Free Movement of Inventors: Open-Border Policy and Innovation in Switzerland*

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Abstract

We study the innovation effects of the Agreement on the Free Movement of Persons, signed by Switzerland and the EU in 1999. We exploit a quasi-experimental setting created by Switzerland's implementation policy, which initially eased off entry restrictions only for commuters from neighboring countries and induced a large inflow of "cross-border inventors" in the regions next to the border. We find that this increased patenting in such regions, relative to comparable ones farther away from the border. We do not find evidence indicating the displacement of native inventors nor a reduction in the patenting activity of Switzerland's neighboring countries. We find that incumbent inventors in regions next to the border increased their productivity, thanks to patents in collaboration with cross-border inventors. We provide evidence suggesting that cross-border inventors contributed to Swiss patenting by enabling R&D laboratories to enlarge by hiring inventors with valuable skills, albeit without increasing the productivity of local peers outside direct collaborations.

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1. Introduction

The international migration of skilled workers is historically tied to innovation. Itinerant craftsmen were the main agents for diffusing technical knowledge in early modern Europe (Cipolla 1972; Belfanti 2004; Hilaire-Pérez and Verna 2006), and the forced relocation of religious minorities after the Reformation remarkably contributed to host countries' technological progress (Scoville 1952a,b; Luu 2005; Hornung 2014). The same applies to more recent migration events, such as the flight of Jewish scientists from Nazi Germany (Moser et al. 2014) or Russian emigration following the collapse of the Soviet Union (Borjas and Doran 2012; Ganguli 2015).

Today, foreign-born individuals constitute a large share of science, technology, engineering, and mathematics (STEM) workers in many advanced economies (Kerr 2008; Miguelez and Fink 2017), in a context of revived global migration (Kerr et al. 2016) and of rising importance of teamwork in R&D activities (Wuchty et al. 2007; Jones 2009; Agrawal et al. 2016). A growing literature investigates the effects of immigration on innovation in destination countries, mostly with reference to the United States and often focusing on the implications of policy changes (Kerr and Lincoln 2010; Hunt and Gauthier-Loiselle 2010; No and Walsh 2010; Hunt 2011; Stuen et al. 2012; Kerr et al. 2015b; Burchardi et al. 2020; Doran et al. 2022; Glennon 2023). Related research questions concern the existence of positive peer effects between immigrants and natives (Bernstein et al. 2021); or, instead, of displacement effects, due to substitability and competition (Borjas and Doran 2012, 2015).

In this paper, we study the innovation effects of the Agreement on the Free Movement of Persons (AFMP), a treaty signed by Switzerland and the EU in 1999. The treaty prescribed the elimination of most restrictions to the mobility of workers between Switzerland and the EU, as part of a more general liberalization of economic exchanges. Its application in Switzerland was gradual and differentiated across regions and immigrant permit types. This generates a quasi-experimental setting that we exploit to study the effects of the treaty introduction on innovation at the regional and at the individual level, using patent and inventor data, which we match to administrative records on immigrants.

Despite its small size, Switzerland is both an innovation powerhouse and a leading destination of international high-skilled workers, making it a highly relevant case study. From 2013 to 2019, it ranked first worldwide in terms of patent applications per million inhabitants, and it currently ranks 11th for the number of full-time R&D employees relative to the population (Dutta et al. 2021; EPO 2020). Many of these employees are immigrants. For example, patent data for the decade 2001–2010 indicate that one-third of inventors residing in Switzerland were foreign nationals (versus 12% in the UK and 16% in the US; see Miguelez and Fink 2017). Up until the signing of the AFMP treaty, however, and notwithstanding the importance of European workers for its economic system, Switzerland did not lower its entry barriers from the EU, which were also binding for highly skilled individuals (Piguet 2009).

As for the AFMP's value as a natural experiment, this has been first exploited by Beerli et al. (2021), who show how its early implementation phase (1999–2007) caused a sudden labor supply shock in some regions of Switzerland but not in others, the difference depending on the distance from the country's international borders. In particular, the regions very close to the border experienced a disproportionate increase in the number of cross-border commuters (the first category of visa holders for which restrictions were removed), especially in skilled professions.

We rely on an original dataset of 67,087 patent applications filed at the European Patent Office (EPO) between 1990 and 2012 to protect inventions that resulted from Swiss-located R&D activities. By comparing the personal and company addresses reported on patent applications, we identify a large number of "cross-border inventors," namely inventors living in commuting zones across the border but working in Switzerland. For a subset of relatively recent years (2002–2012), we verify this patent-based definition of cross-border inventors by comparing it to one based on administrative information, using personal records on immigrant permit holders from the Swiss Central Migration Information System (ZEMIS). The database covers the entire immigrant population in Switzerland since 2002 and provides valuable information on immigrants' age, entry date, and other personal characteristics.

We first show that the AFMP led to a large increase in the number of cross-border inventors, but only for regions close to the international border. We argue that this differential effect is not due to any unobserved trend affecting jointly innovation and immigration. This creates a powerful treatment-control setting, which we exploit to study the effects of immigration on innovation. Using an event study approach, we estimate an annual increase in patenting between 15% and 55% in treated regions during the first eight years following the AFMP's ratification. The temporal evolution of our estimates indicates that those inventions would have remained unrealized in the absence of the AFMP.

Our results do not depend exclusively on giant multinational conglomerates, which could have anticipated the AFMP, but also and predominantly on large- and medium-sized patent applicants. Nor do they depend on new firms or firms moving to the treated regions to profit from the increased supply of inventors, owing instead to incumbent firms increasing their patenting activity. They are largely driven by patents in the instruments, chemicals, and pharmaceuticals fields, which collectively account for over half of our sample and represent the main patented technologies from regions close to the international border.

We do not find evidence suggesting that the policy-induced inflow of cross-border inventors occurred to the detriment of Swiss inventors, whose number does not appear to have decreased in treated regions, relative to control ones, after the AFMP introduction. We also fail to detect adverse effects on the inventive output of regions in France, Germany, or Italy close to the Swiss border, where the number of patent filings did not appear to have declined relative to that of other areas in the same countries.

We next conduct our analysis at the individual level. We first focus on incumbent inventors, namely Swiss and foreign residents whose patenting activity started before the AFMP's signing and whose location and specialization decisions can be assumed to be exogenous to the treaty.

We find that, relative to those in the control regions, the incumbent inventors in the treated ones increased their annual patent filings by 17% to 46% in the post-AFMP period, with most of the additional patents resulting from new collaborations with cross-border inventors. Several pieces of evidence suggest that this outcome is due to the availability of a greater number of skilled cross-border workers as collaborators, with a profile complementary to incumbent inventors.

First, we observe that the newly arrived cross-border inventors tend to be rather young workers, with no previous patenting experience, while many incumbents are more senior, possibly in positions of responsibility within their R&D labs. Second, we find that, in the post-AFMP period, incumbent inventors in treated regions increase the number of distinct co-inventors they team up with, relative to those in control ones. Third, we show that the cross-border inventors bring with them some distinctive knowledge assets, but not enough to generate major knowledge transfer effects, capable of changing the direction of R&D of the firms they join. In particular, we find that incumbent inventors in treated regions cite more prior art from the cross-border inventors' countries than those in the non-treated ones—in the post-AFMP period—and that this effect is entirely due to patents in collaboration with the cross-border inventors. At the same time, these patents do not introduce novel terms in the text of their abstract, relative to the stock of Swiss patents accumulated before the AFMP introduction; nor, they substantially depart from the technological classes where incumbent inventors patented before.

The second part of our individual-level analysis focuses on more junior Swiss resident inventors. Identifying the effects of the AFMP on those who started patenting after its ratification is particularly challenging. Their decision to become inventors and their location choices are unlikely to be exogenous to the treaty, and we cannot observe them before the date of their first patent. As a partial remedy, we focus on Swiss residents who started patenting right before the AFMP's introduction, but whose subsequent career took place entirely in the post-AFMP context, in both the treated and control regions. We adopt a difference-in-differences strategy and compare their patenting activity to that of similar inventors of previous cohorts, whose career unfolded entirely in the pre-AFMP context. Our estimates suggest that the AFMP introduction had a positive effect on the patenting activity of junior inventors located in treated regions (similar in magnitude, albeit in fewer years that for incumbent inventors), once again in the absence of major knowledge transfers from cross-border ones.

Our results relate to those of Kerr and Lincoln (2010) for the United States, who find that more admissions of foreign workers in specialty occupations, based on the H-1B visa scheme, increased patenting by foreign inventors in highly H-1B-dependent locations, with no displacement nor productivity effects on natives. In a related study, Kerr et al. (2015a) stress the young age of H-1B visa holders and find firm-level evidence that their recruitment can occur at the expense of older, native incumbent workers with similar qualifications. In terms of age, most cross-border inventors who get their first Swiss entry permit are similar to H-1B visa holders, but our findings differ in that we observe a positive effect on Swiss inventors' productivity, particularly incumbent ones. We attribute this to the greater availability of skilled cross-border inventors, with a complementary profile to more senior incumbent inventors, which allowed the latter to engage in more R&D projects, with respect to a previously constrained situation.

The profile of cross-border inventors may also explain why we find no evidence of major knowledge transfer effects. Different from the German Jewish scientists in Moser et al. (2014) or the Russian ones in Ganguli (2015), most cross-border inventors in our study filed their first patent after moving to a Swiss firm, and later pursued their entire inventor career in Switzerland. Nevertheless, our inventor-level findings point to a mechanism through which junior co-inventors can enhance the productivity of their peers, particularly the more experienced ones. This differs from prior research on peer effects in R&D teams, which finds positive effects to be driven either only by high-standing scientists (Azoulay et al. 2010; Oettl 2012) or by the slow accumulation of team-specific capital between frequent collaborators (Jaravel et al. 2018; Bernstein et al. 2021).

The absence of major knowledge transfer effects can be also due to our limited timeframe. For example, Hunt and Gauthier-Loiselle (2010) show that, for the period 1940–2000, an increase of immigrant college graduates' proportion in a US state corresponded to a large surge in patenting, with evidence of productivity spillovers from foreigners to natives. We cannot exclude that larger knowledge transfers, potentially leading to greater effects on the productivity of natives, may arise over a longer time horizon in our setting, with cross-border inventors progressively integrating within the Swiss R&D system and establishing team-specific capital with other Swiss inventors, while at the same time importing knowledge from their home countries.

Unlike Borjas and Doran (2012), who demonstrate that the influx of Soviet mathematicians to the US after the Soviet Union's collapse negatively affected the careers of their American junior peers, we do not find adverse effects of immigration on the productivity of the younger domestic inventors. This can be attributed to the higher elasticity of labor demand in industrial R&D relative to the academic labor market. In our setting, companies can expand their R&D laboratories to absorb new foreign workers without displacing their domestic counterparts. In contrast, academic positions in research universities are more rigid.

Our study is also an important addition to more general research on immigration and innovation in Europe. Existing studies find a positive association between the two, based on cross-firm, cross-regional, or cross-country variation in immigrants' share of the workforce or population and its association with various measures of innovation (Ozgen et al. 2013; Parrotta et al. 2014; Bosetti et al. 2015; Nathan 2015; Ferrucci and Lissoni 2019). However, no evidence has been produced at the inventor level, nor any study has directly investigated the effects of policies based on the Freedom of Movement of Workers principle, which is a pillar of the European Union and the main source of migration to its member countries (Kahanec et al. 2016; Dustmann and Preston 2019; Dorn and Zweimüller 2021).

The main exception to this dearth of studies is, once again, the work of Beerli et al. (2021). Based on survey data, they find a positive effect of the AFMP on Swiss firms' propensity to file a patent. Our study goes deeper in many respects. First, by using the full set of patents filed by Swiss firms at the EPO, we can better quantify and qualify the AFMP's innovation effects. Second, we can establish a direct link between the AFMP-induced supply shock of foreign inventors and the increase in patenting. Third, we extend the analysis to Switzerland's neighboring countries. Fourth, we study individual inventors' productivity and collaborations, making use of information on inventor teams.

The rest of the paper proceeds as follows. Section 2 provides some essential background information on Swiss immigration laws, before and after the AFMP. Section 3 describes our data collection methodology and the resulting dataset. Section 4 outlines our quasi-experimental setting and describes the cross-border inventors' supply shock. Section 5 presents the results of our regional analysis, Section 6 reports the results of our inventor-level analysis, and Section 7 concludes.

2. The Swiss Immigration System and the AFMP

The inflow of foreign workers in Switzerland is regulated by a "demand-based" system: only those with a job offer are eligible to apply for an immigrant permit. Due to the peculiar geography of Switzerland, which is surrounded by the three largest EU countries and Austria, with some densely populated agglomerations on both sides of the border, permits for cross-border workers are as important as those for resident immigrants.

Resident immigrants are foreigners working and residing anywhere in Switzerland. Their entry permit can be either a "B" valid for 5 years, or an "L" valid for 1 year. After 5 years of uninterrupted stay in Switzerland (10 years for non-EU citizens), a resident immigrant may request a permit "C" with unlimited validity. Cross-border workers, instead, are foreign commuters to Basel, Geneva, Lugano, and other Swiss cities close to the international border. They hold a work permit "G" which has been historically regulated by bilateral treaties. Until 2002, these treaties included some geographical restrictions, as they indicated the across-the-border designated areas inside Austria, France, Germany, and Italy where the foreign workers had to reside in order to be eligible to the permit, as well as the Swiss "border regions" in which the permit allowed them to work.[1]

On June 21, 1999, Switzerland and the EU signed the AFMP. Gradually implemented during the subsequent years, this treaty lifted most restrictions to workers' immigration from the EU to Switzerland (and vice versa). Its negotiation had started in 1994 as part of a series dealing with the relationship between the EU and Switzerland, two years after Swiss voters rejected, with a referendum, their government's proposal to join the European Economic Area. The result of the negotiation remained in doubt until common ground was found in 1998, and the introduction of the AFMP became certain only after the positive outcome of another referendum held on May 21, 2000. Swiss entrepreneurs could scarcely anticipate its introduction nor make plans based on it.

Before the AFMP's implementation, the concession of work permits for both cross-border workers and resident immigrants was subject to many limitations. Sponsoring employers had to go through a costly and time-consuming application process, which included demonstrating that they had searched and failed to find a native worker with the required skills. Although cross-border workers were not subject, like resident immigrants, to immigration quotas, they had to respect a specific set of restrictions. First, they were required to have resided in the across-the-border designated areas for at least six months before applying for a G-permit. Second, they had to commute back to their countries of residence on a daily basis. Third, their work permits had to be renewed every year and were tied to a specific employer. Fourth, they could only work in a border region corresponding to their G-permit designated area.

These restrictions were progressively lifted during the AFMP's implementation. Immediately after the treaty was signed in 1999, the procedures for firms to obtain G-permits were

[1] The treaties were signed in 1928 with Italy, 1946 with France, 1970 with Germany, and 1973 with Austria. The treaties with Germany and Austria indicated precisely in which cities and/or districts commuters must reside. For France and Italy, the treaties simply mentioned the obligation to reside at no more than 10 km from the border. Appendix Table B6 reports the specific administrative units in Austria, France, Germany, and Italy corresponding to a G-permit-designated area, based on information from the State Secretariat for Migration (`https://www.sem.admin.ch/sem/de/home/publiservice/weisungen-kreisschreiben/auslaenderbereich.html`, last visit: January 2024). Figure D16, also in the Appendix, shows them on a map. Swiss border regions close to Germany and Austria were once again defined at the district level, while those adjacent to France and Italy simply followed the 10 km limit. For Swiss border regions, we rely on the list used by Beerli et al. (2021).

informally simplified. Then, after its official introduction on June 1, 2002, the duration of G-permits was extended to five years and no longer tied to a specific employer. In addition, the compulsory daily commute was transformed into a weekly one, and the six-month residence requirement to be eligible for a G-permit was dispensed with (still, residence in a G-permit designated area after obtaining it was required). In 2004 all residual restrictions for G-permit holders in border regions were dropped, while the non-border regions still remained under a separate regime.

Finally, in 2007, nationals of EU15 (EU member countries in 2004) and EFTA (European Free Trade Area, which in 1999 included Iceland, Liechtenstein, and Norway) gained full freedom to work in Switzerland without distinction between border regions and non-border regions, regardless of their working permit.[2]

In summary, the AFMP's introduction laid down the conditions for a geographically heterogeneous labor supply shock: stronger in the border regions, to which cross-border workers were admitted, and weaker in the non-border regions, which admitted only resident immigrants. As we will discuss below, the shock was also asymmetric within the border regions, with the new cross-border workers moving almost exclusively in locations at a short commute from an international border crossing point. This provides us with a quasi-experimental setting, on which we will return in Section 4.

3. Data

Our main data source is the Worldwide Patent Statistical Database (Patstat), version 2017b.[3] Despite their well-known limitations, patent statistics are a key innovation measure in R&D-intensive economies such as Switzerland (Griliches 1990; Nagaoka et al. 2010). Patent documents, in addition, provide rich information on both the inventions they protect and their

[2] Appendix Figure A1 illustrates the AFMP implementation timeline, by region and immigrant category. Notice that potential resident immigrants also experienced a gradual relaxation of immigration restrictions, starting in 2002, but with no differences across regions.

[3] See `https://www.epo.org/searching-for-patents/business/patstat.html` (last visit: January 2024).

inventors and applicants.[4] We extract from Patstat all the patent applications filed at the EPO, whether granted, under examination, or rejected (for ease of exposition, we often refer to all of them simply as "patents").[5] One reason for focusing on EPO patents is that they contain accurate information on the address of both inventors and applicants, which we need for geocoding purposes (Breschi and Lissoni 2004). At the same time, filing through the EPO represents a convenient way for Swiss companies to obtain patent protection at the continental level and beyond (via international extension). We date each application with its priority year.[6]

3.1. Sampling, Disambiguation, and Geolocation

We consider all patents with priority years comprised between 1990 and 2012. This time frame ensures a decade or so of observations both before and after the AFMP's signing. Since we want to focus only on the output of R&D labs located in Switzerland, we proceed as follows. First, we retain all patents that include at least one inventor with a Swiss address (67,993 patents) regardless of the applicant's address. To these, we add the patents filed by applicants with a

[4]By law, the applicants are the persons (either physical or juridical) who file the patent application at the patent office, that is, who pay the filing fees and claim the intellectual property. The inventors are instead the physical persons who have produced the ideas described and protected by the patent, which the applicant has the duty to designate on the patent itself (in jargon, the inventors "sign", rather than "file", the patent). Inventors and applicants can be the same in the case of independent inventors, but in the overwhelming majority of cases, the inventors are the applicant's R&D employees. In other cases they may be external consultants or independent inventors who sell their intellectual property to a company, as part of a research contract or sponsorship (a typical case being that of a university professor hired by a company on a project basis). For a detailed discussion and some examples, see Giuri et al. (2007) and Lissoni et al. (2008).

[5]We focus on applications rather than only granted patents for the following reasons. First, several non-granted patents are withdrawn by their applicants during the examination time, which may range from a few months to many years, rather than rejected by the patent office for lack of novelty or obviousness. Reasons behind a withdrawal may have to do with the excessive length of the ongoing patent examination, which makes the invention obsolete in the meantime, or the intervening of new economic calculations. This means that while the patents for the most novel and non obvious inventions are usually granted, a large number of granted ones are not necessarily better than the non-granted ones. Second, being property titles, patents can be bought and sold, also as part of M&As and asset exchanges, and this applies especially to granted patents (Serrano 2010). But the new assignees, not being the original applicants, bear no association to the inventors and the original R&D activity they undertook. By focusing on patent applications, which are the earliest documents filed at the patent office, we minimise the risk of making a false inventor-company association. Nevertheless, in a series of robustness checks we replicate all our main results using only granted patents.

[6]Swiss companies seeking patent protection in one or more European countries can file their patents either directly at the EPO or first at a national patent office (such as the Swiss Federal Institute of Intellectual Property or IGE) and subsequently extend them abroad. Most extensions pass again through the EPO. All these cases are captured by our data, and we miss only the patents that Swiss companies do not extend abroad or otherwise bypass the EPO, which expert opinion at IGE and EPO suggest to be few. Notice that applicants have either 12 or 36 months since their first patent filing to complete their extensions, depending on the procedure they choose. Since extensions lead to additional patent applications, each with its own filing date, the date of the first filing is indicated as the "priority" one (being essential for resolving priority disputes over initial invention claims). For our purposes, the "priority year" is the closest point in time to the invention conception.

Swiss address and no inventors with a Swiss address, but at least one inventor with an address in a G-permit-designated area in Austria, France, Germany, or Italy (3,462 patents).

Second, we disambiguate inventors and applicants. Patstat data provide unique identifiers for inventors and applicants, but inconsistencies like simple spelling mistakes or address changes can result in the same person (or firm) receiving multiple identifiers across different patents. Further disambiguation is therefore necessary to track both individuals and firms over time and across locations. For inventors, we used the identifiers produced by Pezzoni et al.'s (2014) algorithm. For the applicants, we used the identifiers produced by Du Plessis et al. (2009), which we improved by manually checking all applicants in our data with at least 20 patents (accounting for roughly 57% of all patents in our dataset), in order to verify their company or group affiliation.

Third, we assign each patent to the location where the inventive activity presumably took place and filter out those originating from outside of Switzerland. Patent data do not explicitly report the address of the R&D laboratories (or other facilities) that sourced the inventions they protect. They only include the address of applicants and inventors. Hence, we must deduce the presumed location of the invention source (to which we will from now on refer as "R&D location") from either one or both sets of addresses.

With regard to the applicant's address, the larger the company, the more likely the address coincides with that of the company's headquarters or intellectual property division. These may be located in different cities than those hosting the R&D laboratories. In the case of multinationals, even the countries may not coincide.[7]

As for the inventors' address, the most common practice followed by patent attorneys is to report their home ones, which we expect to be relatively close to the inventors' workplaces. In this case, the inventor and applicant addresses differ. When they coincide, it is because the

[7]For example, the municipality of Rüschlikon (Zurich) hosts one of IBM's 12 global research labs. Out of all IBM's 603 patents in our dataset, only one mentions it in the applicant's address. All others indicate the IBM's headquarters in Armonk, New York. In contrast, 80% of the inventors' addresses indicate municipalities around Zurich.

attorney preferred using the applicant address also for the inventors.

Based on these considerations, we infer each applicant's R&D location(s) from the distribution of its inventor addresses, with the applicant addresses playing an auxiliary role. We first use the Google Maps Geolocation API to geocode each Swiss address and assign it to a spatial mobility region (henceforth "MS region" from the French "Mobilité Spatiale"). For each applicant, we calculate the frequency distribution of all its inventor-patent instances across MS regions, thus obtaining one or more candidate R&D locations.[8]

When applicants have just one candidate R&D location (22% of all patents in the dataset), we retain this as the only relevant one. When applicants have multiple candidate locations and at least 20 patents in their portfolios (58% of all patents), we extensively search the companies' websites and other online resources and we retain only the candidate R&D locations that match them. For the remaining applicants with multiple candidate R&D locations, but fewer than 20 patents (20% of total patents), we retain only the location that corresponds to the MS region with the highest number of inventor-patent instances. In this case, we perform no systematic manual checking except for ambiguous cases (e.g., when the number of patents in two or more candidate locations are close). We also look for any false R&D location to filter out, corresponding to applicants whose patents never report a Swiss address nor have any known Swiss-based facility and yet hold a few patents with one or more Swiss-based inventors. Such patents are typically due to collaboration between a Swiss academic and a foreign research institution or a Swiss-based inventor consulting internationally.[9]

Fourth, we identify the inventors with a likely cross-border worker status ("cross-border

[8]MS regions are defined by the Swiss Federal Statistical Office as travel-to-work areas for micro-regional analyses (Schuler et al. 2005). They consist of agglomerations of municipalities and are large enough to track our inventors' commutes to work. They are also ideal units of analysis for our econometric exercises due to their heterogeneity in terms of G-permit holders' presence (see Section 4).

[9]We search and eliminate the former by looking at keywords such as "university" or "foundation" in the applicants' names (237 patents). As for the latter, we search online for corporate information and eliminate all those for which no Swiss-based R&D facility is ever mentioned (3,540 patents). We believe our method of identifying R&D locations to be accurate and necessary, due to the need to remove the noise contained in the applicants' and inventors' addresses and to locate correctly within Switzerland the patents signed by local inventors and foreign-resident ones. However, we also experiment with simpler methods, which do not require the use of personal judgment and external information. In one case we simply assign each patent and inventor to the applicant's MS region, alternatively we use the inventor's residential MS region.

inventors"). We distinguish them from the inventors working and residing in Switzerland (or "Swiss resident inventors," whether Swiss nationals or not) and also from other inventors collaborating with a Swiss R&D lab from abroad, that is, without any connection to the Swiss labor market. We provide further details in Section 3.2.

Our final sample thus includes all patents by Swiss resident inventors and/or cross-border inventors, assigned to the Swiss location where the inventive activity presumably occurred, amounting to 67,087 patents, 13,820 applicants, and 85,870 inventors. Around 91% of all patents in our dataset are filed by firms. Patents filed by universities and nonprofit research organizations are just about 2%, while the remaining 7% is filed by independent inventors. Most patents originate either from applicants with just one R&D location or, for applicants with multiple R&D locations, from just one of them (47,108 patents, approximately 70% of all patents). In these cases, we treat all the inventors listed on the patent as employed in that location, even if their addresses are outside the corresponding MS region. As for the patents with multiple R&D locations, they may originate from multiple labs of the same company or joint applications by different companies, each one with its own lab. In both cases, we assign each inventor to one or another location (and the corresponding MS region) by simply picking the closest to the inventor's address, and assign patents fractionally to each location.

We complement our main dataset with one containing all the patents filed in Austria, France, Germany, and Italy, for the limited purpose of testing any possible first-order effect of the AFMP on Switzerland's neighbor countries. We extract from Patstat all EPO patents filed between 1990 and 2012 and listing at least one inventor with an address in one of the four countries. After discarding any patent filed or co-filed by applicants with a Swiss address or listing a cross-border inventor as co-inventor, we assign each remaining patent to the NUTS-3 region where most of the inventor team is located. If no clear majority exists, we assign it to the applicant's location. The final sample consists of 28,361 patents for Austria, 161,183 for France, 429,280 for Germany, and 83,485 for Italy.[10]

In what follows, we illustrate the methodology we adopted to identify cross-border inventors and describe their main characteristics. More details about our procedures for disambiguating inventors and applicants and and assigning patents to their R&D locations can be found in Appendix B.

3.2. Cross-Border and Swiss Resident Inventors

We define as cross-border inventors all the inventors who, according to patent information, reside in a G-permit-designated area in Austria, France, Germany, or Italy and work in a nearby Swiss R&D location (MS region).[11] We define instead as Swiss resident inventors all those with a Swiss address. In this way, we count 6,205 cross-border inventors associated with 10,443 patents and 56,381 Swiss resident inventors associated with 64,415 patents.

Note that the Swiss resident inventors category does not distinguish between Swiss and foreign nationals (holders of B, C, or L permits). This is because EPO patents do not report any useful information in this regard. For this reason, when applicable, we focus on what we refer to as the EPO-PCT subsample, which consists of patents first filed at EPO, from the 1990s to 2010, and then extended to the United States via the Patent Cooperation Treaty procedure (PCT). For administrative reasons, explained by Miguelez and Fink (2017), patents in this

[10] In Austria, NUTS-3 regions correspond to districts' aggregations, in France to departments, in Germany to districts, and in Italy to provinces. These are substantially larger geographical units than Swiss MS regions, making the misassignment of inventions to their R&D location less likely.

[11] For each G-permit designated area, we consider as "nearby" all the MS regions in cantons with the same official languages, which we know to be spoken across the border. The only exceptions are the MS regions in the cantons of Bern, Fribourg, Grisons, and Valais, which have two or more official languages, and the cantons of Basel-Stadt and Basel-Landschaft, which share borders with both France and Germany. In those cases, we opt for a conservative definition strictly based on the G-permit-designated areas' geographic proximity to avoid false positives. See Table B7 for the complete pairwise list of G-permit designated areas and "nearby" MS regions. It is worth noting that, after 2007, cross-border inventors could also reside outside the G-permit designated areas, but that we do not adapt our address-based definition to this change. This is because outside such areas we cannot distinguish the inventors employed by a Swiss R&D lab from other inventors who collaborate with a Swiss lab as a result of an international partnership (that is, without being one of its employees). The only exception are the very few cases in which we observe the same inventor on more than one patent, first with an address in a G-permit designated area and then in a location further away from the Swiss border (most often large cities such as Milan, Munich, and Stuttgart). As long as all the patents are filed for a Swiss-based applicant, we keep labeling the inventor as a cross-border inventor even after the change of address. We are aware that this methodology may lead us to underestimate the number of cross-border inventors after 2007, but a different choice would introduce too many false cross-border inventors in our sample. Nevertheless, using information from immigration records we show that cross-border inventors residing outside G-permit designated areas are few (Appendix Figure C4).

subset contain information on the inventors' nationality, which allows us to distinguish fully between cross-border inventors, other foreign inventors, and Swiss inventors.

Figure 1 shows the distribution of cross-border inventors across Switzerland's neighboring countries. The colored areas indicate the municipalities where the cross-border inventors reside. All municipalities are located at a short distance from the border. Those with the highest proportion of cross-border inventors are, in general, immediately adjacent to it. Germany hosts the largest share of them, followed by France, and, way behind, Austria and Italy.

For the 2002–2012 period, we verify our patent-based cross-border inventor definition by comparing it to one based on administrative records, namely those of the ZEMIS archive. These records provide data on all foreign nationals working and/or residing in Switzerland, including their permit types (with issue and renewal dates) as well as their addresses, nationality, and dates of birth. Using a supervised machine learning strategy first proposed by Feigenbaum (2016), we match all the inventor and ZEMIS records and identify as cross-border inventors all matches holding a G-permit. We also classify all the matches with permits other than "G" as foreign resident inventors and all the non-matches as Swiss nationals.[12]

Appendix Figure C1 compares the spatial distribution of cross-border inventors identified with the two methods, finding them to be very similar. Appendix Figure C2 compares the number of cross-border inventors identified with the two methods in each year. The two figures are very close for the years from 2002 to 2008, which speaks in favor of the accuracy of the patent-based definition. Later, the two figures diverge. Our explanation is that patent filing practices have changed for the most recent years of our sample, with patents increasingly reporting the inventors' work address instead of their residence. When this happens, we cannot identify cross-border inventors based only on patent information, which ultimately leads to an underestimation

[12] While this would have been the ideal way to define cross-border inventor status for the entire database, we could not adopt it as the ZEMIS records start after the AFMP was signed. Appendix Section B.4 describes the matching procedure in detail. Feigenbaum's (2016) approach is particularly suited to data linkage settings where the researcher lacks a pre-existing ground-truth training set and needs to create it directly from the data. See Abramitzky et al. (2021) for an in-depth review of record linkage methods.

of their number.[13]

The ZEMIS biographical information also allows us to better characterize cross-border inventors, albeit only for the post-AFMP period. Panels (a) and (b) of Figure 2 confirm that most cross-border inventors are either German or French citizens and that they are disproportionately active in chemical and pharmaceutical technologies. Panels (c) and (d) indicate that cross-border inventors generally enter the Swiss innovation system early on in their inventor careers. Depending on their technology field, only 12% to 17% of them obtained the G-permit after having filed at least one patent abroad. Their average age at arrival in Switzerland is 33.7 years and the median and modal age are both 32 years, all close to the average age of first-time inventors indicated by the literature (Jones 2009; Breschi et al. 2020; Kaltenberg et al. 2023). In contrast, after their first filing for a Swiss-based R&D lab, about half of cross-border inventors patent at least once again in Switzerland.[14]

When considering their entire observable patenting career, we find that cross-border inventors are more productive than the Swiss ones. We obtain this evidence by regressing an inventor's productivity measure on an dummy variable equal to 1 for cross-border inventors and 0 for Swiss inventors, and controlling for inventors' first patent cohort, technology field, and key applicant and co-inventors' characteristics (panel (e) in Figure 2). We find that cross-border inventors file around 29% more patents and receive 21% more citations. These results do not change much when we exclude independent inventors and cross-border inventors who already patented before moving to a Swiss employer.

We also find that patents filed by inventor teams including at least one cross-border inventor

[13]In accordance with rule 19 of the Implementing Regulations of the Europe Patent Conventions, applicants must indicate the names and residence of the inventors, but the EPO does not verify the accuracy of the information (`https://www.epo.org/en/legal/epc/2020/r19.html`, last visit: January 2024). Informal conversations with EPO officers suggest that some applicants, especially large ones, increasingly try to save time by not looking for their inventors' addresses and using instead their own. Appendix Figure C3 (panels (a) and (b)) shows that both the number and share of patents with inventors reporting their work address increase considerably after 2005.

[14]Compared to cross-border inventors, resident foreign inventors are both less experienced when they enter Switzerland and less likely to patent more than once afterwards. In the Appendix we provide evidence confirming this difference by regressing the immigrant inventors' probability of patenting more than once as a function of their permit type and other control variables (see Table D1).

generally cite more prior art from Switzerland's neighboring countries than patents filed by teams including only Swiss nationals or resident foreign inventors. Panel (f) in Figure 2 provides evidence in this sense, based on estimations where the number of citations to patents filed in Switzerland's neighboring countries is regressed on an indicator for cross-border inventors' patents, plus filing year, MS region, applicant, and technology field fixed effects.[15]

Lastly, we find that the majority of cross-border inventors employed in Switzerland in the post-AFMP period resides in G-permit designated areas (Appendix Figure C4). We also find that most of the Austrian, Italian, and, to a lesser extent, German ones were also born there or nearby (Appendix Figure C5). This suggests that the majority of the post-AFMP cross-border inventors originate from G-permit designated areas, and did not move there from other locations far from the Swiss border. In the case of France, the pattern is less clear cut, as nearly half of the cross-border inventors were not born in a G-permit designated area.

4. Quasi-Experimental Setting

As discussed in Section 2, G-permit holders were the first immigrant category to experience a progressive relaxation of immigration restrictions after the AFMP was signed. In addition, until 2007, G-permits were granted only to employees of firms located in border regions. The most intuitive empirical approach would then be to compare border regions to non-border regions, before and after the AFMP. This strategy would exploit the exogenous exposure of border regions to cross-border inventors' influx, entirely determined by a legal change rather than any economic force simultaneously driving the local performance and the influx of cross-border inventors. However, a close look at the data reveals that most cross-border inventors work predominantly in a subset of the border regions, those located at very short commuting times

[15]Prior art consists of all the patent and non-patent literature concerning inventions produced worldwide before the focal patent's filing date. We focus on so-called front-page citations to prior patents as reported on the focal patent's legal documentation and do not consider in-text ones (for the difference between the two, see Bryan et al. 2020). For more information on the estimates in Figure 2 panels (e) and (f) see Appendix Table D2 and Table D3, respectively. When we run panel (f) estimations switching to citations to prior art from non-neighboring countries such as the US, we do not detect any significant difference between cross-border inventors' and other Swiss residents' patents (Appendix Table D4).

from their residences in neighboring countries.

Figure 3 shows the relationship between driving times from the closest international border crossing and the share of cross-border inventors relative to total inventors, for both border regions and non-border regions, before and after the AFMP ratification. The relationship is strong and negative, with the border regions situated at up to 10 minutes from the border crossing exhibiting by far the largest shares of cross-border inventors, both before and especially after the AFMP. We find a similar pattern in the regions at 10 to 20 minutes from the border crossing. In contrast, the cross-border inventor shares in more distant border regions as well as in all the non-border regions are both low and unaffected by the AFMP.[16]

These descriptive statistics suggest us to consider distance from the border a more relevant source of exogenous geographic variation in cross-border inventor presence than the administrative distinction between border and non-border regions. We thus restrict our analysis only to the border regions and elect as the "treated regions" all those at no more than a 20-minute drive from the border. All the other border regions, at more than 20 minutes from the border, constitute the "control regions" (see the map in Figure 4). As for the non-border regions, we include them in the control group only in the robustness checks, whose results we report in Appendix D (with no meaningful change in the results).[17]

One additional advantage of this identification strategy is that, unlike border regions compared to non-border ones, all border regions, whether treated or not, are very similar in terms of innovation activities. They both include several top Swiss innovation hubs, while the non-border regions contain none. As an example, consider the four largest Swiss cities: Zurich, Geneva, Basel, and Lausanne. All of them fall into a border region, with Basel and Geneva right on the

[16] Each MS region's driving time is defined as the average driving time between its municipalities and their closest international border crossing. All driving times are calculated with the Google Maps Distance Matrix API. We obtained the border crossings' locations from Hennerberger and Ziegler (2011).

[17] Our empirical strategy is equivalent to Beerli et al.'s (2021), except for different driving distance cutoffs (20 minutes rather than 30 minutes). That is explained by our use of MS regions as units of observation, rather than municipalities as in Beerli et al. (2021). Appendix Figure C7 shows that MS regions at an average driving distance below 20 minutes from the border encompass nearly all municipalities at up to 15 minutes from the border and the large majority of those between 15-30 minutes. Notice that some cross-border workers commute by ferry across Lake Léman and Lake Constance, with travel time between 20 and 35 minutes. This does not alter the assignment to the treated or control group of the MS regions around Lausanne and Konstanz.

international border (and therefore treated) and Zurich and Lausanne both at approximately 30-minute drives from the closest border crossing (controls). These four cities are Switzerland's leading economic centers, concentrate most of its patenting activity, and host its top research universities. Table 1 provides more general evidence and shows how, in the pre-AFMP period, control regions were very close to treated ones in terms of the average number of patent filings and inventors, while the non-border ones reported much lower values.

When looking at trends concerning the number of cross-border inventors active in treated and in control regions, we see that they are parallel until the AFMP's ratification and then diverge. The three lines in Figure 5 report yearly figures for all groups of regions, including, for the sake of completeness, the non-border regions. Markers indicate, for validation, the same counts for the ZEMIS-based definition of cross-border inventors, when available. We observe that before 1999, the number of cross-border inventors in treated and control regions differ but increase at the same moderate pace. Between 2000 and 2003, the growth rate in treated regions increases sharply but does not change in the control ones. This diverging trend persists until 2005, when the number of cross-border inventors in the treated regions starts declining. Notice, however, that this decline is visible only for the patent-based definition of cross-border inventors (lines) and not for the ZEMIS-based one (markers), which suggests instead that the gap between treated and control regions, after increasing with the AFMP, does not revert. This is due to a measurement problem, which, as explained in Section 3.2, causes an underestimation of the number of cross-border inventors based solely on their address on patents starting in 2007. Panels (c) and (d) of Appendix Figure C3 shows that the problem is almost exclusively concentrated in the treated regions.

In addition to the proximity to the commuters' residences, a factor potentially explaining the different increase in the number of cross-border inventors across treated and control regions could be the influence of cross-border workers' personal networks. It is possible that information on how to access to the Swiss labor market is passed by commuters already working in

Switzerland to prospective ones in their residential locations. Since most commuters worked in treated regions even prior to the AFMP introduction, information about specific job openings in Switzerland might have been mostly related to firms in those locations, therefore attracting the majority of commuters hired after the AFMP was signed.[18]

5. Regional Analysis

For the regional analysis, we organize our dataset of Swiss-filed patents in a panel of MS regions, which we observe yearly from 1990 to 2012. We then compare treated and control regions over time, based on an event study approach. Formally, we estimate the following equation:

$$E[y_{m,t}|X_{m,t}] = exp[\alpha + \sum_{\substack{t=1990 \\ t\neq 1999}}^{2012} \beta_t \cdot I_{year=t} \times Treated_m + \gamma_m + \phi_t] \quad (1)$$

where $y_{m,t}$ is an innovation outcome for MS region m in year t; $I_{year=t}$ is an indicator equal to 1 in year t and 0 otherwise (with 1999 as the reference year); $Treated_m$ is a dummy variable equal to 1 for the treated regions and 0 for the control ones; γ_m are regional fixed effects, which capture time-invariant characteristics of each MS region; and ϕ_t are year fixed effects, which account for time-variant shocks common to all MS regions. The parameters of interest are the β_t, which measure the yearly difference in the conditional mean of y between treated and control regions.

With one exception, our innovation outcomes always consist of patent counts. We expect the effects of the AFMP to be detectable starting in 2000, which implies a one-year delay between the kick-off of at least some of the new R&D projects and the first patent filings. This is in accordance with both what Figure 5 shows for the number of cross-border inventors and with the literature on the gestation lags between between R&D and innovation.[19]

[18] This explanation follows an intuition similar to that adopted by studies exploiting the past geographic distribution of immigrants as an instrumental variable to address endogeneity problems in new immigrants' location choices (Altonji and Card 1991; Card 2001, 2009).

[19] The studies surveyed by Hall et al. (2010) estimate that such lags to range between 2 and 6 years; but since they define innovation as either the launch of a new commercial product or the occurrence of the first revenues, the lag to the first patent filing must necessarily be shorter (otherwise the invention would go unprotected). More recently, de Rassenfosse et al. (2019) have estimated that, in the United States, the lag from the signing

Our main identifying assumption is the parallel evolution of outcomes in treated and control regions had the AFMP not been introduced. The assumption cannot be tested directly but appears reasonable whenever the estimated β_t for the pre-AFMP period do not differ significantly from zero. We follow other econometric studies of innovation and science (e.g., Henderson and Cockburn 1994, Blundell et al. 1995, Azoulay et al. 2019, Catalini et al. 2020) and produce pseudo-maximum-likelihood (PML) estimates based on Hausman et al.'s (1984) Poisson fixed effects model. In regard to inference, we report robust standard errors clustered at the MS region level (Liang and Zeger 1986).[20]

5.1. Patenting in Switzerland

Panel (a) of Figure 6 reports the estimation results for Equation 1, where $y_{m,t}$ equals the number of patents filed in region m at time t. The black circles and vertical dashed bars correspond, respectively, to the estimated β_t coefficients and their 95% confidence intervals. For $t < 2000$, all estimates are close to zero and display no particular trend, providing reassuring evidence in support of our parallel trends assumption. For $t \geq 2000$, the coefficients first increase then also become statistically significant (starting in 2001). This trend reverts in 2008, when all regions finally implement the AFMP.

We interpret these results as evidence that, after the AFMP was signed, the R&D locations in the treated regions progressively increased their patenting output relative to the control ones due to the inflow of cross-border inventors. The positive and statistically significant coefficients for the post-AFMP period imply large effects: compared to control MS regions, patenting in treated MS regions increased by 15% to 55% from 2001 to 2007. For the mean MS region in 1999, this corresponds to an increase of 5 to 18 additional patents per year.[21]

of a public R&D contract to the patent filing is around 33 months, while the lag measured since the end of the contract is less than 6 months.

[20]We also estimate an equivalent fixed effects difference-in-differences regression, in which we compare two periods, pre- and post-AFMP (respectively, up to 1999 and from 2000). The results are reported in Appendix D.

[21]The magnitude of our estimates falls between those of two previous studies on the effects of sudden immigration shocks on innovation: they are larger than those of Kerr and Lincoln (2010) regarding the effects of increased H-1B admissions in the US during the early 2000s, but smaller than those of Moser et al. (2014) about the arrival of German Jewish scientists in the US during the 1930s. In the first case, the difference may be due to the differences in the policy environments under examination: the AFMP lifted all restrictions faced by Swiss

The temporal evolution of our estimates indicates that the AFMP introduction did not permanently increase the patenting activity of the treated regions, relative to the control ones. However, it suggests that the firms in the treated regions undertook some R&D investments that they would have not otherwise afforded, lacking the necessary scientific and engineering workforce. These resulted in patented inventions that would have not materialized absent the AFMP, and not just in the acceleration of their research agenda. In fact, the positive and statistically significant coefficients we estimate up until 2007 gradually diminish to zero, rather than becoming negative and offset the prior increase.

We continue our analysis by testing whether the patenting increase is driven by firms setting up new R&D labs in the treated regions or relocating there from the control ones. Such circumstances would raise an identification issue in our exercise, namely the impossibility of retaining our definition of treatment and control regions over the entire study interval, due to the changes in the structural conditions caused by the AFMP itself. We also investigate whether the effects are driven only by few very large companies, which might have lobbied influentially in favor of the AFMP while preparing to recruit large numbers of cross-border inventors after its signing.

First, we re-run our estimations for a reduced sample of "incumbent applicants," that is, those with at least one patent filed before the AFMP's ratification. While a small number of these applicants have or used to have R&D labs in both the treated and control regions, only three of them opened up a new lab after 2000 (with little more than 100 patents attached). Second, we identify the "top" applicants in our sample as those in the 99.9th percentile of the inventive workforce distribution and re-run the regressions after dropping them.[22]

Panels (b) and (c) of Figure 6 report the event study results for the two reduced samples.

firms to hire foreign workers, while the H-1B program temporarily increased its national admission cap. In the second case, the difference may be explained by the characteristics of the immigrant population studied: Moser et al. (2014) focus on high-standing senior scientists, while our study predominantly involves inventors at the early stages of their careers. We elaborate on this aspect in our individual-level analysis in Section 6.

[22] We defined the inventive workforce as the total number of inventors associated with a given applicant over the entire investigation period. We count 14 top applicants, which have 45 R&D locations and around 23% of the total patents in our sample (15,530 patents). Most of them are large corporations, either Swiss or foreign ones with R&D sites in Switzerland. Appendix Figure C9 shows that firms with a large inventive workforce are also large in terms of sales and employees.

The plot in panel (b) is strikingly similar to that in panel (a) and suggests that the results owe much more to the incumbent firms in the treated regions than to any firms moving in after the treatment. Panel (c) shows that the results are robust to the exclusion of top applicants.

Turning our attention to the mechanisms underlying the patenting surge, we first observe that, before and after the AFMP, no less than 80% of the cross-border inventors' patents were co-signed by a Swiss resident inventor, most often a Swiss national (see Appendix Figure C6). We then investigate how much of the cross-border inventors' impact on their host regions' patent output depends on such collaborations. To do so, we distinguish between patents by inventor teams including at least one cross-border inventor (*cross-border inventor in team*) and patents signed by teams with only resident inventors (*resident-only team*). We then run separate regressions for the two types of patents.

Panel (d) of Figure 6 reports the results. The black circles show the estimated parameters for the *cross-border inventor in team* patents, while the gray squares indicate *resident-only* teams. We can see that it is mainly the parameters for the *cross-border inventor in team* patents that become positive and significant after the AFMP's introduction. This suggests that the post-AFMP growth in patenting is mostly due to the cross-border inventors' direct contribution.

We deepen our investigation by examining the effects of the AFMP introduction on Swiss patenting by technology field. Appendix Figure D1 reports event study results for our regional specification, where the dependent variable is the number of patents filed in a given region and year, for each of Schmoch's (2008) five main technology fields. Our estimates suggest that the post-AFMP increase in patenting is concentrated in the instruments, chemicals, and pharmaceutical fields. Those technologies account for around 56% of patents in our sample in the pre-AFMP period (Appendix Figure C10).[23]

We also test whether the patenting increase was driven by incumbent applicants with specific

[23] Appendix Figure C11 shows the distribution of patents in our dataset across a more granular technology categorization. Within the technology groups displaying a patenting increase in the wake of the AFMP, the technological categories accounting for the largest proportion of patents are organic fine chemistry, basic materials chemistry, chemical engineering, biotechnology, pharmaceuticals, measurement instruments, and medical devices.

pre-AFMP characteristics. Panel (a) in Appendix Figure D2 reports event study estimates considering only either the patenting output of applicants employing at least one cross-border inventor or that of applicants employing none. Our results indicate that the surge in patenting after the AFMP introduction primarily originates from the first group. This suggests that networks of cross-border workers, sharing information about increased job opportunities in Switzerland following the AFMP, could explain the concentration of cross-border inventors' influx in areas at close commuting distance from the border. In contrast, the patenting output of incumbent applicants not employing any cross-border inventor in the pre-AFMP period decreased after its introduction.

Additional results in Appendix Figure D2 reveal that the post-AFMP patenting increase is due predominantly to applicants whose patents disproportionately cite foreign prior art (panel (b)) or the scientific literature (panel (c)), rather than just other patents. However, when focusing only on the chemicals and pharmaceuticals fields—where new technologies are generally more likely than others to build on scientific discoveries—such differences are less pronounced (panel (d)).

Lastly, we test whether the post-AFMP patenting increase is driven chiefly by inventive activities in the Basel and Geneva agglomerations, the two most populous areas and main innovation hubs in the treated regions. Basel accounts for around 42% of patents filed in the treated regions in the post-AFMP period (13% of all patents filed in Switzerland), while Geneva makes up for about 13% of them (4% of all patents filed in Switzerland).

In Appendix Figure D3 we report the event study estimates replicating the results of Panel (a) in Figure 6, after excluding from the sample the MS regions associated with the Basel and/or Geneva agglomerations. The estimates are unchanged when we drop only Geneva (panel (c)). When we exclude Basel, either alone or jointly with Geneva, the estimated coefficients for the post-AFMP period remain positive, mostly statistically significant, and with the same temporal pattern of our baseline estimates. The size of the coefficients is slightly smaller, implying a patenting increase of 26% to 45% between 2005 and 2007, compared to the 35% to 55% increase based on full sample estimates. These results suggest that the post-AFMP patenting increase is the result of inventive activities located across the entire treated region and not only those from Basel and Geneva.

All these results pass several robustness checks. First, we include non-border region regions in the control group (Appendix Figure D4). Second, we re-estimate the model including NUTS-2-specific time trends to account for potentially unobserved regional-specific shocks (Appendix Figure D5). Third, we test different methods for assigning patents to MS regions, using either the inventors' residential address or the applicant's address (Appendix Figure D6). In each case, our results do not change. Fourth, we examine the results' sensitivity to an alternative statistical model, based on OLS estimates and a logarithmic transformation of the dependent variable (Appendix Figure D7). We still find a positive and statistically significant impact of the AFMP's introduction on patenting in treated regions, with one main difference from our baseline results: when considering only incumbent applicants, the post-AFMP coefficients stay positive but lose significance. Last, we re-estimate our model using analogous dependent variables based only on granted patents, finding unchanged estimates in terms of sign, statistical significance, and temporal evolution, albeit with slightly smaller coefficients (Appendix Figure D8).[24]

5.2. Displacement and Brain Drain Effects

The growth in patenting induced by the AFMP's introduction could have come with two adverse effects. First, native inventors could have been displaced, suggesting some degree of substitutability, rather than complementarity, between foreign and native inventors. Second, there could have been a brain drain of scientists and engineers from across the border into Switzerland, possibly resulting in a decline of patenting in the cross-border inventors' residence regions. The presence of either effect would imply that the innovation gains for Switzerland

[24]We have conducted analogous robustness checks for all our subsequent regressions presented in the paper, consistently yielding results congruent with our baseline estimates. The interested reader can consult them in Online Appendix D, although we will not refer to these additional estimates in the remainder of the paper.

might have come at some loss for its native inventors or its neighboring countries.

To investigate displacement, we again estimate Equation 1, this time with $y_{m,t}$ equal to the number of Swiss resident inventors active in each region and year. Panel (a) of Figure 7 reports the results. The estimated β_t are positive and statistically significant in the period immediately after the AFMP's signing and are very close to zero afterwards. This suggests that Swiss resident inventors did not experience any displacement. If anything, there are signs of a moderate but short-lived crowding-in effect.

Our main sample of Swiss resident inventors, however, includes both Swiss nationals and foreign residents, and a decline in the former might have been possibly compensated by an increase in the latter. For this reason, we replicate the exercise using the EPO-PCT subsample, which includes information on the inventors' nationality. We then set $y_{m,t}$ equal to the number of inventors with Swiss nationality active in each region and year. Panel (b) of Figure 7 shows that the post-AFMP coefficients are either positive or close to zero until 2006; they then become negative but are never statistically significant. While any indication of a possible crowding-in effect disappears, the results exclude any displacement of native inventors during the period immediately after the AFMP introduction.[25]

To investigate the brain drain hypothesis, we adapt Equation 1 to the study of Switzerland's neighboring countries (Austria, France, Germany, and Italy), with NUTS-3 regions in each country as our units of observation. The dependent variable $y_{m,t}$ is now equal to the yearly patent output of foreign region m in year t, from 1990 to 2012. $Treated_m$ is an indicator for the regions where the pre-AFMP legislation required G-permit holders to reside. As for control

[25] The only possible hint of a displacement effect comes from the two-period difference-in-differences estimates based on the EPO-PCT subsample (Appendix Table D10). The negative coefficients we obtain in columns (2) and (4) tell of a decline in the number of inventors with Swiss nationality active in treated regions after the AFMP introduction, mostly affecting the entrant ones. However, when we introduce in the regression NUTS-2 specific time trends the coefficients become statistically indistinguishable from zero (Appendix Table D12). We also investigate the possibility of displacement effects being heterogeneous, depending on the natives' inventive experience. When we set $y_{m,t}$ equal to the number of "entrant inventors"—the inventors whose first ever patent dates back to year t and can be located in region m—we find results remarkably similar to the full sample (panels (a) and (b) in Appendix Figure D9). When we set $y_{m,t}$ equal to the number of "incumbent inventors"—the inventors who patented at least once before the AFMP's introduction—we still exclude any displacement effect, finding potentially positive effects instead (panels (c) and (d) in Appendix Figure D9).

regions, in the baseline regression we consider as such all other NUTS-3 areas (see Appendix Figure D16 for a map of treated and control regions).

Figure 8 reports the results. Panel (c) shows the β_t estimates for Germany. Both the pre- and post-AFMP estimated coefficients are all close to zero and display no trend. The results for France (Panel (b)) are very similar, with the exception of negative coefficients after 2008, although mostly not statistically significant. Panel (d) reports the results for Italy. Different from France and Germany, most coefficients for the post-AFMP period have a negative sign but are close to zero and not statistically significant. The results are not as conclusive for Austria (panel (a)). The estimated coefficients are negative although not statistically significant in 2002 and 2003, while positive and mostly statistically significant from 2004 onwards. We interpret this result with caution, given a possible diverging trend between treated and control regions' patenting before the AFMP signing, as evidenced by the coefficients for the years 1990-1999.[26]

These findings indicate that the introduction of the AFMP did not negatively impact innovation in the cross-border inventors' regions of origin from the three largest countries of interest. This suggests that the increase in patenting observed in Switzerland following the AFMP's implementation likely represents a net gain in global innovation. While studying the mechanisms behind the absence of negative effects on patenting in cross-border inventors' origin regions is outside the scope of this paper, three non-mutually exclusive factors may have played a role. First, the AFMP could have improved the matching of STEM workers with firms across the Swiss border, enabling the relatively young commuters to increase their productivity or even to access a patenting career, which might have been less available in their native labor markets. Second, internal migration within the large French, German, and Italian national labor markets could have provided replacements for the commuters who entered the Swiss labor market.

[26] In Appendix Table D15 we report comparable estimates from a two-period difference-in-differences model. We also check the sensitivity of the results to the choice of different control groups. We first exclude from the regressions the NUTS-3 areas immediately bordering the treated ones. We do this because the AFMP might have affected them indirectly, for example, by inducing internal migration, which would introduce a bias in the estimates. Our results do not change (Appendix Figure D18). We then test an alternative control group based on Mahalanobis matching, an approach similar to that adopted by Hafner (2021). Also in this case, the estimates do not change in any meaningful way (Appendix Figure D20).

Third, the presence of internal migrants among commuters, particularly in the case of France, might have reduced the severity of the scientists' and engineers' emigration.

6. Inventor-level Analysis

We deepen our analysis by shifting the focus from regions to individuals, so to explore the interactions between Swiss and cross-border inventors. Identifying any causal effect of the AFMP is possible only for incumbent Swiss resident inventors, namely, the inventors who patented at least once before the AFMP's introduction. These are the only individuals we can observe both before and after the AFMP's introduction, and whose decision to become inventors and location choice pre-date the policy change, so that it can be considered exogenous. The same cannot be said for any inventor whose first patent was filed after the AFMP introduction. Still, we can produce some additional evidence for an intermediate group of inventors, namely the incumbents whose careers started right before the AFMP's introduction, but took place entirely afterwards. We examine the two types of inventors in turn.

6.1. Incumbent Inventors

For each incumbent inventor, we track the patents filed in each year, before and after the AFMP's introduction. Because some inventors might have responded to the introduction by changing their workplace, we fix each inventor's location after 1999 in the MS region where they were last observed patenting up to and including that year, irrespective of their real location afterwards. We thus obtain an unbalanced panel of 14,212 incumbent inventors observed between 1990 and 2012, out of which 4,867 active in the treated regions and 9,345 in the control ones (plus 4,186 in the non-border regions). We then estimate the following event study specification:

$$E[y_{i,m,t}|X_{i,m,t}] = exp[\alpha + \sum_{\substack{t=1990 \\ t\neq 1999}}^{2012} \beta_t \cdot I_{year=t} \times Treated_m + \theta_i + \gamma_m + \phi_t] \qquad (2)$$

where $y_{i,m,t}$ is the patenting output of inventor i located in MS region m in year t, $I_{year=t}$ is an indicator equal to 1 in year t and 0 otherwise (with 1999 as the reference year), $Treated_m$ is a dummy variable equal to 1 if inventor i is in a treated region, and ϕ_t are year fixed effects. Inventor fixed effects θ_i control for any unobserved time-invariant characteristics of inventor i, while MS region fixed effects γ_m account for time-invariant MS region heterogeneity. Similar to the regional analysis, we assume that the outputs of treated and control inventors would have followed the same trends in the absence of the AFMP.[27]

Panel (a) of Figure 9 reports the results. The estimated β_t coefficients in the pre-AFMP period follow a flat trend and are mostly close to zero. Starting from 2002, many of them become positive and statistically significant. This result indicates that the incumbent inventors in the treated regions significantly increased their productivity following the AFMP's introduction, with the number of patents signed from 2002 to 2011 growing by around 17%-46% per year. For the average incumbent inventor active in 1999, this corresponds to an increase of 0.22 to 0.60 additional patents per year.

Next, we investigate the extent to which this productivity growth is due to direct collaborations with cross-border inventors rather than indirect effects, such as localized spillovers driven by physical proximity. To this end, we again estimate Equation 2 after excluding from $y_{i,m,t}$ all patents listing a cross-border co-inventor. We report the estimated β_t as black circles in panel (b) of Figure 9. When comparing them to the circles in panel (a), those in panel (b) appear to be generally smaller and less often significant. When we further exclude from the baseline sample all patents in which the inventors report their work address instead of their home one, so to correct for the underestimation of cross-border inventors after 2007 (see the discussion of Figure 5 in Section 4), we obtain null results. When comparing the new series of estimated coefficients (grey squares) to the baseline one, we see that the two of them coincide up to 2004 and show no effect of the AFMP's introduction. After then, the estimates for the corrected sample indicate no effect at all. We obtain a similar evidence from the two-period

[27] In Appendix Table D21 we report the estimation results of an equivalent two-period difference-in-differences specification, where $I_{year=t}$ is replaced by $AFMP_t$, a dummy variable equal to 1 after 1999.

difference-in-differences specification, as reported in Appendix Table D21 (in particular, the estimated coefficient in column (2) of is less than half that of column (1) and is not statistically significant).

These findings indicate that only the incumbent inventors collaborating with the cross-border ones increased their productivity, with the additional patents being exclusively those produced thanks to these collaborations. This suggests that cross-border inventors possess some distinctive characteristics, which make them complementary to the incumbents. At the time of our study, in fact, many such incumbents were senior enough to be laboratory directors or project leaders, with the potential to pursue a greater number of R&D projects by assembling more inventor teams, provided they could find the right human capital. Cross-border inventors would suit them for this purpose. As explained in Section 3.2, most of them entered Switzerland at the beginning of their career, while at the same time possessing distinctive knowledge assets and skills, witness their higher productivity and propensity to cite foreign prior art, relative to Swiss inventors. At the same time, it appears unlikely that, right upon entry, they could extend their influence beyond their immediate collaborators or significantly alter the research agendas of their companies.

We test this interpretation by estimating again Equation 2 with two new outcomes, namely: the number of distinct co-inventors with whom each incumbent inventor collaborates yearly; and the number of prior art items from the cross-border inventors' home countries cited by each incumbent inventor patent.[28]

Panels (c) to (f) of Figure 9 show our results. When the dependent variable is the number of distinct co-inventors (panel c), the pre-AFMP coefficients are never significant and follow an overall flat trend. The post-AFMP period coefficients start increasing in 2002 and then become positive and mostly statistically significant. When the dependent variable is the number of

[28] We find prior art from cross-border inventors' home countries by geolocating the cited patents based on the applicants' and inventors' addresses. We first drop all those with at least one Swiss address, whether it belongs to an inventor or applicant. Then we retain as coming from Austria, France, Germany, or Italy any cited patent with at least one inventor from such countries and no Swiss inventor or applicant.

citations to prior art from the cross-border inventors' home countries (panel e), the post-AFMP coefficients progressively increase in size and become statistically significant in the few, final years of the observed period.

The results change when we exclude from the dependent variable the co-inventors and citations on patents that list at least one cross-border inventor. In panel (d), all the post-AFMP coefficients are positive but less frequently statistically significant when using the baseline sample (black circles) and not significant when using the corrected one, excluding patents with the inventors' work address (gray squares). Similar comments apply to panel (f). This indicates that the inflow of cross-border inventors induced by the AFMP increased the number of potential collaborators for incumbent inventors as well as their access to the foreign prior art, but only when collaborating with a cross-border inventor.

We further deepen our analysis by studying the contents of the incumbent inventors' patents and whether cross-border inventors may have changed them. To do so, we analyse both the patents' abstracts and technological classifications. For the abstracts, all of which are in English, we first parse their texts by removing all natural language stopwords and by tokenizing and lemmatizing each word. Next, we create a vector of terms describing the main features of each patent and a cumulative repertoire of all terms representing the state of the art of Swiss patented inventions in each year. Then, for each incumbent inventor and year, we count all the patents that introduce a novel word in their abstract, relative to the state of the art in the previous year; and re-estimate equation Equation 2 with this count as the new dependent variable.[29]

Regarding the patents' technological classification, we consider all IPC codes at the class, subclass, group, and subgroup level appearing on each patent.[30] Then, for each incumbent

[29] Iaria et al. (2018) use a similar approach to study the effects of World War I on the productivity of scientists from Central Empires, focusing on the introduction of novel words in their scientific articles.

[30] IPC stands for International Patent Classification, a classification system used by the patent offices of more than 100 countries, including the EPO. It consists of a hierarchical system of language independent codes composed of up to 10 digits (letters and numbers, for a total of over one million codes). IPC classes refer to the first three digits, subclasses to the first four, and groups to the first six; while the entire code indicates a subgroup. Each patent can be classified in multiple classes, groups and subgroups, depending on the complexity of the invention it protects. More details can be found at `https://www.wipo.int/classifications/ipc/en/` (last visit: January 2024).

inventor and year, we count all the patents that introduced a novel IPC code relative to their patent stock, up to the previous year. We repeat the exercise four times, each time for an increasingly stringent classification level, from technology classes down to subgroups. This generates four sets of dependent variables, which we use for re-estimating equation Equation 2 as many times. Our goal is to assess the degree to which incumbent inventors' new patented inventions diverge technologically from their previous body of patented work.

Panel (a) in Figure 10 reports our results for novelties in abstracts; panel (b) those for new IPC classes and subclasses. Virtually all estimated coefficients are not statistically significant. Panel (c) reports our estimates for new IPC groups or subgroups. In this case, the estimated coefficients are close to zero and statistically insignificant in the pre-AFMP years, progressively becoming positive and statistically significant for several years after 2000, particularly at the subgroup level. Overall, these results indicate that the Swiss resident incumbent inventors increased their patenting activity in the same domains in which they had been active before the introduction of the AFMP, albeit with some novel applications, as measured by IPC groups and subgroups. We interpret these results as further evidence of the positive effects of the availability of a greater number of collaborators with useful and complementary skills, absent any major knowledge transfer.[31]

Lastly, we expand our analysis by looking at whether the inventor-level effects we have found so far may be heterogeneous across technology fields and locations. With respect to technologies, Appendix Figure D24 shows that, in line with to our regional level results, the incumbent inventors' increase in productivity is concentrated in the chemical and pharmaceutical fields. As for locations, Appendix Figure D25 reports the event study results we get when excluding

[31] Additional results about this mechanism are detailed in an econometric analysis at the R&D lab level, which we fully report in Appendix D.7. We compare the outcomes of R&D labs in treated and control regions, before and after the AFMP implementation. While we do not find significant changes in inventor teams' size or experience in treated labs, we observe a significant increase in the total number of inventors and cross-border inventors active in treated labs. This suggests that the influx of cross-border inventors increased the patenting productivity of treated R&D labs by expanding their scientific workforce, without altering the organization of teamwork or the average seniority of their teams. We believe that this mechanism benefited the productivity of local inventors, in particular the more experienced incumbent ones, who were more likely to join more research projects starting in the wake of the AFMP.

inventors based in the agglomerations of Basel and Geneva, which account for respectively 50% and 10% of all incumbent inventors in the treated regions (63% and 15% for the chemicals and pharmaceutical field). Our estimates are unchanged when we drop Geneva. When we exclude Basel, instead, most coefficients become smaller and lose statistical significance, except for the year 2005. This contrasts with our findings at the regional level, which did not change considerably when excluding Basel. On the one hand, this may indicate that the micro-level mechanisms behind the patenting surge differed between Basel and the other Swiss areas close to the border. On the other hand, it may simply be that any effect at the inventor-level is more difficult to detect without considering Basel, due to the severe cut of our sample size that comes with it.

6.2. Junior Inventors

The choice of focusing on incumbent Swiss resident inventors, while motivated by identification issues, comes at a price. It limits us to study the interaction of cross-border inventors only with the more senior researchers (some of them already active before 1990) and not with the junior ones, especially those starting their inventive career after the AFMP introduction. As a partial remedy, we examine the patenting activity over the first eight years of careers (years from the first patents) of two cohorts of inventors: those first patenting in 1999 and 2000 and those first patenting between 1990 and 1993. For inventors in both cohorts, we can assume that the decision to start an R&D career in a given location was exogenous with respect to the AFMP's introduction and the subsequent cross-border inventors' inflow. But in the case of inventors in the 1999-2000 cohort, their entire career took place after the policy shock; while for the 1990-2003 one the first eight years of career took place before it.[32]

We adopt a difference-in-differences strategy and compare the activity of inventors in treated

[32] Eight years is the average lag between the first and fourth patent by inventors in our sample. In other words, it is a reasonable time window to examine the early-career patenting activity of new inventors. We consider also inventors first patenting in 2000 in order to enlarge our sample of junior inventors. We think that their location choices can also be considered exogenous to the AFMP: their first patents were filed right when the confirmatory referendum was held, such that their selection of employer and region is very likely to have occurred before the AFMP. Notice that we do not consider the cohorts from 1994 to 1998 because the first eight years of their career span across both the pre- and post-AFMP periods.

regions to those in control regions, for both inventor cohorts, in each year since their first patent. Formally, for each year of inventors' activity $\tau \in \{1,2,3,4,5,6,7,8\}$ we estimate the following specification:

$$E[y_i|X_i] = exp[\alpha + \beta\tau(AFMP_{c(i)} \times Treated_{m(i)}) + \gamma_{m(i)} + \phi_{t(i)} + \lambda_{k(i)}] \tag{3}$$

where y_i represents an outcome for inventor i, from cohort c, located in region m, active in year t, and in technology field k. As with the incumbent inventors, the outcomes we consider include the number of patents filed, the number of distinct co-inventors, and citations to prior art. $AFMP_{c(i)}$ is an indicator equal to 1 for inventors in the 1999-2000 cohorts. $Treated_m$ is an indicator equal to 1 for inventors whose first patent occurred in a treated region. $\gamma_{m(i)}$, $\phi_{t(i)}$, and $\lambda_{k(i)}$ are respectively region, calendar year, and technology field fixed effects. We cluster standard errors at the MS region level. $\beta\tau$ are our parameters of interest. For example, β_1 is the difference-in-differences estimate obtained by comparing treated and control inventors in their first year of activity, β_2 is the estimate for the second year of activity, and so forth.[33]

Our sample includes 12,568 inventors, of which 5,476 are in the 1999-2000 cohorts and 7,092 are in the others. Figure D37 reports our estimated $\beta\tau$. When we consider as dependent variables all patents filed in each year (panel (a)), we obtain positive estimated coefficients from the second patenting year onward, with only the coefficients for the third, fourth, and seventh year statistically significant. This implies an increase in patenting of respectively 16%, 34%, and 53% (or about 0.24, 0.5, and 0.9 additional patents relative to junior inventors' mean patenting output in those years). For the 1999-2000 cohorts, the third to eight patenting years correspond to the calendar years between 2001 and 2007. When we exclude from the dependent variable the patents co-filed with a cross-border inventor (panel (b)), all estimated coefficients are either negative or not statistically significant.

[33]This empirical strategy is similar to those adopted in the literature on the persistent effects of initial labor market conditions (von Wachter 2020, Rothstein 2023).

When we use, as dependent variable, the number of distinct co-inventors in year τ, most estimated $\beta\tau$ are statistically indistinguishable from zero (panels (c) and (d)). When we replace it with the number of citations to cross-border inventors' home countries, most estimated coefficients are not statistically significant (panels (e) and (f)).

These findings indicate that junior inventors that started patenting in treated regions just before the AFMP introduction experienced — like the incumbents —a productivity increase relative to their peers in the control ones, but to a lesser extent and only in the years right after the AFMP introduction. Besides, they saw no corresponding increase in the number of collaborators or in the access to foreign prior art.

Taken together, our inventor-level analysis suggests that the influx of cross-border inventors triggered by the treaty's introduction benefited the more senior inventors, to be found among the incumbents, who could work on more projects and take advantage of the skills of the newly arrived cross-border inventors. The effects for more junior ones, those who started their patenting careers in the wake of the AFMP introduction, appear more limited.

7. Conclusions

In this paper, we have studied the innovation effects of the Agreement on the Free Movement of Persons (AFMP), a treaty signed in 1999 by Switzerland and the European Union as part of the progressive extension of the Free Movement of Workers principle in Europe. To do so, we have exploited the quasi-experimental regional variation in the influx of foreign inventors holding a cross-border worker permit (cross-border inventors), the first permit category to experience a relaxation of immigration restrictions during the AFMP's implementation phase (1999-2007).

We have first shown that, after the AFMP signing and introduction, the number of cross-border inventors sharply increased in the Swiss regions next to the international border (treated regions), but not in similar ones farther away (control regions). We have then shown that patenting activity in treated regions increased relative to control ones after AFMP introduction, primarily in the instruments, chemicals, and pharmaceuticals technology fields. We did not find evidence of displacement of local inventors, nor of adverse effects on patenting in Switzerland's neighboring countries.

In the second part of the paper, we have focused on Swiss-resident inventors, in particular those already active before the AFMP's signing (incumbent inventors), and found that those located in the treated regions increased their productivity relative to those in control ones. Four pieces of evidence suggest that this result is likely due to the availability of more collaborators with valuable and potentially complementary skills, in the absence of major knowledge transfers. First, based on a combination of inventor data and immigrant administrative records, we show that most cross-border inventors entered Switzerland at a relative young age and with no or little prior patenting experience. This contrasts with most incumbent inventors' seniority, which we can deduce from their patent records. Second, incumbent inventors' productivity increased almost exclusively due to the patents they co-signed with the cross-border inventors, who expanded the number of distinct co-inventors with whom the incumbents themselves could collaborate. Third, the patents co-signed by the incumbent and cross-border inventors are more likely to cite some prior art from the latter's countries, but the same does not hold for other incumbents' patents. Fourth, the rise in productivity among incumbent inventors was not due to patents that significantly diverged in abstract text content from the pre-AFMP Swiss patent stock, or in terms of technological classification from their prior patents. When focusing on inventors who started their patenting careers right before the AFMP introduction, we still find positive effects, albeit more limited than those for more senior incumbent inventors.

A joint reading of our results and those of Beerli et al. (2021) indicate that contemporary high-skilled immigration flows between advanced countries, such as Switzerland and its neighbours, can significantly increase the supply of knowledge workers in the receiving economies, with positive effects on their innovation activities. Our results also suggest that, in a context of rising importance of R&D teamwork and division of labor (Wuchty et al. 2007; Jones 2009), these additional foreign STEM workers may both ease a supply shortage and complement established native ones. Given their age and experience profile, however, most migrant STEM workers are not likely to open up new research pathways, as found by studies of migration episodes concerning experienced scientists and technologists (Moser et al. 2014). Nor they can induce a major technological diversification in the host country, as found—among others—by Bahar et al. (2020), when considering the migration of inventors with previous experience in their home countries (and for countries with more distant technological specializations than Switzerland and its neighbours).

Still, the patents co-signed by Swiss resident inventors with the cross-border ones include more-than-expected citations to prior art from the latter's home countries. This resonates with Ariu's (2022) findings of the AFMP's impact on trade, by which the Swiss firms that hired the cross-border workers were able to find better intermediate inputs from the workers' country.

Our study has three main limitations, which we hope to overcome in future research. First, we do not investigate the mechanisms that have avoided the cross-border workers' regions of origin to decrease their patenting output. Evidence could be obtained by studying the careers of STEM workers who did not leave those labor markets, the evolution of R&D jobs postings in those areas before and after the AFMP introduction, and the recruitment of scientists and engineers from regions farther away from the Swiss border.

Second, our analysis of inventors' characteristics is limited to the data we can obtain from patent documents. In particular, we have no information on the specific tasks performed by cross-border and incumbent inventors collaborating on the same R&D projects. Additional information on such tasks could be obtained through inventor surveys, such as those conducted by Giuri et al. (2007) for Europe and Walsh et al. (2016) for the United States and Japan. This would allow to further investigate the degree of substitability and complementarity of native and immigrant scientists and engineers.

Last, we do not observe the long-term consequences of the inventor immigration wave we studied. It may be that the large knowledge transfer effects we do not detect in the first decade after the introduction of the AFMP have or will become more visible later on, when some of the relatively young cross-border inventors entered in Switzerland in the wake of the AFMP introduction reach more senior positions.

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Tables

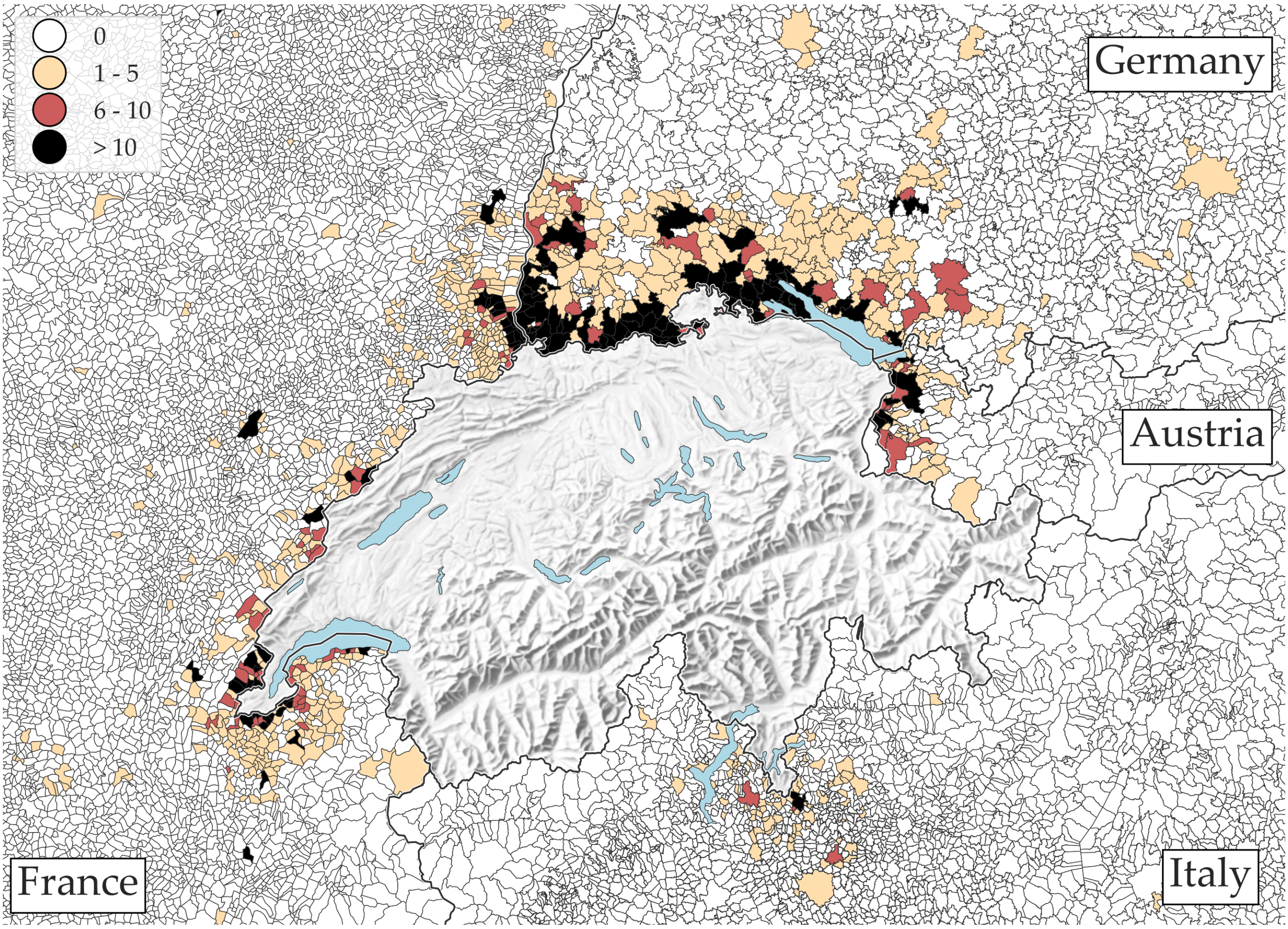
Table 1: MS regions' outcomes: mean and standard deviation by area and period

	Pre-AFMP (1990-1999)			**Post-AFMP (2000-2012)**		
	Treated	Control	Non-border regions	Treated	Control	Non-border regions
Patents	27.1	25.4	10.1	50.5	42.0	16.7
	(38.7)	(35.1)	(16.0)	(65.3)	(62.5)	(26.9)
Patents (incumbent applicants)	27.1	25.4	10.1	32.7	27.7	9.7
	(38.7)	(35.1)	(16.0)	(52.5)	(44.9)	(18.2)
Patents (excluding top applicants)	18.3	19.5	8.9	38.3	31.7	14.1
	(20.7)	(25.1)	(14.0)	(41.8)	(44.2)	(21.3)
Patents (cross-border inventor in team)	7.9	1.2	0.2	19.6	3.7	0.5
	(17.2)	(4.2)	(0.8)	(36.0)	(8.5)	(1.5)
Patents (resident only)	19.3	24.3	9.8	30.9	38.3	16.2
	(23.2)	(32.6)	(15.5)	(32.5)	(55.8)	(26.0)
Inventors (Swiss res.)	31.6	33.0	12.7	59.9	61.9	22.6
	(49.4)	(46.4)	(20.7)	(83.8)	(99.8)	(34.8)
Inventors (Swiss nat.)	4.8	2.0	1.0	10.0	7.1	3.1
	(13.8)	(4.4)	(2.4)	(19.3)	(13.7)	(5.7)

Notes: The table reports mean values for MS regions' yearly innovation outcomes. Standard deviation values are reported in parentheses.

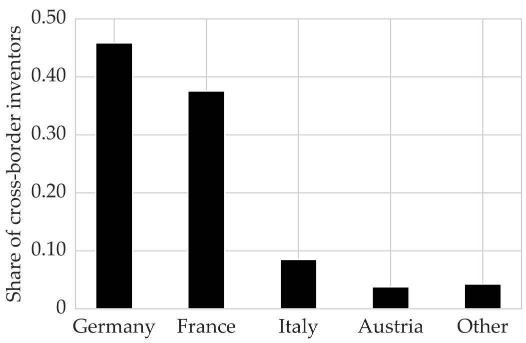
Figures

Figure 1: Number of cross-border inventors by municipality of residence, 1990-2012

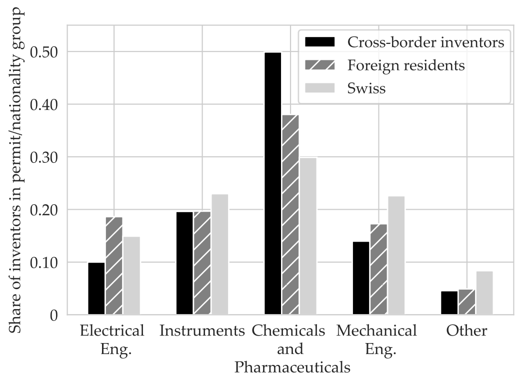


Notes: The map shows the municipalities in Austria, France, Germany, and Italy where cross-border inventors reside, according to the address found on their patents.

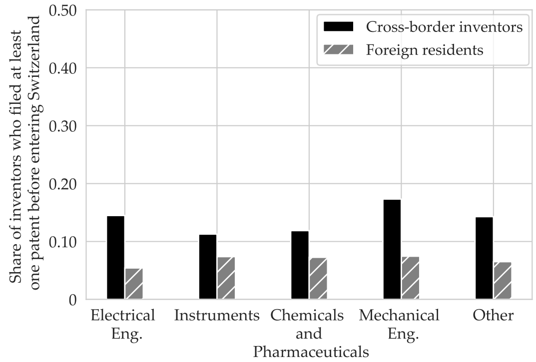
Figure 2: Cross-border inventors' characteristics (ZEMIS-based definition)



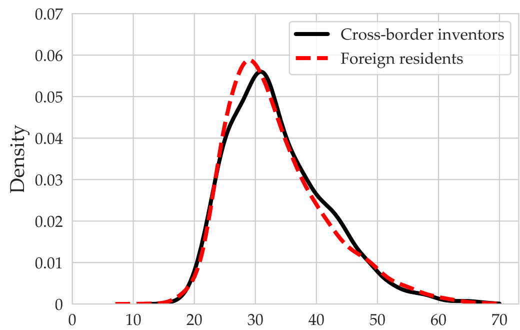
(a) Nationalities



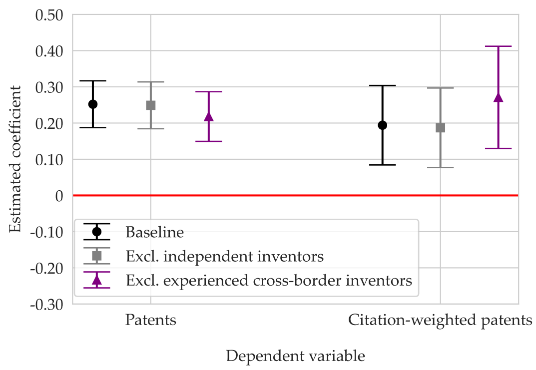
(b) Technologies



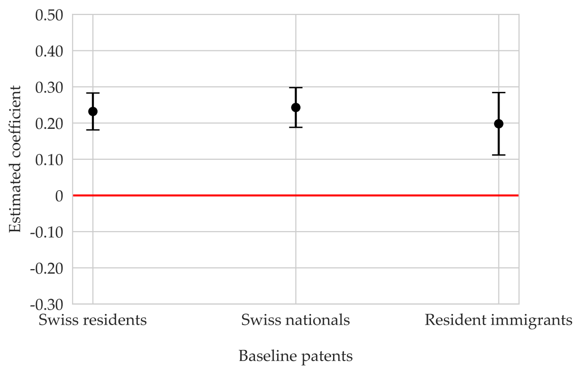
(c) Pre-arrival patenting



(d) Age at arrival in Switzerland



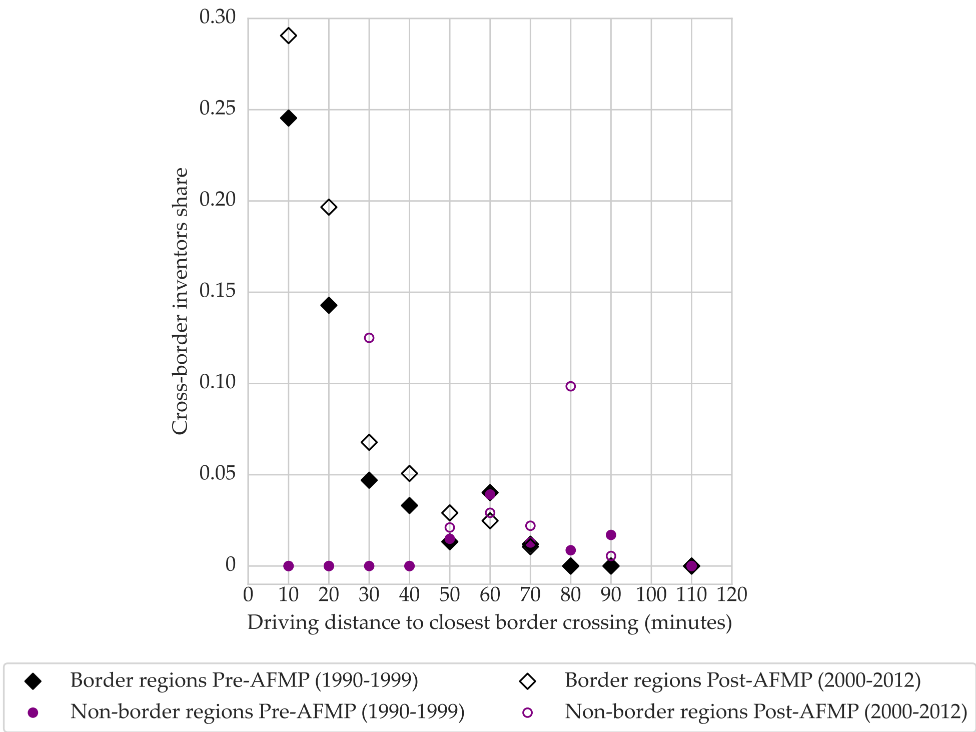
(e) Full career productivity vs. Swiss inventors



(f) Citations to neighboring countries' prior art

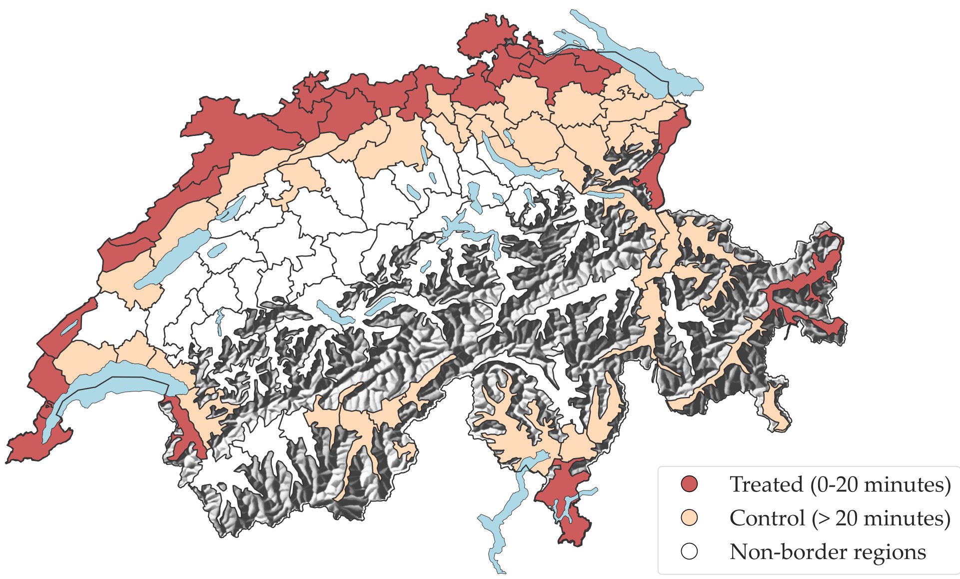
Notes: Panel (a) shows cross-border inventors' main nationalities. Panel (b) plots the distribution of active cross-border inventors, foreign resident inventors (B, C, and L permit holders), and Swiss inventors by technology field (Schmoch 2008). Panel (c) shows the share of cross-border inventors and foreign resident inventors who filed at least one patent before entering Switzerland, by technology field. Panel (d) shows the distribution of age at arrival in Switzerland for cross-border inventors and foreign resident inventors (kernel density). Panel (e) reports β estimates and 95% confidence intervals from $E[y_i|X_i] = exp[\alpha + \beta PermitG_i + \delta X_i]$, where y_i is the number of total patents or citation-weighted filed by inventor i during their full observable career, $PermitG_i$ is an indicator equal to 1 for cross-border inventors and equal to 0 for inventors with Swiss nationality, and X_i is a vector of controls, including the inventors' average number of co-inventors, average applicant size, the number of applicants they have patented during their career, as well as technology field and first patent cohort fixed effects. Panel (f) reports β estimates and 95% confidence intervals from an equivalent specification, where i indexes a patent, y_i is the number of citations made by patent i to prior art from Switzerland's neighboring countries, while $PermitG_i$ is an indicator equal to 1 for patents listing at least one cross-border inventor, and 0 for patents listing only Swiss resident inventors, only Swiss nationals, or only resident immigrants. We control for patents' filing year, MS region, applicant, and technology field fixed effects. Both panel (e) and (f) plot Poisson pseudo-maximum-likelihood estimates, which are reported with more details in Appendix Table D2 and Table D3, respectively. All figures refer to the post-AFMP period, except for panel (e).

Figure 3: Cross-border inventors' share of total inventors by driving distance to border crossing



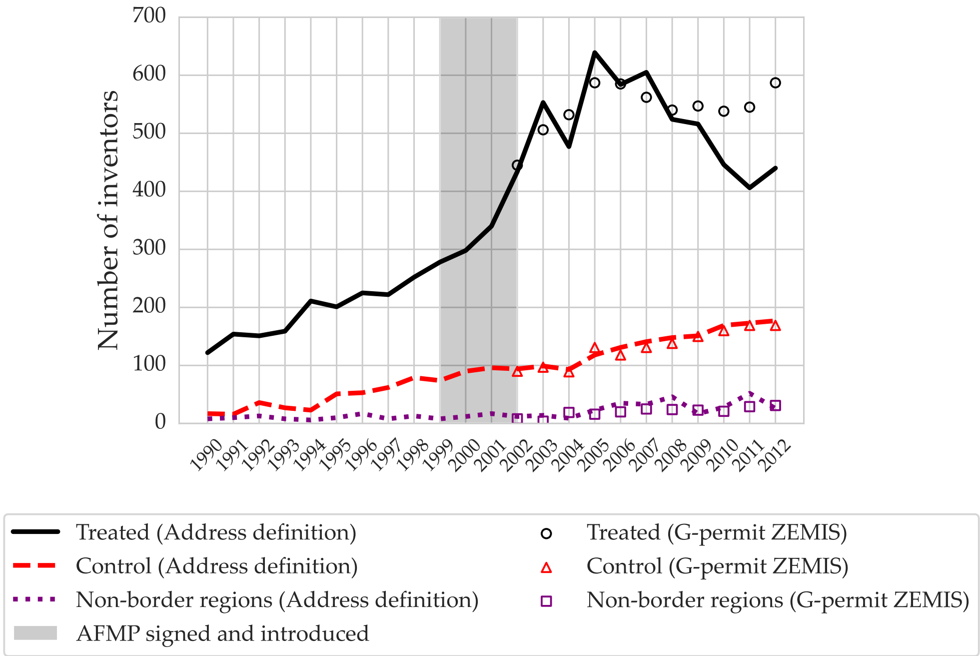
Notes: Each marker in the figure shows the share of cross-border inventors relative to the total of active inventors in MS regions' groups sorted according to their distance from the closest international border crossing, comparing the periods before and after the AFMP signing and introduction. Diamond markers indicate border regions while circle markers indicate non-border regions. The high share of cross-border inventors in non-border regions and post-AFMP period are outliers referring to regions with few total inventors.

Figure 4: MS regions in Switzerland by driving distance area



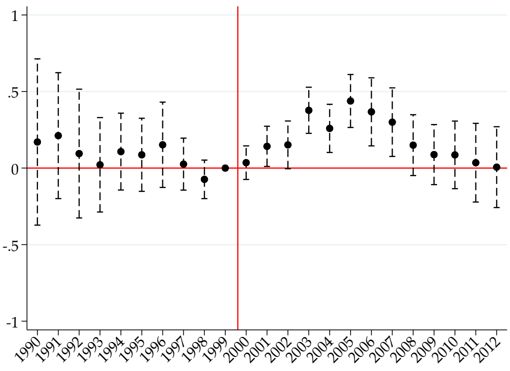
Notes: The definition of treated and control border regions is based on their distance from the closest international border crossing. MS regions are plotted in terms of their productive areas, as defined by the Swiss Federal Statistical Office, rather than their purely political boundaries.

Figure 5: Active cross-border inventors by driving distance area

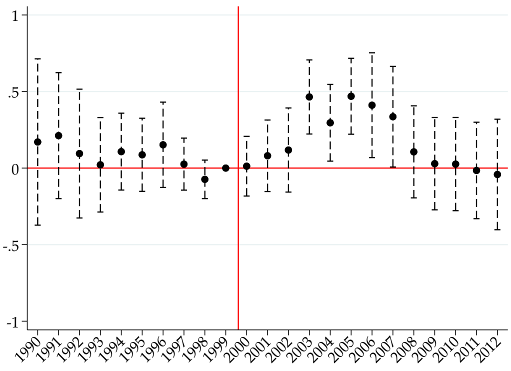


Notes: The figure shows the yearly number of active cross-border inventors by driving distance area in the Border Regions (border regions) and Non-Border Regions (non-border regions). Lines indicate cross-border inventors identified with addresses found on their patents. Markers show cross-border inventors defined according to their residence permit (*i.e.*, permit G; EPO patents-ZEMIS match).

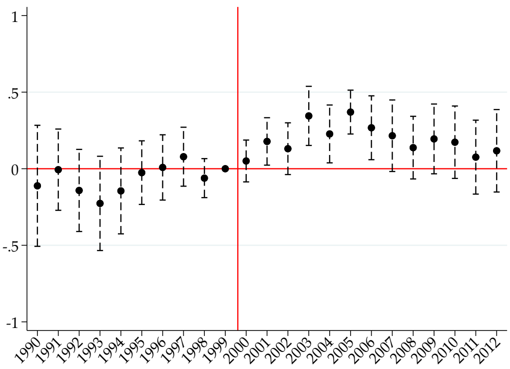
Figure 6: Regional patent count: event study results



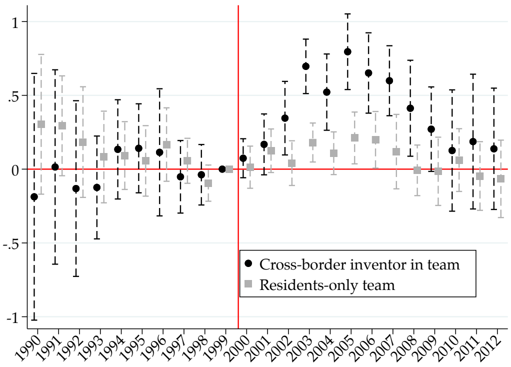
(a) Full sample



(b) Incumbent applicants only



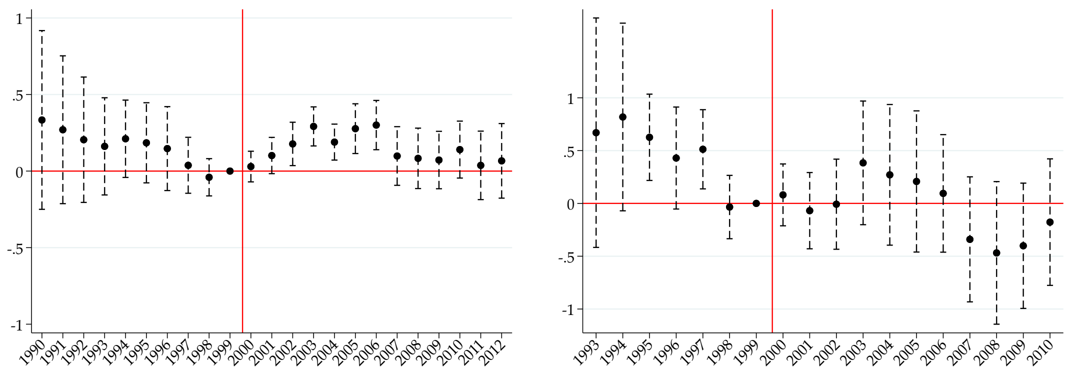
(c) No top applicants



(d) Cross-border inventor-in-team VS. Resident-only

Notes: The dependent variable is the number of patents filed in MS region m in year t. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. For the estimations in panel (a) we count all patents. For those in panel (b) we count only patents associated with "incumbent applicants;" for those in panel (c) we exclude patents associated with "top applicants". For the estimations in panel (d) we decompose each treated MS region's yearly patent output, distinguishing between patents including at least one cross-border inventor (*Cross-border inventor in team*) and patents including only resident inventors (*Resident-only team*) and running two separate event study regressions. The estimated parameters related to cross-border inventor-in-team patents are shown as black circles. Those related to Resident-only team patents are shown as gray squares. All regressions include MS region and year fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 1,449; Pseudo R^2 = 0.88. Panel (b): N = 1,403; Pseudo R^2 = 0.86. Panel (c): N = 1,449; Pseudo R^2 = 0.84. Panel (d): Cross-border inventor in team: N = 1,426; Pseudo R^2 = 0.89; Resident-only team: N = 1,449; Pseudo R^2 = 0.86.

Figure 7: Active Swiss inventors: event study results

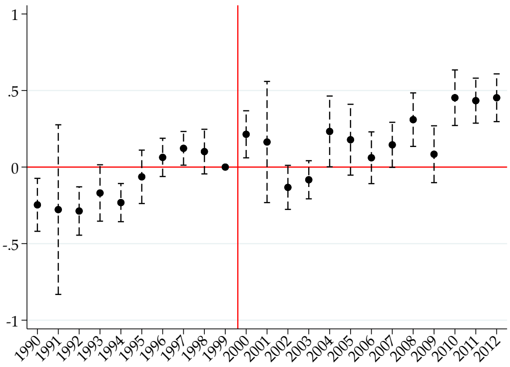


(a) Swiss residents

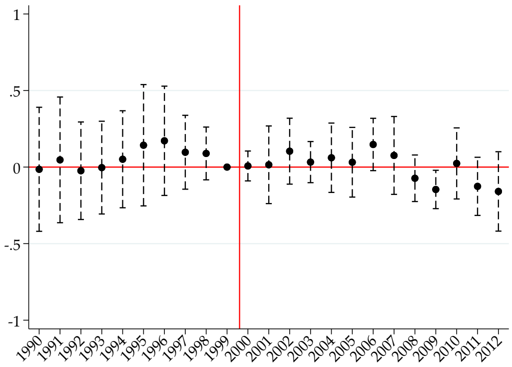
(b) Swiss nationals (subsample)

Notes: In panels (a) the dependent variable is the number of Swiss-resident inventors active in MS region m in year t. Panels (b) reports equivalent estimates using the sample of Swiss national inventors (identified through PCT nationality information). The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include MS region and year fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 1,449; Pseudo R^2 = 0.91. Panel (b): N = 1,044; Pseudo R^2 = 0.77.

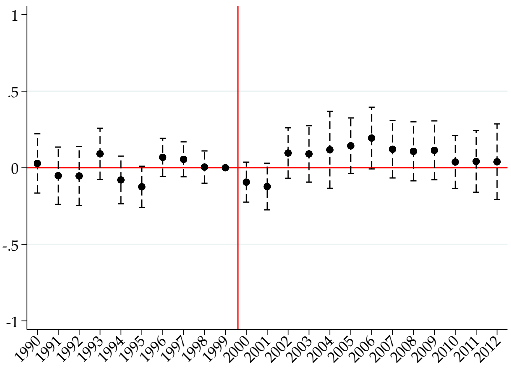
Figure 8: Regional patent count in neighbouring regions: event study results



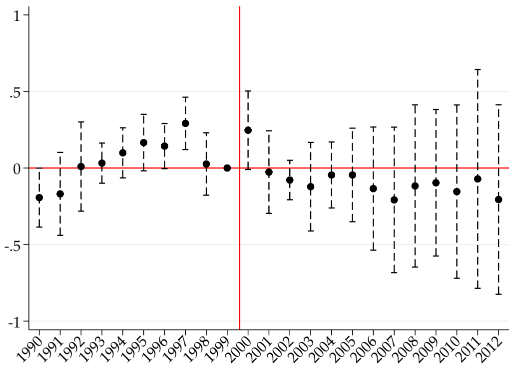
(a) Austria



(b) France



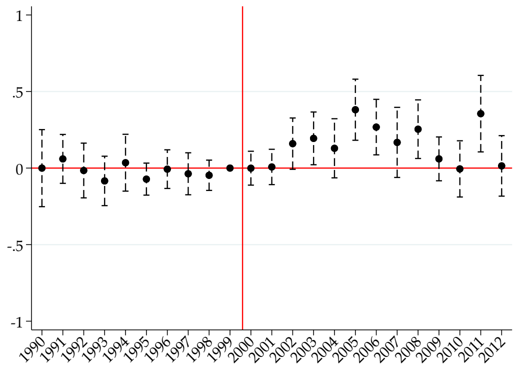
(c) Germany



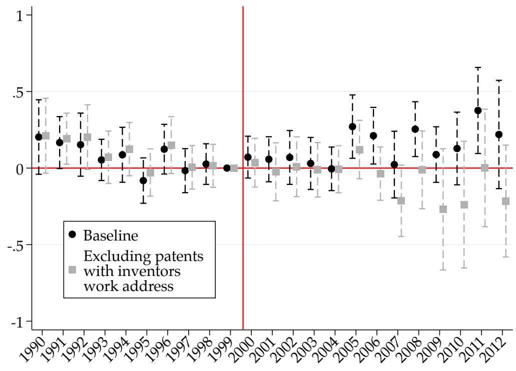
(d) Italy

Notes: The dependent variable is the number of patents filed in NUTS-3 area m in year t. For each country, the treated group includes NUTS-3 areas where the pre-AFMP legislation required G-permit holders to reside. The control group includes all other NUTS-3 areas. All regressions include NUTS-3 area and year fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the NUTS-3 area level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 759; Pseudo R^2 = 0.87. Panel (b): N = 2,189; Pseudo R^2 = 0.95. Panel (c): N = 8,944; Pseudo R^2 = 0.91. Panel (d): N = 2,224; Pseudo R^2 = 0.91.

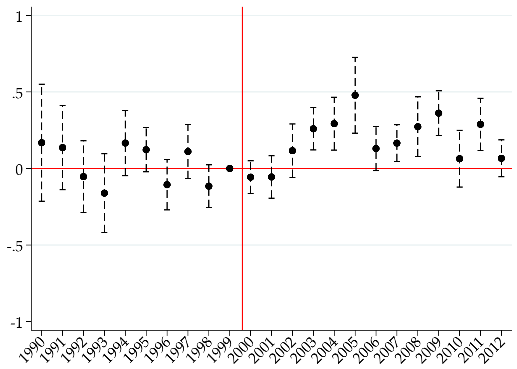
Figure 9: Incumbent inventors' patenting: event study results



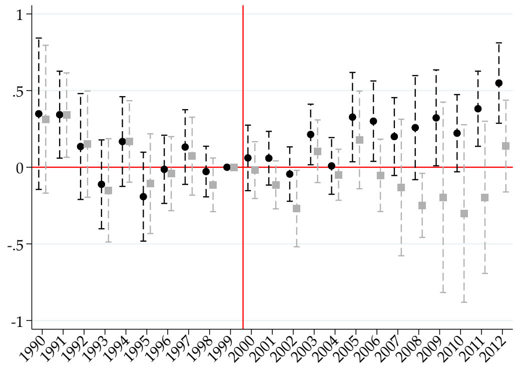
(a) Patents



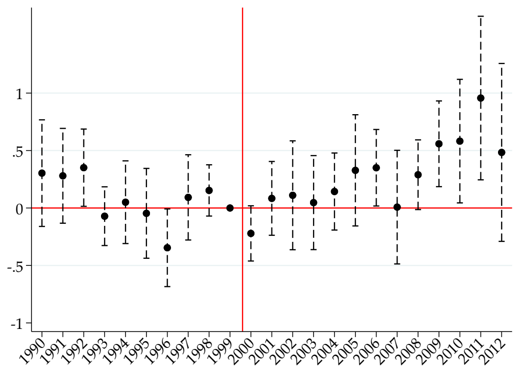
(b) Patents (excl. cross-border inventors)



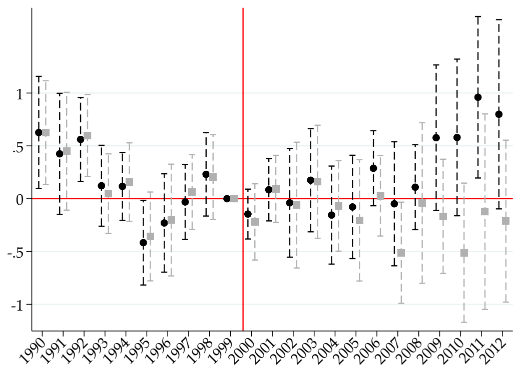
(c) Distinct co-inventors



(d) Distinct co-inventors (excl. cross-border inventors)



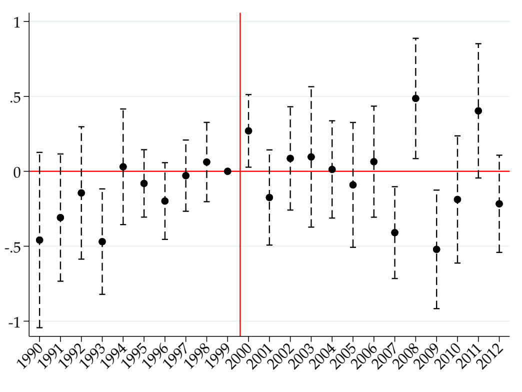
(e) Cites to cross-border inventor-country prior-art



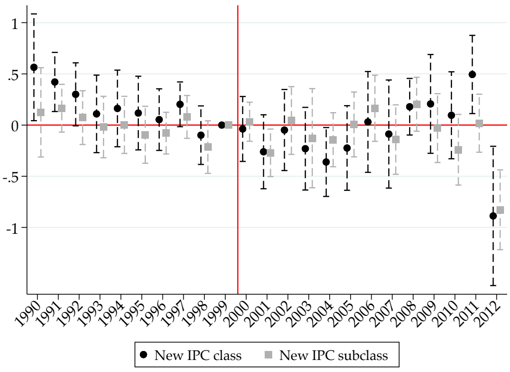
(f) Cites to cross-border inventor-country prior-art (excl. cross-border inventors)

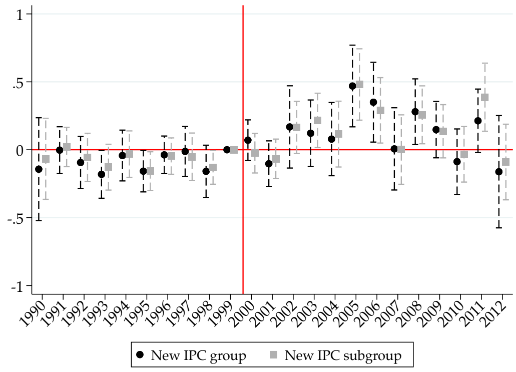
Notes: The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include inventor, year, and MS region fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. In panels (b), (d), and (f), black dots represent the coefficients from regressions where we exclude patents filed by one or more cross-border inventors; gray squares represent the coefficients from regressions where we exclude both patents filed by one or more cross-border inventors *and* patents reporting the inventors' work addresses, rather than their residential one. Panel (a): N = 17,490; Pseudo R^2 = 0.10. Panel (b): Baseline: N = 16,995; Pseudo R^2 = 0.11; Excl. work address patents: N = 16,788; Pseudo R^2 = 0.12. Panel (c): N = 15,536; Pseudo R^2 = 0.28. Panel (d): Baseline: N = 14,569; Pseudo R^2 = 0.22; Excl. work address patents: N = 14,399; Pseudo R^2 = 0.22. Panel (e): N = 13,879; Pseudo R^2 = 0.33. Panel (f): Baseline: N = 12,744; Pseudo R^2 = 0.30; Excl. work address patents: N = 12,487; Pseudo R^2 = 0.28.

Figure 10: Incumbent inventors' patent characteristics: event study results



(a) Patents with novel terms



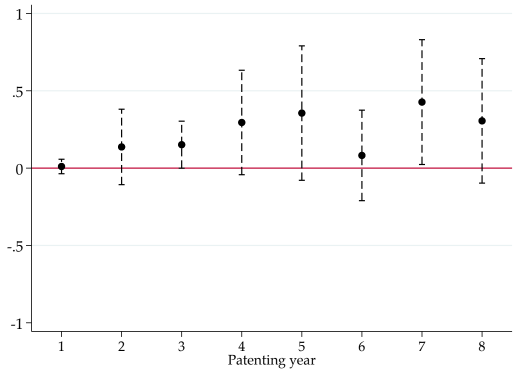


(b) Patents with new IPC class or subclass

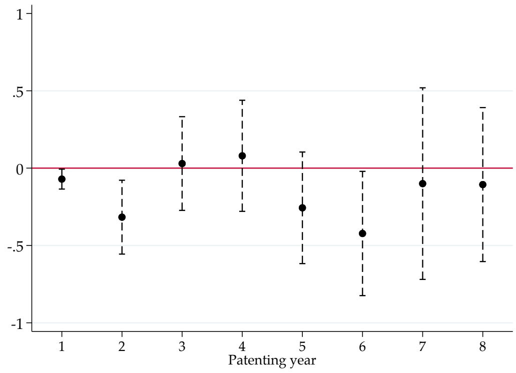
(c) Patents with new IPC group or subgroup

Notes: In panel (a), the dependent variable is the number of patents filed by inventor i in MS region m in year t containing at least one novel term in their abstract, relative to all EPO patents filed in Switzerland up to the previous year $t-1$. In panels (b) and (c), the dependent variable is the number of patents filed by inventor i in year t containing at least one new IPC class, subclass, group, or subgroup relative to all EPO patents filed by inventor i up to the previous year $t-1$. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include inventor, year, and MS region fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 12,123; Pseudo R^2 = 0.11. Panel (b): New IPC class: N = 17,462; Pseudo R^2 = 0.16; New IPC subclass: N = 17,472; Pseudo R^2 = 0.16. Panel (c): New IPC group: N = 17,477; Pseudo R^2 = 0.09; New IPC subgroup: N = 17,490; Pseudo R^2 = 0.09.

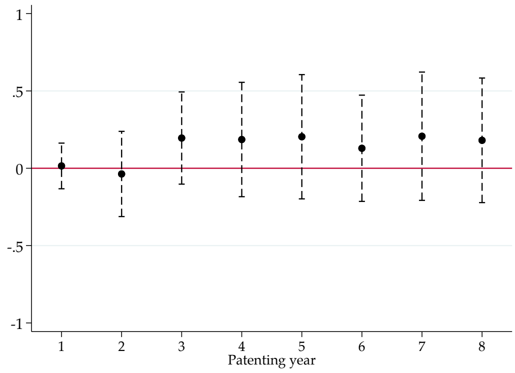
Figure 11: Junior inventors' patenting: difference-in-differences results by patenting year



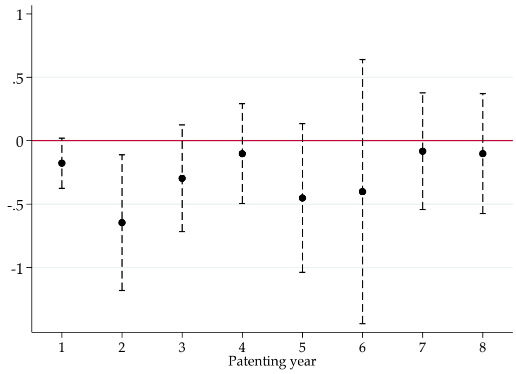
(a) Patents



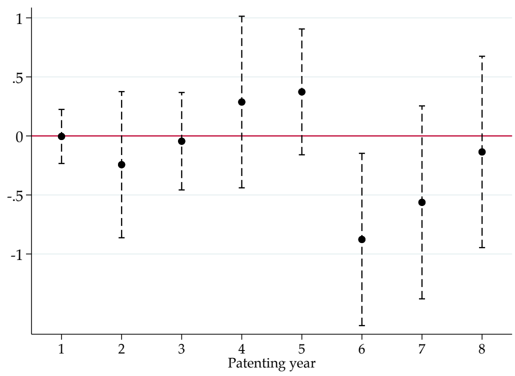
(b) Patents (excl. cross-border inventors)



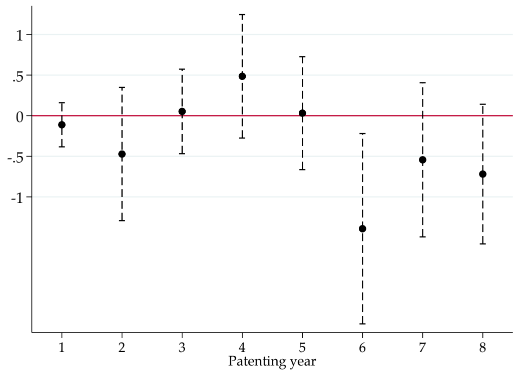
(c) Distinct co-inventors



(d) Distinct co-inventors
(excl. cross-border inventors)



(e) Cites to CBI-country prior-art



(f) Cites to cross-border inventor-country
prior-art (excl. cross-border inventors)

Notes: The treated group includes all inventors who filed their first ever patent in MS regions in the BR whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all inventors who filed their first ever patent in MS regions in the BR whose driving distance from the closest border crossing is above 20 minutes. All regressions include year and MS region fixed effects. Vertical bars represent 95% confidence intervals. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. For each panel, we report estimated coefficients, standard errors, observations, and Pseudo R^2 in Appendix Table D28.

Appendix - For Online Publication Only

"Free Movement of Inventors: Open-Border Policy and Innovation in Switzerland"

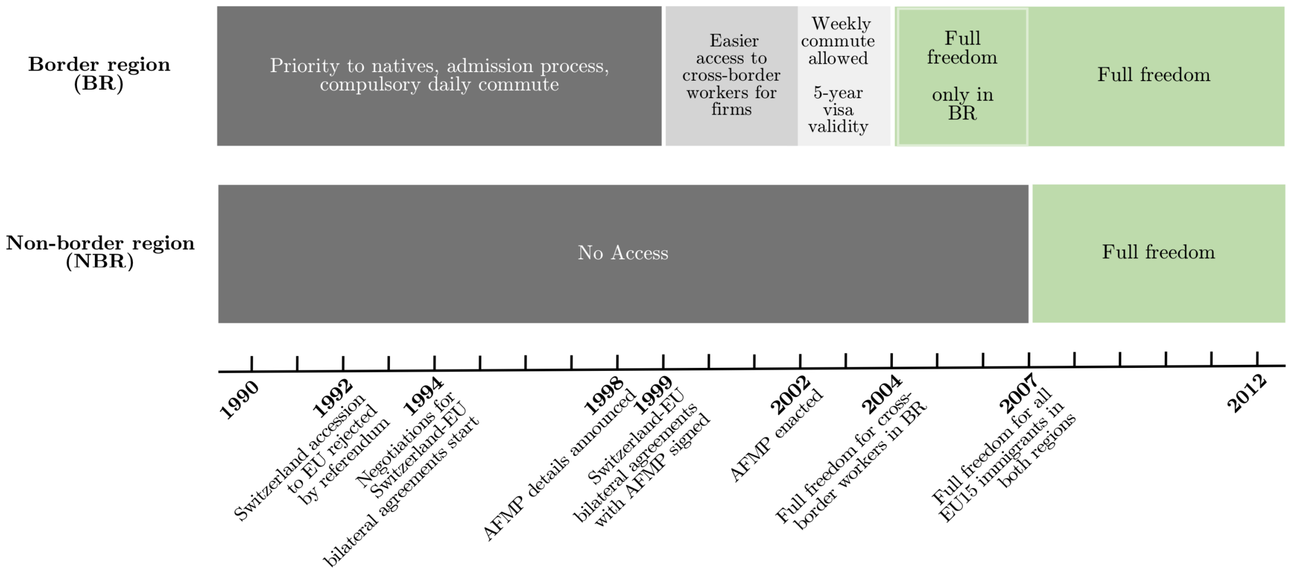
by Gabriele Cristelli and Francesco Lissoni

January 2024

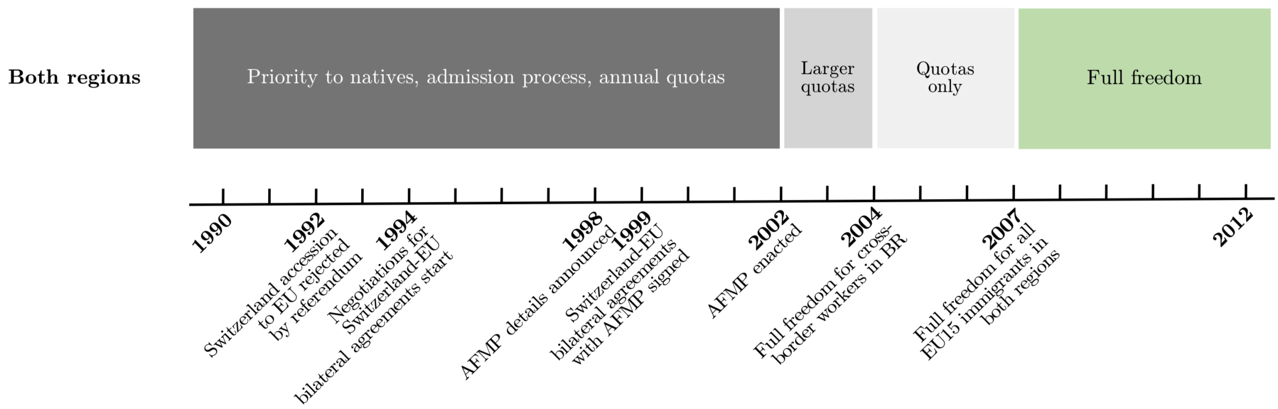
Contents

A. The Agreement on the Free Movement of Persons (AFMP)

Figure A1: Agreement on the Free Movement of Persons (AFMP) introduction timeline



(a) Cross-border workers



(b) Resident immigrants

B. Dataset Construction

B.1. Inventor and Applicant Disambiguation

Patstat data come with unique identifiers for both inventors and patent applicants. However, it occurs too often that the same inventor (or applicant) on distinct patents is not identified as the same person (or firm) and receives different identifiers, due to spelling mistakes or address changes that the Patstat disambiguation algorithms do not treat. (Instead, it never occurs that distinct inventors or applicants are treated as one).

Further disambiguation is therefore necessary to track both individuals and firms over time and across locations. Absent this treatment, we would overestimate the number of inventors and applicants in our database and underestimate, for many of them, the count of patents filed. For inventors with multiple patents, this also means that we would fail to identify many of their collaborators (co-inventors), to whom we are very much interested when it comes to study personal interactions. For companies, we would also lose useful information needed to locate their R&D labs in space, for reasons that will become clear below.

We disambiguated inventors using the inventor ids generated by Pezzoni et al. (2014) algorithm and already employed by Breschi et al. (2017), Kogler et al. (2017), Akcigit et al. (2018), and Ferrucci and Lissoni (2019). The algorithm first cleans/parses each inventor's name, surname, and address strings. Then, it selects inventor pairs (found across different patents) which could potentially be associated to the same individual, based on perfectly matching name-surname combinations or name-surname string similarity. It then filters out false positive cases using score-weighted information on common co-inventors, geographical location, and patenting technology classes, with the scores obtained from two training sets for calibration. By adjusting the scores, the algorithm can be calibrated in order to balance precision and recall.

Incidentally, one of the training sets consists of inventors affiliated to the École Polytechnique Fédérale de Lausanne (EPFL), one of the two Swiss Federal Institutes of Technology, and it is highly representative of the mix of names in French, German, Italian and other languages one can find in many large R&D labs across Switzerland.[34]

We disambiguated patent applicants by first employing the unique identifiers produced by Du Plessis et al. (2009). These are well known to Patstat users, but still present numerous instances where a single applicant is mistakenly categorized as two distinct entities. In particular, we know that different divisions of the same company are often treated as separate entities. For this reason, we manually checked all applicants in our data with at least 20 patents, which include the majority of suspect cases. Altogether, they amount to 497 initial entities and account for

[34]On technicalities of inventor disambiguation see also Raffo and Lhuillery (2009) and Li et al. (2014).

roughly 57% of all patents in our dataset (see Table B1). For each one, we consulted the companies' websites as well as several online resources containing business history information to verify their company or group affiliation. Table B2 provides some examples of the type of patent applicants we inspected and shows how we disambiguated them.

Table B1: Distribution of applicants and patents, by patent portofolio size

Patent Portfolio Size	Number	Percent	Percent of total patents
$\geq$ 1000	6	0.03	12.82
(1000, 500]	11	0.06	8.68
(500, 100]	81	0.46	18.24
(100, 50]	99	0.56	7.23
(50, 20]	300	1.69	9.95
(20, 10]	570	3.22	8.55
(10, 5]	1,201	6.78	8.79
$<$ 5	15,443	87.20	25.74
Total	12,844	100.00	100.00

Notes: The table shows the number of applicants and percent of patent filings for each applicant portfolio size bracket. The data covers EPO applications filed between 1990-2012 and including at least one Swiss-based inventor or an inventor residing in a G-permit-designated area and a Swiss-based applicant.

Table B2: Examples of applicants' disambiguation refinement

Disambiguated ID	Not-Disambiguated ID	Not-Disambiguated Name	Patent applications	Address
4485157	4485157	CIBA-GEIGY	3,262	Klybeckstrasse 141,CH-4002 Basel
4485157	4485021	CIBA HOLDING	129	Klybeckstrasse 141,4057 Basel
4485157	4485050	CIBA SC HOLDING	14	Klybeckstrasse 141,4057 Basel
23665187	23665187	ROCHE	2,898	Grenzacherstrasse 124,4070 Basel
23665187	23665421	ROCHE GLYCART	61	Wagistrasse 18,8952 Schlieren
23665187	23665767	ROCHE VITAMINS	15	4070 Basel
23665187	23665334	ROCHE DIAGNOSTICS	8	68298 Mannheim
23665187	23665299	ROCHE CONSUMER HEALTH	1	Wurmisweg,4303 Kaiseraugst
23665187	23665300	ROCHE CONSUMER HEALTH (WORLDWIDE)	1	1214 Vernier, Genève
23665187	23665628	ROCHE MTM LABORATORIES	1	Im Neuenheimer Feld 583,69120 Heidelberg
20140831	20140831	NESTEC	1,408	Avenue Nestlé 55,1800 Vevey
20140831	20142953	NESTLE	799	Case postale 353,1800 Vevey
27296576	27296576	SYNGENTA PARTICIPATIONS	897	Schwarzwaldallee 215,4058 Basel
27296576	27296548	SYNGENTA	16	European Regional Centre Priestley Road Surrey Research Park
27296576	27296559	SYNGENTA CROP PROTECTION	1	Schwarzwaldallee 215 4058 Basel
27296576	27296564	SYNGENTA FOUNDATION FOR SUSTAINABLE AGRICULTURE	1	Schwarzwaldallee 215,4058 Basel
23665187	23665187	IBM (INTERNATIONAL BUSINESS MACHINES CORPORATION)	605	New Orchard Road,Armonk, NY 10504
23665187	23665421	IBM RESEARCH	7	IBM-Research Zurich 8803 Rueschlikon Saumerstrasse 4
23665187	23665767	COMPAGNIE IBM FRANCE	1	Tour Descartes, La Défense 5, 2, avenue Gambetta,92400 Courbevoie
23665187	23665334	IBM DEUTSCHLAND	1	71137 Ehningen Patentwesen Und Urherberrecht
23665187	23665299	IBMO INTERNATIONAL	1	Grundstrasse 12,6343 Rotkreuz
20975654	4485157	OMYA INTERNATIONAL	144	Baslerstrasse 42,4665 Oftringen
20975654	20975643	OMYA DEVELOPMENT	68	Baslerstrasse 42,4665 Oftringen
20975654	20975638	OMYA	6	Baslerstrasse 42,4665 Oftringen
23777044	23777044	ROLEX	127	3-5-7 rue François Dussaud,1211 Genève 26
23777044	19342948	MONTRES ROLEX	17	3, Rue François-Dussaud,CH-1211 Genève 24

Notes: Disambiguation performed only within the dataset of patent applications originating from Switzerland. Applicants with more than one R&D laboratory are assigned to multiple locations at a later stage.

B.2. Assignment of Patents to R&D Locations

Patent data do not explicitly report the address of the R&D laboratories (or other facilities) that sourced the inventions they protect. They only include the address of applicants and inventors. Hence, we must deduce the presumed location of the invention source (to which we most often refer as "R&D location") from either one or both sets of addresses.

With regard to the applicant's address, the larger the company, the more likely the address coincides with that of the company's headquarters or intellectual property division. These may be located in different cities than those hosting the R&D laboratories. In the case of multinationals, even the countries may not coincide. As for the inventors' address, the most common practice followed by patent attorneys is to report their home ones, which we expect to be relatively close to the inventors' workplaces. In this case, the inventor and applicant addresses differ. When they coincide, it is because the attorney preferred using the applicant address also for the inventors.[35]

Based on these considerations, we infer each applicant's R&D location(s) from the distribution of its inventor addresses, with the applicant addresses playing an auxiliary role.[36] We first use the Google Maps Geolocation API to geocode each Swiss address and assign it to a spatial mobility region (henceforth "MS region" from the French "Mobilité Spatiale").[37] For each applicant, we calculate the frequency distribution of all its inventor-patent instances across MS regions, thus obtaining one or more candidate R&D locations. When applicants have just one candidate, we retain this as the one and only relevant R&D location. Together, these cases account for 22% of all patents in the dataset.

When applicants have multiple candidate locations and at least 20 patents in their portfolios, we extensively search the companies' websites and other online resources. In this way, we manually identify as many of their R&D laboratories as possible (some of which are currently inactive but were active during our observation period), and we retain only the candidate R&D locations that match them. These cases account for about 58% of all patents in the dataset. For the remaining applicants with multiple candidates, but fewer than 20 patents (20% of total patents), we retain only one R&D location that corresponds to the MS region with the highest

[35] For example, the municipality of Rüschlikon (Zurich) hosts one of IBM's 12 global research labs. Out of all IBM's 603 patents in our dataset, only one mentions it in the applicant's address. All others indicate the IBM's headquarters in Armonk, New York. In contrast, 80% of the inventors' addresses indicate municipalities around Zurich.

[36] Only for this purpose, we extend the time frame of our data before 1990, using EPO patents filed in Switzerland from 1978 onwards.

[37] MS regions are defined by the Swiss Federal Statistical Office as travel-to-work areas for micro-regional analyses (Schuler et al. 2005). MS regions consist of agglomerations of municipalities and are large enough to track our inventors' commutes to work. They are also ideal units of analysis for our econometric exercises due to their heterogeneity in terms of G-permit holders' presence.

number of inventor-patent instances. In this case, we perform no systematic manual checking except for ambiguous cases (e.g., when the number of patents in two or more candidate locations are close).

We conclude by looking for any false R&D location to filter out. These correspond to applicants whose patents never report a Swiss address nor have any known Swiss-based facility and yet hold a few patents with one or more Swiss-based inventors. Such patents are typically due to collaboration between a Swiss academic and a foreign research institution or a Swiss-based inventor consulting internationally.[38]

These procedures result in a final sample of 67,087 patents, 13,820 applicants, and 85,870 inventors. Around 91% of all patents in our dataset are filed by firms. Patents filed by universities and nonprofit research organizations are just about 2%, while the remaining 7% is filed by independent inventors (Table B4). Most patents originate either from applicants with just one R&D location or, for applicants with multiple R&D locations, from just one of them (47,108 patents, approximately 70% of all patents). In these cases, we treat all the inventors listed on the patent as employed in that location, even if their addresses are outside the corresponding MS region. As for the patents with multiple R&D locations, they may originate from multiple labs of the same company or joint applications by different companies, each one with its own lab. In both cases, we assign each inventor to one or another location (and the corresponding MS region) by simply picking the closest to the inventor's address, and assign patents fractionally to each location.

We believe our method of identifying R&D locations to be accurate and necessary, due to the need to remove the noise contained in the applicants' and inventors' addresses and to locate correctly within Switzerland the patents signed by local inventors and foreign-resident ones. However, we also experiment with simpler methods, which do not require the use of personal judgment and external information. In one case we simply assign each patent and inventor to the applicant's MS region, alternatively we use the inventor's residential MS region.

[38]We search and eliminate the former by looking at keywords such as "university" or "foundation" in the applicants' names (237 patents). As for the latter, we search online for corporate information and eliminate all those for which no Swiss-based R&D facility is ever mentioned (3,540 patents).

Table B3: Applicant categories based on inventor-patent instances distribution

	Applicants		Patents	
	Number	Percent	Number	Percent
Single R&D location candidate	11,723	69.68	18,461	21.85
Multi R&D location candidate (hand-checked)	350	2.08	48,653	57.57
Multi R&D location candidate (partly hand-checked)	4,752	28.24	17,394	20.58
Total	16,825	100.00	84,508	100.00

Notes: The table shows the number of applicants and their associated patent filings for each applicant portfolio size bracket. The sample includes EPO patents filed in Switzerland between 1976 and 2012. The time window is extended from our baseline 1990-2012 in order to gather more information about R&D laboratories potential location.

Table B4: Patents by applicant type

	Number	Percent
Firms	60,984	90.90
Universities and research labs	1,350	2.01
Independent inventors	4,753	7.09
Total	67,087	100.00

Notes: Patents filed by universities and research laboratories are identified based on the name of the applicant, *i.e.,* if the string contains either: "`universit`", "`EPFL`", "`ETHZ`", "`federal institute of technology`", "`polytechnique`", "`technische hochschule`", "`CERN`", "`paul scherrer`". Independent inventors' patents are those associated to inventors always patenting without collaborators and filing patents as both inventor and applicant. The remaining patents are labeled as filed by firms.

Table B5: Top five applicants by type

	Firms		
	Number	% (category)	% (total)
ABB	2,512	4.12	3.74
Novartis	2,185	3.58	3.26
Roche	2,160	3.54	3.22
Nestlé	1,710	2.80	2.55
Alstom Technology	1,539	2.52	2.29
	Universities and research labs		
	Number	% (category)	% (total)
ETHZ	353	26.15	0.53
EPFL	326	24.15	0.49
University of Zurich	186	13.78	0.28
Paul Scherrer Institut	111	8.22	0.17
University of Geneva	100	7.41	0.15

B.3. Cross-Border Workers Residence and Work Locations

Table B6: G-permit-designated areas in Austria, France, Germany, and Italy

Country	First Administrative Unit		Second Administrative Unit
Austria	Bezirk (District)	NUTS-3 code	Bundesland (State)
	Bludenz	AT341	Vorarlberg
	Bregenz	AT341/AT342	Vorarlberg
	Dornbirn	AT342	Vorarlberg
	Feldkirch	AT342	Vorarlberg
	Landeck	AT334	Tirol
France	Département (Department)	NUTS-3 code	Région (Region)
	Ain	FR711	Auvergne-Rhône-Alpes
	Haute-Savoie	FR718	Auvergne-Rhône-Alpes
	Doubs	FR431	Bourgogne-Franche-Comté
	Jura	FR432	Bourgogne-Franche-Comté
	Territoire de Belfort	FR434	Bourgogne-Franche-Comté
	Haut-Rhin	FR422	Grand Est
Germany	Landkreis (District) or Stadt (City)	NUTS-3 code	Land (State)
	Biberach	DE146	Baden-Württenberg
	Bodenseekreis	DE147	Baden-Württenberg
	Breisgau-Hochschwarzwald	DE132	Baden-Württenberg
	Freiburg im Breisgau	DE131	Baden-Württenberg
	Konstanz	DE138	Baden-Württenberg
	Lörrach	DE139	Baden-Württenberg
	Ravensburg	DE148	Baden-Württenberg
	Sigmaringen	DE149	Baden-Württenberg
	Schwarzwald-Baar-Kreis	DE136	Baden-Württenberg
	Tuttlingen	DE137	Baden-Württenberg
	Waldshut-Tiengen	DE13A	Baden-Württenberg
	Emmendingen	DE133	Baden-Württenberg
	Kempten (Allgäu)	DE273	Bavaria
	Lindau	DE27A	Bavaria
	Oberallgäu	DE27E	Bavaria
Italy	Provincia (Province)	NUTS-3 code	Regione (Region)
	Aosta	ITC20	Valle d'Aosta
	Bolzano	ITH10	Trentino-Südtirol
	Como	ITC42	Lombardia
	Lecco	ITC43	Lombardia
	Monza e Brianza	ITC4D	Lombardia
	Varese	ITC41	Lombardia
	Sondrio	ITC44	Lombardia
	Verbania-Cusio-Ossola	ITC14	Piemonte

Notes: The table shows the administrative units in Austria, France, Germany, and Italy we used to: (i) select patent applications filed by Swiss-based applicants and potential cross-border inventors employed in Switzerland and not collaborating with any Swiss-based inventor on those specific projects; (ii) identify cross-border inventors; (iii) select treated regions in Switzerland's neighbouring countries to test brain drain effects following the AFMP introduction. These are the areas where prospective cross-border workers were required to reside for at least six months before being eligible to apply for a Permit G to work in Switzerland, before the AFMP introduction (G-permit designated areas). They remained cross-border border workers' main residential areas also in the post-AFMP period.

Table B7: Cross-border inventors potential residential districts for MS region groups

MS regions	**cross-border inventors potential districts of residence**
(1) Zurich, (2) Glattal-Furttal, (3) Limmattal, (4) Knonaueramt, (5) Zimmerberg, (6) Pfannenstiel, (7) Zurcher Oberland, (8) Winterthur, (9) Weinland, (10) Zurcher Unterland, (26) Luzern, (27) Sursee-Seetal, (28) Willisau, (29) Entlebuch, (30) Uri, (34) Sarneraatal, (35) Nidwalden, (38) Zug, (50) Schaffhausen, (76) Thurtal, (77) Untersee, (78) Oberthurgau	Germany: Biberach, Bodenseekreis, Breisgau-Hochschwarzwald, Freiburg, Konstanz, Lörrach, Ravensburg, Sigmaringen, Schwarzwald-Baar-Kreis, Tuttlingen, Waldshut-Tiengen, Emmendingen, Kempten (Allgäu), Lindau, Oberallgäu
(11) Bern, (12) Erlach-Seeland, (13) Biel/Bienne, (14) Jura bernois, (15) Oberaargau, (16) Burgdorf, (17) Oberes Emmental, (18) Aaretal, (19) Schwarzwasser, (20) Thun, (21) Saanen-Obersimmental (22) Kandertal, (23) Oberland-Ost, (24) Grenchen, (25) Laufental, (44) Olten, (45) Thal, (46) Solothurn, (47) Basel-Stadt, (48) Unteres Baselbiet, (49) Oberes Baselbiet	France: Doubs, Haut-Rhin, Territoire de Belfort Germany: Biberach, Bodenseekreis, Breisgau-Hochschwarzwald, Freiburg, Konstanz, Lörrach, Ravensburg, Sigmaringen, Schwarzwald-Baar-Kreis, Tuttlingen, Waldshut-Tiengen, Emmendingen, Kempten (Allgäu), Lindau, Oberallgäu
(31) Innerschwyz, (32) Einsiedeln, (33) March, (36) Glarner Unterland, (37) Glarner Hinterland, (51) Appenzell A. Rh., (52) Appenzell I. Rh., (53) St.Gallen, (54) Rheintal, (55) Werdenberg, (56) Sarganserland, (57) Linthgebiet, (58) Toggenburg, (59) Wil	Austria: Bludenz, Bregenz, Dornbirn, Feldkirch, Landeck Germany: Biberach, Bodenseekreis, Breisgau-Hochschwarzwald, Freiburg, Konstanz, Lörrach, Ravensburg, Sigmaringen, Schwarzwald-Baar-Kreis, Tuttlingen, Waldshut-Tiengen, Emmendingen, Kempten (Allgäu), Lindau, Oberallgäu
(39) La Sarine, (40) La Gruyere, (41) Sense, (42) Murten/Morat, (43) Glane-Veveyse	France: Doubs, Haut-Rhin, Haute-Savoie, Territoire de Belfort
(60) Chur, (61) Prattigau, (62) Davos, (63) Schanfigg	Austria: Bludenz, Bregenz, Dornbirn, Feldkirch, Landeck
(64) Mittelbunden, (65) Viamala, (66) Surselva, (68) Oberengadin, (69) Mesolcina	Italy: Como, Sondrio
(67) Engiadina Bassa	Austria: Bludenz, Bregenz, Dornbirn, Feldkirch, Landeck Italy: Bolzano, Como, Sondrio
(70) Aarau, (71) Brugg-Zurzach, (72) Baden, (73) Mutschellen, (74) Freiamt, (75) Fricktal	France: Haut-Rhin Germany: Biberach, Bodenseekreis, Breisgau-Hochschwarzwald, Freiburg, Konstanz, Lörrach, Ravensburg, Sigmaringen, Schwarzwald-Baar-Kreis, Tuttlingen, Waldshut-Tiengen, Emmendingen, Kempten (Allgäu), Lindau, Oberallgäu
(79) TreValli, (80) Locarno, (81) Bellinzona, (82) Lugano, (83) Mendrisio	Italy: Como, Lecco, Monza e Brianza, Varese, Verbania-Cusio-Ossola
(84) Lausanne, (85) Morges, (86) Nyon, (87) Vevey, (88) Aigle, (89) Pays-d'Enhaut (90) Gros-de-Vaud, (91) Yverdon, (92) La Vallee, (93) La Broye, (105) Geneve	France: Ain, Doubs, Haute-Savoie, Jura
(94) Goms, (95) Brig, (96) Visp, (97) Luek	Italy: Verbania-Cusio-Ossola
(98) Sierre, (99) Sion, (100) Martigny, (101) Monthey	France: Haute-Savoie Italy: Aosta
(102) Neuchatel, (103) La Chaux-de-Fonds, (104) Val-de-Travers	France: Doubs, Jura, Territoire de Belfort
(106) Jura	France: Doubs, Haut-Rhin, Territoire de Belfort Germany: Biberach, Bodenseekreis, Breisgau-Hochschwarzwald, Freiburg, Konstanz, Lörrach, Ravensburg, Sigmaringen, Schwarzwald-Baar-Kreis, Tuttlingen, Waldshut-Tiengen, Emmendingen, Kempten (Allgäu), Lindau, Oberallgäu

Notes: The table shows cross-border inventors' potential residential areas for groups of MS regions in Switzerland. Since G-permit holders were allowed to obtain a job in Swiss non-border regions after 2007, we also included MS regions in those areas to find potential cross-border inventors. We identified very few of them working in non-border regions.

B.4. Matching EPO Inventors with ZEMIS Immigrant Records

We match foreign inventors working in Switzerland to their immigrant records by linking patent applications filed at the European Patent Office (EPO) with the Swiss Central Information Migration System database (ZEMIS).

Patent applications provide extensive information on scientists and engineers requesting intellectual property protection for their inventions, including their residential location, co-inventors, patent applicants (in many cases their employer), and the inventions' technological features. We select EPO applications because of the quality of their address information and due to the large amount of filings from Swiss-based organizations. The main sample used for the match includes all inventors reporting a Swiss address. In order to capture cross-border commuters working as inventors, we also add all inventors residing in foreign regions bordering Switzerland and appearing on Swiss-based applicants' patents. This sample includes 118,750 inventors, tracked from 1978 onwards.

ZEMIS is the complete census of foreign individuals with a Swiss resident or work permit. It is a mirror of Switzerland's Central Migration Information System, which monitors the country's foreign population, gathering immigrants' information produced by the administrative entities tasked to issue and renew residence and work permits. ZEMIS contains information about immigrants' nationality, residence permit type, entry year, birth year and location, and parents' nationality. The earliest ZEMIS version was issued in 2002. We use a version of the database containing information on about three million individuals, holding immigrant status in Switzerland between 2002-2015.

To prepare ZEMIS and inventor raw records for the match, we parse the individuals' full names in both datasets and harmonize the information about their residence and work location. For name parsing, we split full name strings into first, last, and middle names (if any), and remove all accents. ZEMIS residence and work locations are classified by main administrative units (such as municipalities or cantons). We update all municipalities according to the latest Swiss administrative division, accounting for communities' mergers and incorporations, and assign each municipality to its corresponding "MS Region", small travel-to-work areas defined by the Swiss Federal Statistical Office for micro-regional analyses (Schuler et al. (2005)). EPO patents provide geographic information about an inventor only in the form of address strings. In order to make them comparable to those in ZEMIS, we first submit the address strings to the Google Maps Geolocation API and obtain their administrative units, and then we repeat the municipalities' update and addition of MS regions performed for ZEMIS' records.[39]

[39] For more information on Google Maps Geolocation API: `https://developers.google.com/maps/documentation/geolocation/intro` (last visit: January 2024).

The last data preparation step deals with individuals' disambiguation. For ZEMIS records, we exploit its unique identifier, which is assigned to each person entering the database and never changed thereafter, even if its assignee temporarily exits and subsequently re-enters Switzerland. Inventors found on EPO patents, however, are only mildly disambiguated, based on the perfect similarity of their names and address strings. We rely on the algorithm developed by Pezzoni et al. (2014) and assign a unique identifier to the same individual appearing on different patents with different addresses or different spellings of name and/or surname.

In order to link inventors to their immigrant records in ZEMIS, we adopt a fuzzy match approach, based on the computation of string similarity measures between individuals' names and corresponding geographic and age-based information.[40] We treat the immigrant-inventor matching as a binary classification problem and follow the supervised machine learning strategy originally developed by Feigenbaum (2016). This strategy is particularly suited to situations where a *ground-truth* training set is not readily available and has to be constructed by researchers.

We start by creating a sample of all candidate matches. To do so, we compare first and last names of individuals in ZEMIS and inventors on EPO patents. To exclude false matches and limit the number of comparisons to be performed, we introduce the following blocking conditions:[41]

- The first two initials of first name and last name must coincide;
- The canton of residence/work must coincide;
- The potential match must be between 18 and 75 years old at the time of the patent filing;
- The potential matches must have filed at least one patent during their period of residence/work in Switzerland.

We then produce a Jaro-Winkler string similarity score (Jaro (1989); Winkler (1990)) for the first names and for the last names of each pair of potential matches. We retain only potential matches displaying similarity scores greater or equal to 0.8 for both the first names and last names comparisons, obtaining 889,532 candidate matches.[42]

In order to tune the matching algorithm, we construct a training set by randomly extracting 6,000 candidate matches, stratifying the sampling on individuals' nationality, canton of residence (country in the case of cross-border workers), and year of birth. We then manually check each record, creating a binary indicator "`match`" equal to 1 for those we believe refer to the same

[40] Recent works involving fuzzy matches of inventors to non-patent data sources include Depalo and Di Addario (2014); Jung and Ejermo (2014); Toivanen and Väänänen (2016); Dorner et al. (2016) and Bell et al. (2019).

[41] A comparison based on the full cartesian product of ZEMIS and EPO patents individual records would require enormous computational power, almost exclusively inflated by false matches.

[42] Feigenbaum (2016) uses a similar score threshold. Extensive checks revealed that below that score true matches were unlikely.

individual and equal to 0 in all other cases.[43]

Following Feigenbaum (2016), we train the matching algorithm using a Probit classifier.[44] We essentially run a Probit model, relating the binary indicator "`match`" to a series of predictors, all reported in Table B8.

Based on the coefficients of the Probit regression, we estimate the predicted probability score for each candidate match in the training set. In order to tune the algorithm, we aim at finding a lower bound for the score to declare a match which would simultaneously maximize *precision* (*i.e.*, true positives / true positives + false positives) and *recall* (*i.e.*, true positives / true positives + false negatives). Figure B1 relates these two measures to the predicted probability scores we calculated, evaluating the in-sample performance of the algorithm.

Table B8: List of predictors to train the algorithm

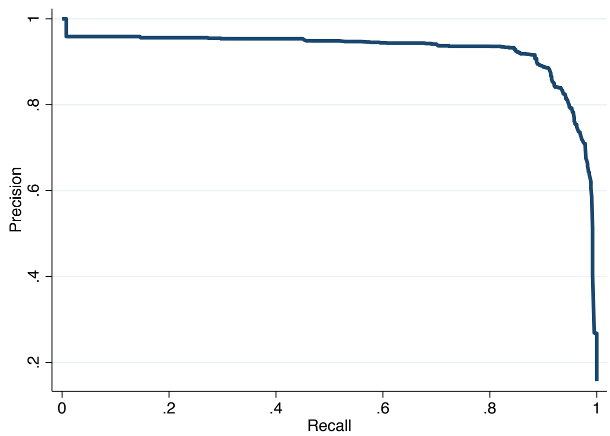
Variable	**Description**
jw_first_name	Jaro-Winkler string similarity between $\texttt{first\_name}_{ZEMIS}$ and $\texttt{first\_name}_{EPO}$
jw_last_name	Jaro-Winkler string similarity between $\texttt{last\_name}_{ZEMIS}$ and $\texttt{last\_name}_{EPO}$
jw_full_name	Jaro-Winkler string similarity between $\texttt{full\_name}_{ZEMIS}$ and $\texttt{full\_name}_{EPO}$
same_first_name	Dummy indicator equal to 1 if $\texttt{first\_name}_{ZEMIS}$ perfectly matches $\texttt{first\_name}_{EPO}$
same_last_name	Dummy indicator equal to 1 if $\texttt{last\_name}_{ZEMIS}$ perfectly matches $\texttt{last\_name}_{EPO}$
same_full_name	Dummy indicator equal to 1 if $\texttt{full\_name}_{ZEMIS}$ perfectly matches $\texttt{full\_name}_{EPO}$
same_lastone_first_name	Dummy indicator equal to 1 if $\texttt{first\_name}_{ZEMIS}$'s last letter perfectly matches $\texttt{first\_name}_{EPO}$'s one
same_lasttwo_first_name	Dummy indicator equal to 1 if $\texttt{first\_name}_{ZEMIS}$'s last two letters perfectly matches $\texttt{first\_name}_{EPO}$'s ones
same_lastthree_first_name	Dummy indicator equal to 1 if $\texttt{first\_name}_{ZEMIS}$'s last three letters perfectly matches $\texttt{first\_name}_{EPO}$'s ones
same_lastone_last_name	Dummy indicator equal to 1 if $\texttt{last\_name}_{ZEMIS}$'s last letter perfectly matches $\texttt{last\_name}_{EPO}$'s one
same_lasttwo_last_name	Dummy indicator equal to 1 if $\texttt{last\_name}_{ZEMIS}$'s last letter perfectly matches $\texttt{last\_name}_{EPO}$'s one
same_lastthree_last_name	Dummy indicator equal to 1 if $\texttt{last\_name}_{ZEMIS}$'s last letter perfectly matches $\texttt{last\_name}_{EPO}$'s one
age_at_appln	Age at the time of invention
age_at_first_inv	Age at first invention
age_20_70	Dummy indicator equal to 1 if age at the time of invention if comprised between 20 and 70 years old
age_25_65	Dummy indicator equal to 1 if age at the time of invention if comprised between 25 and 65 years old
age_30_60	Dummy indicator equal to 1 if age at the time of invention if comprised between 30 and 60 years old
age_35_55	Dummy indicator equal to 1 if age at the time of invention if comprised between 35 and 55 years old
first_age_20_70	Dummy indicator equal to 1 if age at first invention if comprised between 20 and 70 years old
first_age_25_65	Dummy indicator equal to 1 if age at first invention if comprised between 25 and 65 years old
first_age_30_60	Dummy indicator equal to 1 if age at first invention if comprised between 30 and 60 years old
first_age_35_55	Dummy indicator equal to 1 if age at first invention if comprised between 35 and 55 years old
d_loc_city	Dummy indicator equal to 1 if ZEMIS residence or work municipality matches EPO's municipality
d_loc_region	Dummy indicator equal to 1 if ZEMIS residence or work region matches EPO's region*

Notes: *For Swiss locations we use MS Regions, while for Austrian, French, German, and Italian locations we use "Politischer Bezirk", "Départements", "Landkreis", and "Province" respectively.

[43] While the majority of non-matches stem from individuals with similar but clearly different names (*e.g.*, James Page with Jamie Page or Christopher Cornell with Christian Corney), a portion of them involved homonyms. In that case, we defined a match only if the geographic information corresponded.

[44] Feigenbaum (2016) demonstrates how in his case using alternatives such as logistic or non-paramentric classifiers like random forests and support-vector-machines does not improve the matching algorithm performance.

Figure B1: Precision and recall curve, training set



We identify the optimal score lower bound by maximising a function including the sum of *precision* and *recall*. Table B9 reports the results of the optimal score search under different weighting schemes for precision and recall. We opt for a weight of 1.75 on recall defining as matches all those records with a score greater than 0.28. We privilege recall to obtain the highest-number of matches possible with reasonable precision rates, keeping the freedom to raise the lower bound to declare a match in subsequent stages of the analysis for robustness checks.

Table B9: Grid search results according to different weighting schemes

Weight on Precision	**Weight on Recall**	**Score**	**Precision**	**Recall**
3	1	0.580	0.884	0.878
1.75	1	0.560	0.880	0.884
1	1	0.560	0.880	0.884
1	1.75	0.280	0.813	0.936
1	3	0.236	0.785	0.948

Having selected the optimal score to declare a match, we return to the full dataset of candidate matches, run the algorithm we tuned on the training set, estimate each record's predicted probability, and identify as matches all those with a score higher than 0.28. We obtain 23,123 combinations of individuals in ZEMIS matched to EPO inventors.

As a final step, we consider all those ambiguous cases where only one individual in ZEMIS is matched to multiple EPO inventors (*1:m*), multiple individuals in ZEMIS are matched to only one EPO inventor (*m:1*), and multiple individuals in ZEMIS are matched to multiple EPO inventors (*m:m*). Table B10 shows that altogether these cases account for 43% of the matches (that is, 57% are 1:1 matches).

Table B10: Match type breakdown

Zemis : EPO inventors	N. Records	Percent
1 : 1	13,280	57.43
1 : m	4,297	18.58
m : 1	2,677	11.58
m : m	2,869	12.41
Total	23,123	100.00

We restore the remaining records to a *1:1* set up as follows:

- *1:m* : most of these records stem from inventor disambiguation issues not solved by the Pezzoni et al. (2014)'s algorithm. We manually check each record and assign a common identifier to inventors who are clearly the same person (*i.e.*, same applicant, same address declared), reducing the initial 4,297 records to 2,108. For persisting 1:m links we keep the match with highest predicted score, obtaining the final 1,949 1:1 matches.
- *m:1* : we reduce the initial 2,677 matches to 1,003 1:1 links keeping the ZEMIS : EPO inventor combination with the highest predicted score.
- *m:m* : we first get rid of multiple matches on the inventor side assigning a common identifier to inventors with the same identity, reducing the records from 2,869 to 1,984. We subsequently take care of the duplicate matches on the ZEMIS side by selecting the links with the highest predicted score, obtaining 618 1:1 matches.

The final dataset of matched records includes 16,844 unique inventors connected to their ZEMIS immigrant records.

To further assess the matching algorithm performance, we test its precision and recall on an external validation set. Such out-of-sample test should provide a more reliable indication of the algorithm's quality than that inferred at the training stage (in-sample performance). We generate a validation set by selecting all "academic inventors" (namely, the inventors listed on patent applications filed or co-filed by universities and other academic institutions) active in Switzerland and listed on patents filed through the Patent Cooperation Treaty (PCT), which until 2011, if extended to the Unites States, reported the inventors' self-declared nationalities (Miguelez and Fink (2017)).[45] We focus on academic inventors to increase the likelihood of finding online information about their careers and background, as academic researchers are more likely to have public profiles on university or personal websites than scientists involved in industrial R&D. We manually validate each inventor's nationality and (potential) immigrant status browsing their profiles. We define as "immigrants" (*i.e.,* records to be matched) all those whose validated nationality is not Swiss.

[45] The Patent Cooperation Treaty enables inventors to seek patent protection in all of its contracting states through a single patent filing, in one language, and paying a unique set of fees. PCT applications can be filed at a contracting state's national patent office or at the World Intellectual Property Organization (WIPO).

Implementing the same procedure we used to create the final dataset of 16,844 linked inventors, we compare the match prediction of the algorithm with the validation set by immigrant status. Table B11 shows a matrix enabling the calculation of precision and recall scores for this exercise. The ratio of the true positives matches (613) and the sum of true and false positives matches (663) gives us the precision rate, in this case around 93%. The ratio of true positives matches (613) and the sum of true positives and false negatives (863) matches allows to calculate the recall rate, in this case around 71%.

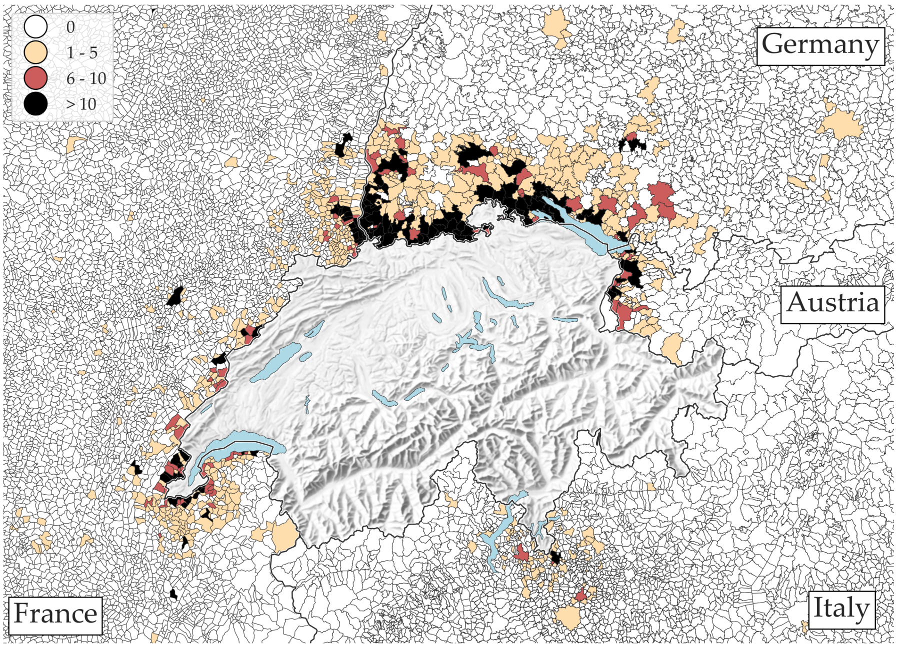
Table B11: Testing the algorithm on the validation set

	Validation set Status		
Algorithm prediction	*Not matched (Swiss)*	*Matched (Foreign national)*	
Not matched	654	250	904
Matched	50	613	663
	704	863	1,567

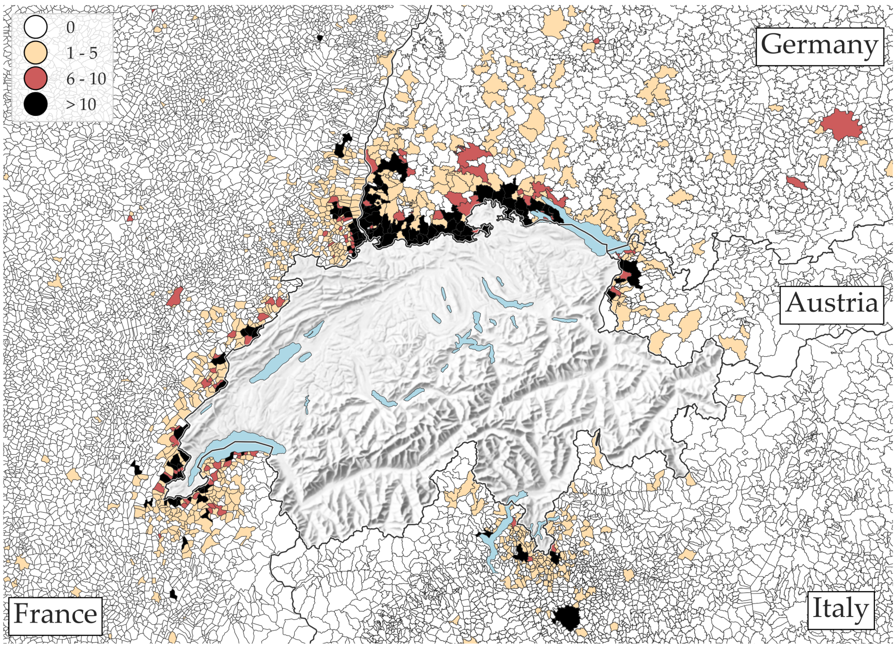
C. Additional Descriptive Evidence

C.1. Cross-Border Inventors

Figure C1: Number of cross-border inventors by municipality of residence



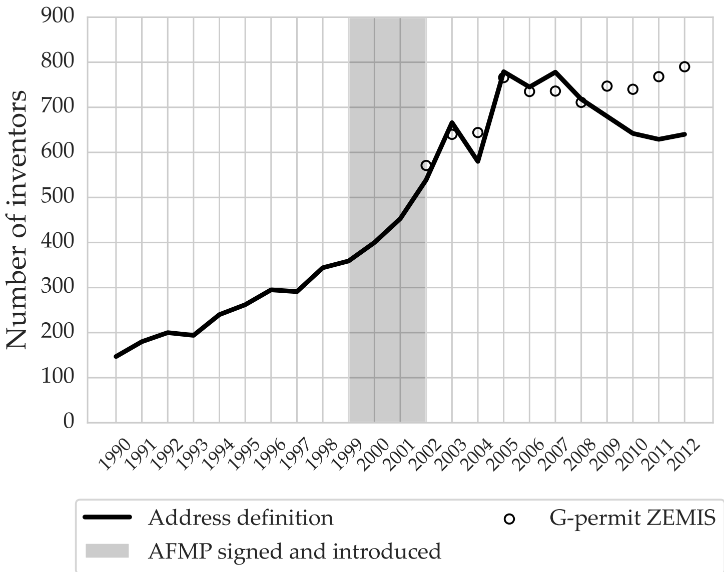
(a) Address definition



(b) G-permit ZEMIS definition

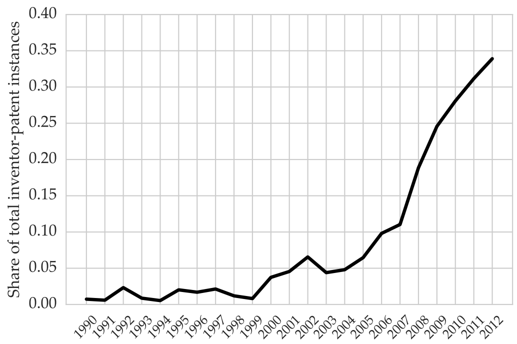
Notes: The two maps show the municipalities in Austria, France, Germany, and Italy where cross-border inventors reside, comparing the geographic distribution of the patent address (panel a) and the G-permit ZEMIS (panel b) cross-border inventors' definition.

Figure C2: Active cross-border inventors, full Switzerland

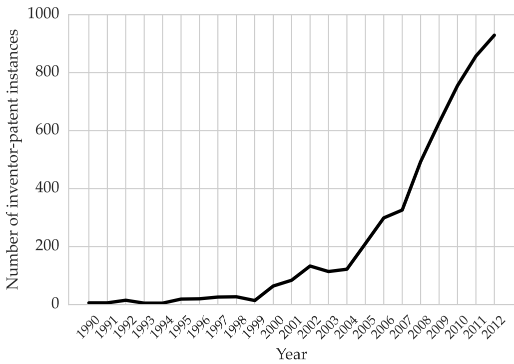


Notes: The solid line indicates cross-border inventors identified with addresses found on their patents. The dashed line indicates cross-border inventors identified according to their residence permit (*i.e.,* permit G; EPO patents-ZEMIS match).

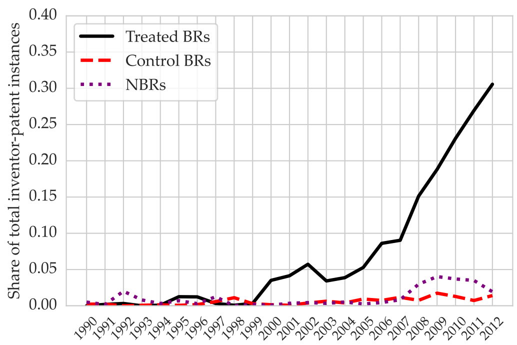
Figure C3: Inventor-patent instances with the inventors' work address



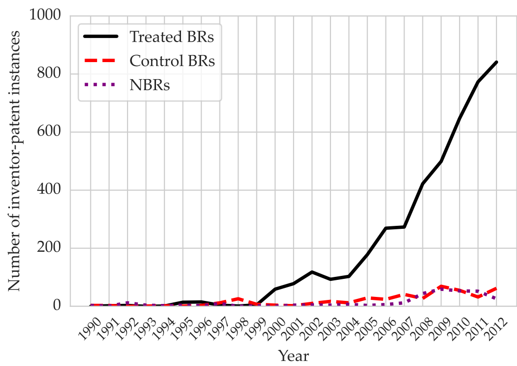
(a) Share



(b) Number



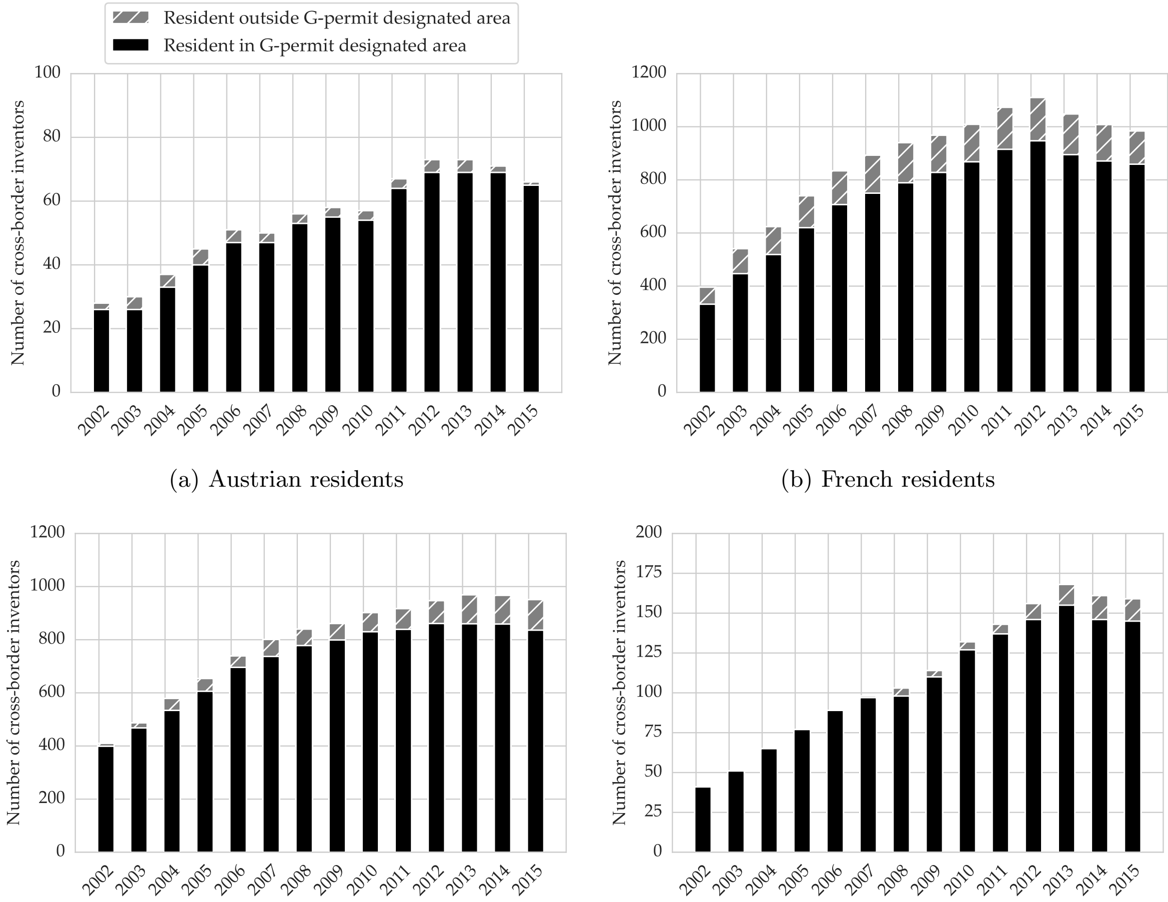
(c) Share, by region



(d) Number, by region

Notes: Inventor-patent instances with the inventors' work address are identified as those containing `"c/o"` or the name of the applicant in the string of the inventor address.

Figure C4: Cross-border inventors by region of residence (post-AFMP, ZEMIS definition)



(a) Austrian residents

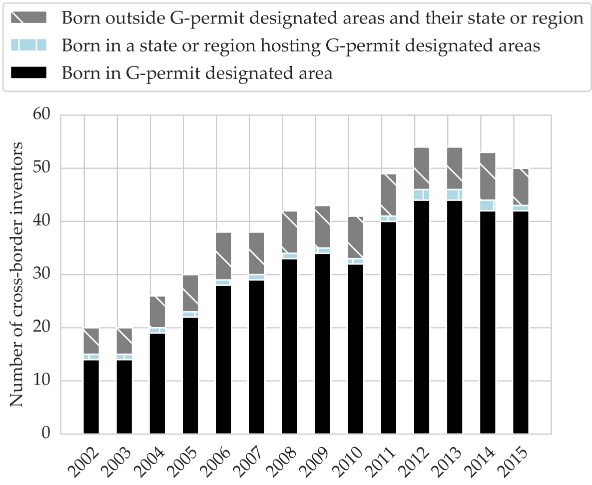
(b) French residents

(c) German residents

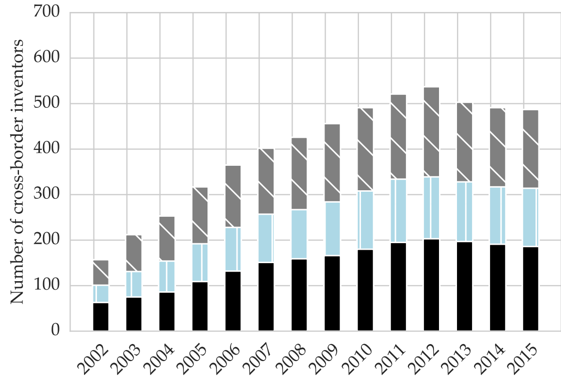
(d) Italian residents

Notes: The graphs show the evolution of Permit G holders employed in Switzerland and residing in Austria (a), France (b), Germany (c), and Italy (d), distinguishing between those resident in G-permit designated areas and those resident in regions farther away. The sample includes only Permit G holders hired in Switzerland for the first time in the post-AFMP period. Data from inventor-ZEMIS matched records.

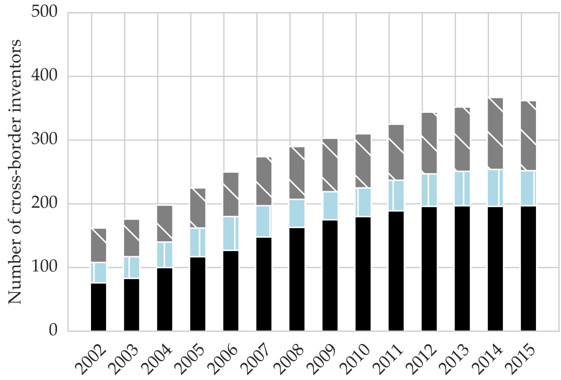
Figure C5: Cross-border inventors by region of birth (post-AFMP, ZEMIS definition)



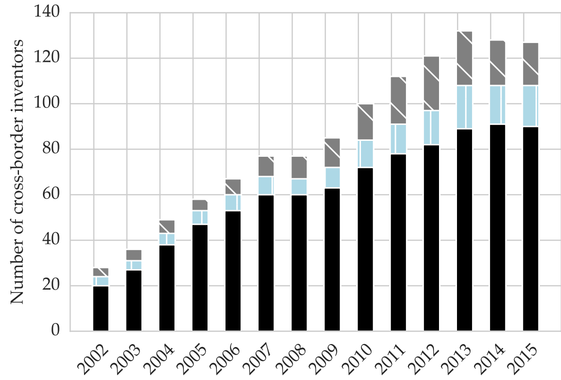
(a) Austria



(b) France



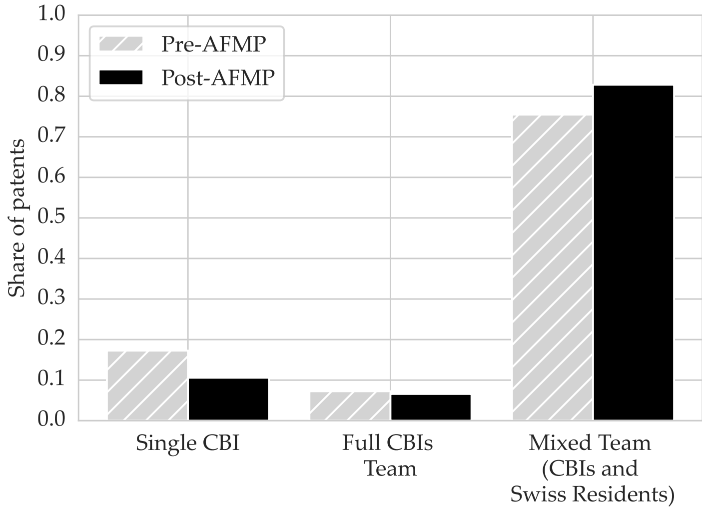
(c) Germany



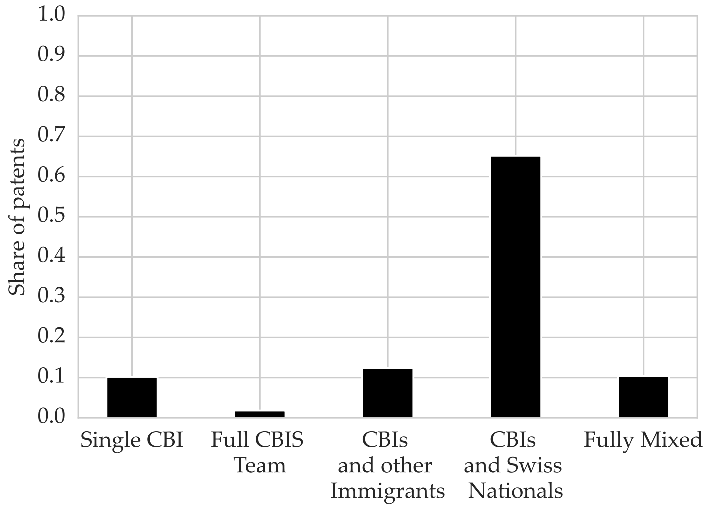
(d) Italy

Notes: The graphs show the evolution of Permit G holders employed in Switzerland and residing in Austria (a), France (b), Germany (c), and Italy (d), distinguishing between those born in G-permit designated areas, those born in the same state or region of G-permit designated areas, and those born in regions farther away. The sample includes only Permit G holders hired in Switzerland for the first time in the post-AFMP period and residing in a G-permit designated area. Data from inventor-ZEMIS matched records.

Figure C6: Cross-border inventors' patents by collaboration type



(a) Address definition (Pre- & Post-AFMP)

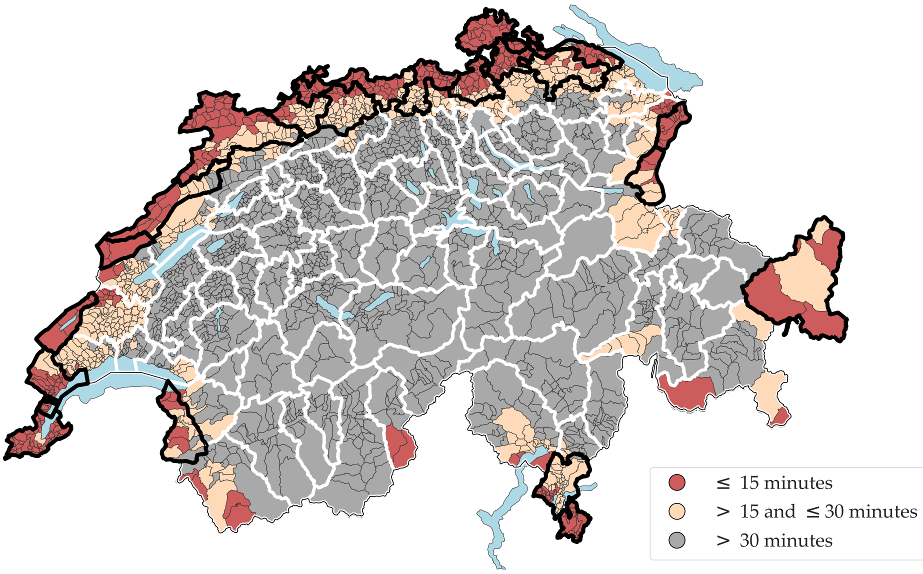


(b) G-permit ZEMIS definition (Post-AFMP only)

Notes: The graphs show the share of cross-border inventors' patents according to the inventor team composition. Panel (a) uses cross-border inventors' patent-based definition and classifies inventors as cross-border inventors and Swiss Resident inventors (which include both Swiss citizens and resident immigrants). Panel (b) uses the ZEMIS-based definition (2000-2012) and inventors are classified as cross-border inventors (G-permit holders), resident immigrants (B-,C-, and L-permit holders), and Swiss citizens.

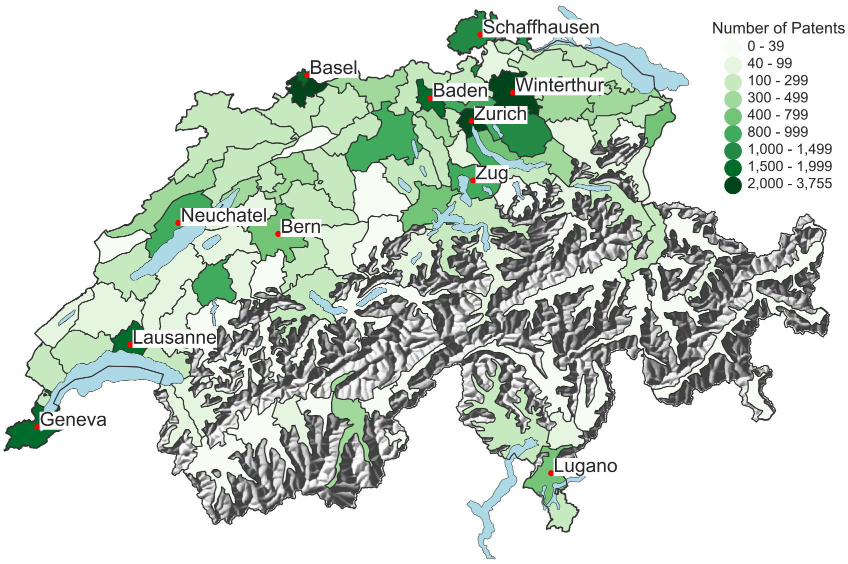
C.2. Swiss Regions and Applicants

Figure C7: Treated MS regions (border regions) vs. municipalities by driving distance area



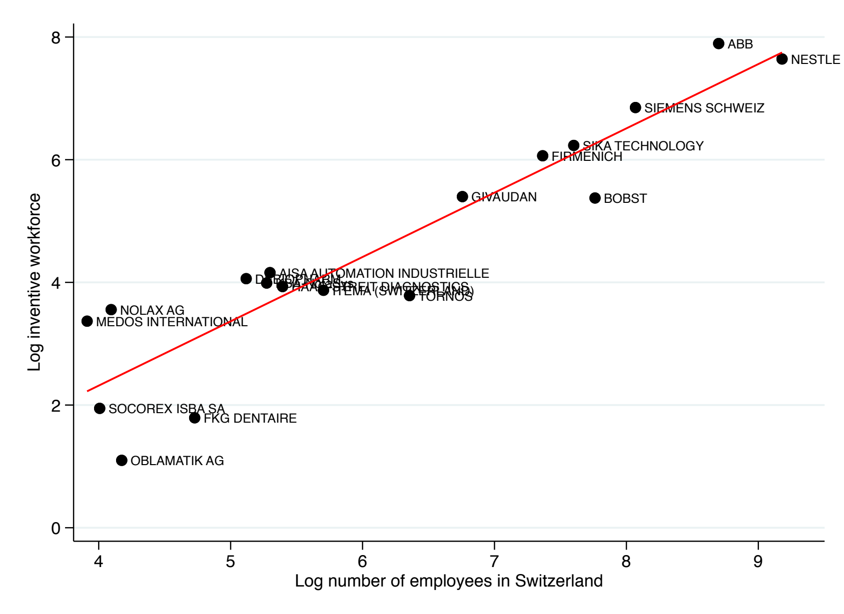
Notes: The map shows Swiss municipalities within 15 minutes and between 15-30 minutes of driving distance to the nearest border crossing. "Treated" MS regions within 20 minutes to the nearest border crossing, as measured by the average distance of their municipalities, are shown with black borders.

Figure C8: MS regions in Switzerland: Patent filings between 1990-1999

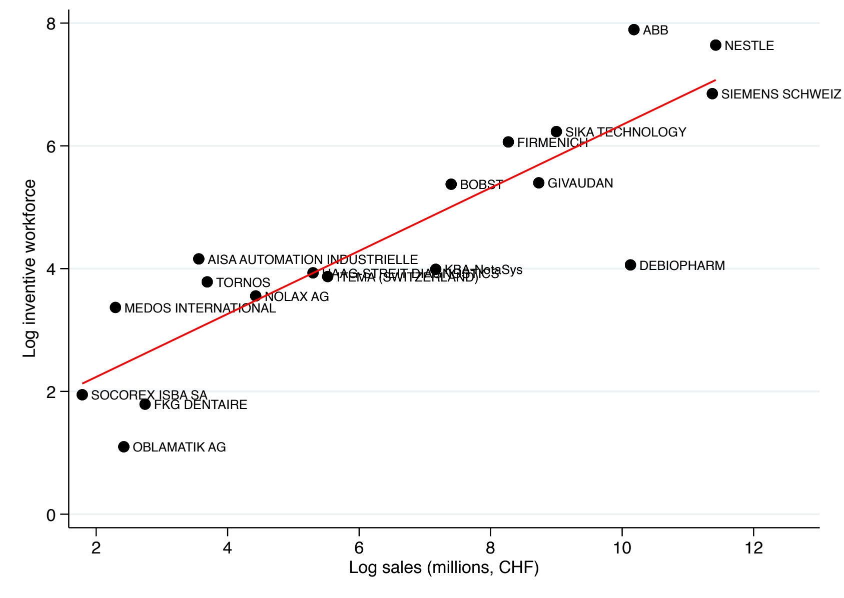


Notes: The map plots MS regions according to the number of patents filed between 1990-1999, before the AFMP was signed and introduced. MS regions are plotted in terms of their productive areas, as defined by the Swiss Federal Statistical Office. This enables a better representation of each MS region's economically active surface with respect to their purely political boundaries.

Figure C9: Relationship between applicants' inventive workforce and other firm size measures



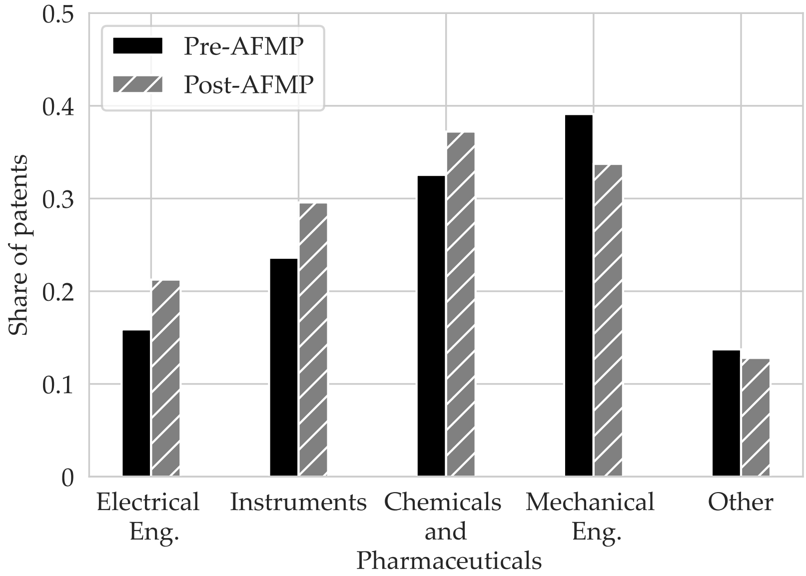
(a) Employees in Switzerland



(b) Sales

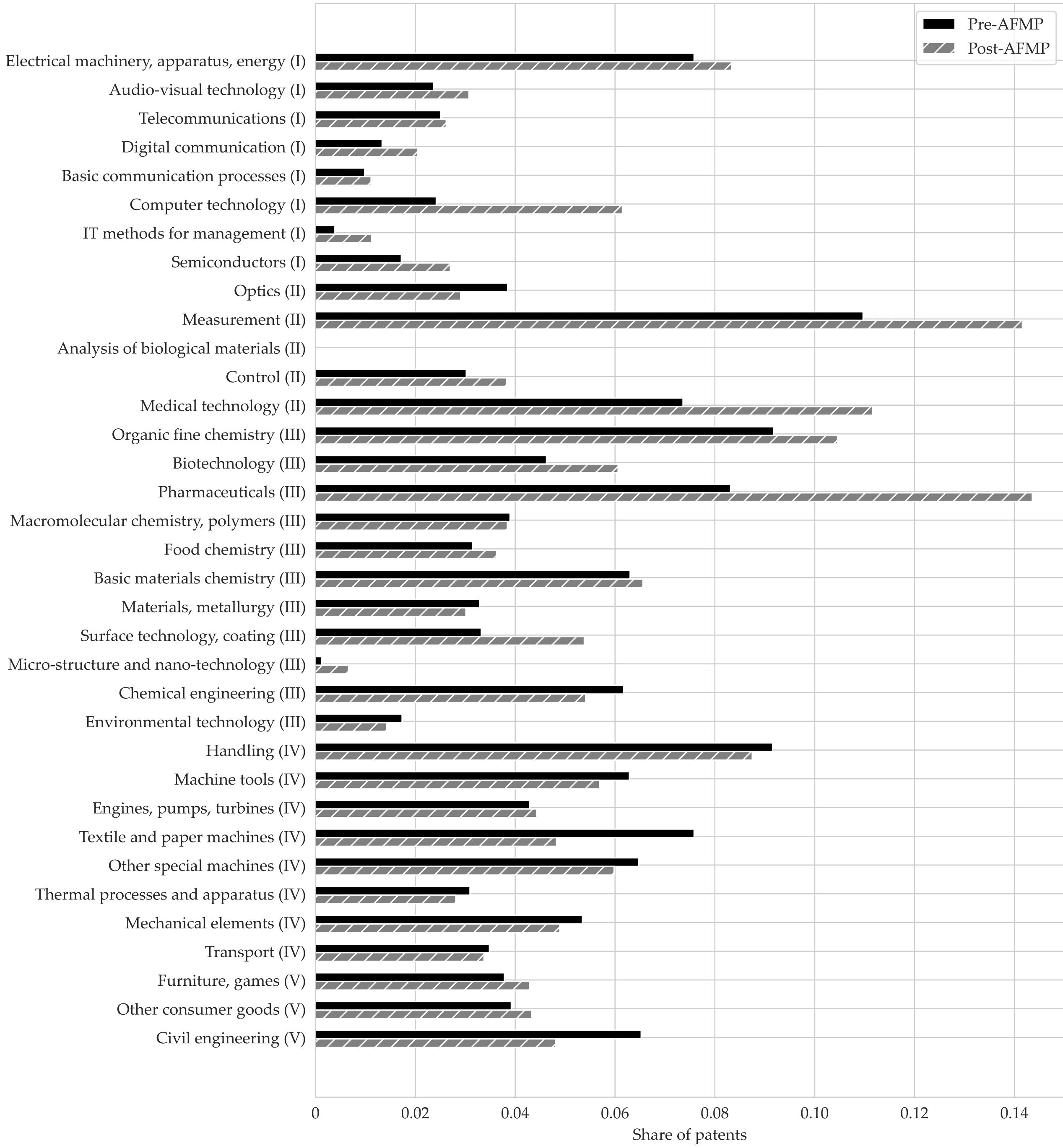
Notes: Relationship between a given applicant's inventive workforce and its employees in Switzerland or its sales (millions, CHF), superimposing a linear fit. The variables are shown as their logarithmic transformation. We randomly extracted five applicants for each applicant size category we defined. Data on employees in Switzerland comes from `www.swissfirms.ch/en` a portal gathering information on firms active in Switzerland obtained from Swiss Chambers of Commerce. Data on sales comes either from companies' official financial statements or from `www.dnb.com`. In both cases, we considered the latest figures available.

Figure C10: Distribution of patents by main technology field, before and after the AFMP introduction



Notes: The plot shows the distribution of patents in our sample by Schmoch's (2008) five main technology fields, before and after the signing and introduction of the AFMP. Notice that a patent can be assigned to more than one technology field.

Figure C11: Distribution of patents by technological category, before and after the AFMP introduction



Notes: The plot shows the distribution of patents in our sample by Schmoch's (2008) thirty-five technological categories, before and after the signing and introduction of the AFMP. Each technological category is associated to a main technology field and labeled accordingly: (I) Electrical engineering; (II) Instruments; (III) Chemistry and pharmaceuticals; (IV) Mechanical engineering; (V) Other. Notice that a patent can be assigned to more than one technology group.

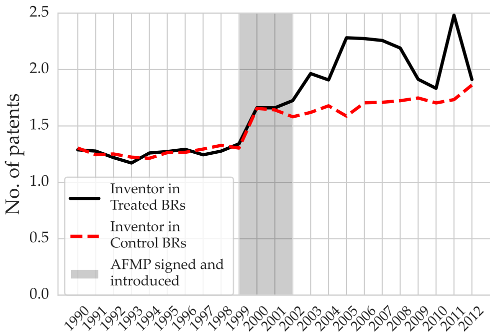
C.3. Inventor-level Analysis: Incumbent Inventors

Table C1: Incumbent inventors' outcomes: mean and standard deviation by area and period

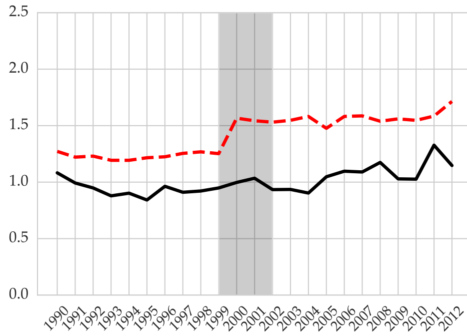
	Pre-AFMP (1990-1999)			**Post-AFMP (2000-2012)**		
	Treated	Control	Non-border regions	Treated	Control	Non-border regions
Patents	1.3	1.3	1.3	1.9	1.6	1.7
	(0.7)	(0.8)	(0.8)	(1.8)	(1.3)	(1.7)
Patents (excl. cross-border inventors)	0.9	1.2	1.2	1.0	1.5	1.7
	(0.7)	(0.8)	(0.8)	(1.2)	(1.2)	(1.7)
Co-inventors	1.7	1.5	1.2	3.4	2.2	2.0
	(2.0)	(1.7)	(1.4)	(3.8)	(2.3)	(2.3)
Co-inventors (excl. cross-border inventors)	0.8	1.4	1.2	1.1	1.9	1.8
	(1.3)	(1.6)	(1.4)	(1.9)	(2.1)	(2.2)
Cit. to cross-border inventor-country	0.9	0.7	0.8	2.5	1.6	2.0
	(1.8)	(1.4)	(1.7)	(6.2)	(3.2)	(4.0)
Cit. to cross-border inventor-country (excl. cross-border inventors)	0.6	0.7	0.8	1.2	1.4	1.9
	(1.4)	(1.4)	(1.7)	(3.8)	(3.1)	(3.8)
Patents with novel terms	0.4	0.3	0.3	0.4	0.3	0.3
	(0.6)	(0.5)	(0.6)	(0.7)	(0.6)	(0.6)
Patents with IPC class	0.9	1.0	1.0	0.3	0.5	0.5
	(0.7)	(0.7)	(0.7)	(0.6)	(0.7)	(0.7)
Patents with IPC subclass	1.0	1.0	1.1	0.5	0.6	0.7
	(0.7)	(0.7)	(0.7)	(0.8)	(0.8)	(0.9)
Patents with IPC group	1.1	1.1	1.1	1.2	0.9	1.0
	(0.7)	(0.7)	(0.7)	(1.2)	(1.0)	(1.1)
Patents with IPC subgroup	1.2	1.2	1.2	1.6	1.3	1.3
	(0.7)	(0.7)	(0.7)	(1.6)	(1.1)	(1.3)

Notes: The table reports mean values for incumbent inventors' yearly innovation outcomes. Standard deviation values are reported in parentheses.

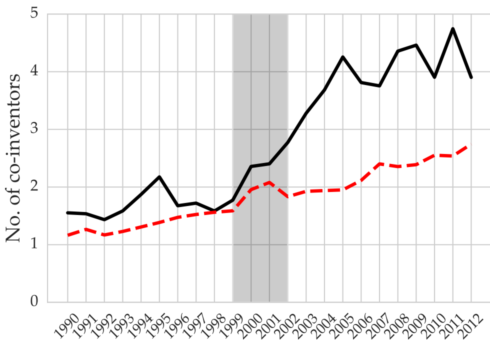
Figure C12: Incumbent inventors' average inventive outcomes



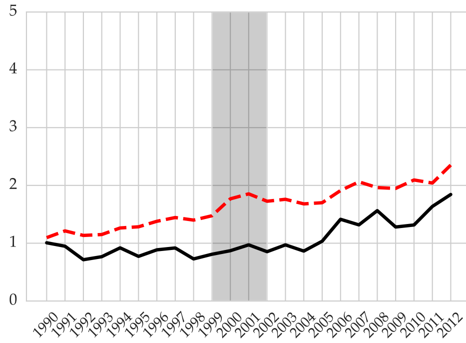
(a) Patents



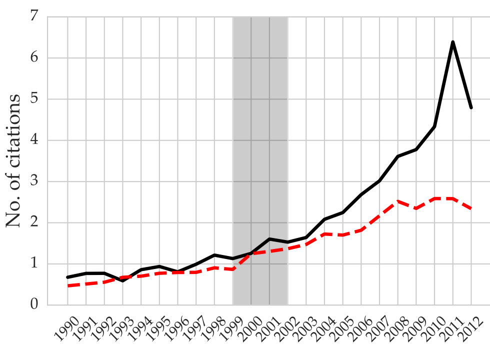
(b) Patents (excl. cross-border inventors)



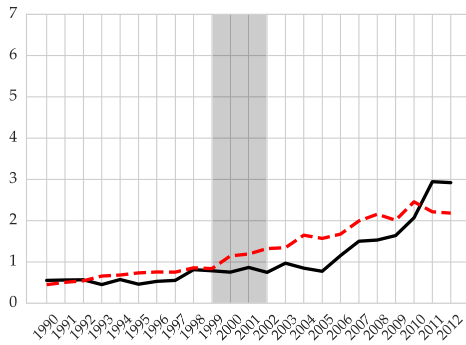
(c) Distinct co-inventors



(d) Distinct co-inventors (excl. cross-border inventors)



(e) Cites to cross-border inventor-country



(f) Cites to cross-border inventor-country (excl. cross-border inventors)

Notes: The figure shows incumbent inventors' average inventive outcomes between 1990-2012. Those located in treated regions (solid black line) and those located in control regions (dashed red line).

C.4. Inventor-level Analysis: Junior Inventors

Table C2: Junior inventors' outcomes: mean and standard deviation by area and cohort

Cohort	**Treated (1999-2000)**			**Control (1990-1993)**		
Region	Treated	Control	Non-border regions	Treated	Control	Non-border regions
Patents	1.6	1.4	1.3	1.3	1.3	1.2
	(1.3)	(0.9)	(0.8)	(1.0)	(0.8)	(0.6)
Patents (excl. cross-border inventors)	0.9	1.2	1.2	0.9	1.2	1.2
	(0.9)	(0.9)	(0.8)	(0.8)	(0.7)	(0.6)
Co-inventors	2.5	1.9	1.4	1.8	1.4	1.1
	(3.2)	(2.0)	(1.5)	(2.3)	(1.6)	(1.4)
Co-inventors (excl. cross-border inventors)	0.8	1.7	1.4	0.8	1.3	1.1
	(1.3)	(1.9)	(1.5)	(1.3)	(1.5)	(1.4)
Cit. to cross-border inventor-country	1.6	1.1	1.0	1.2	0.7	0.8
	(4.9)	(2.3)	(2.2)	(4.0)	(1.4)	(1.8)
Cit. to cross-border inventor-country (excl. cross-border inventors)	0.9	1.0	1.0	0.7	0.6	0.8
	(3.0)	(2.3)	(2.1)	(2.3)	(1.4)	(1.8)

Notes: The table reports mean values for junior inventors' yearly innovation outcomes. Standard deviation values are reported in parentheses.

D. Additional Estimations and Robustness Checks

D.1. Immigrant Patenting and Citations

Table D1: EPO-ZEMIS matched dataset: probability to patent again after first filing in Switzerland (five years after arrival)

	Full (1)	No “L” (2)	No “C” (3)	No “B” (4)	Only Treated border regions (5)
Cross-border inventor	0.119*** (0.0183)	0.113*** (0.0190)	0.121*** (0.0184)	0.144*** (0.0289)	0.096*** (0.0264)
No. of pre migration patents	0.014*** (0.0029)	0.013*** (0.0030)	0.014*** (0.0029)	0.013*** (0.0037)	0.008** (0.0039)
Team-Size	0.003 (0.0029)	0.003 (0.0032)	0.003 (0.0029)	0.002 (0.0044)	- 0.006 (.0050)
Applicant inventive workforce	0.00003*** (0.0000)	0.00003*** (0.0000)	0.00003*** (0.0000)	0.00001 (0.00001)	0.000 (0.00000)
Observations	4,493	3,926	4,429	1,794	1,649
R^2	0.10	0.10	0.10	0.15	0.13
Individual-level controls	✓	✓	✓	✓	✓
MS region dummies	✓	✓	✓	✓	✓
Priority year dummies	✓	✓	✓	✓	✓
Tech. class dummies	✓	✓	✓	✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. Regressions based on a cross section of immigrant inventors entering the Swiss labor market between 2002-2010. The dependent variable is a dummy variable equal to 1 if inventor i patents at least once more in Switzerland after the first patent in the country, during the five years after entry. Cross-border inventor is an indicator taking value 1 if inventor i's working-residence permit of entry in Switzerland is the “G” category. Individual-level controls include gender, nationality, age at first invention in Switzerland, and a dummy variable taking value 1 if the inventor was born in Switzerland. Robust standard errors are given in parentheses. Linear probability models.

Table D2: Inventors' full career productivity: Swiss vs. cross-border inventors

	Patents			Citation-weighted patents		
	(1)	(2)	(3)	(4)	(5)	(6)
$PermitG_i$	0.252***	0.249***	0.218***	0.194***	0.187***	0.271***
	(0.033)	(0.033)	(0.035)	(0.056)	(0.056)	(0.072)
Mean y_i	2.97	2.86	2.79	8.57	8.52	8.23
Pseudo R^2	0.318	0.319	0.307	0.486	0.488	0.483
Observations	47,572	46,297	45,674	47,572	46,297	45,674
Controls	✓	✓	✓	✓	✓	✓
Excl. independent inventors		✓	✓		✓	✓
Excl. experienced cross-border inventors			✓			✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. Regression results from the specification: $E[y_i|X_i] = exp[\alpha + \beta PermitG_i + \delta X_i]$, where y_i is the number of total patents or citation-weighted filed by inventor i during their career. $PermitG_i$ is an indicator equal to 1 for cross-border inventors, that is, inventors who ever held a permit G to work in Switzerland, and equal to 0 for inventors with Swiss nationality. X_i is a vector of controls, including the inventors' average number of co-inventors, average applicant size, the number of applicants they have patented during their career, as well as technology field and first patent cohort fixed effects. Estimations by Poisson pseudo-maximum-likelihood.

Table D3: Citations to prior art from neighbouring countries

	Address-definition		**ZEMIS-definition**		
	Pre-AFMP	Post-AFMP	Post-AFMP	Post-AFMP	Post-AFMP
	(1)	(2)	(3)	(4)	(5)
Cross-border inventor	0.341*** (0.050)	0.262*** (0.029)	0.232*** (0.026)	0.243*** (0.028)	0.198*** (0.044)
Resident-Immigrant				0.026 (0.022)	
Observations	14,328	35,112	36,022	36,022	10,903
Pseudo R^2	0.163	0.226	0.223	0.223	0.216
Year, MS region, Applicant, Tech. field FE	✓	✓	✓	✓	✓
Baseline patents	Swiss residents	Swiss residents	Swiss residents	Swiss nationals	Resident immigrants

Notes: *** p<0.01, ** p<0.05, * p<0.1. Regressions based on a cross section of EPO patents filed in Switzerland. The dependent variable is patent i's number of citations to prior art from Switzerland's neighbouring countries. Cross-border inventor is an indicator taking value 1 if patent i lists one or more cross-border inventors. Resident-immigrant is an indicator taking value 1 if patent i lists one or more immigrants but no cross-border inventors. Robust standard errors are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

Table D4: Citations to prior art from the U.S.

	Address-definition		ZEMIS-definition		
	Pre-AFMP	Post-AFMP	Post-AFMP	Post-AFMP	Post-AFMP
	(1)	(2)	(3)	(4)	(5)
Cross-border inventor	0.075	0.063	0.022	0.027	-0.025
	(0.081)	(0.039)	(0.033)	(0.035)	(0.055)
Resident-Immigrant				0.012	
				(0.028)	
Observations	14,191	35,352	36,243	36,243	11,111
Pseudo R^2	0.275	0.344	0.335	0.335	0.285
Year, MS region, Applicant, Tech. field FE	✓	✓	✓	✓	✓
Baseline patents	Swiss residents	Swiss residents	Swiss residents	Swiss nationals	Resident immigrants

Notes: *** p<0.01, ** p<0.05, * p<0.1. Regressions based on a cross section of EPO patents filed in Switzerland. The dependent variable is patent i's number of citations to prior art from the United States. Cross-border inventor is an indicator taking value 1 if patent i lists one or more cross-border inventors. Resident-immigrant is an indicator taking value 1 if patent i lists one or more immigrants but no cross-border inventors. Robust standard errors are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

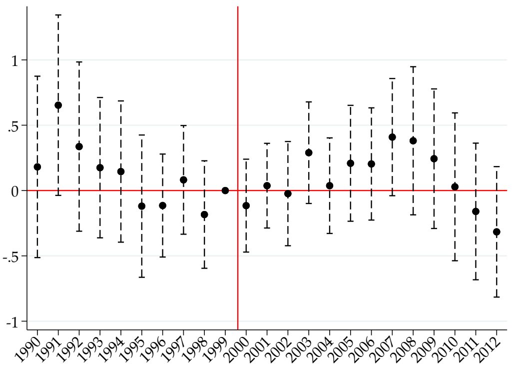
D.2. Regional Analysis: Patenting in Switzerland

Table D5: Regional patent count: difference-in-differences results

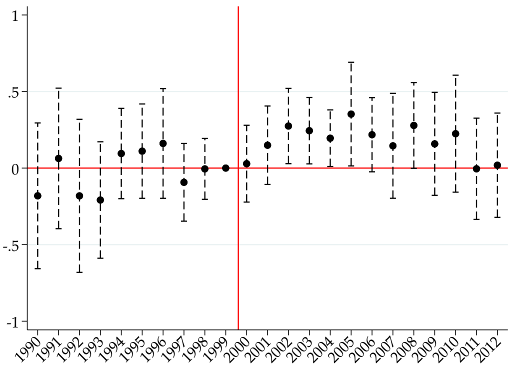
	Full sample		**Incumbents only**		**No top applicants**		**Cross-border inventor in team**		**Residents-only team**	
	Baseline	Until 2007	Baseline	Until 2007	Baseline	Until 2007	Baseline	Until 2007	Baseline	Until 2007
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
AFMP × Treated	0.117	0.200**	0.107	0.209	0.247**	0.285***	0.407***	0.523***	-0.036	0.024
	(0.101)	(0.090)	(0.134)	(0.128)	(0.113)	(0.106)	(0.119)	(0.095)	(0.109)	(0.099)
Observations	1449	1134	1403	1098	1449	1134	1426	1116	1449	1134
Pseudo R^2	0.878	0.875	0.855	0.855	0.841	0.836	0.882	0.880	0.862	0.854
MS region FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. The dependent variable is the number of patents filed in MS region m in year t. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

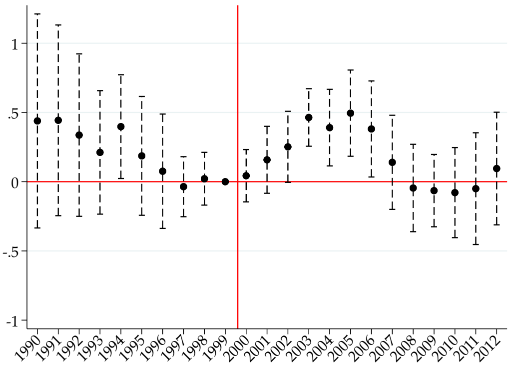
Figure D1: Regional patent count: event study results (by technology field)



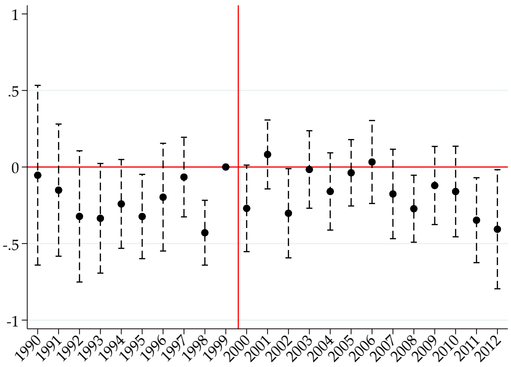
(a) Electrical engineering



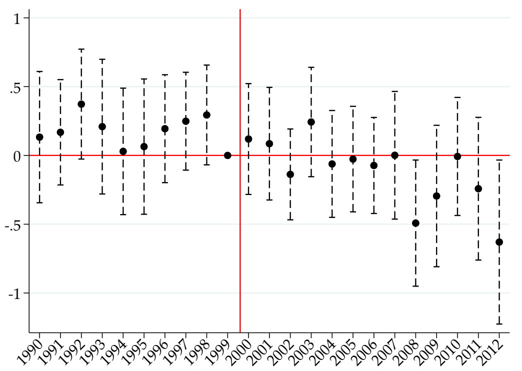
(b) Instruments



(c) Chemicals and pharmaceuticals



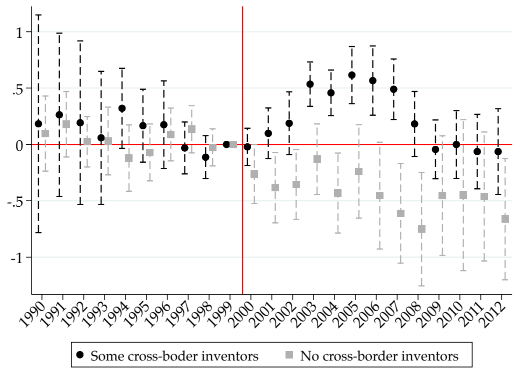
(d) Mechanical engineering



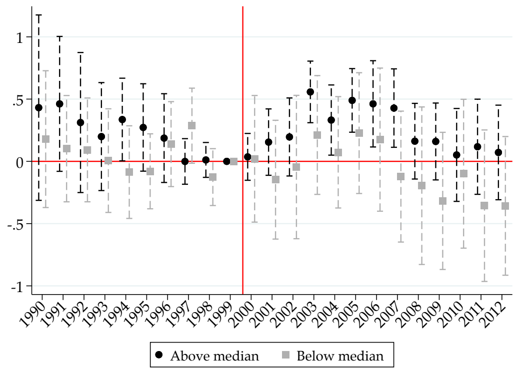
(e) Other

Notes: The dependent variable is the number of patents filed in MS region m in year t. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 1380; Pseudo R^2 = 0.786. Panel (b): N = 1426 ; Pseudo R^2 = 0.783. Panel (c): N = 1403; Pseudo R^2 = 0.857. Panel (d): N = 1403; Pseudo R^2 = 0.755. Panel (e): N = 1403; Pseudo R^2 = 0.564.

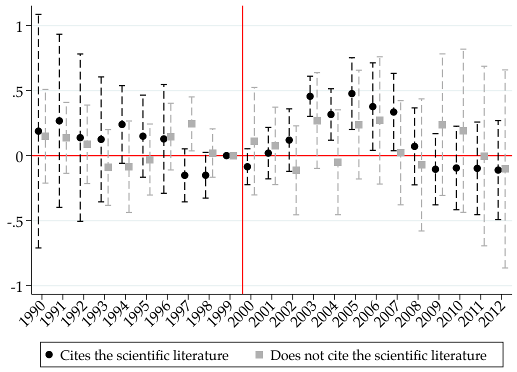
Figure D2: Regional patent count: event study results (by applicants' pre-AFMP characteristics)



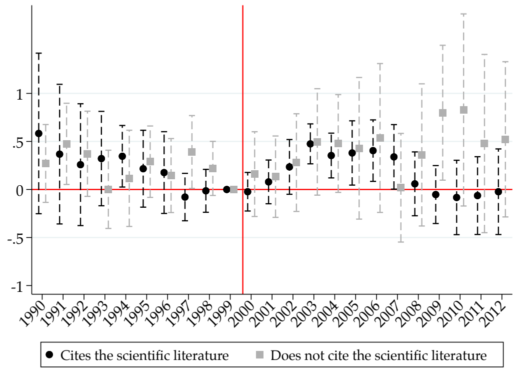
(a) Employing cross-border inventors



(b) Share of citations to foreign prior art



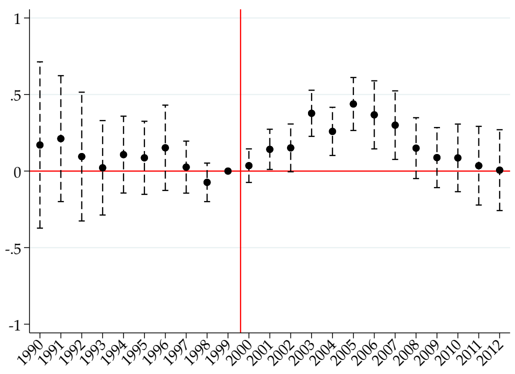
(c) Reliance on scientific literature



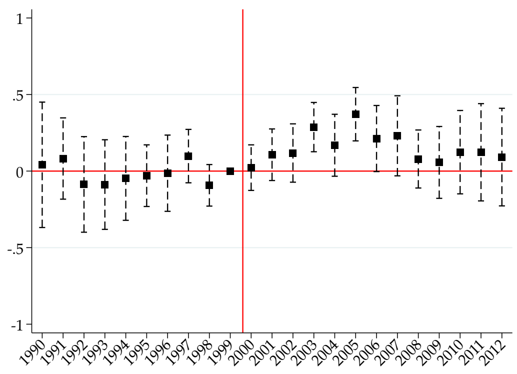
(d) Reliance on scientific literature (only chemicals and pharmaceuticals)

Notes: The dependent variable is the number of patents filed in MS region m in year t. We count only patents from incumbent applicants, comparing the patenting output of different groups based on their pre-AFMP characteristics. In panel (a) we report regressions based on the patenting output of applicants which employed at least one cross-border inventor and compare it with that of applicants which did not employ any. In panel (b) we count only patents from applicants whose share of citations to foreign prior art was either above or below the median in the pre-AFMP. In panel (c) we count only patents from applicants which cited at least one scientific article in the text of their patents, versus those which did not cite any. In panel (d) we repeat the previous exercise, although focusing only on applicants active in the "instruments" or "chemicals and pharmaceuticals" technology fields. Information on patents' in-text citations to the scientific literature is from Verluise and de Rassenfosse (2020). The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): Some cross-border inventors: N = 1104; Pseudo R^2 = 0.875; No cross-border inventors: N = 1403; Pseudo R^2 = 0.733. Panel (b): Above median: N = 1357; Pseudo R^2 = 0.852; Below median: N = 1403; Pseudo R^2 = 0.779. Panel (c): Cites the scientific literature: N = 1219; Pseudo R^2 = 0.874; Does not cite the scientific literature: N = 1380; Pseudo R^2 = 0.629. Panel (d): Cites the scientific literature: N = 1196; Pseudo R^2 = 0.867; Does not cite the scientific literature: N = 1311; Pseudo R^2 = 0.505.

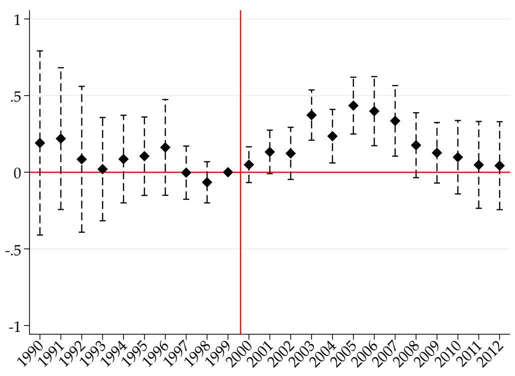
Figure D3: Regional patent count: event study results (excluding Basel and Geneva)



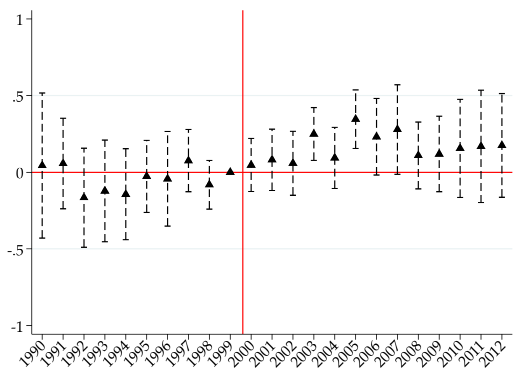
(a) Baseline



(b) Excluding Basel



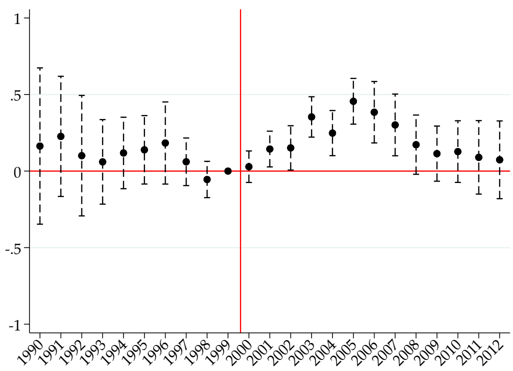
(c) Excluding Geneva



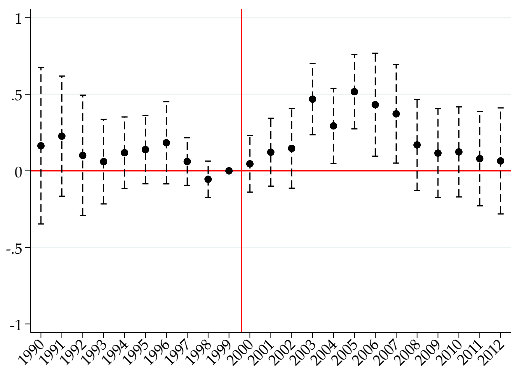
(d) Excluding Basel and Geneva

Notes: The dependent variable is the number of patents filed in MS region m in year t. The treated group includes all MS regions in the BR whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the BR whose driving distance from the closest border crossing is above 20 minutes. All regressions include MS region and year fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 1449; Pseudo R^2 = 0.880. Panel (b): N = 1380; Pseudo R^2 = 0.867. Panel (c): N = 1426; Pseudo R^2 = 0.878. Panel (d): N = 1357; Pseudo R^2 = 0.863.

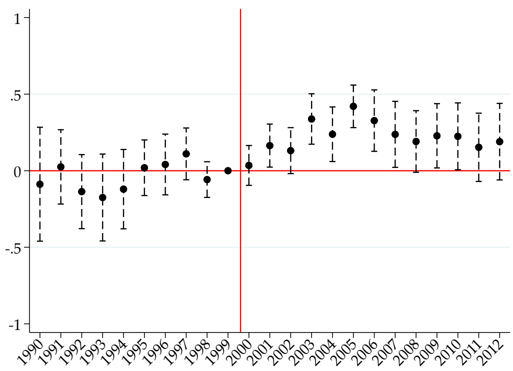
Figure D4: Regional patent count: event study results (including non-border region in the control group)



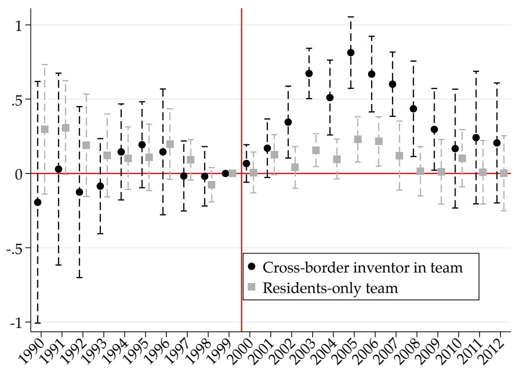
(a) Full sample



(b) Incumbent applicants only



(c) No top applicants



(d) Cross-border inventor in team
VS. Resident-only

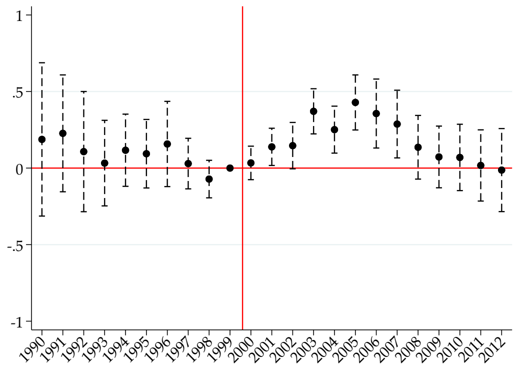
Notes: The dependent variable is the number of patents filed in MS region m in year t. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes and all MS regions in the non-border region. For the estimations in panel (a) we count all patents. For those in panel (b) we count only patents associated with "incumbent applicants;" for those in panel (c) we exclude patents associated with "top applicants". For the estimations in panel (d) we decompose each treated MS region's yearly patent output, distinguishing between patents including at least one cross-border inventor (*Cross-border inventor in team*) and patents including only resident inventors (*Resident-only team*) and running two separate event study regressions. The estimated parameters related to cross-border inventor-in-team patents are shown as black circles. Those related to Resident-only team patents are shown as gray squares. All regressions include MS region and year fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 2438; Pseudo R^2 = 0.877. Panel (b): N = 2392; Pseudo R^2 = 0.858. Panel (c): N = 2438; Pseudo R^2 = 0.841. Panel (d): Cross-border inventor in team: N = 2415; Pseudo R^2 = 0.873; Resident-only team: N = 2438; Pseudo R^2 = 0.861.

Table D6: Regional patent count: difference-in-differences results (including non-border region in the control group)

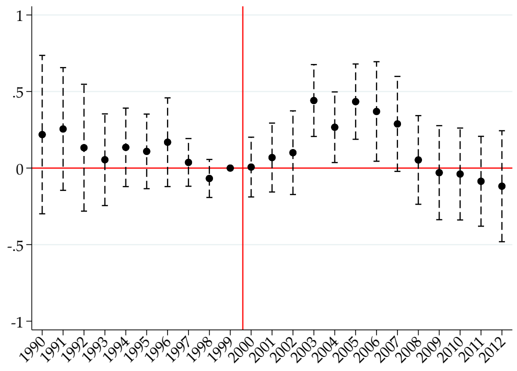
	Full sample		**Incumbents only**		**No top applicants**		**Cross-border inventor in team**		**Residents-only team**	
	Baseline	Until 2007	Baseline	Until 2007	Baseline	Until 2007	Baseline	Until 2007	Baseline	Until 2007
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
AFMP × Treated	0.116	0.180**	0.141	0.216*	0.257***	0.277***	0.406***	0.503***	-0.037	0.005
	(0.080)	(0.070)	(0.119)	(0.116)	(0.095)	(0.089)	(0.102)	(0.076)	(0.089)	(0.080)
Observations	2438	1908	2392	1872	2438	1908	2415	1890	2438	1908
Pseudo R^2	0.876	0.872	0.856	0.855	0.840	0.835	0.871	0.868	0.860	0.853
MS region FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The dependent variable is the number of patents filed in MS region m in year t. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes and all MS regions in the non-border region. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

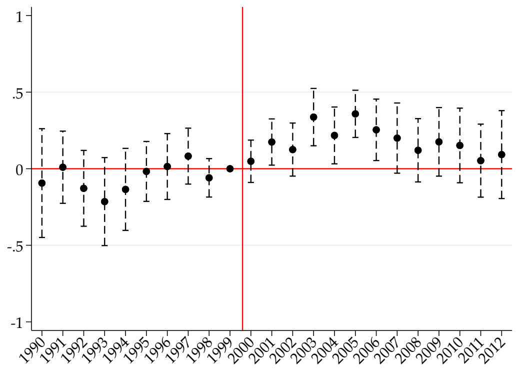
Figure D5: Regional patent count: event study results (including NUTS-2-specific time trends)



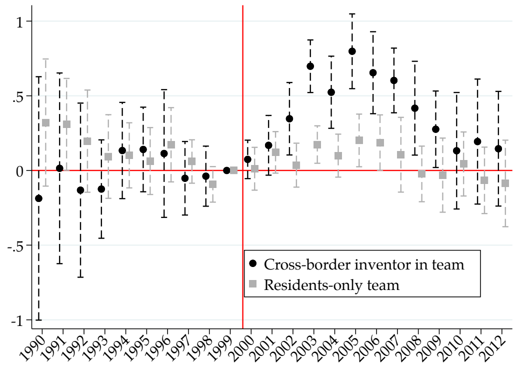
(a) Full sample



(b) Incumbent applicants only



(c) No top applicants



(d) Cross-border inventor in team
VS. Resident-only

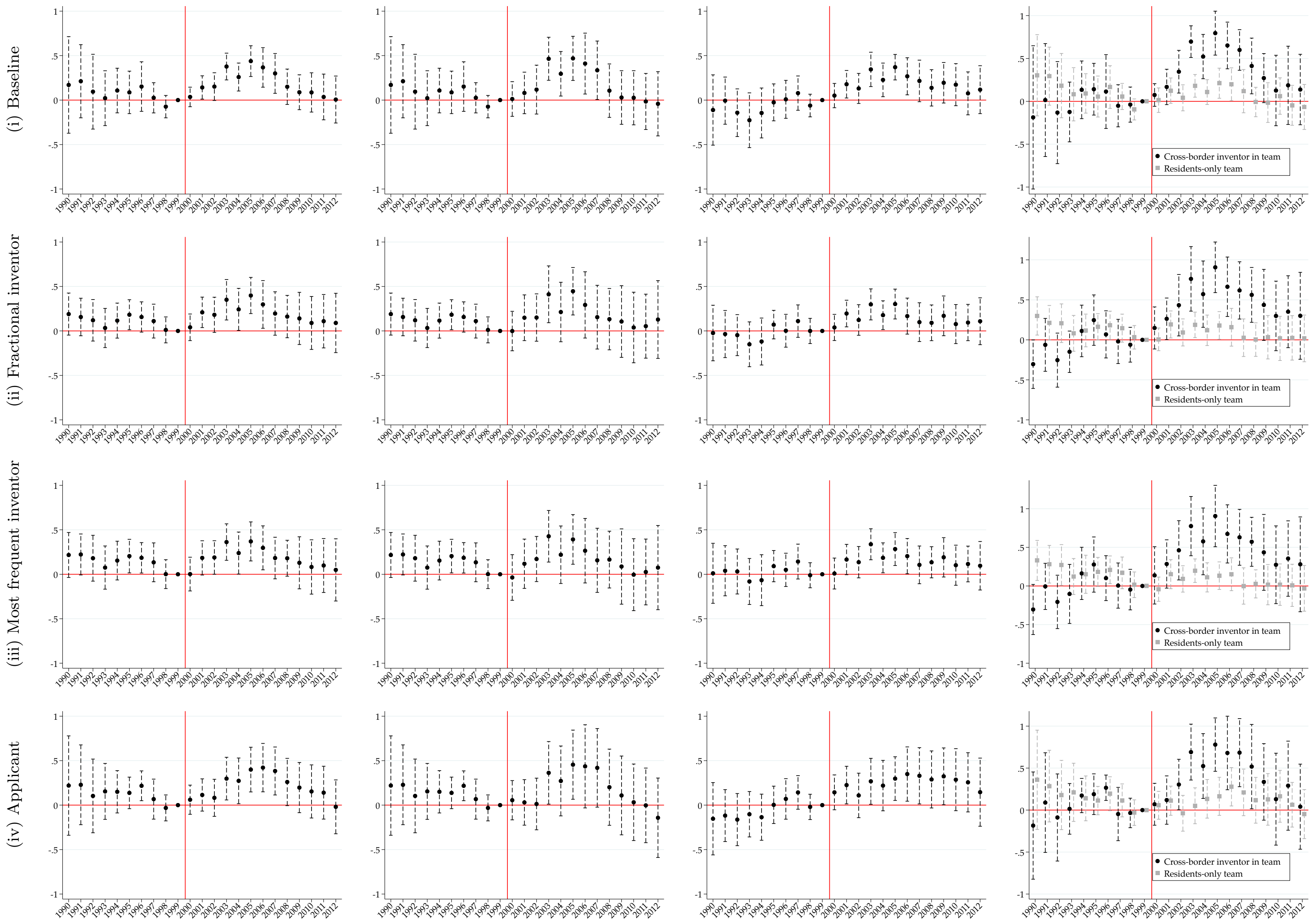
Notes: The dependent variable is the number of patents filed in MS region m in year t. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes and all MS regions in the non-border region. For the estimations in panel (a) we count all patents. For those in panel (b) we count only patents associated with "incumbent applicants;" for those in panel (c) we exclude patents associated with "top applicants". For the estimations in panel (d) we decompose each treated MS region's yearly patent output, distinguishing between patents including at least one cross-border inventor (*Cross-border inventor in team*) and patents including only resident inventors (*Resident-only team*) and running two separate event study regressions. The estimated parameters related to cross-border inventor-in-team patents are shown as black circles. Those related to Resident-only team patents are shown as gray squares. All regressions include MS region fixed effects, year fixed effects, and NUTS-2-specific time trends. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 1449; Pseudo R^2 = 0.882. Panel (b): N = 1403; Pseudo R^2 = 0.863. Panel (c): N = 1449; Pseudo R^2 = 0.844. Panel (d): Cross-border inventor in team: N = 1426; Pseudo R^2 = 0.887; Resident-only team: N = 1449; Pseudo R^2 = 0.865.

Table D7: Regional patent count: difference-in-differences results (including NUTS-2-specific time trends)

	Full sample		**Incumbents only**		**No top applicants**		**Cross-border inventor in team**			**Residents-only team**	
	Baseline	Until 2007	Baseline	Until 2007	Baseline	Until 2007	Baseline	Until 2007		Baseline	Until 2007
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)		(9)	(10)
AFMP × Treated	0.115*	0.211***	0.065	0.187*	0.228**	0.273***	0.419***	0.542***		-0.043	0.045
	(0.066)	(0.052)	(0.120)	(0.102)	(0.092)	(0.084)	(0.072)	(0.061)	(0.079)		(0.062)
Observations	1449	1134	1403	1098	1449	1134	1426	1116		1449	1134
Pseudo R^2	0.879	0.876	0.859	0.857	0.843	0.837	0.884	0.881		0.864	0.856
MS region FE	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. The dependent variable is the number of patents filed in MS region m in year t. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include MS region fixed effects, year fixed effects, and NUTS-2-specific time trends. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

Figure D6: Regional patent count: event study results (alternative patent location assignment)



(a) Full sample

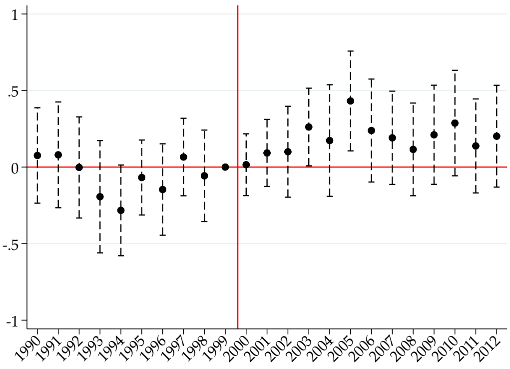
(b) Incumbent applicants only

(c) No top applicants

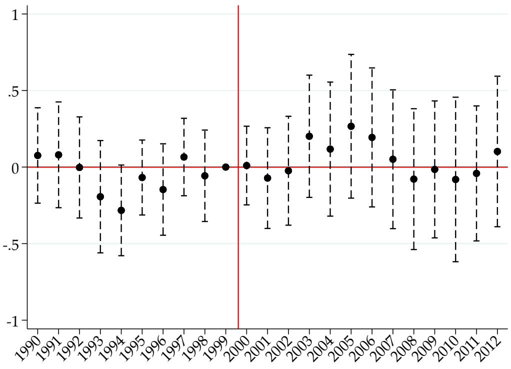
(d) Cross-border inventor-in-team vs. Resident-only

Notes: Row (i) shows our baseline estimates (Figure 6 in the paper). Estimates in row (ii) are based on a sample where we assign each patent to the inventors' MS regions via fractional counting. In row (iii), we assign each patent to the MS region where most of its inventors reside. In row (iv), we assign each patent to its applicant's MS region. All regressions include MS region and year fixed effects. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood.

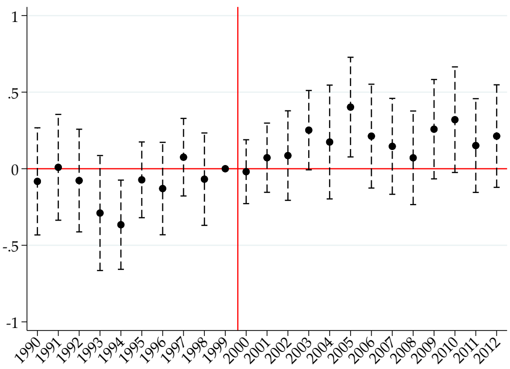
Figure D7: Regional patent count: event study results (OLS)



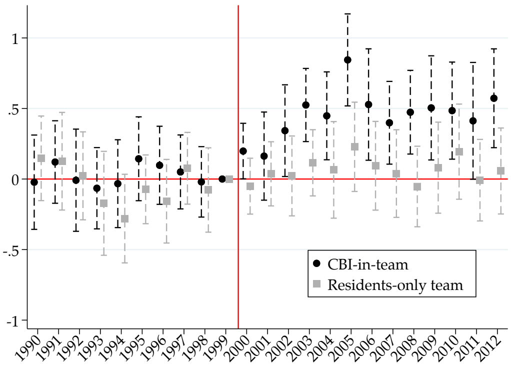
(a) Full sample



(b) Incumbent applicants only



(c) No top applicants



(d) Cross-border inventor in team
VS. Resident-only

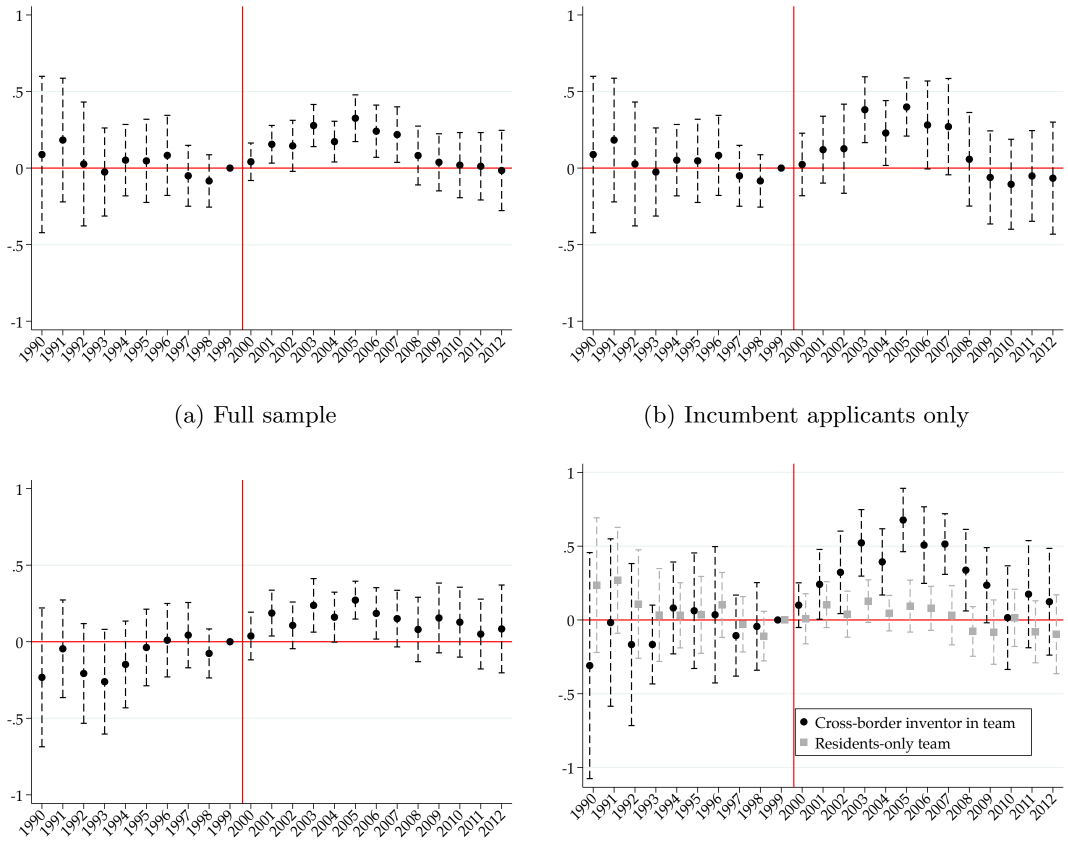
Notes: The dependent variable is the logarithmic transformation ($log(1 + patents)$) of the number of patents filed in MS region m in year t. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes and all MS regions in the non-border region. For the estimations in panel (a) we count all patents. For those in panel (b) we count only patents associated with "incumbent applicants;" for those in panel (c) we exclude patents associated with "top applicants". For the estimations in panel (d) we decompose each treated MS region's yearly patent output, distinguishing between patents including at least one cross-border inventor (*Cross-border inventor-in-team*) and patents including only resident inventors (*Resident-only team*) and running two separate event study regressions. The estimated parameters related to cross-border inventor-in-team patents are shown as black circles. Those related to Resident-only team patents are shown as gray squares. All regressions include MS region fixed effects, year fixed effects, and NUTS-2-specific time trends. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Ordinary Least Squares. Panel (a): N = 1449; R^2 = 0.931. Panel (b): N = 1449; R^2 = 0.916. Panel (c): N = 1449; R^2 = 0.919. Panel (d): Cross-border inventor in team: N = 1449; R^2 = 0.929; Resident-only team: N = 1449; R^2 = 0.926.

Table D8: Regional patent count: difference-in-differences results (OLS)

	Full sample		**Incumbents only**		**No top applicants**		**Cross-border inventor in team**		**Residents-only team**	
	Baseline	Until 2007	Baseline	Until 2007	Baseline	Until 2007	Baseline	Until 2007	Baseline	Until 2007
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
AFMP × Treated	0.203**	0.181*	0.101	0.146	0.280***	0.266***	0.427***	0.405***	0.102	0.107
	(0.094)	(0.102)	(0.144)	(0.137)	(0.078)	(0.080)	(0.099)	(0.091)	(0.071)	(0.075)
Observations	1449	1134	1449	1134	1449	1134	1449	1134	1449	1134
R^2	0.888	0.884	0.915	0.917	0.917	0.914	0.927	0.930	0.924	0.923
MS region FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. The dependent variable is the logarithmic transformation ($log(1 + patents)$) of the number of patents filed in MS region m in year t. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Ordinary Least Squares.

Figure D8: Regional patent count: event study results (only granted patents)



(a) Full sample

(b) Incumbent applicants only

(c) No top applicants

(d) Cross-border inventor-in-team VS. Resident-only

Notes: The dependent variable is the number of *granted* patents filed in MS region m in year t. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. For the estimations in panel (a) we count all patents. For those in panel (b) we count only patents associated with “incumbent applicants;” for those in panel (c) we exclude patents associated with “top applicants”. For the estimations in panel (d) we decompose each treated MS region’s yearly patent output, distinguishing between patents including at least one cross-border inventor (*Cross-border inventor in team*) and patents including only resident inventors (*Resident-only team*) and running two separate event study regressions. The estimated parameters related to cross-border inventor-in-team patents are shown as black circles. Those related to Resident-only team patents are shown as gray squares. All regressions include MS region and year fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 1426; Pseudo R^2 = 0.855. Panel (b): N = 1403; Pseudo R^2 = 0.838. Panel (c): N = 1426; Pseudo R^2 = 0.817. Panel (d): Cross-border inventor in team: N = 1403; Pseudo R^2 = 0.861; Resident-only team: N = 1426; Pseudo R^2 = 0.836.

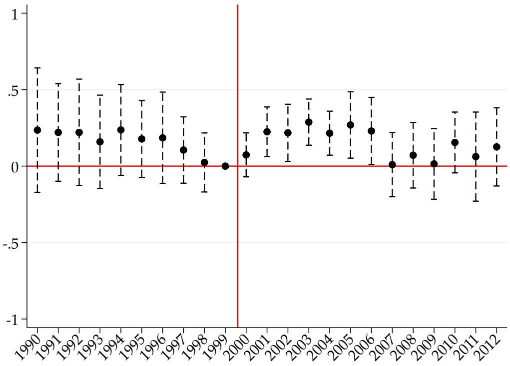
Table D9: Regional patent count: difference-in-differences results (only granted patents)

	Full sample		**Incumbents only**		**No top applicants**		**Cross-border inventor in team**		**Residents-only team**	
	Baseline	Until 2007	Baseline	Until 2007	Baseline	Until 2007	Baseline	Until 2007	Baseline	Until 2007
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
AFMP × Treated	0.104	0.174**	0.099	0.203*	0.228*	0.256**	0.385***	0.484***	-0.049	0.003
	(0.096)	(0.086)	(0.123)	(0.112)	(0.119)	(0.112)	(0.117)	(0.100)	(0.103)	(0.096)
Observations	1426	1116	1403	1098	1426	1116	1403	1098	1426	1116
Pseudo R^2	0.854	0.852	0.835	0.837	0.816	0.813	0.859	0.858	0.835	0.829
MS region FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

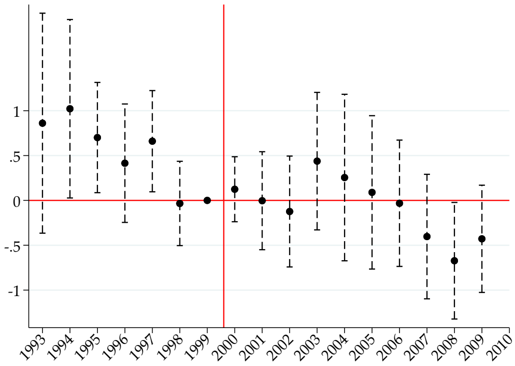
Notes: *** p<0.01, ** p<0.05, * p<0.1. The dependent variable is the number of *granted* patents filed in MS region m in year t.The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

D.3. Regional Analysis: Displacement Effects

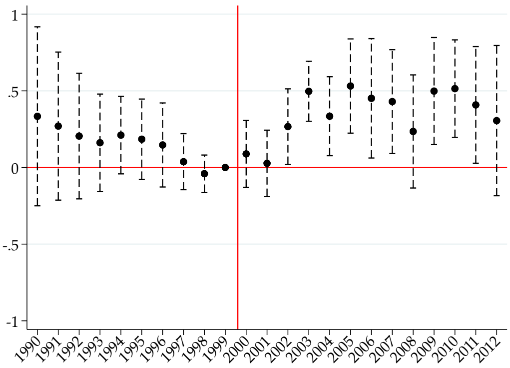
Figure D9: Active Swiss inventors: event study results (entrant and incumbent inventors)



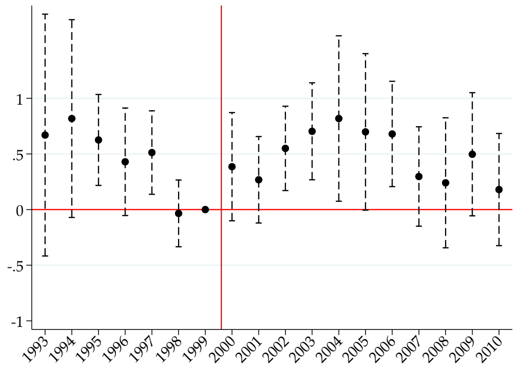
(a) Entrant Swiss residents



(b) Entrant Swiss nationals (subsample)



(c) Incumbent Swiss residents



(d) Incumbent Swiss nationals (subsample)

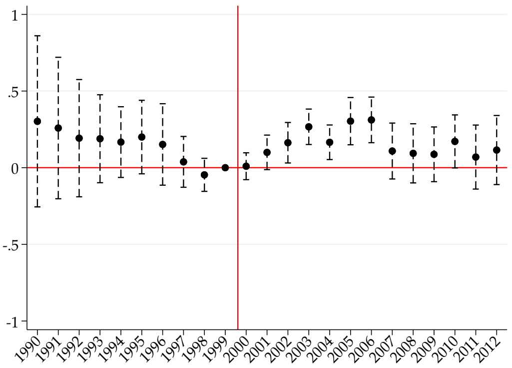
Notes: In panels (a) and (c) the dependent variable is the number of Swiss-resident inventors active in MS region m in year t. Panels (b) and (d) report equivalent estimates using the sample of Swiss national inventors (identified through PCT nationality information). The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include MS region and year fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 1449; Pseudo R^2 = 0.865. Panel (b): N = 986; Pseudo R^2 = 0.626. Panel (c): N = 1403; Pseudo R^2 = 0.872. Panel (d): N = 972; Pseudo R^2 = 0.717.

Table D10: Active Swiss inventors: difference-in-differences results

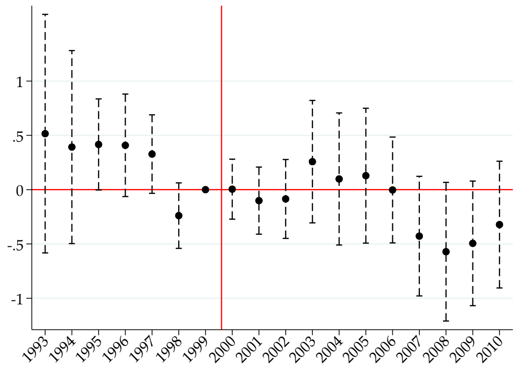
	Swiss residents (1)	Swiss nationals (2)	Entrant Swiss residents (3)	Entrant Swiss nationals (4)	Incumbent Swiss residents (5)	Incumbent Swiss nationals (6)
AFMP × Treated	0.013	-0.469**	0.007	-0.623***	0.161	0.095
	(0.113)	(0.207)	(0.103)	(0.208)	(0.115)	(0.141)
Observations	1449	1044	1449	986	1403	972
Pseudo R^2	0.905	0.767	0.864	0.616	0.870	0.712
MS region FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓

Notes: The dependent variable is the number of inventors resident in Switzerland or with Swiss nationality (EPO-PCT subsample) active in MS region m in year t. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

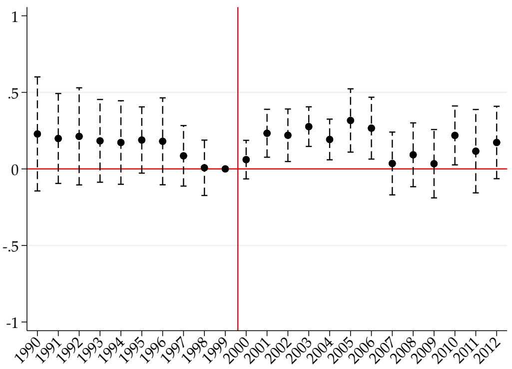
Figure D10: Active Swiss inventors: event study results (including non-border region in the control group)



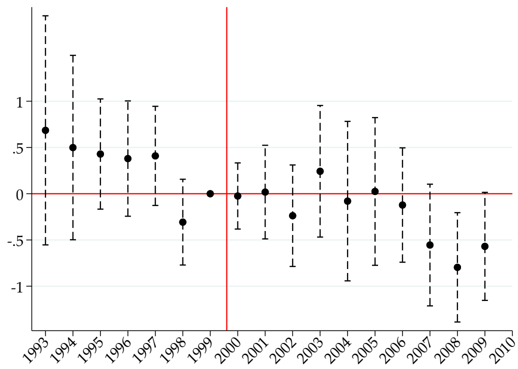
(a) Swiss residents



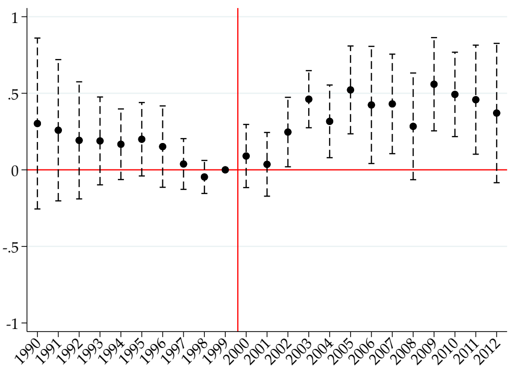
(b) Swiss nationals (subsample)



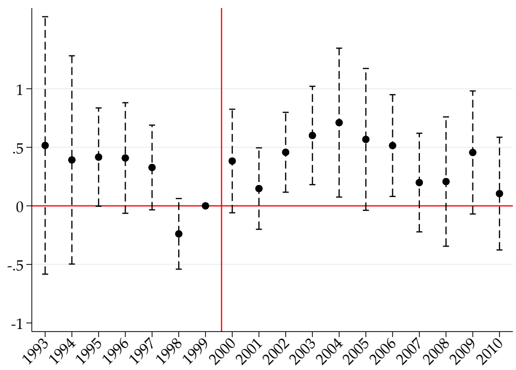
(c) Entrant Swiss residents



(d) Entrant Swiss nationals (subsample)



(e) Incumbent Swiss residents



(f) Incumbent Swiss nationals (subsample)

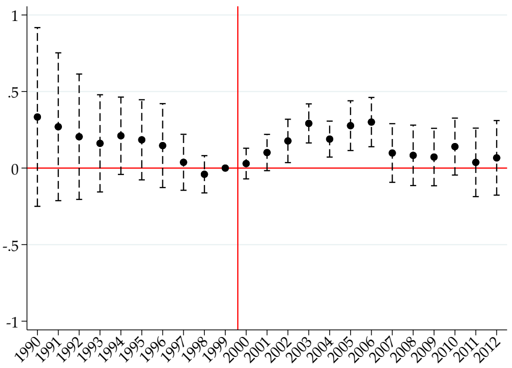
Notes: In panels (a), (c), and (e) the dependent variable is the number of Swiss-resident inventors active in MS region m in year t. Panels (b), (d), and (f) report equivalent estimates using the sample of Swiss national inventors (identified through PCT nationality information). The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes and all MS regions in the non-border region. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimation by Poisson pseudo-maximum-likelihood. Panel (a): N = 2438; Pseudo R^2 = 0.901. Panel (b): N = 1746; Pseudo R^2 = 0.753. Panel (c): N = 2438; Pseudo R^2 = 0.855. Panel (d): N = 935; Pseudo R^2 = 0.606. Panel (e): N = 2392; Pseudo R^2 = 0.867. Panel (f): N = 1548; Pseudo R^2 = 0.688.

Table D11: Active Swiss inventors: difference-in-differences results (including non-border region in the control group)

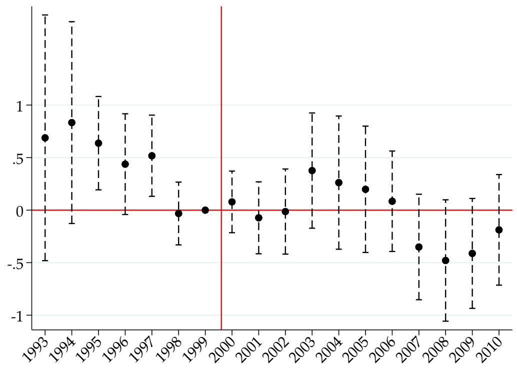
	Swiss residents	Swiss nationals	Entrant Swiss residents	Entrant Swiss nationals	Incumbent Swiss residents	Incumbent Swiss nationals
	(1)	(2)	(3)	(4)	(5)	(6)
AFMP × Treated	0.028	-0.429**	0.042	-0.559***	0.167	0.150
	(0.092)	(0.193)	(0.085)	(0.188)	(0.107)	(0.128)
Observations	2438	1746	2438	1649	2392	1548
Pseudo R^2	0.900	0.747	0.854	0.599	0.866	0.684
MS region FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. The dependent variable is the number of inventors resident in Switzerland or with Swiss nationality (EPO-PCT subsample) active in MS region m in year t. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes and all MS regions in the non-border region. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

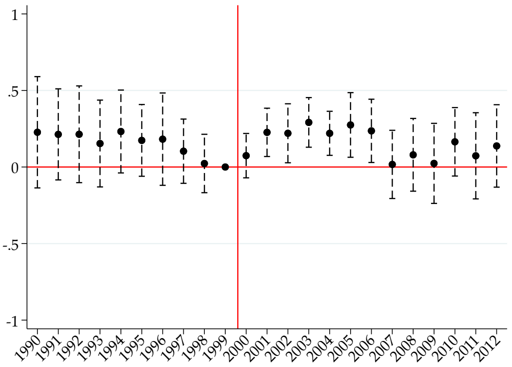
Figure D11: Active Swiss inventors: event study results (including NUTS-2-specific time trends)



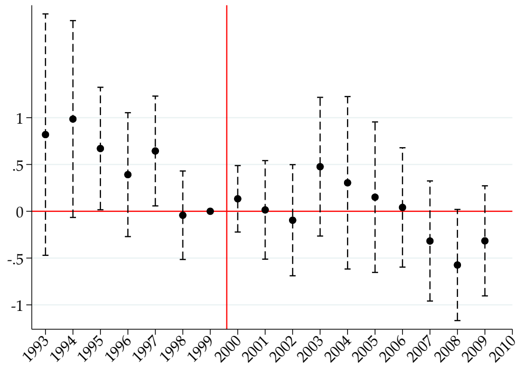
(a) Swiss residents



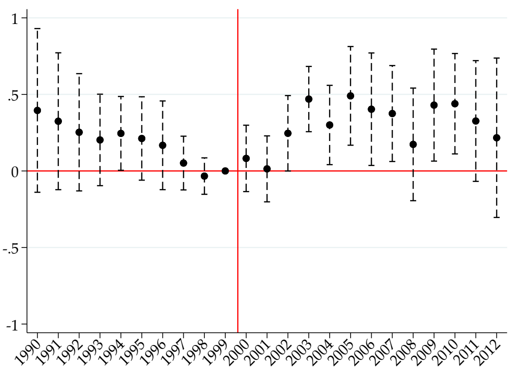
(b) Swiss nationals (subsample)



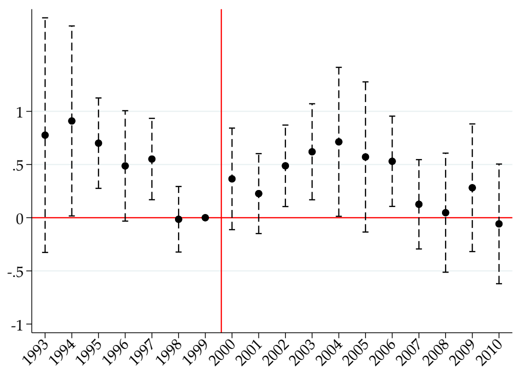
(c) Entrant Swiss residents



(d) Entrant Swiss nationals (subsample)



(e) Incumbent Swiss residents



(f) Incumbent Swiss nationals (subsample)

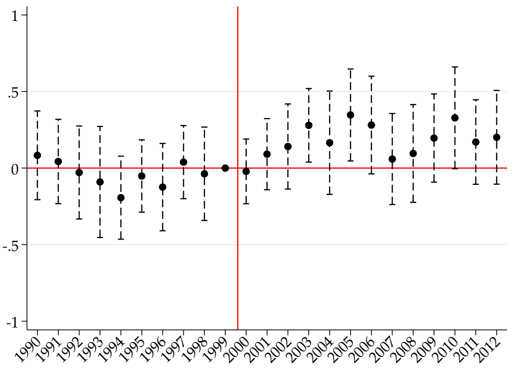
Notes: In panels (a), (c), and (e) the dependent variable is the number of Swiss-resident inventors active in MS region m in year t. Panels (b), (d), and (f) report equivalent estimates using the sample of Swiss national inventors (identified through PCT nationality information). The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include MS region fixed effects, year fixed effects, and NUTS-2-specific time trends. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 1449; Pseudo $R^2 = 0.907$. Panel (b): N = 1044; Pseudo $R^2 = 0.776$. Panel (c): N = 1449; Pseudo $R^2 = 0.865$. Panel (d): N = 986; Pseudo $R^2 = 0.630$. Panel (e): N = 1403; Pseudo $R^2 = 0.872$. Panel (f): N = 972; Pseudo $R^2 = 0.721$.

Table D12: Active Swiss inventors: difference-in-differences results (including NUTS-2-specific time trends)

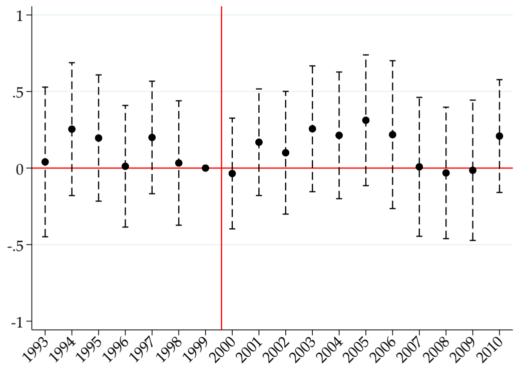
	Swiss residents (1)	Swiss nationals (2)	Entrant Swiss residents (3)	Entrant Swiss nationals (4)	Incumbent Swiss residents (5)	Incumbent Swiss nationals (6)
AFMP × Treated	0.152**	0.051	0.164**	0.101	0.255	0.442*
	(0.067)	(0.132)	(0.068)	(0.199)	(0.166)	(0.234)
Observations	1449	1044	1449	986	1403	972
Pseudo R^2	0.920	0.792	0.877	0.650	0.880	0.731
MS region FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. The dependent variable is the number of inventors resident in Switzerland or with Swiss nationality (EPO-PCT subsample) active in MS region m in year t. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include MS region fixed effects, year fixed effects, and NUTS-2-specific time trends. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

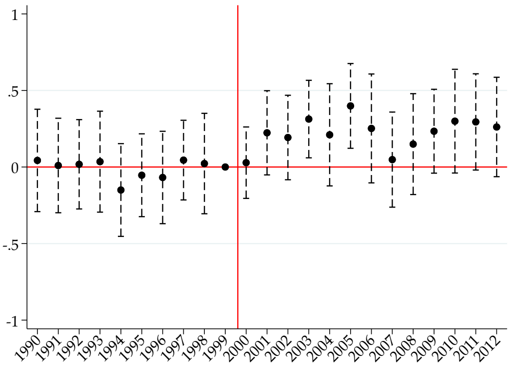
Figure D12: Active Swiss inventors: event study results (OLS)



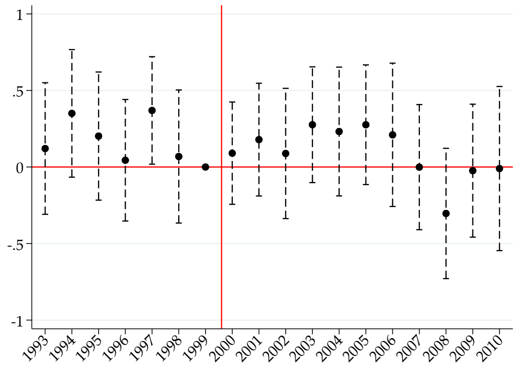
(a) Swiss residents



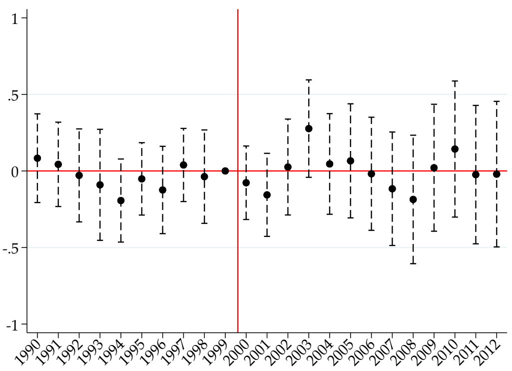
(b) Swiss nationals (subsample)



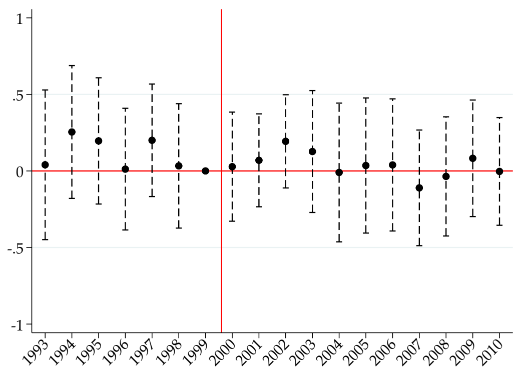
(c) Entrant Swiss residents



(d) Entrant Swiss nationals (subsample)



(e) Incumbent Swiss residents



(f) Incumbent Swiss nationals (subsample)

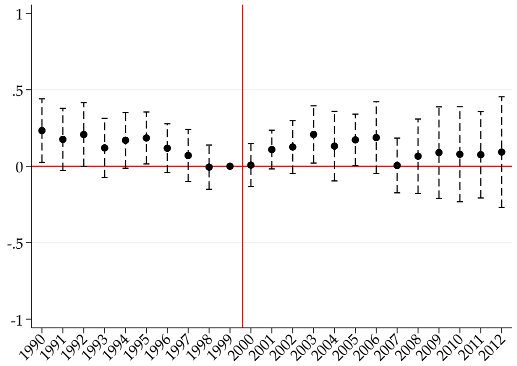
Notes: In panels (a), (c), and (e) the dependent variable is the logarithmic transformation ($log(1+inventors)$) of the number of Swiss-resident inventors active in MS region m in year t. Panels (b), (d), and (f) report equivalent estimates using the sample of Swiss national inventors (identified through PCT nationality information). The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include MS region and year fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 1449; R^2 = 0.933. Panel (b): N = 1134; R^2 = 0.806. Panel (c): N = 1449; R^2 = 0.906. Panel (d): N = 1134; R^2 = 0.683. Panel (e): N = 1449; R^2 = 0.905. Panel (f): N = 1134; R^2 = 0.775.

Table D13: Active Swiss inventors: difference-in-differences results (OLS)

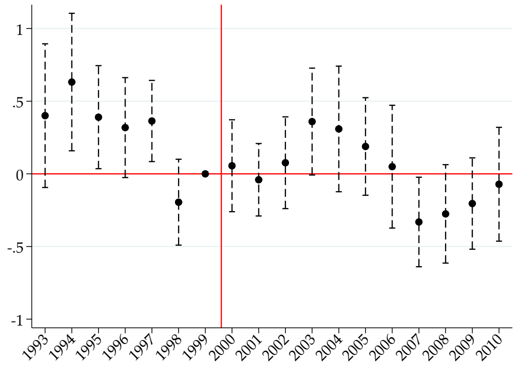
	Swiss residents	Swiss nationals	Entrant Swiss residents	Entrant Swiss nationals	Incumbent Swiss residents	Incumbent Swiss nationals
	(1)	(2)	(3)	(4)	(5)	(6)
AFMP × Treated	0.223***	0.043	0.240***	-0.064	0.012	-0.078
	(0.080)	(0.112)	(0.084)	(0.092)	(0.116)	(0.093)
Observations	1449	1134	1449	1134	1449	1134
R^2	0.932	0.804	0.906	0.677	0.904	0.773
MS region FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. The dependent variable is the logarithmic transformation ($log(1 + inventors)$) of the number of inventors resident in Switzerland or with Swiss nationality (EPO-PCT subsample) active in MS region m in year t. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Ordinary Least Squares.

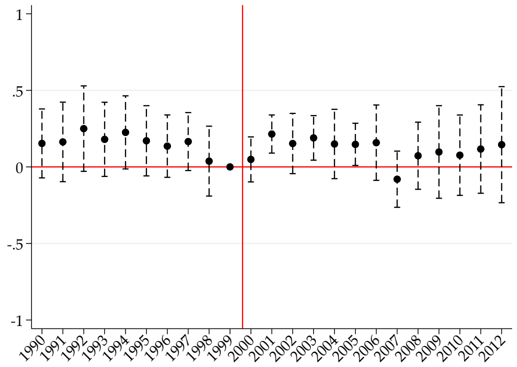
Figure D13: Active Swiss inventors: event study results (alternative location assignment: inventor residential address)



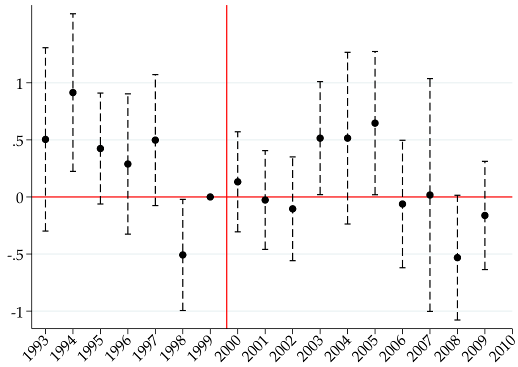
(a) Swiss residents



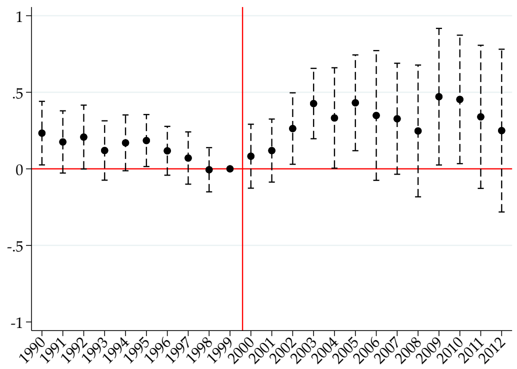
(b) Swiss nationals (subsample)



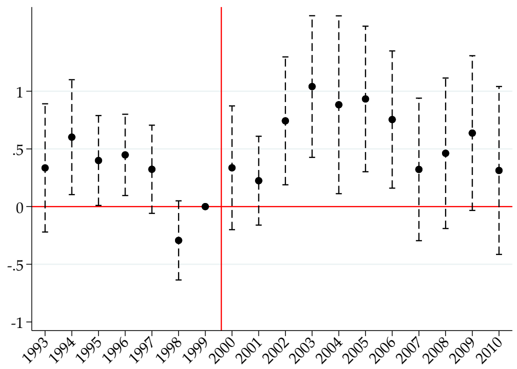
(c) Entrant Swiss residents



(d) Entrant Swiss nationals (subsample)



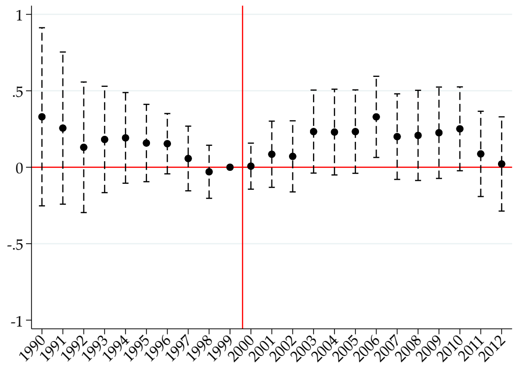
(e) Incumbent Swiss residents



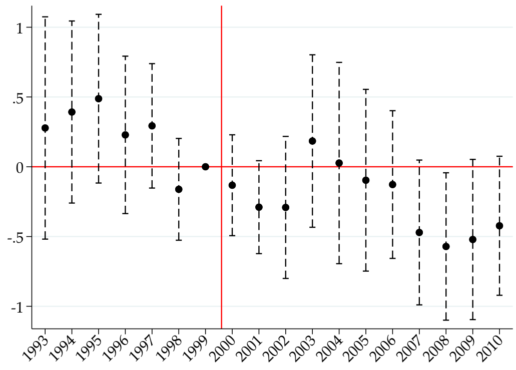
(f) Incumbent Swiss nationals (subsample)

Notes: Inventors are assigned to their MS region of residence instead of the MS region associated to their R&D location. In panels (a), (c), and (e) the dependent variable is the number of Swiss-resident inventors active in MS region m in year t. Panels (b), (d), and (f) report equivalent estimates using the sample of Swiss national inventors (identified through PCT nationality information). The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include MS region fixed effects and year fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimation by Poisson pseudo-maximum-likelihood. Panel (a): N = 1449; Pseudo R^2 = 0.888. Panel (b): N = 1116; Pseudo R^2 = 0.722. Panel (c): N = 1449; Pseudo R^2 = 0.839. Panel (d): N = 1054; Pseudo R^2 = 0.577. Panel (e): N = 1449; Pseudo R^2 = 0.844. Panel (f): N = 1062; Pseudo R^2 = 0.687.

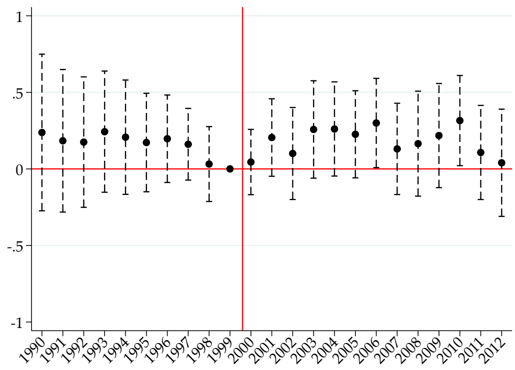
Figure D14: Active Swiss inventors: event study results (alternative location assignment: applicant location)



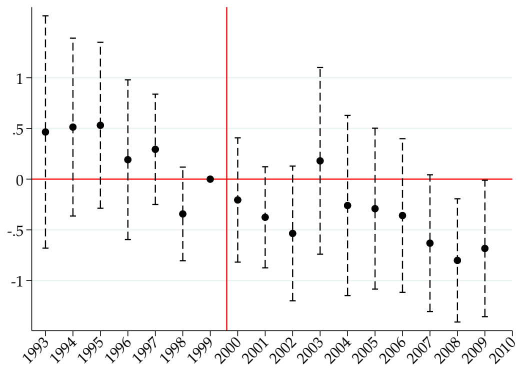
(a) Swiss residents



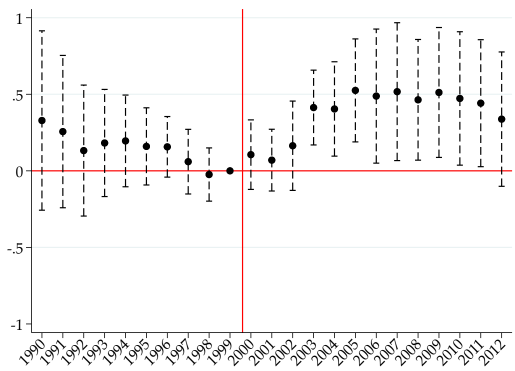
(b) Swiss nationals (subsample)



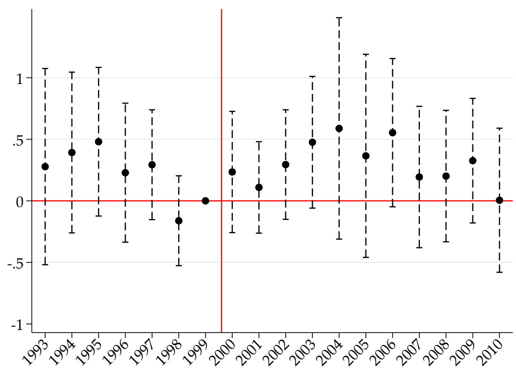
(c) Entrant Swiss residents



(d) Entrant Swiss nationals (subsample)



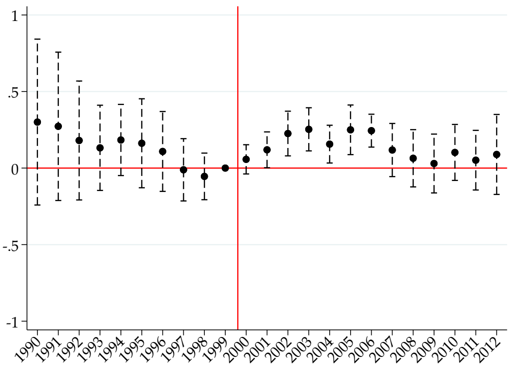
(e) Incumbent Swiss residents



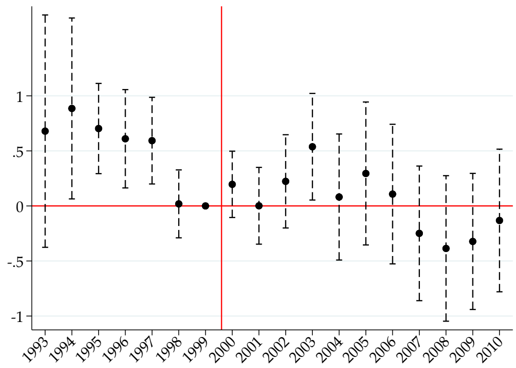
(f) Incumbent Swiss nationals (subsample)

Notes: Inventors are assigned to the MS region of their applicant instead of the MS region associated to their R&D location. In panels (a), (c), and (e) the dependent variable is the number of Swiss-resident inventors active in MS region m in year t. Panels (b), (d), and (f) report equivalent estimates using the sample of Swiss national inventors (identified through PCT nationality information). The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include MS region fixed effects and year fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimation by Poisson pseudo-maximum-likelihood. Panel (a): N = 1449; Pseudo R^2 = 0.901. Panel (b): N = 1080; Pseudo R^2 = 0.79. Panel (c): N = 1449; Pseudo R^2 = 0.856. Panel (d): N = 1020; Pseudo R^2 = 0.648. Panel (e): N = 1403; Pseudo R^2 = 0.878. Panel (f): N = 1008; Pseudo R^2 = 0.781.

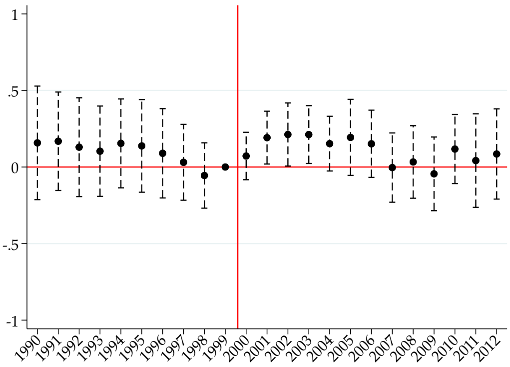
Figure D15: Active Swiss inventors: event study results (only granted patents)



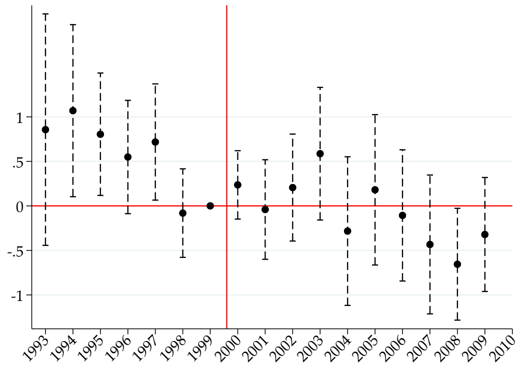
(a) Swiss residents



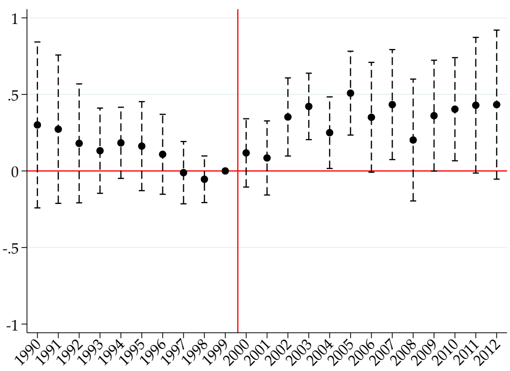
(b) Swiss nationals (subsample)



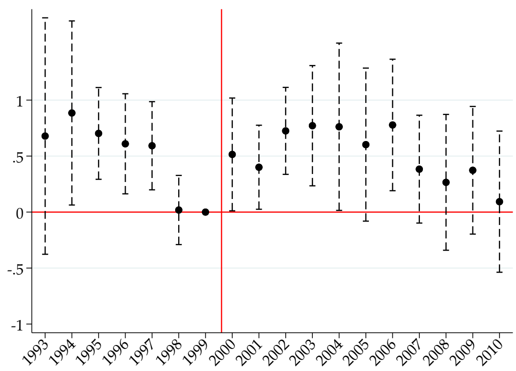
(c) Entrant Swiss residents



(d) Entrant Swiss nationals (subsample)



(e) Incumbent Swiss residents



(f) Incumbent Swiss nationals (subsample)

Notes: In panels (a), (c), and (e) the dependent variable is the number of Swiss-resident inventors active in MS region m in year t. Panels (b), (d), and (f) report equivalent estimates using the sample of Swiss national inventors (identified through PCT nationality information). We count only inventors listed on granted patents. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes and all MS regions in the non-border region. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimation by Poisson pseudo-maximum-likelihood. Panel (a): N = 1426; Pseudo R^2 = 0.888. Panel (b): N = 990; Pseudo R^2 = 0.735. Panel (c): N = 1426; Pseudo R^2 = 0.835. Panel (d): N = 935; Pseudo R^2 = 0.580. Panel (e): N = 1403; Pseudo R^2 = 0.864. Panel (f): N = 918; Pseudo R^2 = 0.688.

Table D14: Active Swiss inventors: difference-in-differences results (only granted patents)

	Swiss residents (1)	Swiss nationals (2)	Entrant Swiss residents (3)	Entrant Swiss nationals (4)	Incumbent Swiss residents (5)	Incumbent Swiss nationals (6)
AFMP × Treated	0.007	-0.490**	0.004	-0.641***	0.172	0.101
	(0.112)	(0.205)	(0.102)	(0.205)	(0.116)	(0.140)
Observations	1449	1044	1449	986	1403	972
Pseudo R^2	0.905	0.767	0.864	0.617	0.870	0.712
MS region FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓

Notes: The dependent variable is the number of inventors resident in Switzerland or with Swiss nationality (EPO-PCT subsample) active in MS region m in year t. We count only inventors listed on granted patents. The treated group includes all MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

D.4. Regional Analysis: Brain Drain Effects

Figure D16: Treated and control NUTS-3 areas in Austria, France, Germany, and Italy

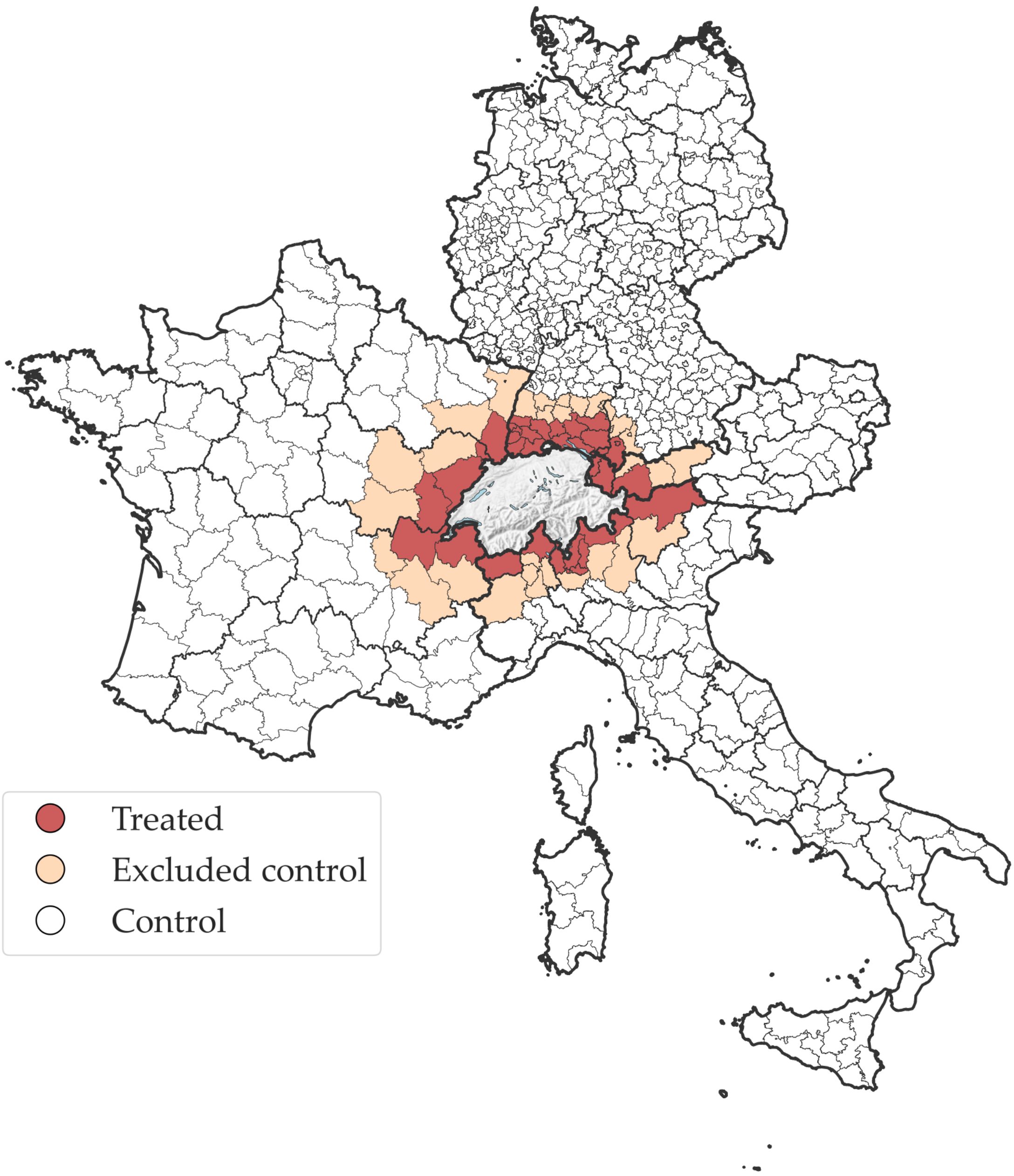
Notes: Treated NUTS-3 regions are those where the pre-AFMP legislation required G-permit holders to reside for at least six months before being eligible to apply for a Permit G to work in Switzerland.

Table D15: Regional patent count in neighbouring regions: difference-in-differences results

	Austria (1)	France (2)	Germany (3)	Italy (4)
AFMP × Treated	0.288***	-0.059	0.063	-0.137
	(0.045)	(0.090)	(0.071)	(0.179)
Observations	759	2189	8944	2224
Pseudo R^2	0.871	0.949	0.914	0.913
NUTS-3 FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓

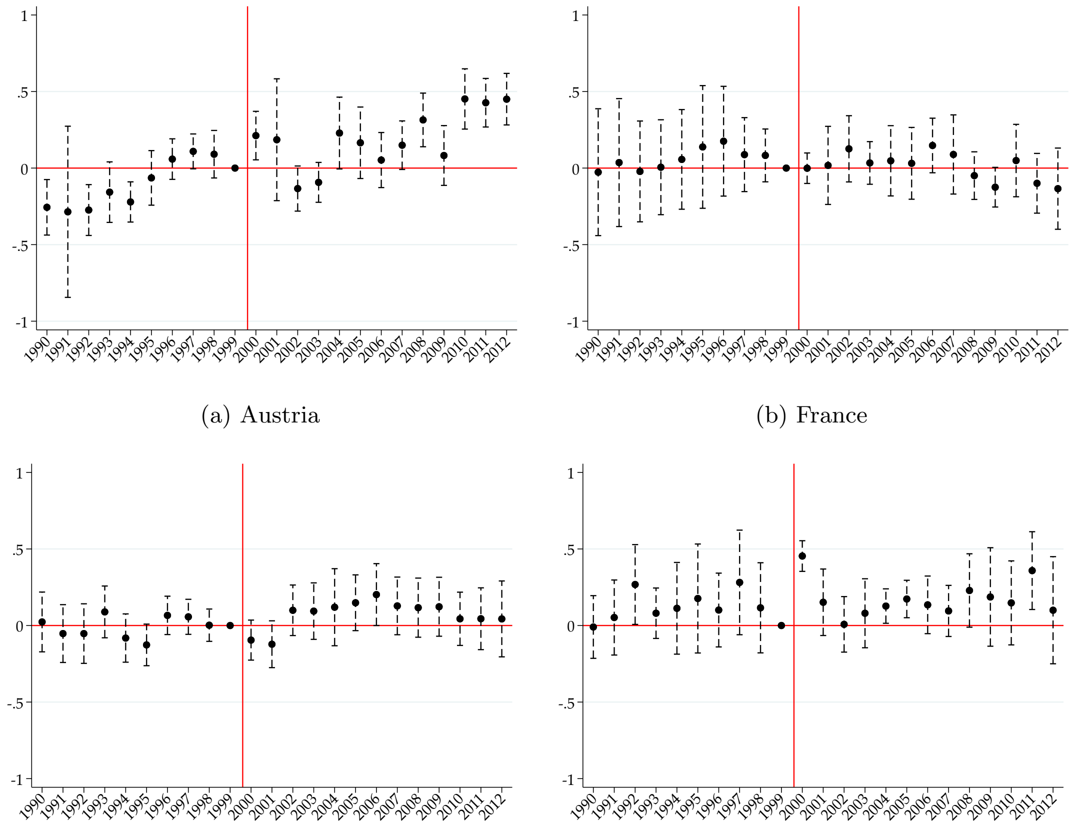
Notes: *** p<0.01, ** p<0.05, * p<0.1. The dependent variable is the number of patents filed in NUTS-3 region m and year t. For each country, the treated group includes Nuts-3 areas where the pre-AFMP legislation required G-permit holders to reside. The control group includes all other NUTS-3 areas. Robust standard errors clustered at the NUTS-3 level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

Figure D17: Treated and control NUTS-3 areas in Austria, France, Germany, and Italy (reduced control group)



Notes: Treated NUTS-3 regions are those where the pre-AFMP legislation required G-permit holders to reside. NUTS-3 areas excluded from the control group are those bordering the treated ones.

Figure D18: Regional patent count in neighbouring regions: event study results (reduced control group)



(a) Austria

(b) France

(c) Germany

(d) Italy

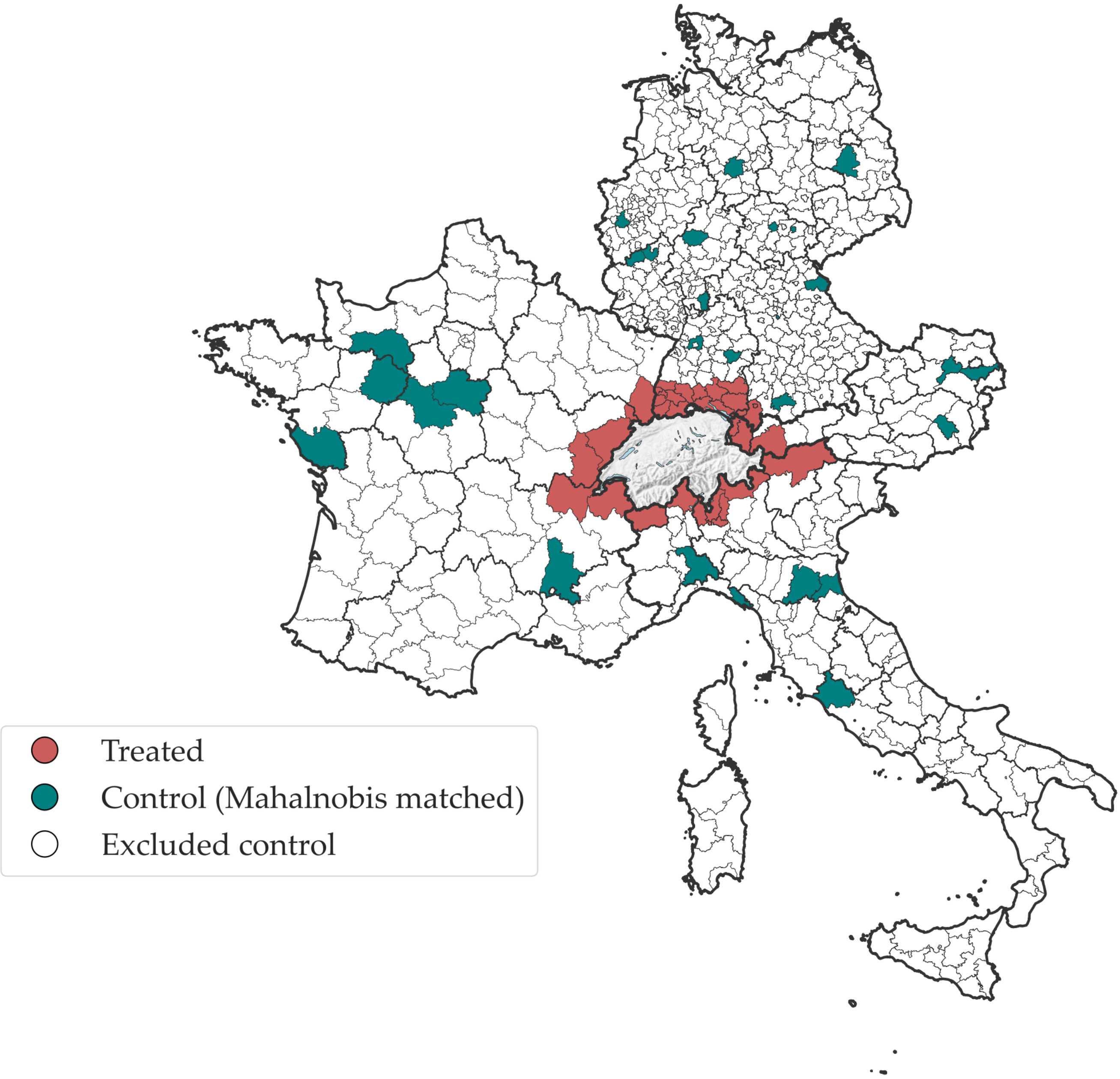
Notes: The dependent variable is the number of patent filings in NUTS-3 area m in year t. For each country, the treated group includes NUTS-3 areas where the pre-AFMP legislation required G-permit holders to reside. The control group includes all other NUTS-3 areas, except those directly bordering the treated ones (see Figure D17). All regressions include NUTS-3 area and year fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the NUTS-3 area level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 690; Pseudo R^2 = 0.881. Panel (b): N = 2005; Pseudo R^2 = 0.947. Panel (c): N = 8646; Pseudo R^2 = 0.916. Panel (d): N = 2017; Pseudo R^2 = 0.864.

Table D16: Regional patent count in neighbouring regions: difference-in-differences results (reduced control group)

	Austria (1)	France (2)	Germany (3)	Italy (4)
AFMP × Treated	0.288***	-0.059	0.079	0.056
	(0.045)	(0.090)	(0.070)	(0.099)
Observations	690	2189	8646	2017
Pseudo R^2	0.879	0.949	0.916	0.863
NUTS-3 FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓

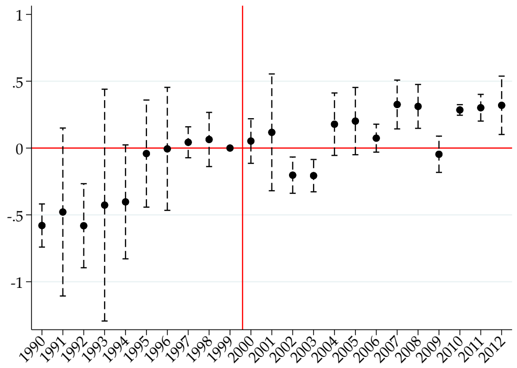
Notes: *** p<0.01, ** p<0.05, * p<0.1. The dependent variable is the number of patent filings in NUTS-3 area m in year t. For each country, the treated group includes NUTS-3 areas where the pre-AFMP legislation required G-permit holders to reside. The control group includes all other NUTS-3 areas, except those directly bordering the treated ones (see Figure D17). Robust standard errors are clustered at the NUTS-3 area level. Estimations by Poisson pseudo-maximum-likelihood.

Figure D19: Treated and control NUTS-3 areas in Austria, France, Germany, and Italy (Mahalanobis matched control group)

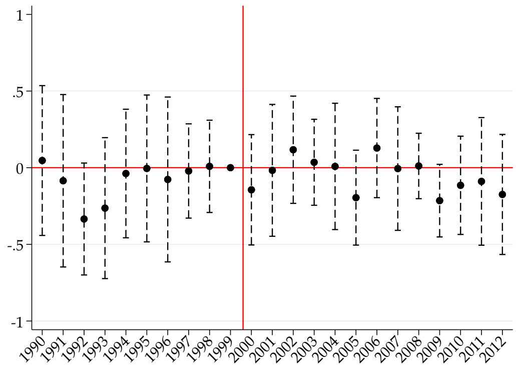


Notes: Treated NUTS-3 regions are the areas where the pre-AFMP legislation required G-permit holders to reside. Control regions are selected via Mahalanobis matching. For each treated region, we select a control that minimizes the normalized Euclidean distance between some selected pre-AFMP features of the two. As matching features, we use the regional average GDP, population, and number of active inventors between 1995 and 1999, as well as the share of patents across the five technology groups of (Schmoch 2008) and across applicants of different size.

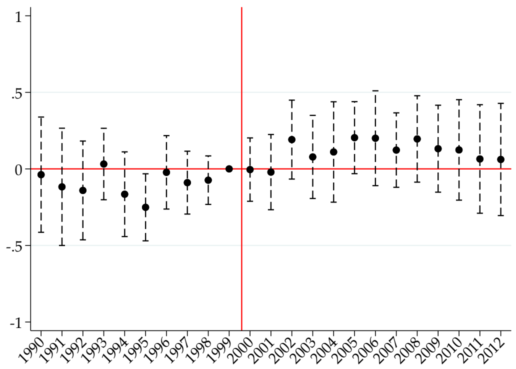
Figure D20: Regional patent count in neighbouring regions: event study results (Mahalanobis matched control group)



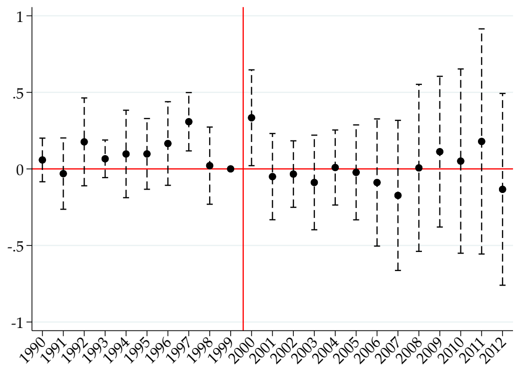
(a) Austria



(b) France



(c) Germany



(d) Italy

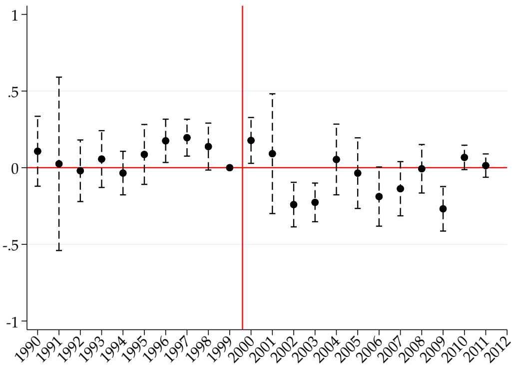
Notes: The dependent variable is the number of patent filings in NUTS-3 area m in year t. For each country, the treated group includes NUTS-3 areas where the pre-AFMP legislation required G-permit holders to reside. The control group includes NUTS-3 areas selected via Mahalanobis matching (see Figure D19). All regressions include NUTS-3 area and year fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the NUTS-3 area level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 136; Pseudo R^2 = 0.883. Panel (b): N = 276; Pseudo R^2 = 0.774. Panel (c): N = 665; Pseudo R^2 = 0.752. Panel (d): N = 269; Pseudo R^2 = 0.902.

Table D17: Regional patent count in neighbouring regions: difference-in-differences results (Mahalanobis matched control group)

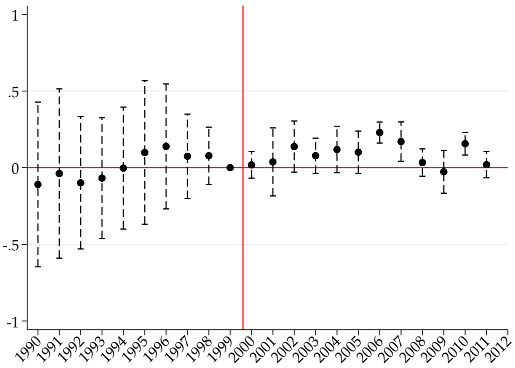
	Austria (1)	France (2)	Germany (3)	Italy (4)
AFMP × Treated	0.359***	0.020	0.196	-0.095
	(0.136)	(0.123)	(0.122)	(0.180)
Observations	136	276	665	269
Pseudo R^2	0.874	0.770	0.750	0.899
NUTS-3 FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. The dependent variable is the number of patent filings in NUTS-3 area m in year t. For each country, the treated group includes NUTS-3 areas where the pre-AFMP legislation required G-permit holders to reside. The control group includes NUTS-3 areas selected via Mahalanobis matching (see Figure D19). Robust standard errors are clustered at the NUTS-3 area level. Estimations by Poisson pseudo-maximum-likelihood.

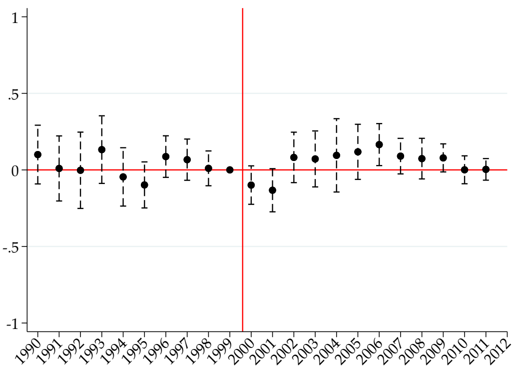
Figure D21: Regional patent count in neighbouring regions: event study results (including NUTS-3-specific time trends)



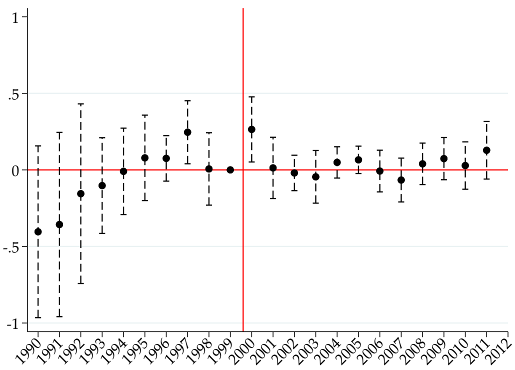
(a) Austria



(b) France



(c) Germany



(d) Italy

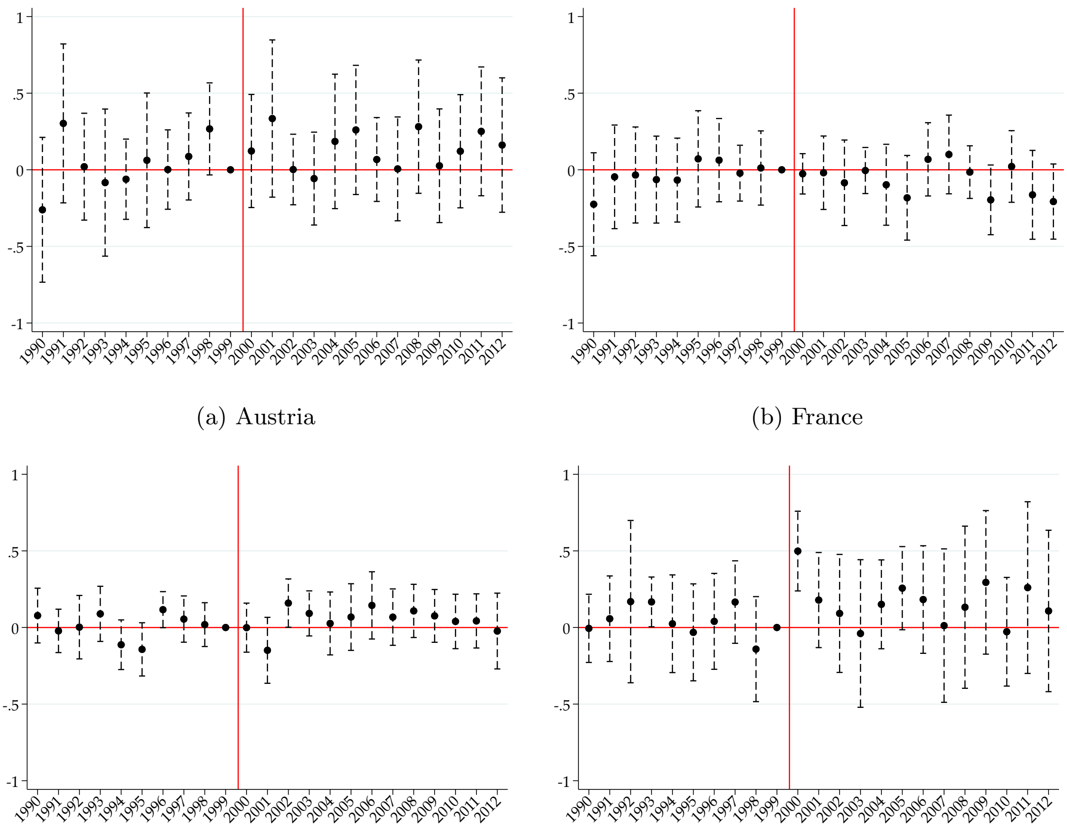
Notes: The dependent variable is the number of patent filings in NUTS-3 area m in year t. For each country, the treated group includes NUTS-3 areas where the pre-AFMP legislation required G-permit holders to reside. The control group includes all other NUTS-3 areas. All regressions include NUTS-3 area and year fixed effects, as well as NUTS-3-specific time trends. Vertical bars represent 95% confidence intervals. The coefficient for baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the NUTS-3 area level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 759; Pseudo R^2 = 0.879. Panel (b): N = 2189; Pseudo R^2 = 0.956. Panel (c): N = 8944; Pseudo R^2 = 0.928. Panel (d): N = 2224; Pseudo R^2 = 0.923.

Table D18: Regional patent count in neighbouring regions: difference-in-differences results (including NUTS-3-specific time trends)

	Austria (1)	France (2)	Germany (3)	Italy (4)
AFMP × Treated	-0.152	0.041	-0.005	-0.024
	(0.158)	(0.061)	(0.088)	(0.052)
Observations	759	2189	8944	2224
Pseudo R^2	0.878	0.956	0.928	0.923
NUTS-3 FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. The dependent variable is the number of patent filings in NUTS-3 area m in year t. For each country, the treated group includes NUTS-3 areas where the pre-AFMP legislation required G-permit holders to reside. The control group includes all other NUTS-3 areas. All regressions include NUTS-3 area and year fixed effects, as well as NUTS-3-specific time trends. Robust standard errors are clustered at the NUTS-3 area level. Estimations by Poisson pseudo-maximum-likelihood.

Figure D22: Regional patent count in neighbouring regions: event study results (OLS)



(a) Austria

(b) France

(c) Germany

(d) Italy

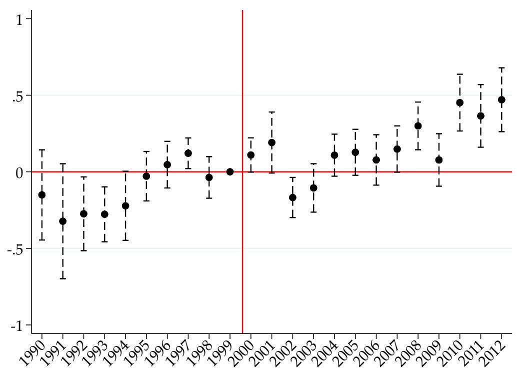
Notes: The dependent variable is the logarithmic transformation ($log(1 + patents)$) of the number of patent filings in NUTS-3 area m in year t. For each country, the treated group includes NUTS-3 areas where the pre-AFMP legislation required G-permit holders to reside. The control group includes all other NUTS-3 areas. All regressions include NUTS-3 area and year fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the NUTS-3 area level. Estimations by Ordinary Least Squares. Panel (a): N = 759; R^2 = 0.919. Panel (b): N = 2189; R^2 = 0.945. Panel (c): N = 8944; R^2 = 0.912. Panel (d): N = 2224; R^2 = 0.932.

Table D19: Regional patent count in neighbouring regions: difference-in-differences results (OLS)

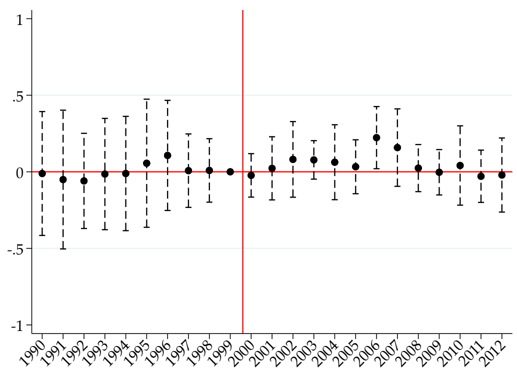
	Austria (1)	France (2)	Germany (3)	Italy (4)
AFMP × Treated	0.174	-0.031	0.042	0.117
	(0.178)	(0.103)	(0.055)	(0.124)
Observations	759	2189	8944	2224
R^2	0.918	0.945	0.912	0.931
NUTS-3 FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. The dependent variable is the logarithmic transformation ($log(1 + patents)$) of the number of patent filings in NUTS-3 area m in year t. For each country, the treated group includes NUTS-3 areas where the pre-AFMP legislation required G-permit holders to reside. The control group includes all other NUTS-3 areas. Robust standard errors are clustered at the NUTS-3 area level. Estimations by Ordinary Least Squares.

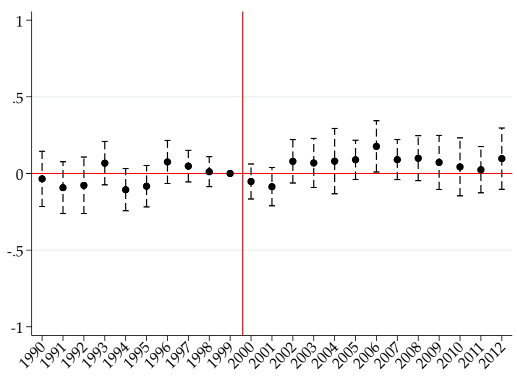
Figure D23: Regional patent count in neighbouring regions: event study results (only granted patents)



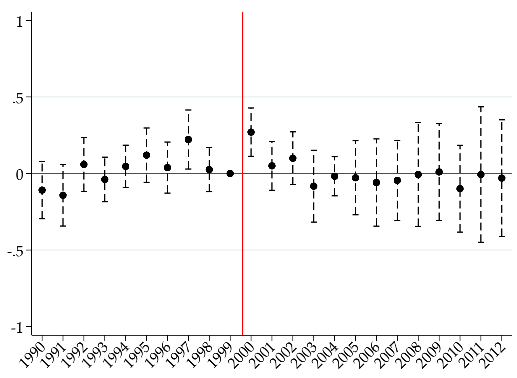
(a) Austria



(b) France



(c) Germany



(d) Italy

Notes: The dependent variable is the number of granted patents filed in NUTS-3 area m in year t. For each country, the treated group includes NUTS-3 areas where the pre-AFMP legislation required G-permit holders to reside. The control group includes all other NUTS-3 areas. All regressions include NUTS-3 area and year fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the NUTS-3 area level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 762; Pseudo $R^2 = 0.844$. Panel (b): N = 2186; Pseudo $R^2 = 0.933$. Panel (c): N = 8944; Pseudo $R^2 = 0.861$. Panel (d): N = 2202; Pseudo $R^2 = 0.889$.

Table D20: Regional patent count in neighbouring regions: difference-in-differences results (only granted patents)

	Austria (1)	France (2)	Germany (3)	Italy (4)
AFMP × Treated	0.274***	0.046	0.072	-0.023
	(0.043)	(0.097)	(0.055)	(0.130)
Observations	762	2186	8944	2202
Pseudo R^2	0.842	0.932	0.861	0.888
NUTS-3 FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The dependent variable is the number of granted patents filed in NUTS-3 region m and year t. For each country, the treated group includes Nuts-3 areas where the pre-AFMP legislation required G-permit holders to reside. The control group includes all other NUTS-3 areas. Robust standard errors clustered at the NUTS-3 level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

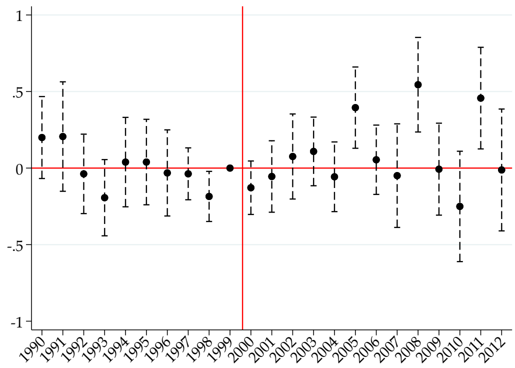
D.5. Inventor-level Analysis: Incumbent Inventors

Table D21: Incumbent inventors' patenting: difference-in-differences results

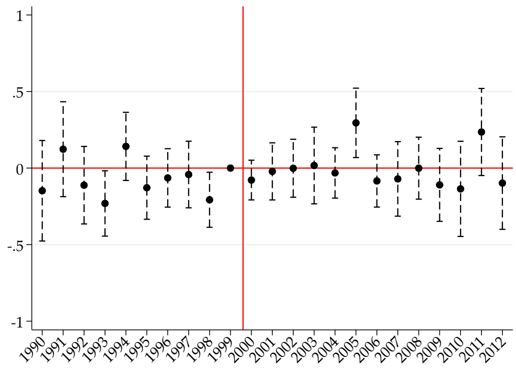
	Patents		**Co-inventors**		**Backward citations to cross-border inventor country prior art**	
	Baseline	Excluding patents with cross-border inventors in team	Baseline	Excluding patents with cross-border inventors in team	Baseline	Excluding patents with cross-border inventors in team
	(1)	(2)	(3)	(4)	(5)	(6)
AFMP × Treated	0.152***	0.064	0.138**	0.132*	0.161*	0.087
	(0.054)	(0.043)	(0.055)	(0.072)	(0.092)	(0.106)
Observations	17490	16995	15536	14569	13879	12744
Pseudo R^2	0.100	0.114	0.274	0.219	0.322	0.295
Inventor FE	✓	✓	✓	✓	✓	✓
MS region FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

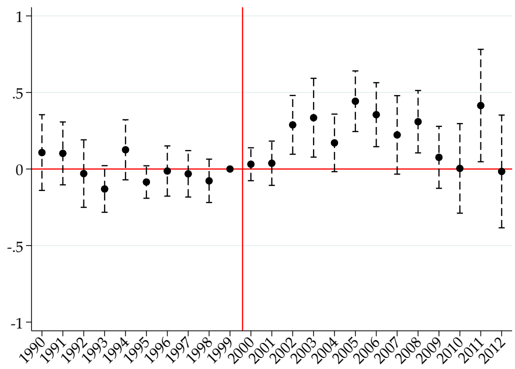
Figure D24: Incumbent inventors' patenting: event-study results (by technology field)



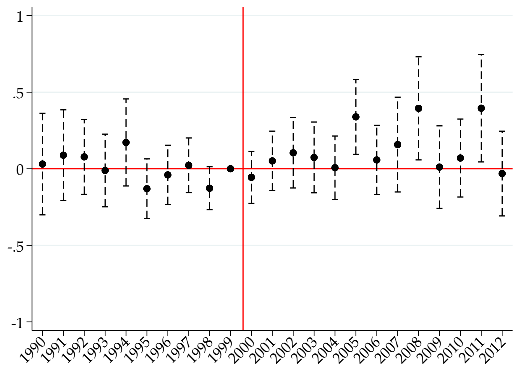
(a) Electrical engineering



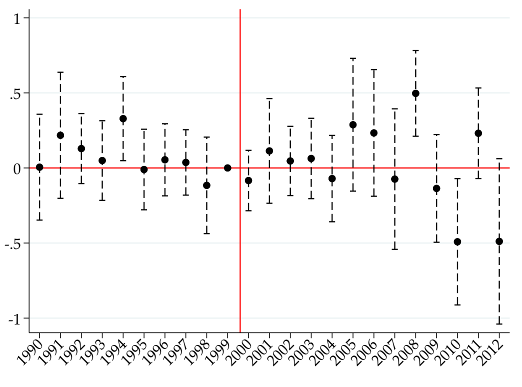
(b) Instruments



(c) Chemicals and pharmaceuticals



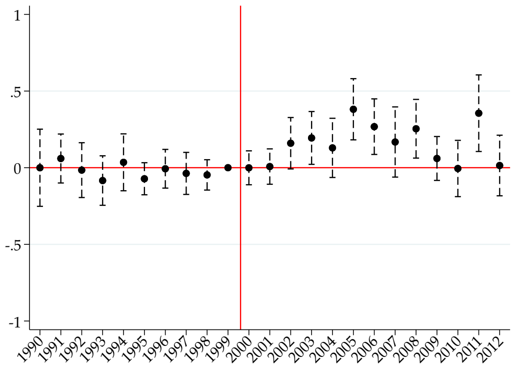
(d) Mechanical engineering



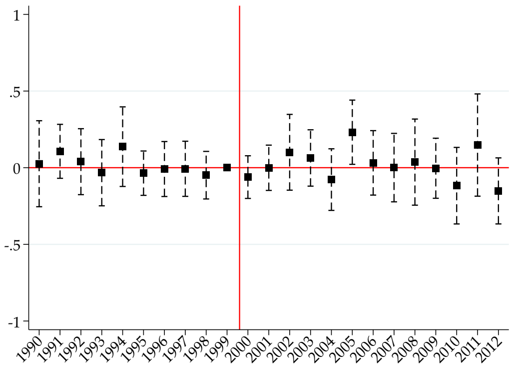
(e) Other

Notes: The dependent variable is the number of patents filed by incumbent inventor i, in MS region m, in year t. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include inventor, year, and MS region fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 5376; Pseudo R^2 = 0.111. Panel (b): N = 7577 ; Pseudo R^2 = 0.104. Panel (c): N = 9906; Pseudo R^2 = 0.119. Panel (d): N = 9811; Pseudo R^2 = 0.107. Panel (e): N = 3455; Pseudo R^2 = 0.133.

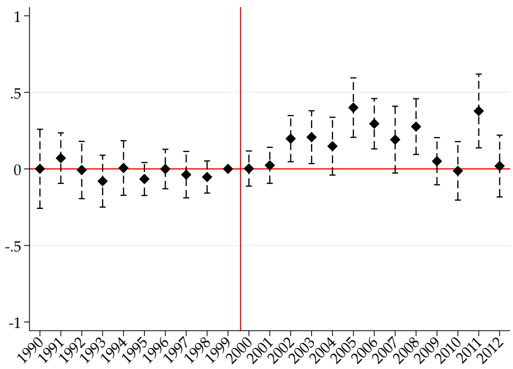
Figure D25: Incumbent inventors' patenting: event-study results (excluding inventors based in Basel or Geneva)



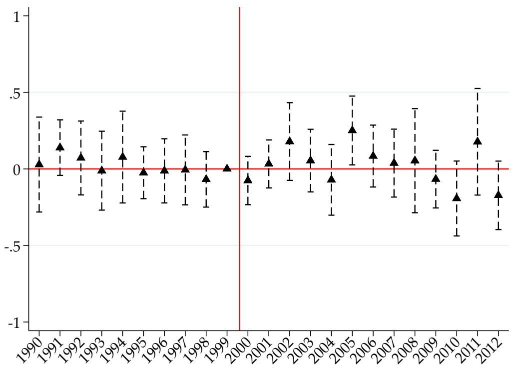
(a) Baseline



(b) Excluding inventors based in Basel



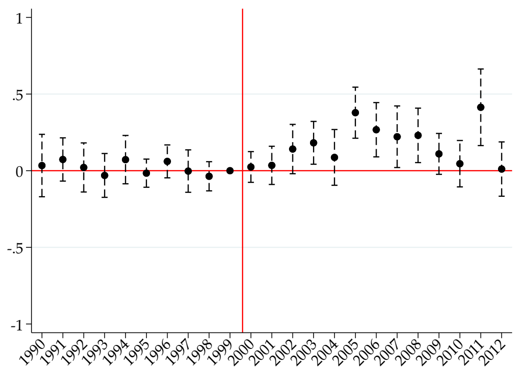
(c) Excluding inventors based in Geneva



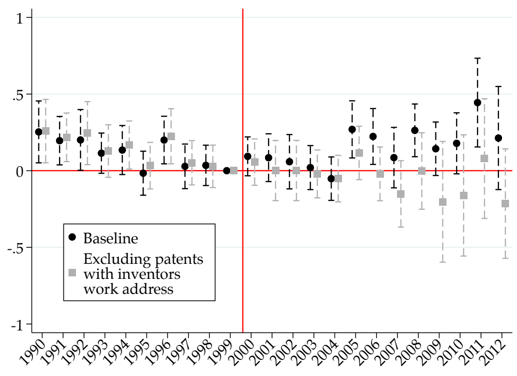
(d) Excluding inventors based in Basel or Geneva

Notes: The dependent variable is the number of patents filed by incumbent inventor i, in MS region m, in year t. The treated group includes all incumbent inventors located in MS regions in the BR whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the BR whose driving distance from the closest border crossing is above 20 minutes. All regressions include inventor, year, and MS region fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 17490; Pseudo R^2 = 0.101. Panel (b): N = 13814 ; Pseudo R^2 = 0.0918. Panel (c): N = 16822; Pseudo R^2 = 0.103. Panel (d): N = 13153; Pseudo R^2 = 0.0934.

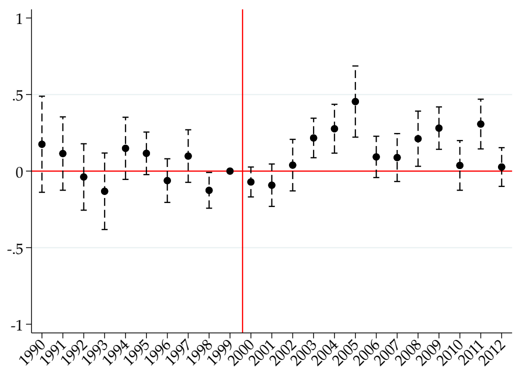
Figure D26: Incumbent inventors' patenting: event-study results (including non-border region inventors in the control group)



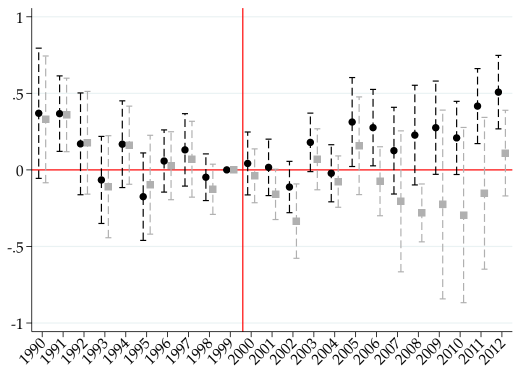
(a) Patents



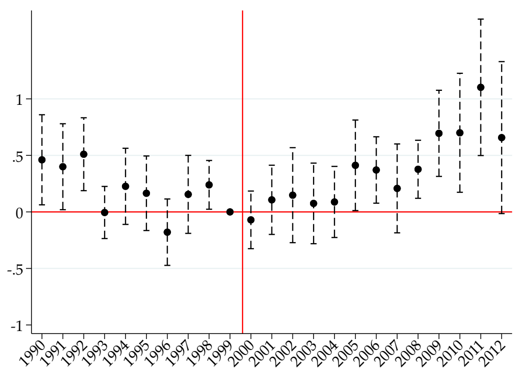
(b) Patents (excl. cross-border inventors)



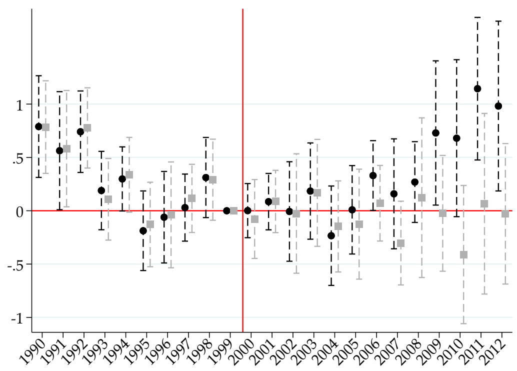
(c) Distinct co-inventors



(d) Distinct co-inventors (excl. cross-border inventors)



(e) Cites to cross-border inventor-country prior-art



(f) Cites to cross-border inventor-country prior-art (excl. cross-border inventors)

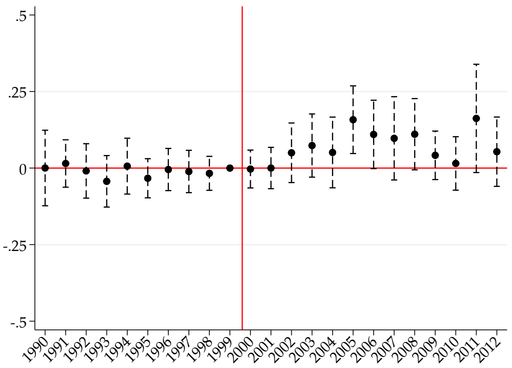
Notes: The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes and all incumbent inventors located in the non-border region. All regressions include inventor, year, and MS region fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. In panels (b), (d), and (f), black dots represent the coefficients from regressions where we exclude patents filed by one or more cross-border inventors; gray squares represent the coefficients from regressions where we exclude both patents filed by one or more cross-border inventors *and* patents reporting the inventors' work addresses, rather than their residential one. Panel (a): N = 21811; Pseudo R^2 = 0.104. Panel (b): Baseline: N = 21309; Pseudo R^2 = 0.116; Excl. work address patents: N = 21102 ; Pseudo R^2 = 0.121. Panel (c): N = 19223; Pseudo R^2 = 0.274. Panel (d): Baseline: N = 18220; Pseudo R^2 = 0.223; Excl. work address patents: N = 18044; Pseudo R^2 = 0.224. Panel (e): N = 17349; Pseudo R^2 = 0.333. Panel (f): Baseline: N = 16180; Pseudo R^2 = 0.314; Excl. work address patents: N = 15899; Pseudo R^2 = 0.298.

Table D22: Incumbent inventors' patenting: difference-in-differences results (including non-border region inventors in the control group)

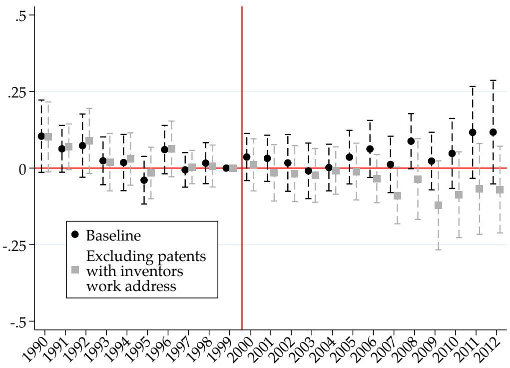
	Patents		**Co-inventors**		**Backward citations to cross-border inventor country prior art**	
	Baseline	Excluding patents with cross-border inventors in team	Baseline	Excluding patents with cross-border inventors in team	Baseline	Excluding patents with cross-border inventors in team
	(1)	(2)	(3)	(4)	(5)	(6)
AFMP × Treated	0.134**	0.042	0.099*	0.084	0.155	0.072
	(0.053)	(0.042)	(0.055)	(0.072)	(0.095)	(0.107)
Observations	21811	21309	19223	18220	17349	16180
Pseudo R^2	0.103	0.116	0.272	0.221	0.329	0.308
Inventor FE	✓	✓	✓	✓	✓	✓
MS region FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes and all incumbent inventors located in the non-border region. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

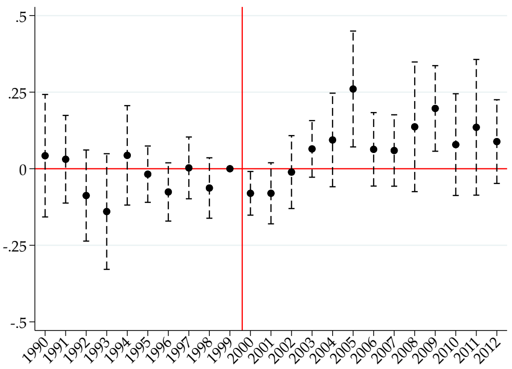
Figure D27: Incumbent inventors' patenting: event-study results (OLS)



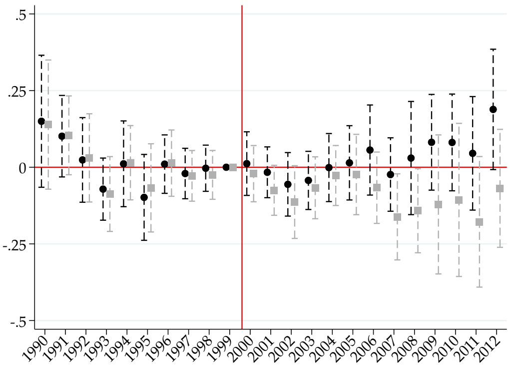
(a) Patents



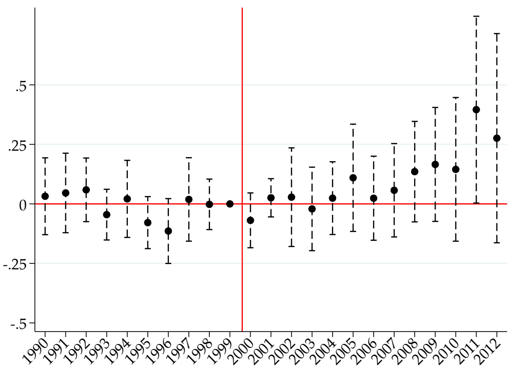
(b) Patents (excl. cross-border inventors)



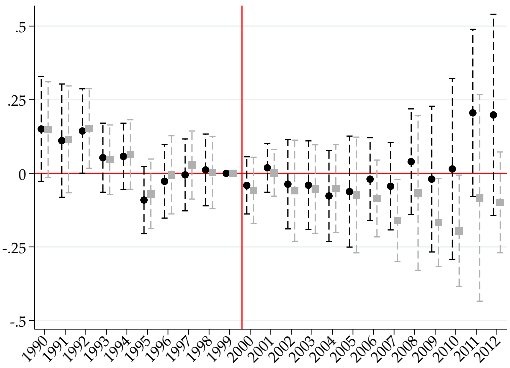
(c) Distinct co-inventors



(d) Distinct co-inventors
(excl. cross-border inventors)



(e) Cites to cross-border inventor-country prior-art



(f) Cites to cross-border inventor-country
prior-art (excl. cross-border inventors)

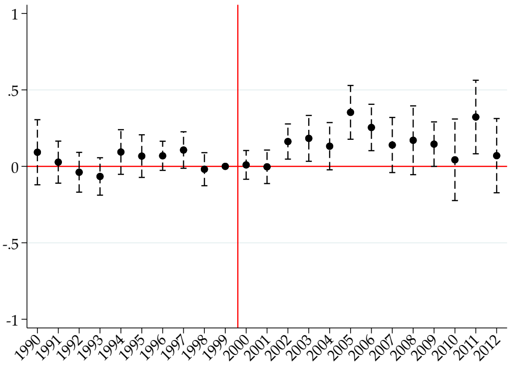
Notes: In panels (a) and (b) the dependent variable is the logarithmic transformation ($log(1 + patents)$) of the number of patents filed by inventor i in MS region m in year t. In panels (b) and (c) the dependent variable is the logarithmic transformation ($log(1 + coinventors)$) of the number of distinct co-inventors collaborating with inventor i in MS region m in year t. In panels (e) and (f) the dependent variable is the logarithmic transformation ($log(1 + citations)$) of the number of citations to cross-border inventor-countries' prior art made by inventor i in MS region m in year t. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include inventor, year, and MS region fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Ordinary Least Squares. In panels (b), (d), and (f), black dots represent the coefficients from regressions where we exclude patents filed by one or more cross-border inventors; gray squares represent the coefficients from regressions where we exclude both patents filed by one or more cross-border inventors *and* patents reporting the inventors' work addresses, rather than their residential one. Panel (a): N = 17490; $R^2 = 0.395$. Panel (b): Baseline: N = 17490; $R^2 = 0.487$; Excl. work address patents: N = 17490 ; $R^2 = 0.531$. Panel (c): N = 17490; $R^2 = 0.637$. Panel (d): Baseline: N = 17490; $R^2 = 0.559$; Excl. work address patents: N = 17490; $R^2 = 0.570$. Panel (e): N = 17490; $R^2 = 0.456$. Panel (f): Baseline: N = 17490; $R^2 = 0.441$; Excl. work address patents: N = 17490; $R^2 = 0.451$.

Table D23: Incumbent inventors' patenting: difference-in-differences results (OLS)

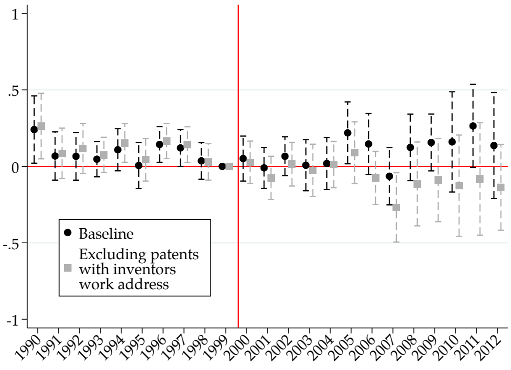
	Patents		**Co-inventors**		**Backward citations to cross-border inventor country prior art**	
	Baseline	Excluding patents with cross-border inventors in team	Baseline	Excluding patents with cross-border inventors in team	Baseline	Excluding patents with cross-border inventors in team
	(1)	(2)	(3)	(4)	(5)	(6)
AFMP × Treated	0.064**	0.015	0.064	0.010	0.060	-0.027
	(0.031)	(0.017)	(0.046)	(0.027)	(0.042)	(0.029)
Observations	17490	17490	17490	17490	17490	17490
R^2	0.393	0.486	0.635	0.558	0.453	0.439
Inventor FE	✓	✓	✓	✓	✓	✓
MS region FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. In columns (1) and (2) the dependent variable is the logarithmic transformation ($log(1 + patents)$) of the number of patents filed by inventor i in MS region m in year t. In columns (3) and (4) the dependent variable is the logarithmic transformation ($log(1 + coinventors)$) of the number of distinct co-inventors collaborating with inventor i in MS region m in year t. In columns (5) and (6) the dependent variable is the logarithmic transformation ($log(1+citations)$) of the number of citations to cross-border inventor-countries' prior art made by inventor i in MS region m in year t. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Ordinary Least Squares.

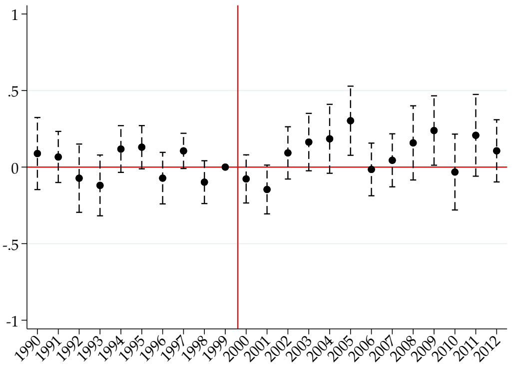
Figure D28: Incumbent inventors patenting: event study results (alternative location assignment: inventor residential address)



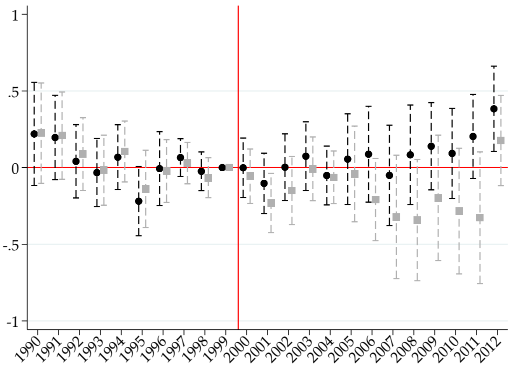
(a) Patents



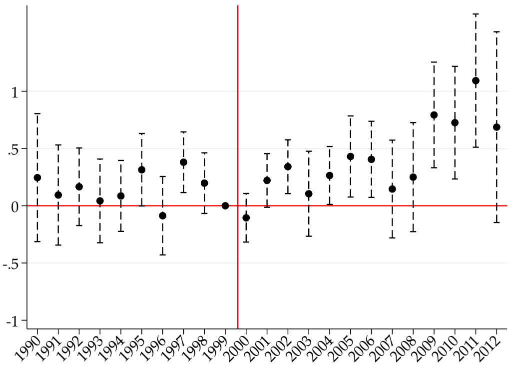
(b) Patents (excl. cross-border inventors)



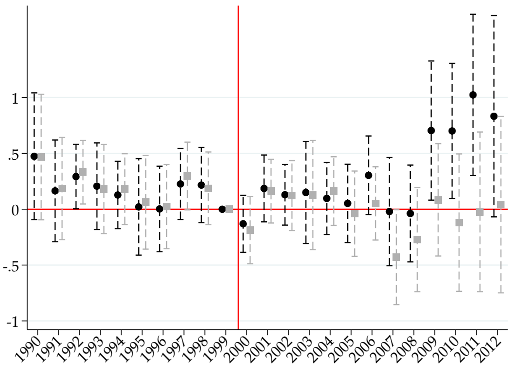
(c) Distinct co-inventors



(d) Distinct co-inventors (excl. cross-border inventors)



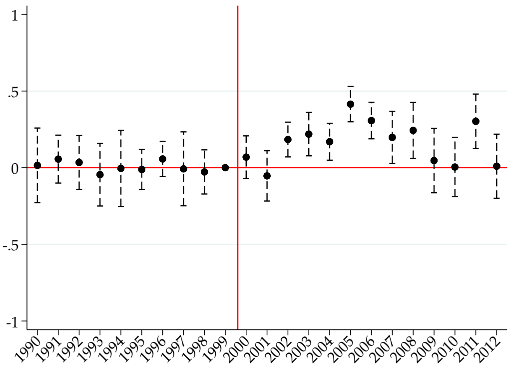
(e) Cites to cross-border inventor-country prior-art



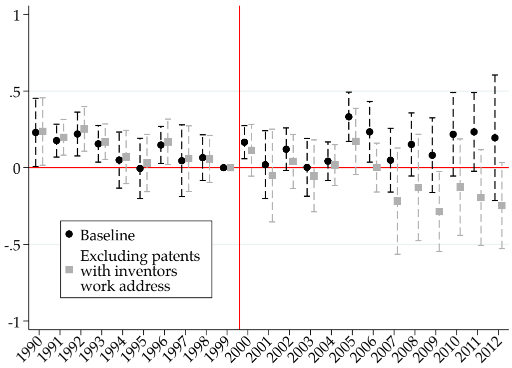
(f) Cites to cross-border inventor-country prior-art (excl. cross-border inventors)

Notes: Inventors are assigned to their MS region of residence instead of the MS region associated to their R&D location. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include inventor, year, and MS region fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. In panels (b), (d), and (f), black dots represent the coefficients from regressions excluding patents from one or more cross-border inventors; gray squares represent the coefficients from regressions excluding both patents filed by one or more cross-border inventors *and* patents reporting the inventors' work addresses. Panel (a): N = 17157; Pseudo R^2 = 0.102. Panel (b): Baseline: N = 16667; Pseudo R^2 = 0.115; Excl. work address patents: N = 16473 ; Pseudo R^2 = 0.121. Panel (c): N = 15217; Pseudo R^2 = 0.277. Panel (d): Baseline: N = 14263; Pseudo R^2 = 0.221; Excl. work address patents: N = 14094; Pseudo R^2 = 0.222. Panel (e): N = 13656; Pseudo R^2 = 0.332. Panel (f): Baseline: N = 12521; Pseudo R^2 = 0.306; Excl. work address patents: N = 12270; Pseudo R^2 = 0.284.

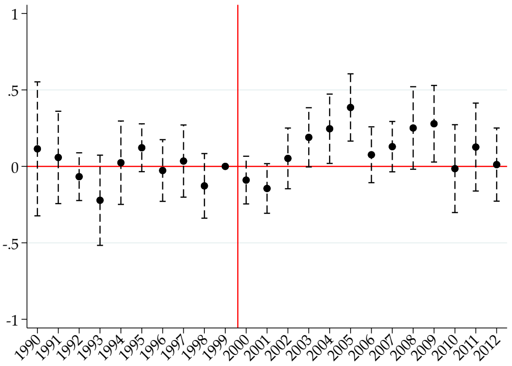
Figure D29: Incumbent inventors patenting: event study results (alternative location assignment: applicant location)



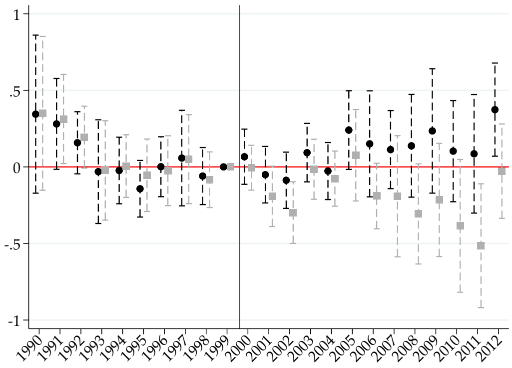
(a) Patents



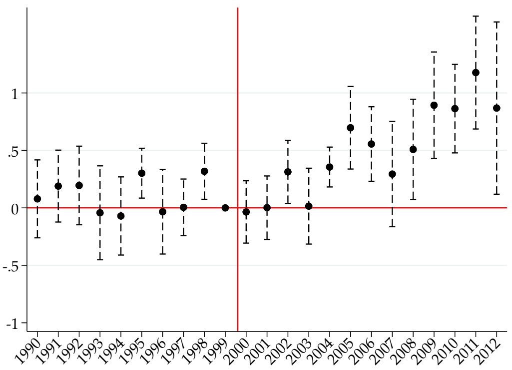
(b) Patents (excl. cross-border inventors)



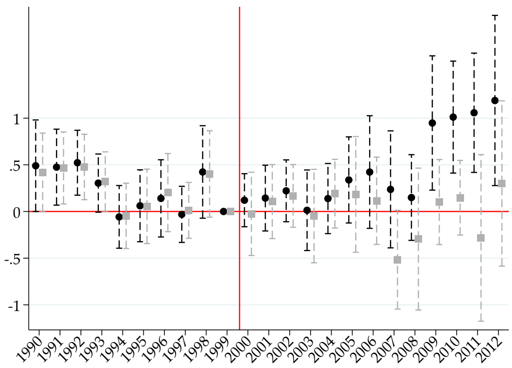
(c) Distinct co-inventors



(d) Distinct co-inventors (excl. cross-border inventors)



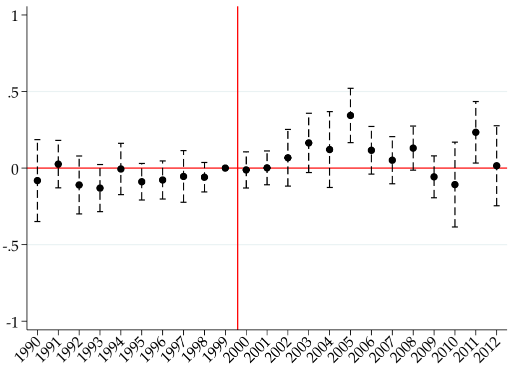
(e) Cites to cross-border inventor-country prior-art



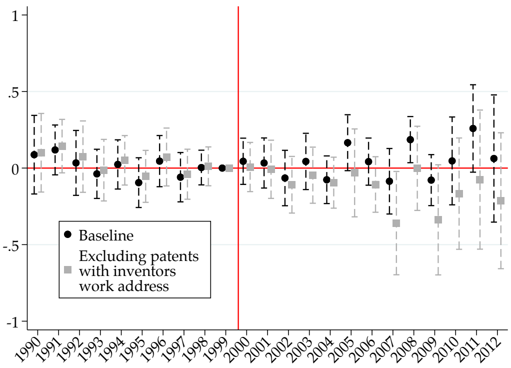
(f) Cites to cross-border inventor-country prior-art (excl. cross-border inventors)

Notes: Inventors are assigned to the applicant's MS region instead of the MS region associated to their R&D location. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include inventor, year, and MS region fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. In panels (b), (d), and (f), black dots represent the coefficients from regressions where we exclude patents filed by one or more cross-border inventors; gray squares represent the coefficients from regressions where we exclude both patents filed by one or more cross-border inventors *and* patents reporting the inventors' work addresses, rather than their residential one. Panel (a): N = 14958; Pseudo R^2 = 0.108. Panel (b): Baseline: N = 14497; Pseudo R^2 = 0.120; Excl. work address patents: N = 14427 ; Pseudo R^2 = 0.126. Panel (c): N = 13490; Pseudo R^2 = 0.282. Panel (d): Baseline: N = 12681; Pseudo R^2 = 0.223; Excl. work address patents: N = 12614; Pseudo R^2 = 0.227. Panel (e): N = 11737; Pseudo R^2 = 0.356. Panel (f): Baseline: N = 10722; Pseudo R^2 = 0.332; Excl. work address patents: N = 10595; Pseudo R^2 = 0.309.

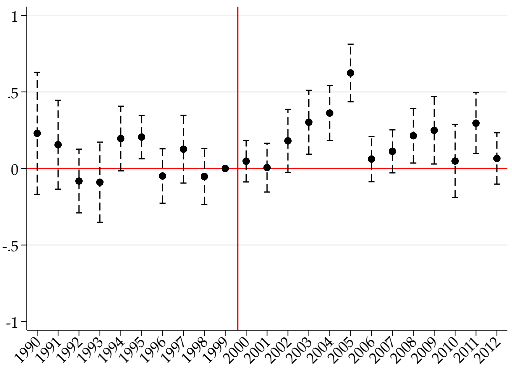
Figure D30: Incumbent inventors' patenting: event study results (only granted patents)



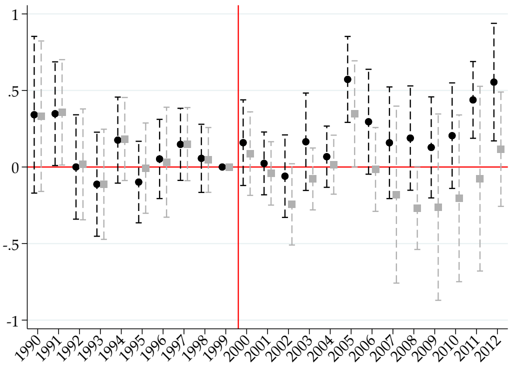
(a) Patents



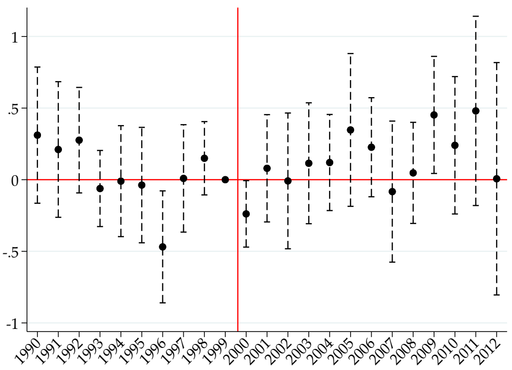
(b) Patents (excl. cross-border inventors)



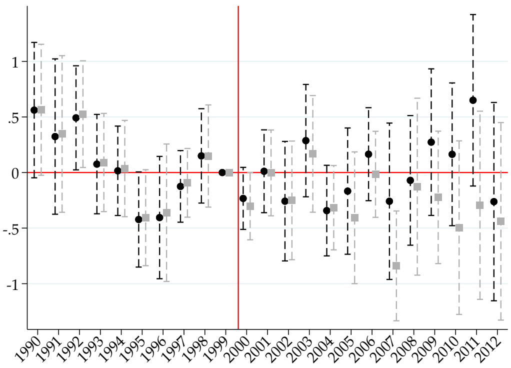
(c) Distinct co-inventors



(d) Distinct co-inventors
(excl. cross-border inventors)



(e) Cites to cross-border inventor-country prior-art



(f) Cites to cross-border inventor-country
prior-art (excl. cross-border inventors)

Notes: The sample is based only on information from granted patents. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. All regressions include inventor, year, and MS region fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. In panels (b), (d), and (f), black dots represent the coefficients from regressions where we exclude patents filed by one or more cross-border inventors; gray squares represent the coefficients from regressions where we exclude both patents filed by one or more cross-border inventors *and* patents reporting the inventors' work addresses, rather than their residential one. Panel (a): N = 14318; Pseudo R^2 = 0.0865. Panel (b): Baseline: N = 13838; Pseudo R^2 = 0.106; Excl. work address patents: N = 13772 ; Pseudo R^2 = 0.109. Panel (c): N = 12752; Pseudo R^2 = 0.269. Panel (d): Baseline: N = 11885; Pseudo R^2 = 0.219; Excl. work address patents: N = 11817; Pseudo R^2 = 0.218. Panel (e): N = 11346; Pseudo R^2 = 0.308. Panel (f): Baseline: N = 10366; Pseudo R^2 = 0.299; Excl. work address patents: N = 10264; Pseudo R^2 = 0.288.

Table D24: Incumbent inventors' patenting: difference-in-differences results (only granted patents)

	Patents		**Co-inventors**		**Backward citations to cross-border inventor country prior art**	
	Baseline	Excluding patents with cross-border inventors in team	Baseline	Excluding patents with cross-border inventors in team	Baseline	Excluding patents with cross-border inventors in team
	(1)	(2)	(3)	(4)	(5)	(6)
AFMP × Treated	0.129**	0.033	0.143**	0.118	0.083	-0.040
	(0.053)	(0.042)	(0.067)	(0.089)	(0.086)	(0.106)
Observations	14318	13838	12752	11885	11346	10366
Pseudo R^2	0.086	0.106	0.267	0.217	0.305	0.295
Inventor FE	✓	✓	✓	✓	✓	✓
MS region FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓

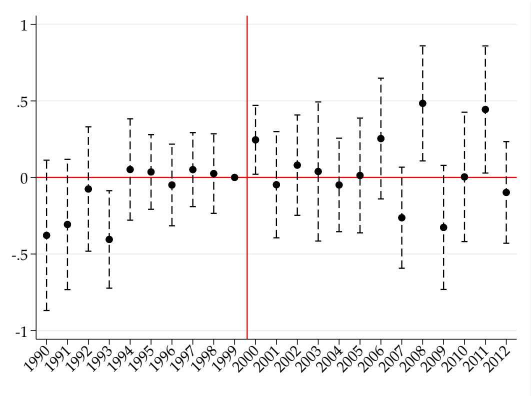
Notes: *** p<0.01, ** p<0.05, * p<0.1. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. The sample is based only on information from granted patents. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

Table D25: Incumbent inventors' patent characteristics: difference-in-differences results

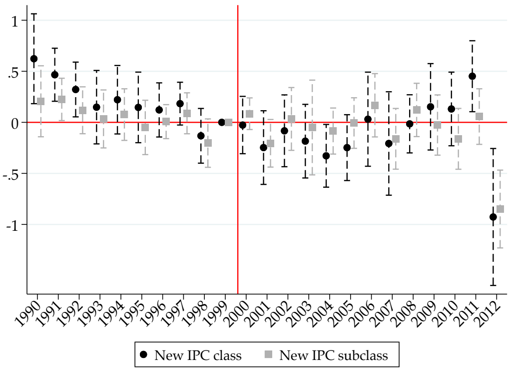
	Patents with novel terms (1)	Patents with new IPC class (2)	Patents with new IPC subclass (3)	Patents with new IPC group (4)	Patents with new IPC subgroup (5)
AFMP × Treated	0.105	-0.192***	-0.043	0.180*	0.179**
	(0.089)	(0.068)	(0.071)	(0.096)	(0.081)
Observations	12123	17462	17472	17477	17490
R^2	0.105	0.162	0.117	0.087	0.089
Inventor FE	✓	✓	✓	✓	✓
MS region FE	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓

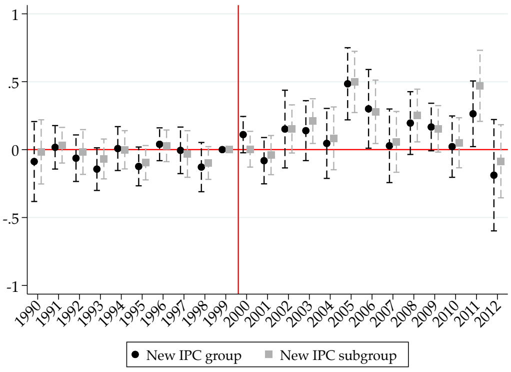
Notes: *** p<0.01, ** p<0.05, * p<0.1. In column (1) the dependent variable is the number of patents filed by inventor i in MS region m in year t containing at least one novel term in their abstract, relative to all EPO patents filed in Switzerland up to the previous year $t-1$. In columns (2), (3), (4), and (5), the dependent variable is the number of patents filed by inventor i in MS region m in year t containing at least one new IPC class, subclass, group, or subgroup relative to all EPO patents filed by inventor i up to the previous year $t-1$. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

Figure D31: Incumbent inventors' patent characteristics: event study results (including non-border region inventors in the control group)



(a) Patents with novel terms





(b) Patents with new IPC class or subclass

(c) Patents with new IPC group or subgroup

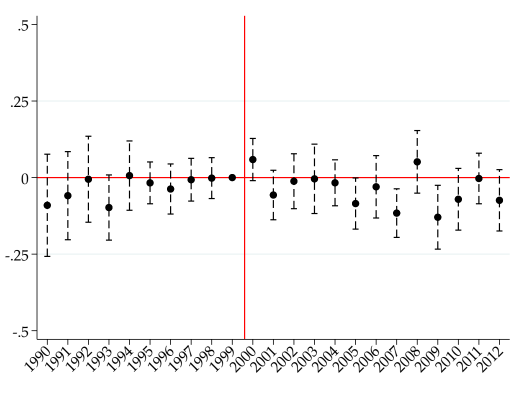
Notes: In panel (a), the dependent variable is the number of patents filed by inventor i in MS region m in year t containing at least one novel term in their abstract, relative to all EPO patents filed in Switzerland up to the previous year $t-1$. In panels (b) and (c), the dependent variable is the number of patents filed by inventor i in year t containing at least one new IPC class, subclass, group, or subgroup relative to all EPO patents filed by inventor i up to the previous year $t-1$. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes and all incumbent inventors located in the non-border region. All regressions include inventor, year, and MS region fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood. Panel (a): N = 14927; Pseudo R^2 = 0.110. Panel (b): New IPC class: N = 21804; Pseudo R^2 = 0.159; New IPC subclass: N = 21807; Pseudo R^2 = 0.118. Panel (c): New IPC group: N = 21807; Pseudo R^2 = 0.0902; New IPC subgroup: N = 21811; Pseudo R^2 = 0.0902.

Table D26: Incumbent inventors' patent characteristics: difference-in-differences results (including non-border region inventors in the control group)

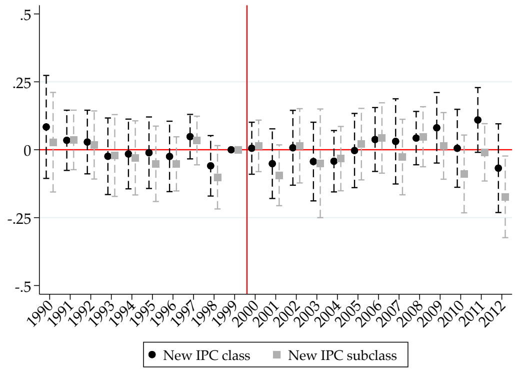
	Patents with novel terms (1)	Patents with new IPC class (2)	Patents with new IPC subclass (3)	Patents with new IPC group (4)	Patents with new IPC subgroup (5)
AFMP × Treated	0.110	-0.213***	-0.045	0.163*	0.164**
	(0.077)	(0.061)	(0.066)	(0.093)	(0.079)
Observations	14927	21804	21807	21807	21811
R^2	0.108	0.158	0.117	0.089	0.089
Inventor FE	✓	✓	✓	✓	✓
MS region FE	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. In column (1) the dependent variable is the number of patents filed by inventor i in MS region m in year t containing at least one novel term in their abstract, relative to all EPO patents filed in Switzerland up to the previous year $t-1$. In columns (2), (3), (4), and (5), the dependent variable is the number of patents filed by inventor i in MS region m in year t containing at least one new IPC class, subclass, group, or subgroup relative to all EPO patents filed by inventor i up to the previous year $t-1$. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes and all incumbent inventors located in the non-border region. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

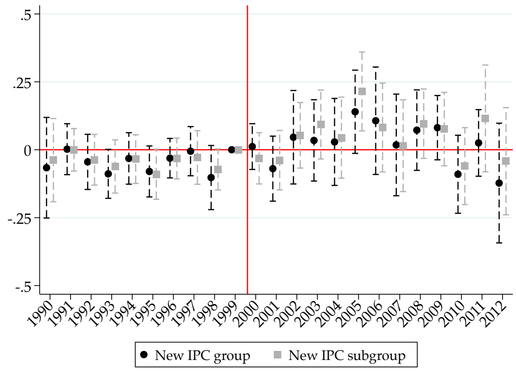
Figure D32: Incumbent inventors' patent characteristics: event study results (OLS)



(a) Patents with novel terms



(b) Patents with new IPC class or subclass



(c) Patents with new IPC group or subgroup

Notes: In panel (a), the dependent variable is the logarithmic transformation ($log(1 + patents)$) of number of patents filed by inventor i in MS region m in year t containing at least one novel term in their abstract, relative to all EPO patents filed in Switzerland up to the previous year $t-1$. In panels (b) and (c), the dependent variable is the logarithmic transformation of number of patents filed by inventor i in year t containing at least one new IPC class, subclass, group, or subgroup relative to all EPO patents filed by inventor i up to the previous year $t-1$. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes and all incumbent inventors located in the non-border region. All regressions include inventor, year, and MS region fixed effects. Vertical bars represent 95% confidence intervals. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Ordinary Least Squares. Panel (a): N = 17490; $R^2 = 0.386$. Panel (b): New IPC class: N = 17490; $R^2 = 0.404$; New IPC subclass: N = 17490; $R^2 = 0.356$. Panel (c): New IPC group: N = 17490; $R^2 = 0.302$; New IPC subgroup: N = 17490; $R^2 = 0.315$.

Table D27: Incumbent inventors' patent characteristics: difference-in-differences results (OLS)

	Patents with novel terms (1)	Patents with new IPC class (2)	Patents with new IPC subclass (3)	Patents with new IPC group (4)	Patents with new IPC subgroup (5)
AFMP × Treated	-0.005	0.001	0.003	0.062	0.074
	(0.017)	(0.026)	(0.032)	(0.055)	(0.050)
Observations	17490	17490	17490	17490	17490
R^2	0.383	0.402	0.353	0.299	0.311
Inventor FE	✓	✓	✓	✓	✓
MS region FE	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓

Notes: *** p<0.01, ** p<0.05, * p<0.1. In column (1) the dependent variable is the logarithmic transformation ($log(1 + patents)$) of the number of patents filed by inventor i in MS region m in year t containing at least one novel term in their abstract, relative to all EPO patents filed in Switzerland up to the previous year $t-1$. In columns (2), (3), (4), and (5), the dependent variable is the logrithmic transformation of the number of patents filed by inventor i in MS region m in year t containing at least one new IPC class, subclass, group, or subgroup relative to all EPO patents filed by inventor i up to the previous year $t-1$. The treated group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is below or equal to 20 minutes and all incumbent inventors located in the non-border region. The control group includes all incumbent inventors located in MS regions in the border region whose driving distance from the closest border crossing is above 20 minutes. Robust standard errors clustered at the MS region level are given in parentheses. Estimations by Ordinary Least Squares.

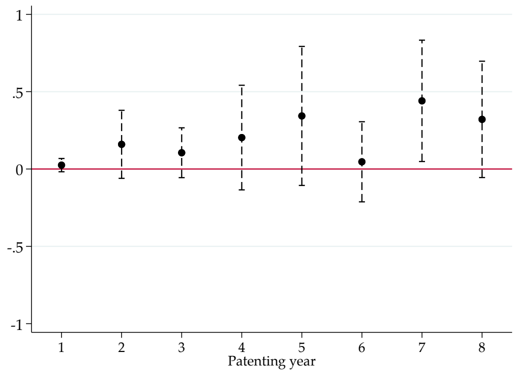
D.6. Inventor-level Analysis: Junior Inventors

Table D28: Junior inventors' patenting: difference-in-differences results by patenting year

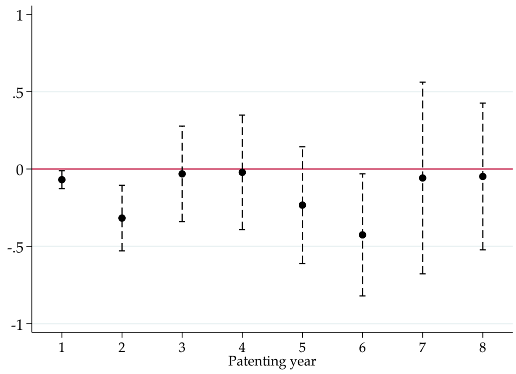
	Patenting year							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(a) Patents								
AFMP × Treated	0.011	0.137	0.152*	0.295*	0.356	0.082	0.427**	0.306
	(0.024)	(0.124)	(0.077)	(0.172)	(0.222)	(0.149)	(0.206)	(0.205)
Observations	7241	858	662	522	466	398	351	333
Pseudo R^2	0.003	0.029	0.035	0.037	0.058	0.043	0.077	0.095
(b) Patents (excl. cross-border inventors)								
AFMP × Treated	-0.071**	-0.317***	0.030	0.080	-0.257	-0.423**	-0.100	-0.106
	(0.033)	(0.122)	(0.155)	(0.183)	(0.184)	(0.205)	(0.316)	(0.254)
Observations	7241	858	662	522	466	398	351	333
Pseudo R^2	0.009	0.054	0.050	0.066	0.083	0.081	0.110	0.098
(c) Co-inventors								
AFMP × Treated	0.015	-0.037	0.195	0.186	0.204	0.129	0.207	0.181
	(0.075)	(0.141)	(0.152)	(0.189)	(0.205)	(0.175)	(0.212)	(0.205)
Observations	7224	850	662	516	464	383	349	328
Pseudo R^2	0.066	0.134	0.177	0.186	0.190	0.199	0.215	0.217
(d) Co-inventors (excl. cross-border inventors)								
AFMP × Treated	-0.177*	-0.646**	-0.297	-0.103	-0.452	-0.402	-0.083	-0.102
	(0.101)	(0.273)	(0.215)	(0.201)	(0.299)	(0.531)	(0.235)	(0.241)
Observations	7216	845	662	509	459	378	343	326
Pseudo R^2	0.059	0.134	0.153	0.149	0.128	0.193	0.211	0.176
(e) Cit. to cross-border inventor-country								
AFMP × Treated	-0.005	-0.244	-0.045	0.287	0.373	-0.877**	-0.563	-0.136
	(0.117)	(0.316)	(0.211)	(0.371)	(0.272)	(0.372)	(0.417)	(0.413)
Observations	7146	819	630	484	441	378	329	315
Pseudo R^2	0.105	0.202	0.213	0.172	0.229	0.241	0.172	0.285
(f) Cit. to cross-border inventor-country (excl. cross-border inventors)								
AFMP × Treated	-0.112	-0.472	0.053	0.485	0.031	-1.392**	-0.543	-0.719
	(0.139)	(0.419)	(0.266)	(0.388)	(0.355)	(0.598)	(0.484)	(0.439)
Observations	7146	819	630	480	425	367	327	311
Pseudo R^2	0.094	0.207	0.220	0.215	0.256	0.246	0.183	0.208

Notes: *** p<0.01, ** p<0.05, * p<0.1. The treated group includes all inventors who filed their first ever patent in MS regions in the BR whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all inventors who filed their first ever patent in MS regions in the BR whose driving distance from the closest border crossing is above 20 minutes and all inventors who filed their first patent in the non-border region. Robust standard errors are clustered at the MS region level and shown in parentheses. Estimations by Poisson pseudo-maximum-likelihood.

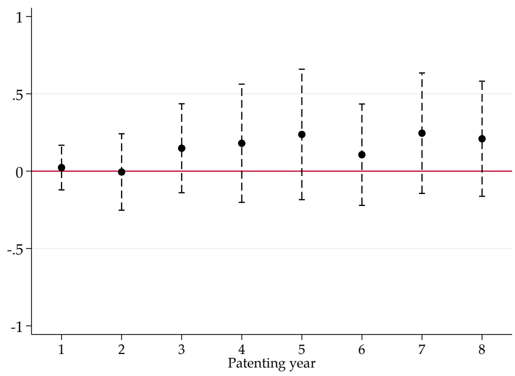
Figure D33: Junior inventors' patenting: difference-in-differences results by patenting year (including non-border region inventors in the control group)



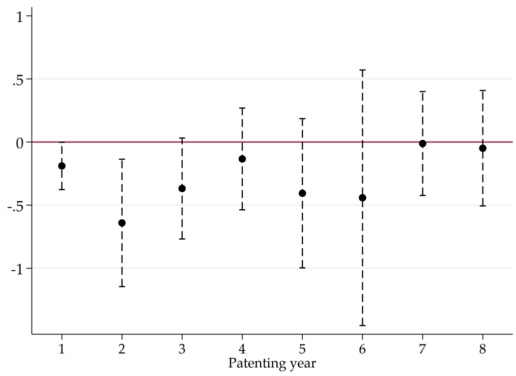
(a) Patents



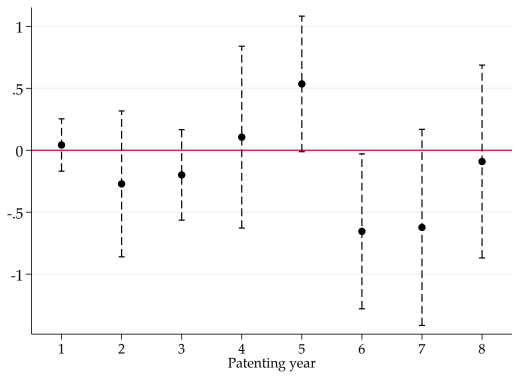
(b) Patents (excl. cross-border inventors)



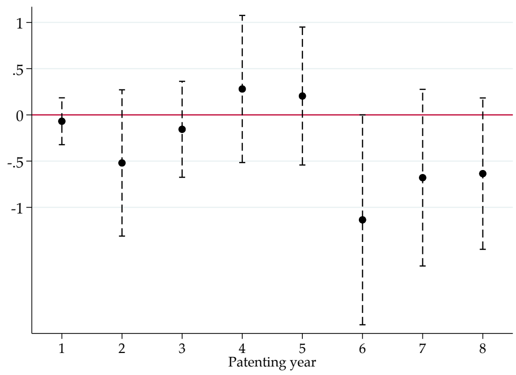
(c) Distinct co-inventors



(d) Distinct co-inventors
(excl. cross-border inventors)



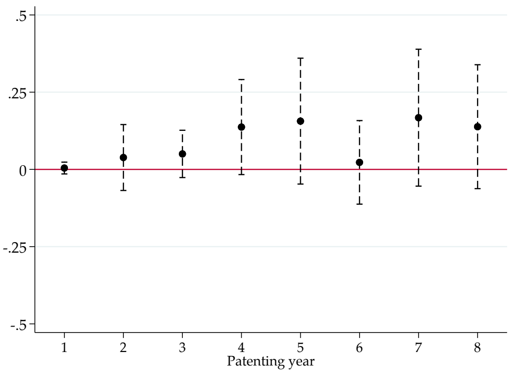
(e) Cites to CBI-country prior-art



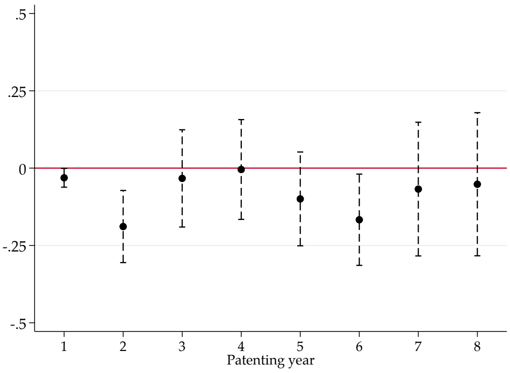
(f) Cites to cross-border inventor-country prior-art (excl. cross-border inventors)

Notes: The treated group includes all inventors who filed their first ever patent in MS regions in the BR whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all inventors who filed their first ever patent in MS regions in the BR whose driving distance from the closest border crossing is above 20 minutes and all inventors who filed their first patent in the non-border region. All regressions include year and MS region fixed effects. Vertical bars represent 95% confidence intervals. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood.

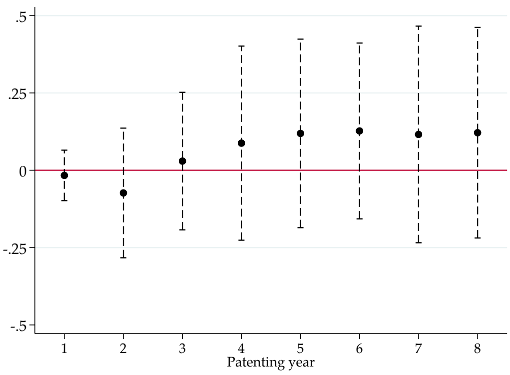
Figure D34: Junior inventors' patenting: difference-in-differences results by patenting year (OLS)



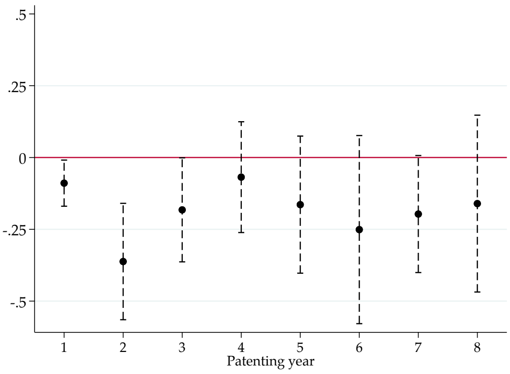
(a) Patents



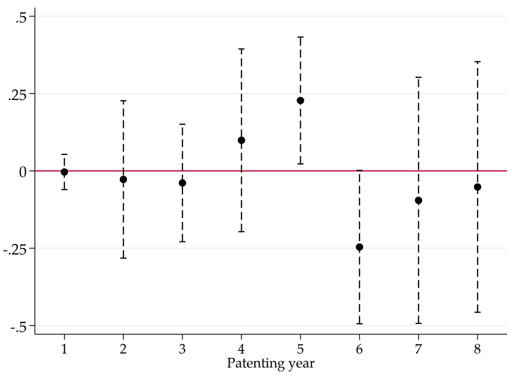
(b) Patents (excl. cross-border inventors)



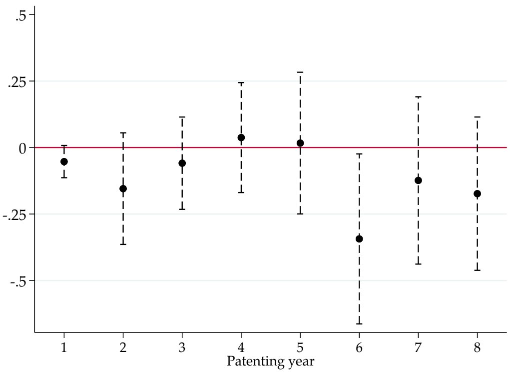
(c) Distinct co-inventors



(d) Distinct co-inventors
(excl. cross-border inventors)



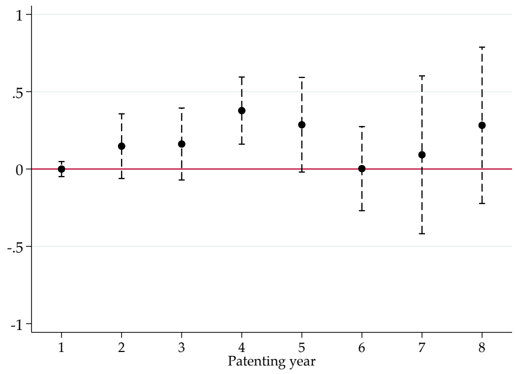
(e) Cites to CBI-country prior-art



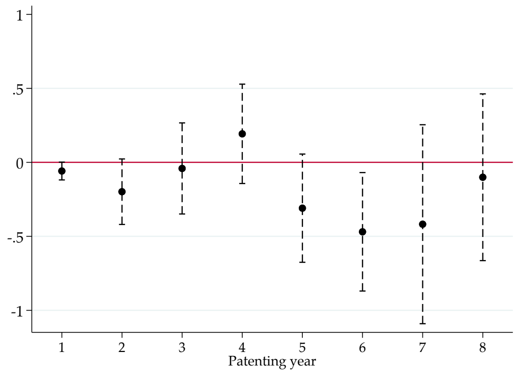
(f) Cites to cross-border inventor-country
prior-art (excl. cross-border inventors)

Notes: The treated group includes all inventors who filed their first ever patent in MS regions in the BR whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all inventors who filed their first ever patent in MS regions in the BR whose driving distance from the closest border crossing is above 20 minutes. All regressions include year and MS region fixed effects. Vertical bars represent 95% confidence intervals. Robust standard errors are clustered at the MS region level. Estimations by Ordinary Least Squares.

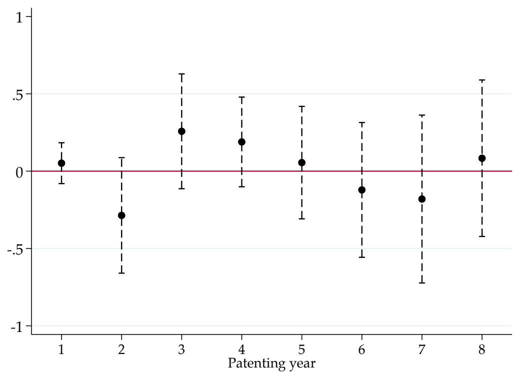
Figure D35: Junior inventors' patenting: difference-in-differences results by patenting year (alternative location assignment: inventor residential address)



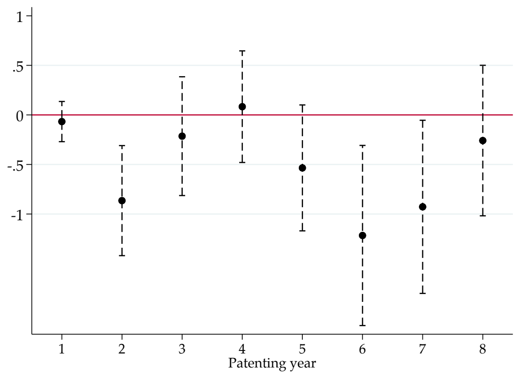
(a) Patents



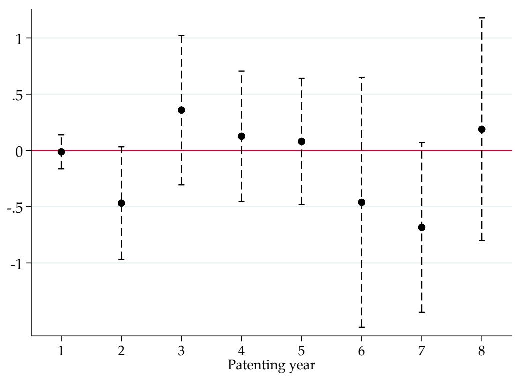
(b) Patents (excl. cross-border inventors)



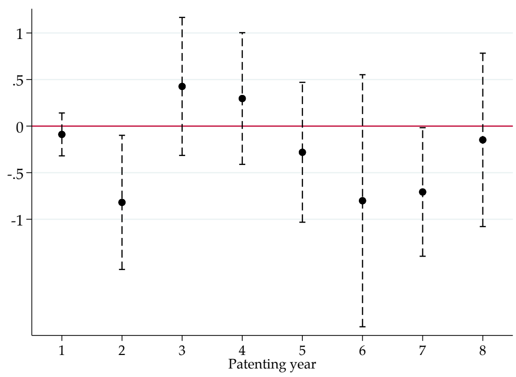
(c) Distinct co-inventors



(d) Distinct co-inventors (excl. cross-border inventors)



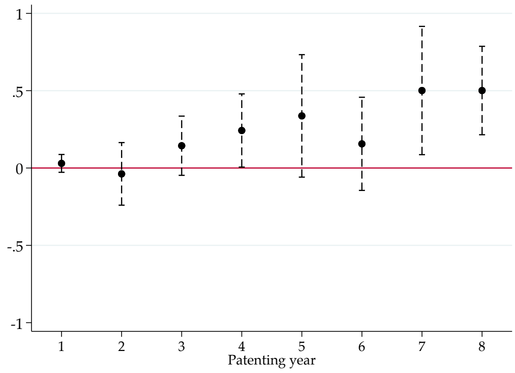
(e) Cites to CBI-country prior-art



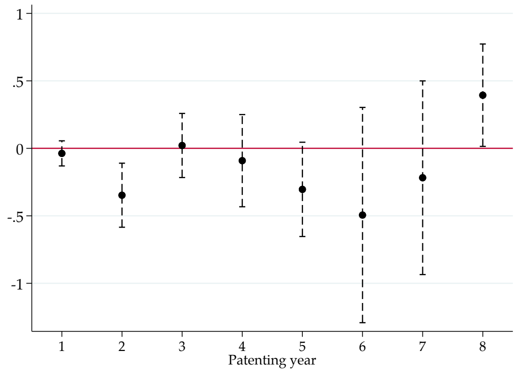
(f) Cites to cross-border inventor-country prior-art (excl. cross-border inventors)

Notes: Inventors are assigned to their MS region of residence instead of the MS region associated to their R&D location. The treated group includes all inventors who filed their first ever patent in MS regions in the BR whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all inventors who filed their first ever patent in MS regions in the BR whose driving distance from the closest border crossing is above 20 minutes. All regressions include year and MS region fixed effects. Vertical bars represent 95% confidence intervals. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood.

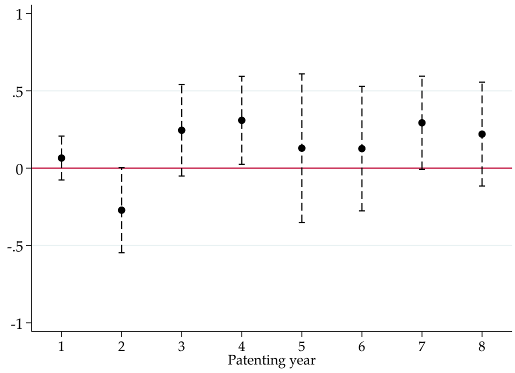
Figure D36: Junior inventors' patenting: difference-in-differences results by patenting year (alternative location assignment: applicant location)



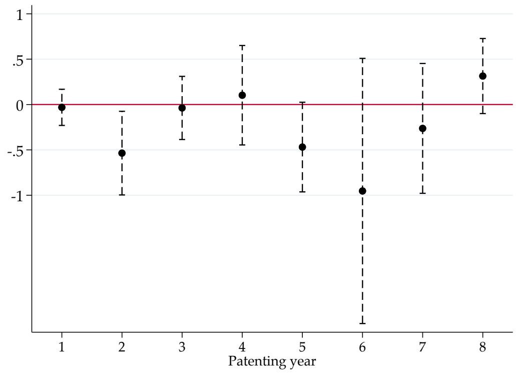
(a) Patents



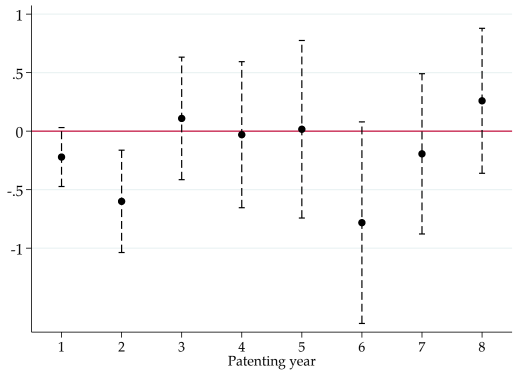
(b) Patents (excl. cross-border inventors)



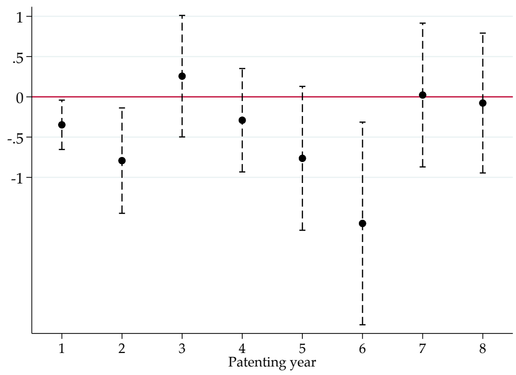
(c) Distinct co-inventors



(d) Distinct co-inventors (excl. cross-border inventors)



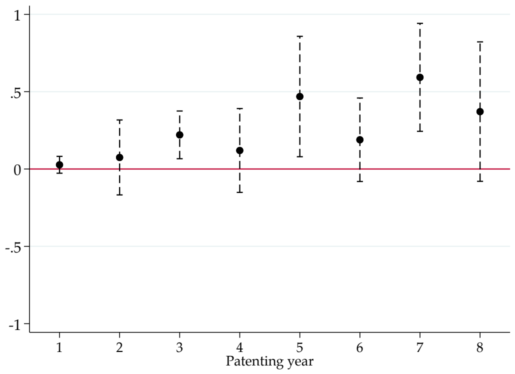
(e) Cites to CBI-country prior-art



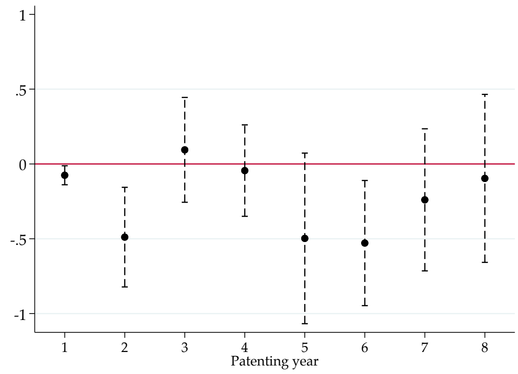
(f) Cites to cross-border inventor-country prior-art (excl. cross-border inventors)

Notes: Inventors are assigned to the applicant's MS region instead of the MS region associated to their R&D location. The treated group includes all inventors who filed their first ever patent in MS regions in the BR whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all inventors who filed their first ever patent in MS regions in the BR whose driving distance from the closest border crossing is above 20 minutes. All regressions include year and MS region fixed effects. Vertical bars represent 95% confidence intervals. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood.

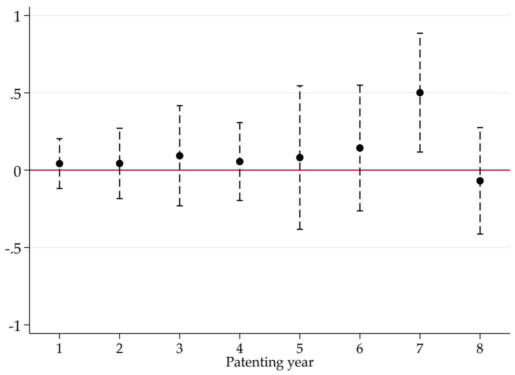
Figure D37: Junior inventors' patenting: difference-in-differences results by patenting year (only granted patents)



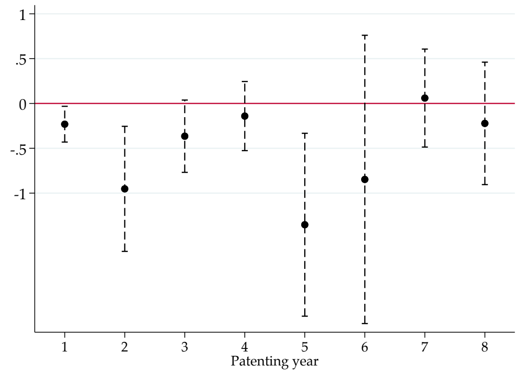
(a) Patents



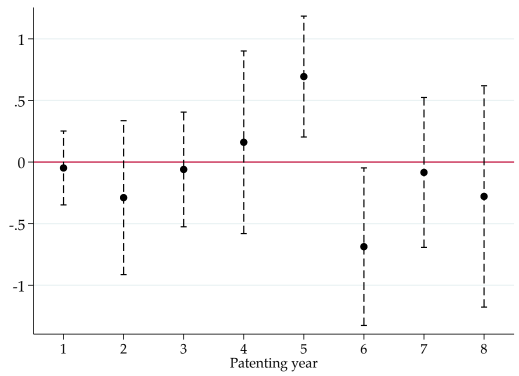
(b) Patents (excl. cross-border inventors)



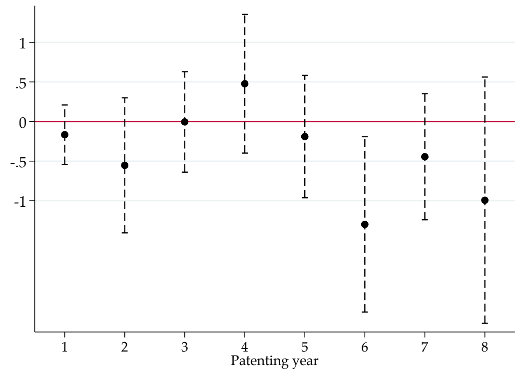
(c) Distinct co-inventors



(d) Distinct co-inventors
(excl. cross-border inventors)



(e) Cites to CBI-country prior-art



(f) Cites to cross-border inventor-country prior-art (excl. cross-border inventors)

Notes: The sample is based only on information from granted patents. The treated group includes all inventors who filed their first ever patent in MS regions in the BR whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all inventors who filed their first ever patent in MS regions in the BR whose driving distance from the closest border crossing is above 20 minutes. All regressions include year and MS region fixed effects. Vertical bars represent 95% confidence intervals. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood.

D.7. R&D Lab Analysis

In this section, we study the contribution of cross-border inventors to the Swiss R&D labs and teams they joined, adding an intermediate layer of analysis, between regions and individual inventors. We focus on R&D labs already active before the pre-AFMP period and track their patenting activity between 1990 and 2012, estimating the following event study specification:

$$E[y_{j,m,t}|X_{j,m,t}] = exp[\alpha + \sum_{\substack{t=1990 \\ t\neq 1999}}^{2012} \beta_t \cdot I_{year=t} \times Treated_{m(j)} + \xi_j + \phi_t] \quad (4)$$

where $y_{j,m,t}$ is an innovation outcome for R&D lab j, located in MS region m, and patenting in year t; $I_{year=t}$ is an indicator equal to 1 in year t and 0 otherwise (with 1999 as the reference year); $Treated_{m(j)}$ is a dummy variable equal to 1 for R&D labs located in a treated region; ξ_j are R&D lab fixed effects, which capture time-invariant characteristics of each R&D lab; and ϕ_t are year fixed effects, which account for time-variant shocks common to all R&D labs. We cluster standard errors at the MS region level.

We test four innovation outcomes. First, we calculate the average number of inventors in all teams patenting for R&D lab j in year t, allowing us to asses changes in the organization of R&D teamwork. Second, we compute the average number of patents filed by all members of an inventor team by $t-1$, for all teams patenting in R&D lab j and year t. Tracking the average experience of inventor teams enables us to test for any change in the average seniority of Swiss R&D labs' inventor teams. Third, we count the total number of unique inventors active in R&D lab j and year t. Last, we count the total number of cross-border inventors active in R&D lab j and year t. These measures are aimed at study changes in the size of R&D labs.

Table D29 reports descriptive statistics, while Figure D38 shows the estimation results. When the dependent variable is the average team size (panel (a)), all estimated coefficients are close to zero and, except one for 2002, statistically insignificant. When we test the average team experience (panel (b)), we find several estimated coefficients for the post-AFMP period to be positive, although none of them is statistically significant. When the dependent variable is the number of total active inventors in a given year (panel (c)), we estimate positive and statistically significant coefficients for the years between 2002 and 2007. We find similar results when the dependent variable is the number of cross-border inventors active in a given year (panel (d)), albeit with slightly larger estimated coefficients and standard errors.

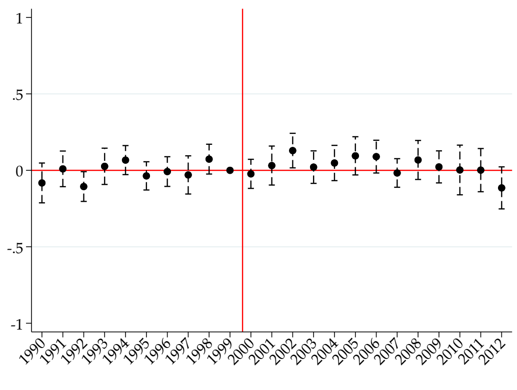
These results suggest that the incoming cross-border inventors increased the patenting productivity of R&D labs in the treated region by enabling them to expand their laboratory size with more scientists and engineers. Those R&D labs did not change their work organization, as suggested by the absence of changes in their teams' average size and experience. In contrast, R&D labs were able to assemble more inventor teams relative to the pre-AFMP period, as indicated by the increase in their total number of inventors (including cross-border ones).

Table D29: R&D lab outcomes mean and standard deviation by area and period

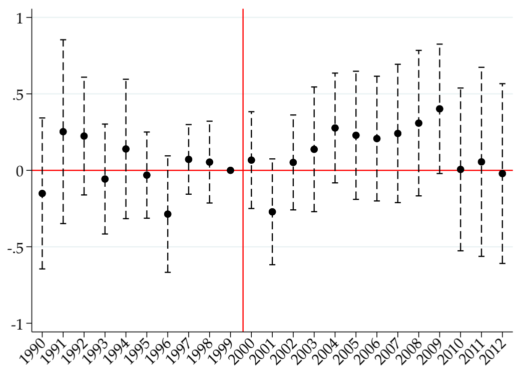
	Pre-AFMP (1990-1999)			Post-AFMP (2000-2012)		
	Treated	Control	Non-border regions	Treated	Control	Non-border regions
Average team size	1.49 (0.88)	1.47 (0.78)	1.45 (0.77)	1.92 (1.10)	1.84 (1.00)	1.79 (0.95)
Average team experience	1.61 (4.20)	1.56 (3.81)	1.54 (5.90)	3.06 (5.38)	2.48 (4.28)	2.93 (5.57)
Active inventors	3.49 (14.64)	3.39 (10.01)	2.19 (3.50)	10.37 (31.58)	9.74 (25.88)	4.96 (9.04)
Active cross-border inventors	0.72 (3.98)	0.13 (1.12)	0.03 (0.23)	2.96 (11.07)	0.49 (2.26)	0.06 (0.37)

Notes: The table reports mean values for R&D labs' yearly outcomes. Standard deviation values are reported in parentheses.

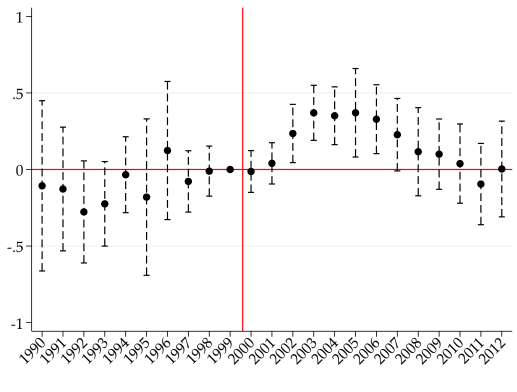
Figure D38: R&D lab outcomes: event study results



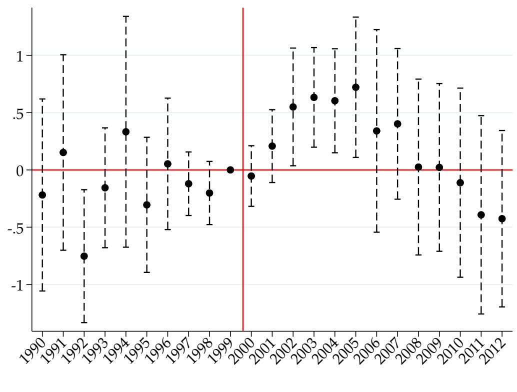
(a) Average team size



(b) Average team experience



(c) Active inventors



(d) Active cross-border inventors

Notes: The treated group includes all R&D labs located in border regions whose driving distance from the closest border crossing is below or equal to 20 minutes. The control group includes all R&D labs located in borde regions whose driving distance from the closest border crossing is above 20 minutes. All regressions include R&D lab and year fixed effects. The coefficient for our baseline year 1999 is set to zero and shown without confidence interval. Robust standard errors are clustered at the MS region level. Estimations by Poisson pseudo-maximum-likelihood.

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