, we weight our regressions by county population. This way, counties with many residents have a higher impact than counties with low population. Consequently, our estimates cannot be disproportionally driven by a few small counties. Our results are not representative for the average county, but for the population average in Germany.

Variables measuring structural characteristics of the counties in our sample control for remaining factors that could potentially impact the immigration destination and the inventor count alike. These include the industry quota (Number of employees in the industrial sector in county i devided by the total number of employees in the county) as a proxy for the structure of the county's economy. A dummy for the presence of a university (*Universität* or *Fachhochschule*) in the county serves as a proxy for the presence of scientific research. One could also argue that Polish immigration and an increasing inventor count in a county are a result of increasing trade and, therefore, more intense cooperation between Germany and Poland. As a consequence of the EU enlargement, German firms might, for example, replace their former French suppliers with Polish suppliers and consequently also employ more Polish staff. We control for the relevance of trade and cooperation with Poland by adding the road distance to the next Polish border crossing to our estimation. As we only consider West Germany, there are no counties in our sample that are located directly at the border to Poland.

We add state fixed effects to the equation because our instrument might also be slightly correlated with the economic situation of the German federal states (*Bun-*

desländer) and therefore potentially with the location of innovative industries. In Section 2.2 we will show that Polish political refugees in the 1980s were, in a first step, allocated to German federal states according to the *Königsteiner Schlüssel* which is partly based on economic characteristics. However, in a second step, refugees were distributed according to state-specific criteria, which we will argue to be nearly random. Still, we are cautious and add state fixed effects so as to control for any remaining correlation of the distribution criteria of the refugees and our outcome variable. The fixed effects cover only territorial states and exclude the city-states Hamburg, Berlin, and Bremen.

2.2 A Brief History of Polish Immigration to Germany

Polish immigration has a long-standing tradition in Germany. At the end of the 19th, beginning of the 20th, century, around 300,000 ethnic Poles, generally called the *Ruhr-Polen*, moved to Western Prussia to work in mining and other industries (Kaluza, 2002).[4] Due to assimilation to the German environment, return migration after foundation of the Polish national state in 1918, and persecution by the Nazi regime, their descendants cannot be identified as such today. Directly after World War II, hundreds of thousands of Polish-speaking forced laborers and concentration camp prisoners were still in Germany but most of them soon left the country. According to Kaluza (2002), approximately 40,000 of them stayed on (*displaced persons*).

Polish immigration in the 1980s

We base our shift-share identification strategy on political refugees from Poland to Germany in the 1980s. In this context, it is crucial to distinguish the political refugees from two other, larger, Polish immigrant groups arriving during the same time period: ethnic Germans and economic refugees. The three groups differed with regard to their legal situation. In the aftermath of the war and up until 1990, a great number of ethnic

[4]Technically speaking, these were internal migrants from the Eastern provinces of Prussia and therefore had the German citizenship. For our setting, however, it would be crucial, that they were culturally Polish.

Germans from Poland moved to the Federal Republic of Germany (*Aussiedler*). They were not considered asylum seekers but were awarded German citizenship immediately after their arrival and do not enter immigration statistics as Polish nationals.

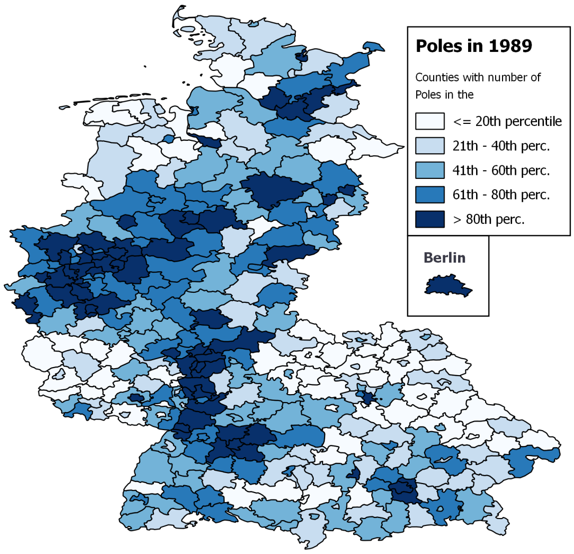
However, German statistics on asylum seekers (see Table A1) document an increasing number of Poles at the end of the 1980s. Economic refugees from the deteriorating economic situation in socialist Poland account for a large share of these asylum seekers. Their chances of being granted asylum were extremely low, though. Most of them were only granted an exceptional leave to remain (*Duldung*), meaning that they could stay on because West Germany would not send refugees back to a socialist country. These immigrants did not have access to the labor market and had to cope with an uncertain residence permit. In the years 1986 and 1987, immigration laws were liberalized and refugees from the Soviet Bloc who were not granted asylum had the right to apply for a temporary work permit after a one-year waiting period. In reality, however, few work permits were issued and the immigrants' situation remained extremely tenuous[5] (Meister, 1992).

The third largest group of immigrants arriving from Poland in the 1980s and a small fraction of the asylum seekers were political refugees. The construction of this analysis' instrument is based on their regional distribution (see Figure 1). The failure of the Solidarnosc movement and the imposition of martial law in Poland in 1981 drew many activists and workers to Germany. In West Germany, they could pursue their political activities and publish their work. These people were granted asylum ex officio and had immediate access to the labor market.

We consider the distribution of these political refugees across German counties in the 1980s (here: 1989) to be exogenous to today's innovative industry structures, which

[5] Work permits could only be issued for a particular job and under the condition that there was no German worker available for the job. Furthermore, a survey among German firms in 2017 shows that employers generally hesitate to recruit refugees due to their uncertain residence permit situation (ifo Personalleiterbefragung 1. Quartal 2017). With the fall of the Iron Curtain, German authorities proceeded to expel this group from the country. However, many Polish nationals received a permanent right of residence by referring to customary law, albeit their access to the legal labor market remained restricted (Kaluza, 2002; Meister, 1992).

Figure 1: Geographic distribution of Polish employees in 1989 across Germany in percentiles of counties



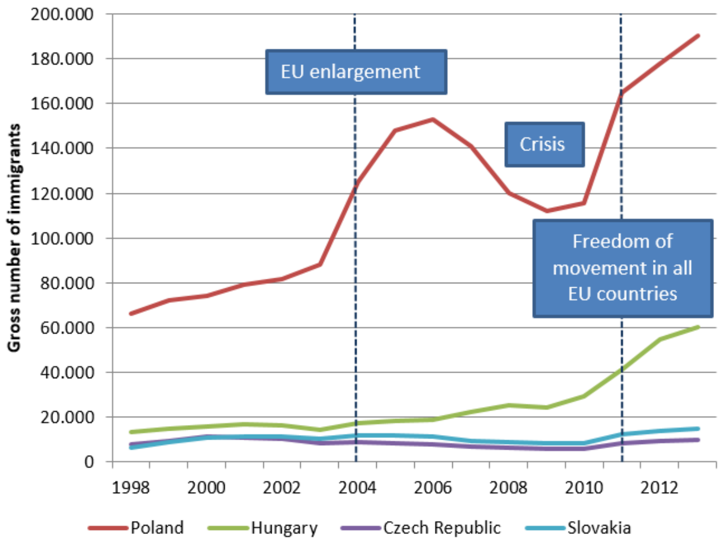
Source: Own presentation based on data from German Social Security Records provided by the Institute for Employment Research, Nuremberg.

qualifies this variable for the construction of our instrument (see Equation 2). First, these immigrants did not leave their home country so as to improve their work and economic situation and, second, refugees were distributed across West German states (NUTS1 level) according to an allocation key called *Königsteiner Schlüssel* based on tax revenue and population. The distribution within the states and to the district (NUTS3) level, however, followed state-specific criteria and was mostly affected by factors such as the availability of adequate real estate for the accommodation of the refugee groups or the negotiation skills of the governing mayor. Due to the structure of the state-level allocation key, we add federal state fixed effects to the equation. Furthermore, we have to exclude the Eastern German counties, which joined the Federal Republic only in 1990, from our analysis.

Polish immigration in the 2000s

Migration from Poland to Germany in 2001–2010, the period of our analysis, was subject to different legal limitations. After the fall of the Iron Curtain, migration from Poland stopped (except for the late *Aussiedler (Spätaussiedler)*) due to strict new asylum legislation in Germany but also partly to improved living conditions in the former Soviet Bloc. Before the Eastern enlargement of the European Union in 2004, Poles mainly could migrate temporarily as seasonal workers; other possibilities were very restricted.[6] With Poland's accession to the European Union, the freedoms

Figure 2: Immigration from new member states to Germany 1998–2012



Source: Own presentation based on data from the German foreigners registry (German Ausländerzentralregister) provided by the Bundesverwaltungsamt, Köln.

of the single market did not apply entirely and immediately in the case of moving to Germany. Temporary transition rules in force until 2011 can be summarized as follows: First, Poles willing to take a job in Germany needed a work permit, which was granted upon proof of a concrete job proposal by the employer and after checking whether job-seekers with a prior claim (e.g., EU 15 citizens) were available on the labor market (*Vorrangprüfung*). However, this last regulation did not apply to highly qualified job-seekers. Managers, researchers, and scientific staff could be employed in their domain without requiring a *Vorrangprüfung* (Bundesamt für Migration und Flüchtlinge, 2006). Second, freedom to provide services across borders was restricted in some areas such as construction or cleaning. In other sectors, established entrepreneurs from Poland

[6]From 2000 to 2004, a German Green card system was in place and facilitated hiring IT experts from countries outside of the European Union for jobs with a salary above 51,000 Euros per year. A total of 17,931 Green cards were granted, but only around 13,000 of them were finally issued. Indians and Eastern Europeans such as experts from the Baltic states, the Czech, and the Slovak Republic were the largest groups benefitting from this system. Poles accounted only for a very small fraction (Bundesamt für Migration und Flüchtlinge, 2006). The European Blue Card was only introduced in 2012 and therefore does not coincide with our period of interest.

could offer their services in Germany. Third, freedom to establish a business was unrestricted and so Poles could found firms in Germany right after the accession on May 1, 2004.

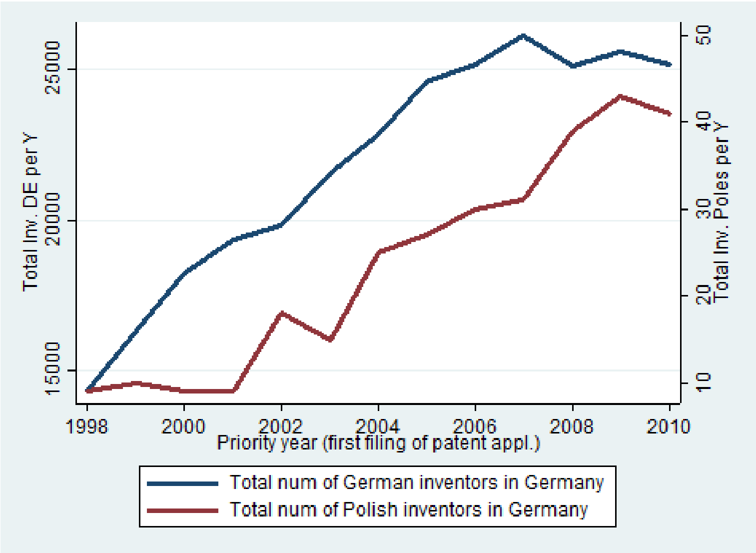
According to numbers from the German foreigners registry (see Figure 2) around 1.16 million Polish citizens migrated to Germany from 2001 to 2010 and 913,000 of them after the EU enlargement[7]. The increase in immigration after the accession is surprising at first sight because labor market access remained very restricted. The freedom to establish a business, however, was effective immediately and is one important reason for this development. German Mikrozensus data show that the self-employment rate of Polish citizens in Germany increased from around 6 percent before 2004 to more than 20 percent afterward. Dietz (2005) collected data on 11 German regions and reports that, after the enlargement, 3,157 new businesses were founded by Polish nationals, whereas only 275 new businesses were founded previously by nationals of all new member states together. The new entrepreneurs after the enlargement were mostly operating in non-innovative craftsman professions. The accession also made migration to Germany easier for inventors: they were free to travel to Germany and use this geographic proximity to firms and the German innovative industries to find a job. Furthermore, employers no longer had to give priority to German citizens: highly qualified job-seekers from the new member states had the same rights.

In our data as in most official socio-economic statistics, we cannot distinguish Polish residents in Germany according to their time of arrival.[8] Still, the available data allow some insightful conclusions regarding the Polish immigrants arriving in our time period of interest, 2001–2010. In 2010, 419,435 Polish nationals were living in

[7]In contrast to the Polish emigration data we use for our instrument, German immigration data also include temporary migration. Seasonal workers immigrating only for some months represent a large share of the 1.16 million.

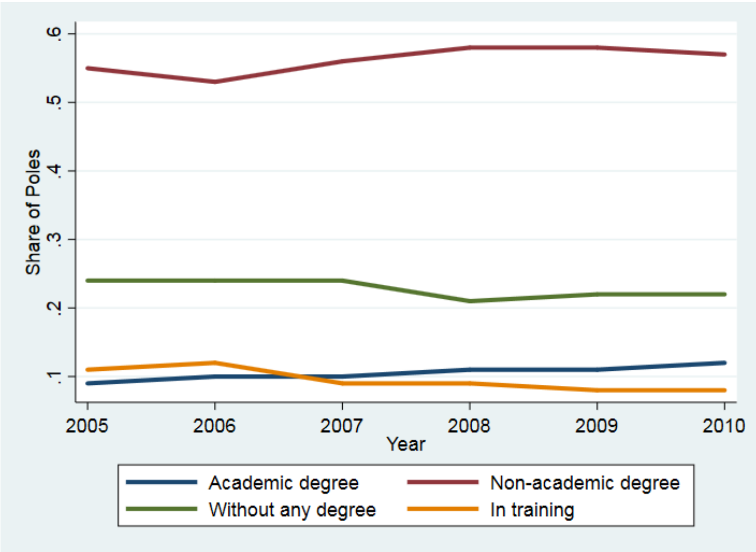
[8]An exception, but not directly relevant for our analysis, is a survey by Luthra et al. (2014) on migration motives of recently-arrived Polish immigrants living in one of the following German cities: Berlin, Hamburg, Munich, Cologne in 2010 and 2011. Out of the 1516 respondents, 23 percent came for family reasons (marriage or following a partner that moved), 66 percent came for work, 15 percent for education and 7 percent "just because", i.e., by cultural interest or for self-development (note that multiple reasons for migration could be reported).

Figure 3: Number of German and Polish inventors in Germany 1998–2010



Source: Our dataset with data provided by REGPAT and WIPO.

Figure 4: Education of first-generation Poles in Germany 2005–2010



Source: Own presentation based on data provided by the German Statistical Office in: Ergebnisse des Mikrozensus 2005–2010, Fachserie 1 Reihe 2.2.

Germany, most of them (96 percent) were born in Poland, and a big share (55 percent) had arrived between 2001 and 2010[9]. The Polish inventors in Germany we measure are likely to belong to this group: The number of Polish inventors in Germany did not increase at the same pace as the number of German inventors before the enlargement (see Figure 3). Some of them might already have come as students: In 2001, 7,586 young Poles with Polish schooling were studying at a German university and planning to graduate there[10](Deutscher Akademischer Austauschdienst (DAAD) and Institut für Hochschulforschung (HIS), 2012).

Figure 4 plots the qualification levels of first-generation Poles in Germany in 2005 through 2010 (the earliest years the data is available) and show a slight increase in qualification levels: The share of Poles without any degree decreased, whereas the share of academically trained increased. The largest qualification group are those with non-academic degrees, such as technicians or craftsmen. Dustmann et al. (2012) show in a longer time frame that the education level of Polish emigrants, that is, Poles leaving Poland, increased significantly during the first decade of the new millennium: the share of high-skilled emigrants from Poland rose from 13 percent in 1998 to 20 percent in 2007, the share of low-skilled shrank from 12 to 5 percent. Furthermore, compared to the Polish population, emigrants had higher qualification levels. Still, Poles in Germany are overrepresented in the construction sector and underrepresented in manufacturing or in finance (see Figure A2). It must also be noted that the recognition of foreign degrees is sometimes difficult in Germany and that it is quite likely to find also Poles with a degree working in the construction sector. Overall, we retain from these figures that, in the 2000s, the largest share of Polish immigrants was medium-skilled, whereas high-skilled immigrants represent a small but growing fraction of this group.

[9]Source: Destatis Fachserie 1 Reihe 2, Stand 31.12.2010.

[10]The numbers even increased to 11,588 in 2004 and slightly decreased to 10,289 in 2008.

2.3 Mechanisms of the Impact of Immigrants on Local Innovation

In our causal analysis, we focus on Polish immigrants that came to Germany between 2001 and 2010 and break down their overall effect into two components: In the first estimation, we measure the direct contribution of Polish immigrants to Polish innovativeness in Germany by using the log number of Polish inventors as the dependent variable. We expect a non-negative effect for two reasons. First, immigration to Germany was not restricted to a specific qualification level and it is certain that there were inventors among the new arrivals, which would imply a positive contribution from the immigrants.[11] Second, however, among the Polish inventors we also measure Poles who came to Germany a longer time ago. New arrivals (i.e., within our time window) could have positive or negative spillover effects on these incumbents: they could crowd them out or the two groups could cooperate due to their social or ethnic ties and support and encourage each others' work, as discussed by Lissoni (2018).

In the second estimation, we analyze how Polish immigration impacts the innovativeness of German nationals and whether the immigrants are substitutes or complements. Several potential spillover mechanisms seem feasible. Immigrants of any qualification can contribute to an innovative environment even though they might not be implicated in the innovation process per se. Immigrants with special skills, knowledge, or contacts with new markets can change a firm's strategy or specialization. Influential positions for accomplishing this include management, entrepreneurship, and consulting. Increased or altered research and development activities can enhance job creation (Kerr and Lincoln, 2010) and/or patenting. Ozgen et al. (2013) discuss the impact of diversity, finding that an international working environment can boost inventor cre-

[11]Individuals self-select into migration. According to Borjas (1994) the push and pull effects of migration are based on the wage distribution and unemployment rates in the host and the destination country and determine the (skill) composition of immigrants. Luthra et al. (2014) extend this neoclassical focus on labor migration by identifying different Polish emigrant types such as Temporary, Settler, Family, Student or Adventurer. For our setting, the selection mechanism is not crucial, but Section2.2 gives some indications on the composition of the Polish immigrants group.

ativity. Peri and Sparber (2009) find that low-skilled immigration leads native workers to reallocate their task-supply. In our setting, low-skilled immigrants might replace German workers and thus give them the opportunity for promotion to more inventive occupations. Due to a lower reservation wage, low-skilled immigrants can also be employed in the production process thereby increasing production capacities and making it profitable for the firm to advance innovations in the pipeline. In addition to the mechanisms described, high-skilled immigrants who are inventors themselves can help achieve critical mass in a specialized research area and lead to a breakthrough reflected in new patents and patentees (Hunt and Gauthier-Loiselle, 2010). Immigrating inventors can also have a competitive effect on their teammates with German or other citizenship. Competition can drive innovative productivity by challenging incumbents and pushing them to work more or better. Or, competition can lead to a substitution of German inventors and therefore a negative effect on inventor counts of German nationality. Hence, by regressing the number of German inventors on Polish immigration we capture a number of mechanisms and we cannot predict which effect will prevail and which sign the effect might have.

Taken together, if spillovers to incumbents are positive, then we expect a higher point estimate for the total effects on Polish inventors than for the spillover effects on German inventors: the effect on Polish inventors consists of the direct contribution of immigrants and of spillovers to Polish incumbents in Germany, whereas the German effect has only one dimension.

3 Data and Descriptive Statistics

We construct our core dataset at the county level (*Kreis*, corresponds to NUTS3) using various data sources: patent data provided by OECD and the World Intellectual Property Organization (WIPO), migrant statistics by German and Polish Statistical

Offices, and employee social security records from the German Institute for Employment Research (IAB). Due to the structure of our instrument we focus data collection entirely on counties in West Germany and thus have 326 observations in our sample.

Table 1: Summary statistics of variables

Variable	Obs	Mean	Std. Dev.	Min	Max	P50
Polish inventors	326	.85	2.78	0	36	0
German inventors	326	721.39	1041.12	14	9208	375.5
Non-Polish inventors	326	758.35	1121.47	14	10321	386.5
Polish employees 1989	326	78.48	192.88	10	2753	36
Pole share 1989	326	0.0031	0.0075	0.0004	0.1076	0.0014
Emigration from Poland	1	258368				
Predicted Polish immi (=instr)	326	0.00	12.48	-4.43	173.04	-2.79
ln(Pol inv)	326	.3	.62	0	3.61	0
ln(Ger inv)	326	5.96	1.14	2.71	9.13	5.93
ln(Non-Pol inv)	326	5.99	1.15	2.71	9.24	5.96

Data: Inventor data from REGPAT and WIPO, emigration data from the Polish Statistical Office, distribution of Poles in 1989 from German social security statistics.
Notes: This table reports summary statistics for the inventor and migration variables used in the main estimation.

We obtain inventor records on patent applications via the Patent Cooperation Treaty (PCT) route from OECD's REGPAT database (Maraut et al., 2008). In a first step, they are linked to inventor and nationality records from WIPO's recently published micro dataset on mobile inventors (Miguelez and Fink, 2013), using unique application IDs and inventor names. The latter dataset exploits particular features of the PCT system, specifically that non-US PCT applications needed to list inventors as applicant-inventors if they indicated the United States as a designated state (which was the case for most applications; see Miguelez and Fink, 2013). All applicant-inventors were then required to document their nationalities in the applications. Matched data are then aggregated to counties in West Germany and applications filed in a given year, using REGPAT's regional county codes. The latter code derives from the residence address of the inventor recorded on applications. More precisely, we apply fractional counting when an application involves more than one inventor resident in different counties. Say, for example, when two inventors are assigned to a single application, one from county A and one from B, each county's total number of patent applications increases by only .5. In a last step, we identify the set of unique inventors in a given county and year using parsing and filtering techniques suggested by Raffo and

Lhuillery (2009), disambiguating inventor names (as individual inventors can be listed on several patent applications in a given year), and segregate the latter into groups by nationality of unique inventors. We cumulate unique inventor counts as well as Polish emigration and all control variables over our 10-year period (2001–2010). We use the standard approach of taking the log of the number of inventors +1 in order to keep all observations in the sample.

For computation of our instrument, we use the distribution of Polish employees across German counties in 1989, which we take from IAB social security records. Individuals only show up in social security records when they are or have been employed and they are registered with their nationality. For anonymization reasons, numbers below or equal to 15 in a county are not reported; for these 65 counties, we set the number of Polish employees at ten[12]. Note, that we capture only those Poles who did not acquire German citizenship. In our setting, this allows us to distinguish political refugees of the 1980s from the group of *Aussiedler*, because the latter appear as Germans in our social security statistics (Salentin, 2007). We also can essentially exclude that we are measuring economic refugees from Poland. Recall that migrants who were granted asylum, such as political refugees, received a work permit right away, whereas other migrants from Soviet Bloc countries encountered a more difficult situation. As they could not be expelled, at least not until the fall of the Iron Curtain, they were allowed to apply for a work permit after a certain waiting period, which varied across the 1980s and by states (Bundesländer) and ranged from one to two years. However, even after the waiting period, most applicants were not granted a work permit (Meister, 1992). We are therefore confident to measure the intended political refugee group of Poles with social security statistics.

The distribution of Polish employees per county in 1989 is right-skewed with a mean of 78.48 and a median of 36 (see Table 1). In total, there were 25,586 Polish employees in West Germany in 1989. According to Table A1, the number of Polish

[12]In a robustness check, we choose a uniform distribution of these numbers and obtain qualitatively and quantitatively very similar results.

asylum seekers increased significantly in 1988 and their total number from 1980 to 1989 was over 100 thousand. If we apply the 20 percent share of recognized refugees reported by Meister (1992), we find that most of the Poles we capture with the social security statistics must have been recently arrived immigrants.

The information on total emigration from Poland in 2001 to 2010 stems from the Polish Statistical Office and includes only emigrants who leave for at least one year, thus excluding temporary and seasonal emigration. The Polish statistics report 258,368 permanent emigrants during our period of analysis. This corresponds with the German Statistical Office's report of a net immigration of 224,374 Poles. The gross emigration information from Polish statistics and the net immigration number from German statistics are comparable because the German statistics also count immigrants who do not have the intention or possibility of a permanent stay and, therefore, to a large majority, leave the country after a while. The Polish emigration statistics only report longer stays. Therefore, our instrument does not measure short-term immigrants, which are the biggest group of Polish emigrants from Germany. As we standardize the share of Poles in 1989, which acts like a weight in the construction of our instrument, the predicted immigration has a mean of zero.

The statistical offices do not report Polish immigration to Germany at the county level and for our main, reduced-form instrumental variable model, we do not need these actual (endogenous) immigration numbers. For the 2SLS-specification, we compute Polish net migration per county i by taking the yearly difference in the stock of Polish citizens in i, which we then sum up for the 10-year period[13]. There are 21 of our 326 counties that have a negative net migration (*Pol immi*). As our specification is in logarithms, we set these counties' Polish migration to zero. Descriptive statistics of this variable can be found in Table A3 in the Appendix.

[13] Seasonal workers are generally obliged to register with the municipality authorities but migration researchers and even the German Statistical office agree that the majority of these workers are not found in the official statistics (Dietz, 2005). We therefore measure more permanent migrants. Note, furthermore, that for the federal state of Saarland, the number of foreigners is not reported at the county level. We therefore distribute this state's Polish citizens across the counties based on their total population.

The settlement structure (agglomeration type) fixed effects as well as the time-invariant controls in the specification are added from INKAR database.[14] Descriptive statistics of the two sets of control variables can be found in Table A2 in the Appendix.

4 Immigrants' Contribution to Innovativeness in Germany

4.1 Main Results

Table 2 shows the reduced-form instrumental variable estimations. Polish immigration to Germany positively and significantly impacts the number of Polish inventors and the number of German inventors. In Columns 1 and 2 we present the results without county-specific controls, but with settlement structure fixed effects. In Columns 3 and 4, controls for the industry structure, the distance to the Polish border and the presence of a university are added. Alternative controls are used in Columns 5 and 6. Over the different specifications, the results are very robust and they only change at the third decimal. We take Columns 5 and 6 as our main results.

In counties with 10 percent more Polish new arrivals compared to other counties, there are 0.28 percent more Polish inventors and 0.32 percent more German inventors. We learn from these results that, first, Polish immigrants patent and/or drive the innovativeness of incumbent Polish citizens. Second, Polish immigrants are complements to, not substitutes for German inventors, as reflected by the positive point estimate in Column 6. Third, the spillover effect on the innovativeness of German citizens is slightly higher than the effect on Polish inventors. This (small) difference suggests that the total innovation effect of immigrants comes more from complementary jobs pushing other workers' innovativeness than from immigrants' direct contribution.

[14] Indikatoren und Karten zur Raum- und Stadtentwicklung. Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) im Bundesamt für Bauwesen und Raumordnung (BBR), Bonn 2016.

In absolute terms and at the mean, the direct effect of 0.28 percent corresponds to 1 Polish inventor and the indirect effect of 0.32 percent corresponds to 5 German inventors. As we employ population weights, our estimates are not simply representative of the German counties but of the German population, which means, that small counties contribute less to the estimated effect.

The coefficients on the settlement structure fixed effects are quite sizeable and highly significant for the specification with German inventors. They show that agglomeration characteristics such as population and population density are clearly a relevant factor for the distribution of German inventors across counties whereas the impact is smaller and more diffuse for Polish inventors.

Table 2: Main results: Reduced-form IV estimation

	No controls		With controls		Alternative set of controls	
	(1) ln(Pol inv)	(2) ln(Ger inv)	(3) ln(Pol inv)	(4) ln(Ger inv)	(5) ln(Pol inv)	(6) ln(Ger inv)
ln(Emi) x Poles89	0.0231***	0.0232***	0.0286***	0.0307***	0.0281***	0.0315***
	(0.00269)	(0.00495)	(0.00298)	(0.00302)	(0.00322)	(0.00304)
Agglo: Urbanized	-0.182	0.163	-0.148	0.337***	-0.0542	0.396**
	(0.138)	(0.139)	(0.141)	(0.125)	(0.162)	(0.155)
Agglo: Mostly rural	-0.453***	-0.831***	-0.388***	-0.526***	-0.277	-0.426**
	(0.130)	(0.170)	(0.147)	(0.156)	(0.174)	(0.177)
Agglo: Rural	-0.467***	-1.369***	-0.412***	-1.034***	-0.293	-0.901***
	(0.137)	(0.181)	(0.157)	(0.165)	(0.187)	(0.184)
Constant	-0.240	5.623***	-4.424***	-0.687	-4.324***	0.105
	(0.410)	(0.754)	(1.353)	(1.586)	(1.538)	(1.843)
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Pop. weights	Yes	Yes	Yes	Yes	Yes	Yes
N. of counties	326	326	326	326	326	326

Notes: This table reports linear IV estimations in reduced form at the county level. Dependent variables are the number of Polish inventors and the number of German inventors, aggregated across the 2001 to 2010 time period and in logs. The instrument applies the 1989 distribution of Poles across West Germany (normalized) to the emigration from Poland in 2001 to 2010 (in logs). Controls in Columns 3 and 4: Road distance to Polish border crossing, industry quota (share of industry employees), university location (dummy). Controls in Columns 5 and 6: Linear distance to Polish border, share of medium-skilled workers, number of students. All in logs. Fixed effects: federal states, settlement structure. The regressions are weighted by county population. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Recall that we apply the methodology from Kerr and Lincoln (2010) to the German case, which is why we can directly compare our results to theirs in Table 3. Our

Table 3: Context: Comparing our results to Kerr and Lincoln (2010)

Impact of 10% more immigration on	Our analysis	Kerr & Lincoln (2010)	Comparison
Inventors of relevant immigrant group	Poles: 0.28%	Indian: 2.4% Chinese: 2.9%	Direct effects of non-selective vs. selective immigration
Native inventors	0.32%	0.14% insign.	Spillover effects are more pronounced in Germany than in the US

Notes: The results in the column "Our analysis" stem from Table 2.

coefficients of around 0.03 seem quite small. However, we find a direct effect of about one-tenth of the direct effect for the United States, even though in our analysis we consider all immigrants independent of their skill level, whereas the US effect is based on H1-B immigration only. Remember also that the largest group of first-generation Poles in Germany in the years 2000 is medium- and not high-skilled. In contrast to the US results, we find statistically significant indirect effects from Polish immigrants to German inventors, that is, locals. Our point estimate is twice the size of the US effect, suggesting much stronger spillovers in Germany.

What is the mechanism for spillover effects from new-arrivals to incumbents? New arrivals have a different background with respect to education, experience, market knowledge, and personal networks, all of which can lead to new topics of discussion, give rise to different, innovative ideas, open up new markets, and/or introduce new working processes. Note that we do not count patents but inventors. Thus our effect is not driven by higher productivity of inventors, but by workers joining innovating teams and becoming patentees. Furthermore, we count inventors on patent applications. By considering patent applications instead of patents we avoid taking into account only inventions (and therefore inventors) that are "good" enough to be granted a patent, this way limiting a certain quality bias. Besides, it takes time for a patent to be granted, which, in our 10-year period of analysis, could mean that, by measuring patents, we would not be capture the whole effect.

4.2 Assessing Instrument Validity

Our instrument is based on the argumentation that the distribution of our continuous treatment, the Polish political refugees in 1989, is exogenous to today's geographical locations of innovative industries. We discuss this in detail in Section 2. Furthermore, the different specifications in Table 2 show, that the migration effect is quite robust within the settlement structure groups and that other county characteristics have only a marginal impact. As a further assessment of the instrument's validity, we present a balance table of our covariates conditional on settlement type. To do this, we group the counties in the sample by quintiles of the distribution of Poles in 1989. Then, in six separate regressions, we regress the control variables of both sets on the agglomeration fixed effects and federal state fixed effects. We present the mean predicted residuals of these regressions in differences in a balance table (Table 4). The t-tests show that, except for a weak significant difference of the presence of a university in the higher percentiles, the sample is balanced within agglomeration groups. We therefore conclude that the fixed effects for the countys' settlement structure (city, urban, mostly rural, or rural) sufficiently control for structural differences between the counties.

In the 1980s, West Germany also took in refugees from East Germany and their geographic location might be correlated with the location of Polish refugees. We therefore need to make sure that we are not measuring the Eastern Germans' impact on locals' innovativeness, which is likely to be stronger than the impact of Poles. To this end, we conduct a placebo test replacing the distribution of Poles across Germany in 1989 with the distribution of refugees from Eastern Germany in 1961, which we obtain from Burchardi and Hassan (2013). This share covers about 50 percent of the refugees from the East in the period from 1949 to 1961 because Burchardi and Hassan (2013) were only interested in expellees of German ethnicity who had lived in the Eastern territories before the war. This group of people (2.8 million) was first allocated to Eastern Germany after the war and relocated to West Germany until the construction of the Berlin Wall in 1961. We do not expect a significant difference between their

Table 4: Balance table of covariates

	T-tests Difference bn. quintiles of *Poles1989*			
Covariate	(2) - (1)	(3) - (2)	(4) - (3)	(5) - (4)
Road distance to Poland	0.010	-0.003	-0.014	-0.015
	(0.032)	(0.033)	(0.028)	(0.030)
Industry quota	-0.014	0.039	0.007	-0.041
	(0.061)	(0.053)	(0.060)	(0.065)
University location	0.049	0.073	-0.070	0.159
	(0.077)	(0.085)	(0.088)	(0.076)**
Linear distance to Poland	0.001	0.012	-0.030	-0.009
	(0.032)	(0.031)	(0.027)	(0.030)
Share of medium qualified	0.029	0.041	-0.045	0.009
	(0.052)	(0.044)	(0.041)	(0.038)
Num of students	0.068	0.180	-0.216	0.515
	(0.253)	(0.255)	(0.273)	(0.264)*
Agglo FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Observations	132	132	132	128

Notes: This table reports the differences of mean residuals of covariates conditional on settlement type. It shows that the different quintiles of the distribution of Poles in 1989 across counties are not significantly different from each other once we control for agglomeration types (with the exception of university locations in the higher quintiles). The sample is highly balanced conditional on settlement type. Descriptive statistics for the variables can be found in Table A2 in the Appendix. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

distribution across Germany and the distribution of the other 50 percent coming from Eastern Germany as both groups immigrated with the same background and the same goals. If we construct our instrument with the distribution of expellees from 1961, we do not find any statistically significant effect on the number of Polish inventors (see Table 5, Column 1). This is a strong indication that our chosen distribution using social security statistics is not accidentally measuring refugees from Eastern Germany but is indeed only capturing the intended Polish political refugee group.

Table 5: Robustness checks: Placebo test, inventors of other nationalities

	Placebo test	Non-Polish inv	Other nationalities
	(1) ln(Pol inv)	(2) ln(Non-Pol inv)	(3) ln(Other inv)
ln(Emi) x Expellees67	0.00740		
	(0.00772)		
ln(Emi) x Poles89		0.0356***	0.0505***
		(0.00346)	(0.00505)
Constant	-2.994	-1.192	-12.43***
	(2.323)	(1.881)	(2.359)
State FE	Yes	Yes	Yes
Agglo type FE	Yes	Yes	Yes
Pop. weights	Yes	Yes	Yes
N. of counties	319	326	326

Notes: This table reports reduced-form IV estimations. See notes for Table 2 for instrument, controls, fixed effects, and time period. Column 1 shows a Placebo test for German refugees from Eastern Germany. Column 2 gives the effect for all Non-Polish incumbent inventors, that is, inventors of German or other (non-Polish) nationality. Column 3 also excludes Polish inventors, which is a test whether naturalization of Poles in Germany is driving the spillover effects. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Naturalization could be another factor interfering with the causal interpretation of our results. Although it is quite difficult to gain German citizenship, it is still likely that there are some inventors in our sample who did manage to change their nationality during the period of our analysis and would therefore be counted as new German inventors. As a test we therefore estimate the effect of our instrument on the number of (incumbent) inventors of nationalities other than Polish and German. In the absence of naturalizations, we expect this effect to be similar in size to the effect on German inventors because the same mechanisms apply: Polish immigrants push locals of another nationality then themselves to become patentees. If our test does not yield any significant effect, we can conclude that there are no spillovers from Polish immigrants to non-Polish local inventors and therefore probably also none to German inventors. In this case our baseline spillover effect would be likely to be generated by Poles becoming German citizens. Column 3 of Table 5 shows that, compared to our baseline results, we have a slightly higher, but very similar, coefficient. Hence we are confident that a change of nationality is not essentially driving our effect.

4.3 Effect Heterogeneity and Alternative Model Specification

The different sets of covariates we use in Table 2 are a first test of the robustness of our results and have been discussed above. We also estimate all specifications without the population weights and find no significant changes in the results (see Table 6, Columns 1 and 2). This means that our sample does not seem to include some, in relative terms, particularly innovative but weakly populated counties acting as the main contributors to the estimated innovativeness effect of immigrants. Interestingly, the point estimates almost double when we exclude the five biggest cities in Germany, namely, Berlin, Hamburg, Munich, Cologne, and Frankfurt (see Table 6, Columns 3 and 4). It could have been expected that the biggest agglomeration (compared to other cities) were allocated many refugees in the 1980s, consequently also received many immigrants in the 2000s, and are, at the same time, particularly innovative. This does not seem to be the case and we conclude that the effects are not driven by the biggest German agglomerations either, but, on the contrary, by smaller counties than these.

As our measure of inventor counts is strongly skewed to the right, OLS regressions might be inappropriate. Count data often follow a Poisson distribution. However, a Poisson distribution requires that mean and variance of the dependent variable are equal, which is not the case either for Polish inventors or for inventors of German

Table 6: Robustness checks: Population

	No pop. weights		w/o B, HH, MUC, K, FFM	
	(1)	(2)	(3)	(4)
	ln(Pol inv)	ln(Ger inv)	ln(Pol inv)	ln(Ger inv)
ln(Emi) x Poles89	0.0297***	0.0438***	0.0490***	0.0831***
	(0.00356)	(0.00867)	(0.0103)	(0.00701)
Constant	-2.741**	5.076**	-2.984*	8.074***
	(1.090)	(2.249)	(1.592)	(2.003)
State FE	Yes	Yes	Yes	Yes
Agglo type FE	Yes	Yes	Yes	Yes
Pop. weights	No	No	No	Yes
N. of counties	326	326	321	321

Notes: This table reports reduced-form IV estimations. See notes for Table 2 for dependent variables, instrument, controls, fixed effects, and time period. The effects in Columns 1 and 2 are not weighted by county population. Columns 3 and 4 exclude the five biggest cities in Germany, namely, Berlin, Hamburg, Munich, Cologne and Frankfurt Main. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

or other nationalities. We therefore test for overdispersion with a likelihood-ratio test and conclude that a negative binomial model best fits our data. Furthermore, even though our Polish inventor variable includes many zeros, we can reject a zero-inflated regression model. Zero inflation requires that the excess zeros can be modeled independently, for example, in our case, by considering the total absence of inventors or innovative industries in a county. When looking at total patent counts, there does not seem to be such a zero-generating process with respect to industry structure for the number of Polish inventors. We therefore estimate a negative binomial model without zero-inflation. The coefficients we report in Table 7 are directly comparable to the former results and we find very similar and significant effects.

Following the example of Hunt and Gauthier-Loiselle (2010), we also run our baseline reduced-form specification with granted patents as the dependent variable. There is evidence in the literature that, in recent years, research teams had a tendency to increase in terms of number of members. Column 2 of Table 8 shows the effects on patents, which we can directly relate to the total number of inventors in Column 1. As the estimates are of the same magnitude, we conclude that it does not matter whether we measure inventors or patents: Polish immigrants had a positive effect on

Table 7: Negative binomial regression

	(1) Pol inv	(2) Ger inv
ln(Emi) x Poles89	0.0379***	0.0302***
	(0.00674)	(0.00267)
Constant	-10.31**	-0.0600
	(4.054)	(1.704)
State FE	Yes	Yes
Agglo type FE	Yes	Yes
Population weights	Yes	Yes
N. of counties	326	326

Notes: The table reports a negative binomial estimation. See notes of Table 2, Columns 5 and 6 for time period, dependent variables, instrument, controls, and fixed effects. The effects are weighted by county population. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

total patent production in Germany. We then also compute patents per capita and find an effect that is much smaller than what Hunt and Gauthier-Loiselle (2010) find for the United States. Their main result is that a 1 percentage point higher share of skilled immigrants in the population leads to an increase of 12 to 15 percent in the number of patents per capita. However, our results are not directly comparable. First, Hunt and Gauthier-Loiselle (2010) measure high-skilled migrants. Second, they include immigrants of all nationalities. Third, the mean share of skilled immigrants in their sample is 1.5 percent and a one percentage point increase in the share corresponds to an increase of about 60 percent. Hence, our positive and significant estimate rather reinforces our earlier results.

To estimate the local average treatment effect (LATE), we implement a two-stage least-squares specification. Like Kerr and Lincoln (2010), we do not have information on immigration at the regional level. We therefore compute the differences in the number of Polish inhabitants in each county between two successive years and aggregate these differences to our 10-year period of analysis, thus measuring Polish net migration at the county level, which we use as endogenous variable. Twenty-one out of the 326 West German counties in our sample have negative net migration, which is most likely a result of migration between counties. Internal migration is particularly selective as,

Table 8: Patents

	(1) ln(all inv)	(2) ln(Patents)	(3) ln(Patents p.c.)
ln(Emi) x Poles89	0.0321***	0.0308***	0.00456**
	(0.00309)	(0.00310)	(0.00225)
Constant	-0.150	-0.0977	2.556*
	(1.847)	(1.873)	(1.368)
State FE	Yes	Yes	Yes
Agglo type FE	Yes	Yes	Yes
Pop. weights	Yes	Yes	Yes
N. of counties	326	326	326

Notes: This table reports reduced-form IV estimations with alternative dependent variables: Number of total inventors, Number of patents, Patents per capita (per 10,000 inhabitants of the county). All variables are in logs. See notes for Table 2, Columns 5 and 6 for instrument, controls, fixed effects and time period. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

once an immigrant gets to know local labor market conditions and opportunities, she might readjust her location choice (if she has the right to work and to move). For our analysis, we set the counties with negative net migration to 1 in order to be able to take the logs. Columns 1 and 2 of Table 9 report the OLS with the endogenous immigration variable. Columns 3 and 4 show the 2SLS estimation where we instrument the immigration measure by our predicted migration. The F-statistic of the first stage amounts to 9.86, which is not particularly high but still very close to the rule-of-thumb limit for weak instruments.

The 2SLS results are clearly higher than the OLS for both dependent variables, possibly due to the fact that OLS estimates an average treatment effect across the whole population while the 2SLS identifies a particular subgroup (local average treatment effect). In our case, the latter effect is associated with the Poles who settled across German counties following existing networks of Polish citizens. The Solidarnosc migrants were rather high-skilled and/or intellectual individuals and, according to our results, they attracted inventors or, at least, innovation-boosting immigrants. In their study on immigrant shares and patents in the United States, Hunt and Gauthier-Loiselle

Table 9: Two-stage least-squares

	OLS		2SLS	
	(1)	(2)	(3)	(4)
	ln(Pol inv)	ln(Ger inv)	ln(Pol inv)	ln(Ger inv)
ln(Pol immi)	0.127***	0.160***	0.642***	0.720***
	(0.0301)	(0.0505)	(0.175)	(0.211)
Constant	5.593***	10.88***	-4.739	-0.361
	(1.277)	(2.035)	(3.921)	(5.112)
First stage			0.0437***	0.0437***
F			9.866	9.866
State FE	Yes	Yes	Yes	Yes
Agglo type FE	Yes	Yes	Yes	Yes
Pop. weights	Yes	Yes	Yes	Yes
N. of counties	326	326	326	326

Notes: This table reports two-stage least-squares estimations. See notes of Table 2, Columns 5 and 6 for dependent variables, instrument, controls, fixed effects, and time period. The instrumented variable "Immigration" at the county level is computed as the difference of Polish citizens of the respective county between two years. Negative figures are set to 1 in order to allow for logs. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

(2010) also find a LATE that is larger than the average treatment effect, and they, too, argue that this effect is due to innovative individuals being particularly affected by historical geographic considerations.

5 Conclusion

Accounting for migrants' potentially endogenous location choices, we discover a positive causal effect of Polish migration on county-level innovativeness in West Germany in the years around the EU enlargement in 2004. Greater innovativeness is largely due to indirect spillover mechanisms: Polish migration helps leverage the innovativeness of native (German) inventors, rather than solely consisting of bringing additional Polish inventors into German counties. Hence, Polish inventors are complements, allowing more non-Polish specialists to become inventors. They do not substitute incumbent inventors.

Note that, during the period of our analysis, there had been no skill-selective immigration policy in Germany, which distinguishes the German case from the US-one where H1-B immigrants are chosen because of their skills, special knowledge, and potential. Our analysis underlines that entry of both low- *and* high-skilled migrants can lead to positive contributions in the innovation context. Our example of Polish immigrants' impact on German patenting demonstrates that positive spillovers from migrants to residents do occur. These insights contribute to ongoing public debates over the costs and benefits of migration.

For the spillover effects to unfold, interaction and communication between new arrivals and incumbents is crucial. Poles in Germany are known for their high willingness and capacity to integrate into the society (Loew, 2017), so we can assume a high degree of interaction and communication with their German co-workers. This is not necessarily the case for the Chinese and Indian high-skilled workers in the United States subject of Kerr and Lincoln (2010)'s analysis. This difference in integration motivation might explain the higher spillover effects in the German case of our analysis compared to the results of the U.S. study. It is also intuitive that integration is crucial for immigration to be beneficial for the host country. Interestingly, immigrants' home countries can also experience positive complementarities. Fackler et al. (2016) find positive spillovers from immigrants in Germany coming from new EU member states on patenting activities in their home countries.

However, it must be highlighted that we look at an (Eastern) European immigrant group that is relatively skilled compared to recent refugee groups in Germany. Our results are therefore not necessarily transferable to this latest group of immigrants.

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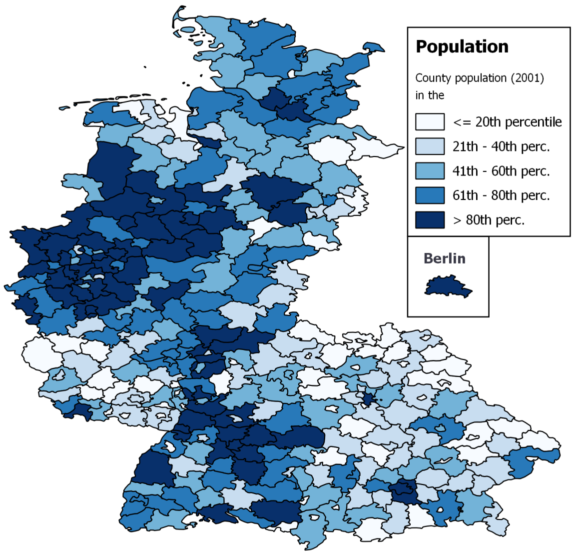
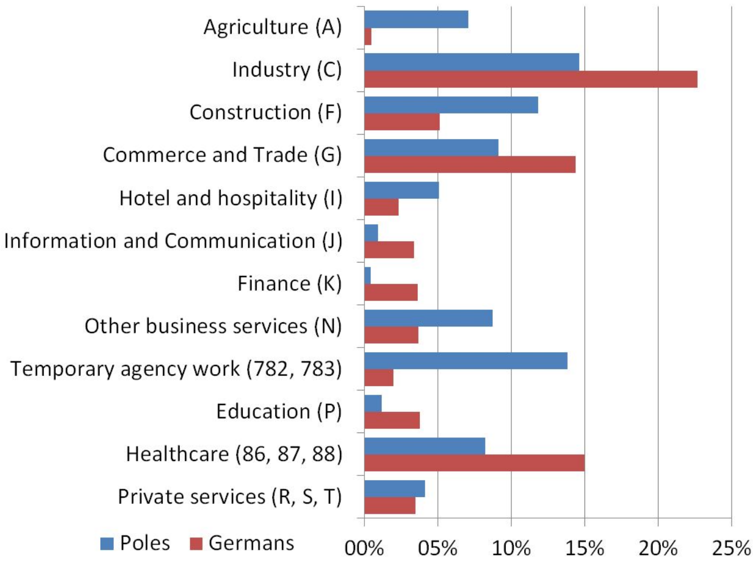
Appendix

Figure A1: Geographic distribution of population in 2001 across Germany in percentiles of counties



Source: Own presentation based on data from Regional Statistics provided by the German Statistical Office.

Figure A2: Sectors of activity of Polish and German employees in Germany



Source: Own presentation based on data from the Migrationsmonitor Arbeitsmarkt, Beschäftigte nach Staatsangehörigkeiten Stand 30.9.2017, provided by the German Employment Office.
Notes: The blue bars show the number of employees with Polish nationality in the respective sector as a share of the total number of Polish employees in Germany. The red bars show the number of employees with German nationality in the respective sector as a share of the total number of German employees in Germany. The data are from 2017, information for earlier years cannot be accessed.

Table A1: Asylum seekers in Germany 1980–1990 by country of origin

Country of Nationality	1980	1983	1984	1985	1986	1987	1988	1989	1990
Europe	86,809	6,589	11,553	18,174	25,164	36,629	71,416	73,387	101,631
including:									
Yugoslavia					1,242	4,713	20,812	19,423	22,114
Poland	2,090	1,949	4,240	6672	10,981	15,194	29,023	26,092	9,155
Romania	777	587	644	887	1,512	1,964	2,634	3,121	35,345
Czechoslovakia	2,385	1,400	1,475	1,411	1,394	1,516	1,686	2,388	781
Turkey	57,913	1,548	4,180	7,526	8,683	11,426	14,873	20,020	22,082
Hungary	1,466	587	485	736	1,116	1,585	1,996	1,583	439
Africa	8,339	3,484	5868	8,083	9,486	3,568	6,548	12,479	24,210
Asia	31,996	5,152	16,849	44,296	56,575	15,961	23,006	32,718	60,900

Data: Bundesamt für die Anerkennung ausländischer Flüchtlinge, Zirndorf. Found in: Statistisches Jahrbuch 1991.

Table A2: Summary statistics controls

Variable	Obs	Mean	Std. Dev.	Min	Max	P50
Road distance to Poland	326	538.94	120.76	102	840	556
Industry quota	326	17.67	8.61	6.4	76	15.95
University location	326	.5	.5	0	1	0
Linear distance to Poland	326	434.49	104.38	77	660	444
Share of medium qualified	326	35.45	11.64	15.2	100.4	32.7
Num of students	326	21	42.05	0	233.94	.99
ln(Road distance to Poland)	326	6.26	.25	4.62	6.73	6.32
ln(Industry quota)	326	2.85	.38	2	4.34	2.83
ln(Linear distance to Poland)	326	6.04	.27	4.34	6.49	6.1
ln(Share of medium qualified)	326	3.52	.29	2.72	4.61	3.49
ln (Num of students)	326	1.53	1.76	0	5.46	.69

Data: Own calculations based on data from INKAR database provided by the Bundesamt für Bauwesen und Raumordnung.
Notes: This table reports summary statistics for the different county-specific control variables added to the baseline specification in Table 2 and discussed in Table 4.

Table A3: Panel summary statistics: Immigrants and net migration

Variable	Obs	Mean	Std. Dev.	Min	Max	P50
Polish residents (county-year)	3257	1022.2	2350.74	43	36660	469
Polish net migration (county-year)	3257	35.64	309.53	-12289	3137	18

Data: Own calculations based on data from Regional Statistics provided by the German Statistical Office.

Notes: This table reports summary statistics on immigration variables before aggregation to the 10-year period of analysis (2001–2010). Polish residents are the stock per county and year. Polish net migration are first differences of the stock variable. Aggregated to the 10-year period, it is used in the 2SLS specification.