Skilled migrants' contribution to innovation

(Executive Summary)

General objectives

The overall objective of this project was to address, in a novel way, the question of whether, and how, skilled migrants affect the host country innovative capacity. The project has first provided a detailed descriptive overview of the international mobility of inventors, identifying the main receiving and sending countries. Second, on the basis of this new knowledge, it has studied the extent to which migration is associated with greater individual productivity. Third, it has analysed the relationship between high-skilled immigration and host country innovative capacity. In order to accomplish these research tasks, the project has been divided into three specific Working Packages (WP). In what follows, we present a brief overview of the different working packages, by describing the specific aim, the results obtained and the research methods used. We then offer some conclusions on the whole of this research.

WP1a: Construction of the database

The cornerstone of this project, and the main task of WP1, has been the construction of a novel database that allows to track international migration patterns of inventors at worldwide level. This task has been, by all means, the most demanding part of the entire project and it has been led by Dr. Orion Penner and Dr. Pellegrino with the remarkable contribution of Dr. Portabella.

First, the team has retrieved and organized in different tables/databases all the information needed to construct the final database. More in details, information at both inventors and patent level has been retrieved from different sources, such the WIPO database, the EPO worldwide Patent Statistical Database (PATSTAT), the OECD REGPAT database, the US Patent and Trademark Office (USPTO) database and the Claravite Derwent Patent Database (DPD). Second, Dr. Penner, has merged the different databases in order to join together all the relevant information. Third, information regarding the address of residence of the millions of inventors included in the database has been extracted, appropriately cleaned and processed. In particular, by making use of a specific Google Maps Application Programming Interface, the team has geolocalized the inventors included in the database, by identifying the latitude and longitude coordinates of their

location. Fourth, this information has been used to assign each inventor to a highly disaggregated and statistically meaningful administrative division (i.e. NUTS3, in Europe). At the same time, Dr. Penner and Dr. Portabella have worked on another important task, namely the disambiguation of inventors' names and surnames to uniquely identify all the inventors included in the database. To this aim, they have applied a complex disambiguation method based on an neural networks algorithms borrowed from computer sciences. The team has been able to satisfactorily disambiguate more than 95% of the inventors included in the database.

WP1b: What are the main spatial trajectories of migrant inventors? A geographic perspective

As part of WP1, the team has used the information collected to provide a detailed descriptive characterization of the the phenomenon of international mobility of inventors. In particular, we have tried to empirically answer to the following questions: "Where do migrant inventors invent?" and "What are the spatial trajectories of migrant inventors?". The report briefly discusses some of the main evidence produced, with a specific focus on EU 28 + Norway, and Switzerland.

Figure 1 presents the spatial distribution of all immigrants inventors residing in the different NUTS3 European areas during the period 1986 to 2010. As can be seen, there is a high concentration of immigrant inventors in some countries, specifically in the central and northern part of Europe. On the other hand, countries located in the eastern part of Europe show a very limited presence of foreign-born inventors.

Table 1 ranks the top 15 countries of origin of the immigrant inventors included in our sample. Germany is the first country of origin with almost the 20% of the total migrant inventors, followed by France (around 10%), the United Kingdom (8%) and Italy (6%). The first giving country outside Europe is the U.S., followed then by China and Canada. Finally, Table 2 shows the top NUTS3 areas with respect to the number of residing immigrant inventors. Quite interestingly, 6 out of 15 top NUTS3 areas are located in Switzerland. More in details, Zurich and Vaud are respectively the first and the second NUTS3 area per number of immigrants inventors, followed by Aargau (fourth), Basel-Stadt (sixth), Geneva (tenth), Basel-Landschaft (eleventh). Other relevant areas are Paris, which ranks third, and Stockholm, which ranks fifth.

WP2: Immigration and Inventor Productivity

WP2 aimed at studying the relationship between migration and the productivity of inventors. In particular, by making use of the disambiguated data previously described, the team has sought to answer the following research question: "Is migration associated with greater individual productivity?".

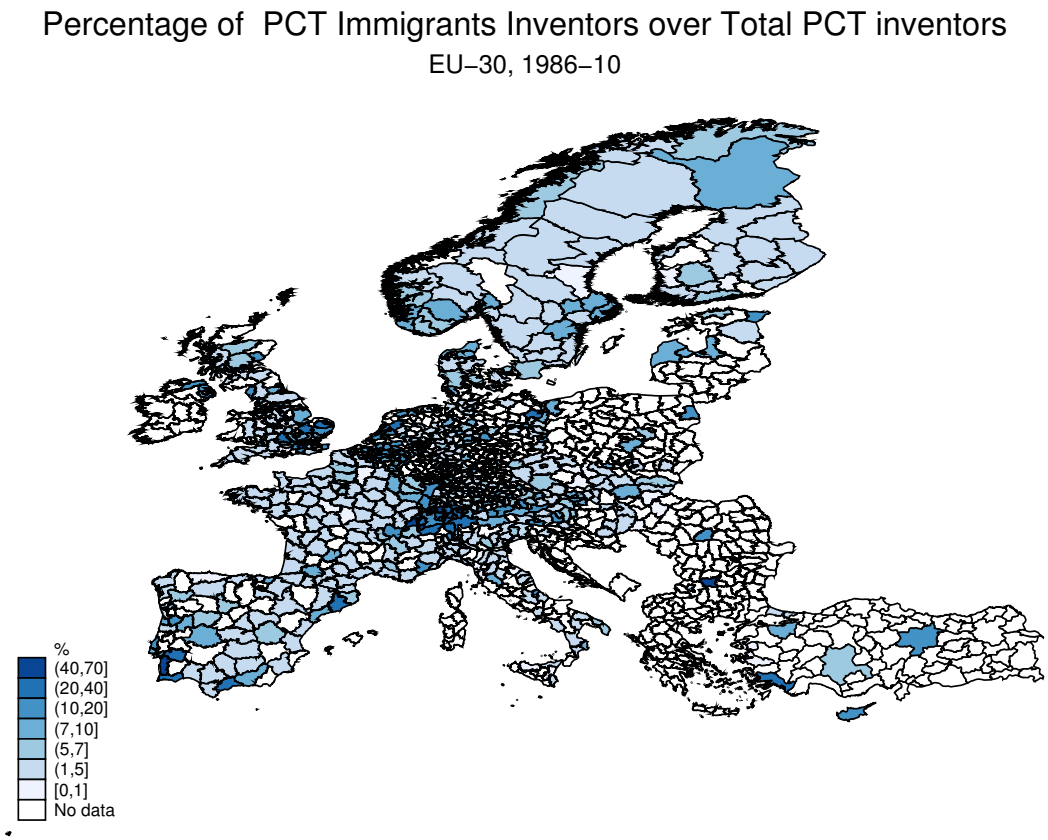


Figure 1: Where do inventors reside?

Table 1: Where do inventors come from?

Nationality	**Freq.**	**%**	**% Cum.**
Germany	6,068	19.19	19.19
France	3,091	9.78	28.97
United Kingdom	2,486	7.86	36.83
Italy	1,824	5.77	42.6
United States of America	1,718	5.43	48.03
Netherlands	1,690	5.34	53.37
China	1,135	3.59	56.96
Austria	859	2.72	59.68
Spain	822	2.6	62.28
Sweden	788	2.49	64.77
Russian Federation	718	2.27	67.04
Switzerland	669	2.12	69.16
Belgium	644	2.04	71.2
India	538	1.7	72.9
Canada	467	1.48	74.37
Others	8,003	25.63	100
Total	31,620	100	

This research question has been studied using a sample of 867,627 disambiguated inventors, who have filed a total of 1,310,850 unique PCT applications in the period 1990–2011. As indicated in table 3, about 9.6% of inventors are immigrants, and they account for 14.8% of total PCT applications. These figures are a first hint that migrant inventors

Table 2: Where do immigrant inventors reside?: main NUTs3

NUTs3	***Country***	***Freq.***	***Perc.***
Zurich	Switzerland	1,961	6.20
Vaud	Switzerland	1,364	4.31
Paris	France	973	3.08
Aargau	Switzerland	881	2.79
Stockholms län	Sweden	818	2.59
Basel-Stadt	Switzerland	775	2.45
Cambridgeshire CC	United Kingdom	772	2.44
Arr. de Bruxelles	Belgium	596	1.88
Wien	Austria	585	1.85
Geneva	Switzerland	537	1.70
Basel-Landschaft	Switzerland	492	1.56
Oxfordshire	United Kingdom	483	1.53
München, Kreisfreie Stadt	Germany	459	1.45
Hauts-de-Seine	France	427	1.35
East Surrey	United Kingdom	382	1.21

could be more "productive" than non-migrants—indeed, they have filed on average 2.34 PCT applications compared to 1.42 for non-migrants (the difference is statistically significantly different from zero at the 1% probability threshold). This evidence is further

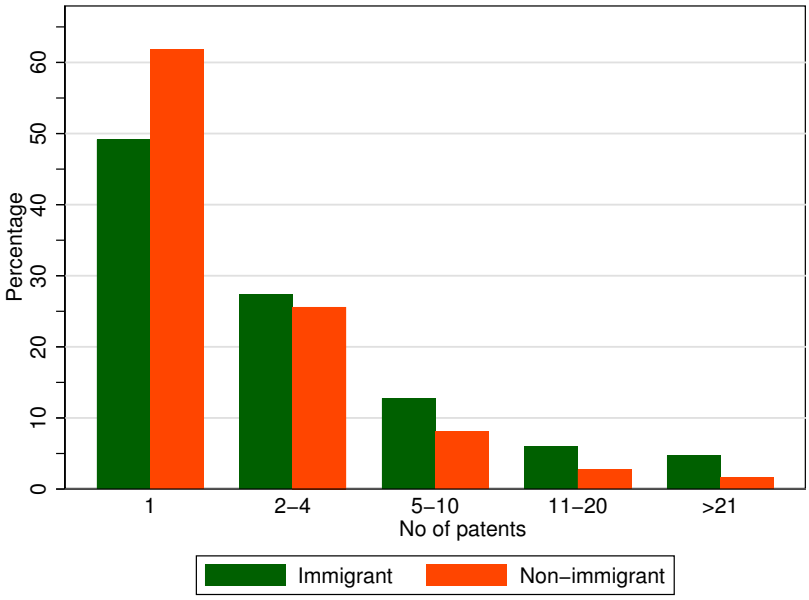
Table 3: Summary statistics

	Total	***Non Immigrant***	***Immigrant***
No. of inventors	867,627	784,233	83,394
No. of applications	1,310,850	1,115,689	195,161
Average no. of applications per inventor	1.51	1.42	2.34
No. of applications with one inventor	661,271	569,011	92,260
No. of applications with at least three inventors	318,056	268,345	49,711

Notes: Immigrant inventors are defined as inventors who have applied for at least one patent while residing in a country different from their country of nationality. Time period:1990–2011

corroborated by figure 2, which depicts the frequency distribution of the number of PCT applications for inventors, by migration status. Compared to migrants, native inventors are more concentrated in the first category, with more than 60% of non-immigrant inventors having filed just one patent application. This percentage is around 50% in the case of immigrant inventors. Conversely, the proportion of immigrant inventors is always greater than the proportion of native ones in all following categories. This difference in patenting performance could be driven by differences in the technological fields of specialization between natives and migrants (migrant inventors could be attracted to more patent-intensive fields). To investigate potential differences across fields, Figure 3 reports the distribution of PCT applications by main technology area for the United States (the country with the largest absolute number of foreign inventors) and the top-4 giving countries to the United States, namely China, India, Canada and the United Kingdom.
Following Schmoch (2008) we have identified four main areas of technology: Chemistry,

Figure 2: Number of PCT applications produced by inventors



Electrical engineering, Instruments, and Mechanical engineering.[1] British, Canadian and Chinese inventors migrating to the United States are more frequently found in chemistry compared to the baseline rate of about 35% for U.S. inventors. Along the same lines, Chinese, Canadian and in particular Indian inventors migrating to the United States are more frequently found in electrical engineering, compared to the baseline of about 25% for U.S. inventors.

In order to complement these descriptive evidence, we have carried out an econometric analysis based on the estimation of the following regression model:

$$y_{i,t} = \beta_1 \mathrm{AfterMove_{i,t}} + \delta_i + \delta_t + \beta_2 \mathrm{X_{i,t}} + \epsilon_{i,t}, \tag{1}$$

where the dependent variable $y_{i,t}$ identifies the number of patents filed by inventor i in year t. The variable of interest, $AfterMove$, is a binary indicator that takes value one starting from the year t in which we observe the first move of inventor i. The sign and significance of the coefficient β_1 therefore provides an indication of whether, and to what extent, inventors who move from one country to another become more productive.

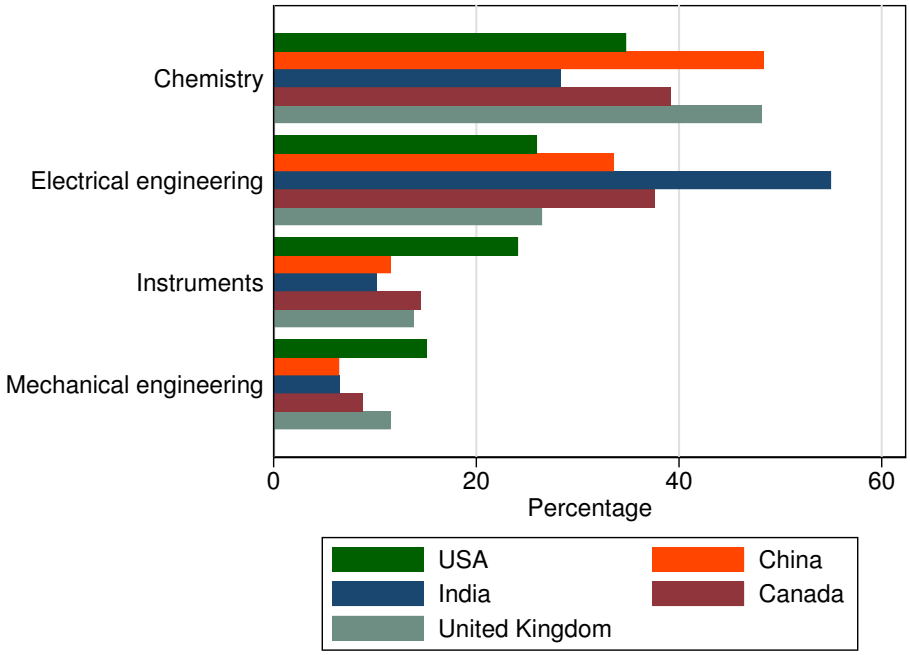
The variable δ_i captures inventor fixed effects, while δ_t includes a vector of year fixed effects that control for systematic variations in patenting activity over time.

Finally, the vector X controls for confounding variables at the inventor level and it includes: 1) a complete set of country of inventor residence fixed effects; 2) a variable controlling for possible variation in productivity over the life cycle of an inventor; 3) a variable controlling for the size of the inventor's collaborative network; 4) a set of main technology class associated with patents by inventor.

Table 4 presents the results of the baseline OLS estimates, with robust standard er-

[1] We exclude some residual sectors accounting for less than 4% of the sample.

Figure 3: Technology fields of U.S inventors alongside those who's country of origin is one of the top-4 "sending" to the U.S.



rors. Column (1) shows a positive and highly significant relationship between the variable $AfterMove$ and the number of patents filed by inventor i in year t. More specifically, the point estimate implies that inventors who move from one country to another show a sensible increase in their productivity of about 0.7 additional patent applications filed each year. The inclusion of the other control variables reduces the magnitude of this point estimate. We add technology fields in column (2), year fixed effects in column (3), the variable "time since last patent" in column (4), and average number of inventors in column (5). The results reported in Table 4 are robust to a broad range of different specifications (see additional analyses in Working Paper 1).

WP3: Do foreign-born inventors contribute to their host city innovation capability? A city-level perspective

As outlined in the proposal, the main aim of this WP is to provide an empirical evaluation of the extent to which the international mobility of foreign-born skilled workers boosts the innovation activity of the host country through the diffusion and spread of new ideas and knowledge. To this aim, we have applied a robust identification strategy and up-to date econometric techniques. More in details, in order to identify the casual effect of migration, we have followed Borjas and Doran (2012) and Ganguli (2015) and draw from the end of the Soviet Union and the consequent disproportionate influx of immigrant inventors to the United States.

Before the collapse of the Soviet Union, there were very limited opportunities for re-

Table 4: Ordinary Least Square regressions

	(1)	(2)	(3)	(4)	(5)
After Move	0.710***	0.711***	0.487***	0.484***	0.481***
	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
Inventors fixed effects	Yes	Yes	Yes	Yes	Yes
Country of Residence fixed effects	Yes	Yes	Yes	Yes	Yes
CPC fixed effects	No	Yes	Yes	Yes	Yes
Year fixed effects	No	No	Yes	Yes	Yes
Productivity	No	No	No	Yes	Yes
Av. no of inventors	No	No	No	No	Yes
Number of observations	915,385	915,385	915,385	915,385	915,385
Number of inventors	262,265	262,265	262,265	262,265	262,265
R^2	0.001	0.001	0.005	0.005	0.005

Notes: The dependent variable measures the number of patents filed by inventor i in year t. The variable $AfterMove$ is a binary indicator that takes value one starting from the year in which we observe the first move of inventor i. Robust standard errors in parentheses.
***, ** and * indicate significance at 1%, 5% and 10% level, respectively.

searchers and scientists to interact with the "Western world". Consequently, Soviet scientists and engineers specialized in technological fields rather different from those in which U.S. inventors were more specialized, and many of them emigrated, with the United States as the main destination country. Some cities/technological fields were marginally affected by the inflow of Soviet inventors, whilst others were exposed to an unexpected major surge of new high-skilled workers, inventors and ideas. We therefore exploit this considerably high geographical and technological variation in the number of immigrant inventors to correct for some potential endogenity issues.

To this aim, we have constructed a dataset of U.S. granted patents at city, technological classes and year level and the corresponding number of patents with at least one ex-Soviet Union inventor. We then estimated the following regression model:

$$y_{c,j,t} = \delta_c + \delta_j + \delta_t + (\delta_j \times \delta_t) + \beta_1 \mathrm{NumberofUSSRpatents_{c,j}} \times \mathrm{post_t} + \beta_2 \mathrm{X_{c,j,t}} + \epsilon_{i,t}, \quad (2)$$

Where the dependent variable $y_{c,j,t}$ identifies the number of patents granted to U.S. inventors in MSA (Metropolitan Statistical Areas) c, technological field j and year t. In order to measure the net effect of the ex Soviet Union immigrant inventors on the level of U.S. innovation, this variable does not take into consideration U.S. patents with at least one ex-Soviet Union inventors.

As for the covariates, δ_c represents a vector of city (MSAs) fixed effects, δ_j controls for technological specificities, δ_t is a vector of year fixed effects while $\delta_j \times \delta_t$ represents technological fields $\times$ year fixed effects.

The variable $NumberofUSSRpatents_{c,j}$ identifies the number of patents with at least one ex-Soviet Union inventor residing in MSA c and patenting in technological field j. The indicator $post_t$ takes value 1 if the year for the particular observation is 1992 or later. The vector $X_{c,j,t}$ includes two additional controls. The first variable is number of patents in city c, technological field j, year y, with at least one foreign-born inventors

with a nationality from countries that were not part of the USSR. Second, in order to control for variation in the speed of invention across the life cycle of a technology, we have constructed a variable measuring the years that have elapsed since the first patent was issued in technological class c and its square.

In order to correct for some possible endogeneity concerns, we then employ instrumental variable techniques based on the idea of the supply-push instrument proposed by Card (2001). The basic exclusion restriction behind the use of this instrument is that the historical immigrant communities and enclaves are relevant in determining the location choices of the immigrant, while it should not have an impact on the level and quality of innovation at city/technological field level.

Table 5 presents the results of the baseline OLS estimates with robust standard errors clustered at the level of MSA and IPC sub-class. Column (1) shows a positive and highly significant relationship between the number of ex-Soviet Union migrant inventors in a given city, field and year and the number of patents granted to native inventors. More specifically, point estimates imply that one more ex-Soviet union granted patent in city c field j and year y yields to around 21 additional domestic patents per year. The inclusion of the other control variables (year x class fixed effects interaction, quadratic age sub-class and number of foreign patents) brings a considerable reduction in the magnitude of the point estimates. Column 4 shows that 1 additional USSR patent translate in around 8 domestic patents. IV estimations (not reported here) largely confirm these results.

Table 5: Ordinary Least Square Regressions (total sample)

	(1)	(2)	(3)	(4)
Number of USSR patents x *post*	21.495***	21.249***	8.167***	8.160***
	(4.445)	(4.380)	(2.528)	(2.528)
Quadratic age subclass	No	No	No	Yes
N. of foreign patents	No	No	Yes	Yes
Year X Class fix. eff.	No	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
MSA fixed effect	Yes	Yes	Yes	Yes
Class fixed effect	Yes	Yes	Yes	Yes
Number of observations	43,795	43,795	43,795	43,795
Number of clusters	6,302	6,302	6,302	6,302
R^2	0.13	0.18	0.27	0.27

Notes: The dependent variable measures the number of U.S. patents issued to U.S. inventors per MSA, IPC sub-class and year, and the variable *Number of USSR patents* measures the number of U.S. patents by ex Soviet Union inventors in class per MSA, IPC sub-class and year. The dummy variable *Post* equals 1 for years after 1991. Patents by ex Soviet Union inventors are excluded from the count of the dependent variable. Standard errors are clustered at the level of MSA and IPC technological class.
***, ** and * indicate significance at 1%, 5% and 10% level, respectively.

Concluding remarks

The international migration of skilled workers is a relevant phenomenon that may cause profound economy and societal effects. Recently, the attention of policy makers in high-income countries has been particularly drawn by the potential positive role played by skilled immigrants in boosting technological development and innovation. Notwithstanding this high policy interest, the scholarship on the topic is still in its infancy and far to be conclusive.

The empirical evidence provided by this project advances our understanding of the phenomenon of high-skilled migration and its possible beneficial role in increasing the level of innovation of the host country.

Quantitative analyses have shown that migrant inventors become more productive after they have migrated. Furthermore, migrants inventors are also intrinsically more productive than non-migrant inventors. Our estimations suggest that about 80% of this difference is explained by post-move productivity increase and the remaining 20% is explained by the fact that migrant inventors exhibit intrinsically higher productivity levels. Moreover, additional analyses have shown that the intrinsic higher productivity that characterizes immigrant inventors positively affects the productivity of the native inventors, through the diffusion of new knowledge.

In light of the increased attention towards migration-related issues, these findings bear an important policy message: they suggest that immigrant inventors, being more productive than natives inventors, positively contribute to the level of innovation of the host country through knowledge spillover.

These preliminary evidence point the way towards a number of useful and interesting extensions of the research reported here. Firstly, it would be important to carry out more detailed analyses with the aim of unveiling the different mechanisms that are behind the increase in productivity of migrant inventors. First, migrants may work harder given their (presumably) more precarious visa status. Second, the skills and potential of migrant inventors may be better exploited by their host country relative to home country. Third, a migrant's level of productivity may genuinely raise as a consequence of the move.

Along the same lines, it would be certainly valuable to carry out a more robust investigation of the possible mechanisms behind the increase in patenting due to the arrival of foreign inventors. In particular, it would be important to try to disentangle pure knowledge spillover effects from other kind of effects, such as collaboration and network effects. We hope that other researchers in the academic community will further analyze these open research questions thus contributing to our overall understanding of the dynamics governing high-skilled migration.

Project output and dissemination

The main outputs of this project are represented by two working papers and the dataset previously described. The first working paper entitled: "International Mobility of

Inventors and Innovation: Empirical Evidence from the Collapse of the Soviet Union" will be published as SSRN working paper in the next few months. The main results of this paper attracted a significant amount of interest and were presented at several scientific events.

The second working paper is entitled: "Immigration and Inventor Productivity" is ready for publication as SSRN working paper and will be soon submitted to the Journal of Economic Geography.

The database previously described, which represents the third output, will be soon released and rendered available to the academic community through the research data repository Harvard Dataverse.

Finally, to further increase the dissemination of the main results of this project, we have organized, jointly with CEPII (Centre d'Etudes Prospectives et d'Informations Internationales), a workshop on "Migration, Globalization and the Knowledge Economy". The workshop, which was held in Paris last November, has attracted a considerable number of people from both academia and policy institutions.

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