# International Mobility of Inventors and Innovation: Empirical Evidence from the Collapse of the Soviet Union *

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**Abstract**

This paper assesses the extent to which the international migration of inventors affects innovation in the receiving country. We exploit a new database that maps migratory patterns of inventors across all technology fields. We draw on the end of Soviet Union and the consequent post-1992 influx of ex-Soviet inventors in the United States. Econometric analysis on a panel of U.S. cities and technological fields shows that the propensity to patent by local inventors increases significantly after the arrival of ex-Soviet Union inventors. Interestingly, the positive impact of migrant inventors is only observed in physics.

**JEL codes**: O31,O34,O51,J61

**Keywords**: Migration, innovation, geographic mobility, inventors, PCT patents

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# 1 Introduction

The international migration of skilled workers is a relevant phenomenon that may cause profound economic and societal effects. Skilled immigrants workers may bring new ideas, complementary skills and workforce diversity, in turn boosting productivity and innovation in the host country, which will ultimately translate into economic growth (see Romer, 1994). This may not be the case, however, in particular if immigrant inventors crowd out natives.

The policy debate on these topics is particularly vibrant in the United States, a country where high-skilled immigrants have always played a central role in the implementation and diffusion of technology (see Kerr and Lincoln, 2010). Indeed, as emerged from the 2008 Current Population Survey, immigrants represent 16 percent of the U.S. workforce with a bachelor's degree and account for 29 percent of the growth in this workforce during the period 1995-2008 (ibidem, pag. 4).

The U.S. government has traditionally been particularly prone to propose and put into effect policies aimed at attracting the brightest minds. At the beginning of 2015 the Congress has approved the bipartisan bill 'Immigration Innovation Act' whose main aim is to drastically increase the number of available H1B visas for temporary high-skilled workers.[1] The implementation of this measure has been characterized by contrasting receptions. On the one hand, many business leaders considered this measure an important first step in the direction of further increasing the number of foreign born high-skilled workers. On the other hand, opponents claim that skilled immigration is already too high and represents a threat for native workers (Lee, 2015).

This intense policy debate is clearly reflected by the contrasting and scant empirical evidence on the subject. Indeed, a handful of recent empirical studies have tried to document the effect of the mobility of high-skilled workers in diffusing knowledge and ideas by exploiting supply shocks generated by natural experiments provided by historical events.

Waldinger (2010) uses data on the dismissal of professors and scientists during the nazi German period to examine the productivity of Ph.D. that were left behind when superstars scientists left the country. He finds that dismissals had a considerable negative effect on doctoral students outcomes. More recently, the same author finds that departments located in Germany with dismissals also experienced a strong and long-term decline in research output (Waldinger, 2016). Furthermore, he provides evidence that the negative effect was mainly caused by a drop in the quality of hires rather than by a pure localized productivity spillovers (Waldinger, 2012). Using the same natural experiment, but analysing a different outcome variable, Moser et al. (2014) show that innovations by German-Jewish immigrants had a significant effect on the rate of innovation of US-born inventors. Borjas and Doran (2012) evaluate the impact of the influx of ex-Soviet mathematicians to the United States on the productivity of native U.S. mathematicians. Their results point to a consistent descrese in the publication rates for natives workers in subfields with an higher level of overlap with ex-Soviet mathematicians. The authors link these results to an increase in the competition in the mathematics labor and publications market. Similarly, Ganguli (2015) finds that the influx of ex-Soviet Union scientists in the U.S. increases the number of citations to Soviet-era papers by native in their new locations.

Finally, Azoulay et al. (2010) report evidence on a sharp decrease in productivity of coauthors

[1] For more details on the Immigration Innovation Act see https://www.congress.gov/bill/114th-congress/senate-bill/153

of superstar scientists in biological labs after the unexpected death of the superstars.

It is therefore clear, that this increasingly growing literature provides mixed evidence about the role played by the human capital externalities -captured by the mobility of high-skilled workers- in contributing to the creation and diffusion of knowledge. Borjas and Doran (2015), provide an interesting explanation of these discordant empirical evidence. They advocate that the diverse natural experiments may actually measure the knowledge spillovers originated by supply shocks in three conceptually distinct dimensions: the space of ideas, the geographic location and the collaboration network. Accordingly, the relevance of the human capital spillovers is determined by the nature of the space as well as by the intrinsic quality of the single actors involved. A supply shock in any specific space may generate both spillover and competition effects, and each of these contrasting forces might diverge in intensity according to the typology of space considered. The observed empirical results would therefore represent the net impact of these two contrasting forces.

Against this background, the present paper's objective is to bring new and robust evidence on this growing and mixed literature. Specifically, we provide an empirical evaluation of the extent to which the international mobility of foreign-born skilled workers boost the innovation activity of the host country through the diffusion and spread of new ideas and knowledge.

Unlike most of the extant literature, our focus is on a specific category of skilled workers who contribute directly to the innovation capacity of a country, namely inventors. As documented by Docquier and Rapoport (2009), there is a considerable heterogeneity among skilled workers which is certainly worth exploring. However, the majority of the extant empirical literature has made use of datasets that collects information on tertiary educated labor force in general, only rarely providing evidence on specific groups of skilled workers, such as PhD holders and IT engineers (Docquier and Rapoport, 2009), doctors (Bhargava et al., 2011), scientists and academic researchers (Waldinger, 2010, 2012; Borjas and Doran, 2012; Franzoni et al., 2014; Ganguli, 2015) and inventors (Miguelez and Fink, 2013; Moser et al., 2014; Breschi et al., 2015). On the contrary, this paper will draw on a recently developed, and largely underexploited, bilateral worldwide dataset which collects relevant information on the international mobility of inventors for both developed and developing economies (Miguelez and Fink, 2013). By making use of this novel and rich data source we provide new empirical evidence on the actual role played by foreign-born inventors in bringing new ideas and in contributing to the diffusion of knowledge in the United States.

Indeed, the contribution of foreign-born inventors to the innovation activity of the host country may manifest itself in other ways than through the quantity of patents. Skilled immigrants may provide an equally relevant (indirect) contribution by means of positive spillovers on fellow workers. Since migrant inventors have a background that is presumably different from that of their native counterparts, they may generate spillovers that could affect the productivity of native inventors in directions that are less familiar to them (see Moser et al., 2014, for evidence using historical data). Taking into account these aspects, the objective of this paper is to provide an empirical assessment of whether and to what extent an influx of foreign-born inventors affects the productivity of native inventors.

In order to gather identification to our research questions, we follow 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 researchers 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. As we document in the next Sections, 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 construct a dataset of U.S. granted patents at city, IPC technological classes and year level and the correspondent number of patents with at least one ex-Soviet Union inventor. We therefore jointly consider two relevant dimensions through which the knowledge brought by immigrant inventors may diffuse to the incumbents, namely the space of ideas and the geographic location.

In order to correct for some possible endogeneity concerns, we then employ instumental 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.

Estimation results point to a positive and large contribution of immigrant inventors on the level of innovation in the United States. Technological fields regression analyses point to a particular important role played by ex-Soviet Union inventors in boosting the productivity of native inventors that are active in physics.

The rest of the paper is organized as follow. The next section provides background information about the Soviet Science System and the mechanisms of immigration after the end of the Soviet Union, Section 3 describes the construction of the dataset, Section 4 outlines our empirical strategy, Section 5 presents the main results and Section 6 concludes.

## 2 Historical background

As pointed out by Graham (1993), since its inception, the Soviet Union government has always attached great importance to science and technology. Starting from the 1920s, a considerable amount of financial resources was devoted to education and research. Large portions of the population that during the czarist regime were completely excluded from any kind of higher education were, now, stimulated to attain it. Moreover, contrary to general belief, in its early years, the Soviet science system was characterized by an high level of internationalization and openness. Indeed, the Soviet Union State understood the importance of interacting with the international scientific community and promoted study periods abroad for Soviet researcher as well as welcomed international visitors at Soviet laboratories. The main aim was to establish and create new scientific networks, to consolidate old ones and to elevate the level of Soviet Science to Western standards.

This inclusive attitude, changed dramatically from the early 1930s as a consequence of different circumstances. Firstly, the Soviet State extensively promoted the involvement of scientists in the solution of practical problems more and more related to the economy and specifically to the army. The new emphasis given to the applications of science, especially in key sectors such as the army, increased the necessity to make much of the science classified and secret. This situation was further exacerbated by the strong isolationist policies introduced by Stalin as a consequence of his increasing suspicious attitude about everything that was outside the Soviet borders. During that period, the Soviet government systematized severe controls regarding any type of interactions between Soviet Union and Western scientists. Restrictions were imposed on scientific travels, access to Western materials and communication with Western peers. Moreover, Stalin's dictatorship implemented authoritarian methods of promoting science, which had a huge influence in shaping its future direction and paradigms. In this respect, for pure ideological reasons, many scientific fields were severely neglected or even completely suppressed, while others were strongly supported and fostered. To reach this goal, and as part of the mass murders and deportations programs established in the 1930s (the so called purges), many prominent scientists active in different fields were indiscriminately murdered or exiled.

These mass murders and deportations were concentrated in two specific periods, namely in the second half of the 1930s and from right after the end of the Second War World till Stalin's death. However, as documented by Hargittai (2013), while in the first wave of terror there was no branch of science where scientists where immune to persecution, in the post- WWII period, physics was exempted. This, of course, was due to the acknowledgement of the importance of the nuclear weapons programme. In this context, an important role was played by Kavrentii Beria, chief of the Soviet security and secret police apparatus from the early 1940s. Although he was not less brutal than his predecessors, starting from the mid-1940s, when he was made responsible for the nuclear weapons program, he put aside ideological and political consideration in favour of scientific performance. Indeed, ex-Soviet union physicists could not have worked on the atomic bomb without the application of the theory of relativity and quantum mechanisms that were both considered the products of bourgeois ideologies (Hargittai, 2013).

Interestingly, this renewed interest on physics was also important in determining the pathways of other scientific fields, with particular reference to chemistry. As a matter of fact, twentieth-century physics and chemistry in the Soviet Union considerably overlapped, as in chemistry, most of the scientists were physicists or received training in physics. The labels of some sub-fields such as physical chemistry and chemical physics, demonstrate the high level of overlap between these two scientific fields. As a concrete example, the main discovers of some of the most notable scientists in the USSR, such us Nikolai Semenov, Yulii Khariton, Boris Belousov, Anatol Zhabotinsky and Aleksander Nesmeyanov were chemical in character even if only Belousov and Nesmeyanov could be considered as genuine chemists (Graham, 1993).

In contrast to this privileged situation of physics, the disadvantage conditions of the other sciences were notable during the Stalin's regime. Among them, biology suffered the most notable damage thanks to the action of Trofim Lysenko, Stalin's henchman and famous for being strongly against modern biology. This was part of the constant effort by Stalin's regime to prevent Western influence from penetrating Soviet society. Other technology-driven disciplines, such as automation and computerization were also singled out for attack.

It is therefore clear that, social, political and ideological factors were pivotal in determining the peculiarities of the Soviet Union science system, which developed in rather distinct ways with respect to what happened in Western Europe and America during the same period.

After the collapse of the USSR in 1991, the Soviet science system faced a tremendous reduction in funding for research and in particular in the wages of the scientists. On the basis of personal interview carried out with former Soviet Union scientists, Ganguli (2014) reports that numerous researchers did not receive their salary for a long period, or received only a small part of their salary payments. Moreover, there was an important reduction of the perceived prestige associated with jobs related to science and research, and recent evidence show that this negative mindset by the Russian population has endured (Gokhberg et al., 2009). At the same time, the end of the Soviet Union opened up new exiting opportunities for Soviet scientists. After many years of 'scientific segregation', they were finally free to travel, communicate and cooperate with foreign fellow researchers and scientists. Lured by much more appealing economic and social conditions, many of them decided to emigrate and to pursue their scientific career abroad.

Graham and Dezhina (2008) make reference to rather prudent estimate of around 7,000 ex USSR researchers and scientists emigrating abroad in the 1990s, while much less conservative estimates point to among 30,000 and 40,000 researchers leaving the country during the same time period. Along the same lines, Gochberg and Nekipelova (2002), by making use of data gathered by the State Committee on Statistics (Goskomstat) point to around 20,000 people employed in science related sectors that emigrated in the 1990s, albeit many of them were not pure research scientists.

A large portion of these high-skilled individuals chose the United States as destination country. Indeed, the US government immediately recognized the collapse of Soviet Union as an exceptional opportunity to attract many talented people with unique skills and expertise in key high-technological fields. In this respect, in 1992, it enacted the Soviet Scientists Immigration act, which granted authorization for engineers and scientists from the post-Soviet states to acquire employment within America. Furthermore, as shown by Wagner et al (2002), in the 1990s the US government spent around $ 350 million per year to support scientific cooperation with ex-Soviet Union Republics, and around $ 200 million per year explicitly on joint research project. As a results of these policy interventions, a considerable numbers of high skilled ex Soviet Union individuals emigrated to the United States in the 1990s. The 2000 U.S. Census reports an estimates of around 10,000 Soviet engineers and scientists specialized in different fields that left their original country to move to the United States in the 1990s (Ganguli, 2015). This sudden influx of Soviet Union scientists and researchers exposed U.S. inventors to a considerable amount of knowledge that in many cases was quite unique. Indeed, before the collapse of USSR, U.S. scientists had very limited opportunities to access Soviet publications and research. As pointed out by Graham and Dezhina (2008), not many people leaving outside the USSR could read Russian. There were, of course, attempts to render Soviet research available to U.S. researchers, but a more systematize translation programme took place only in the 1980s.

After the collapse of the Soviet Union, there was a huge increase in the availability of Soviet publications in the United States, but as noted by (Ganguli, 2015), information took time to diffuse and the most effective transmission channels of Soviet research was through face-to-face contact at conferences during research collaboration and through immigrants.

# 3 Data

In order to perform the analysis, we construct an annual city/technological field level panel identifying the number of ex-Soviet Union inventors arriving to the United States right after the collapse of the USSR, and the corresponding number of patents granted by the United States Patent Office (USPTO) U.S. native inventors. Firstly, information regarding the migration of Soviet Union inventors to the United States are retrieved by the WIPO IPSTAT database. This recently built dataset maps migratory patterns of inventors, by making use of information extracted from patent applications filed under the Patent Cooperation Treaty (PCT). The PCT is an international treaty that aims to facilitate and stimulate international patenting. The treaty is administrated by WIPO (World Intellectual Property Organization) and involves 152 States. The database represents a rich and unique opportunity to study the effects of skilled workers migration. It consists of bilateral counts of migrant inventors over more than three decades, with a worldwide coverage. In particular, the main advantage of using this dataset lies in the accuracy of the information it provides regarding both the residence and the nationality of the applicants. PCT patent application, as is the case of other patent documents, contains information on the name and address of the patent applicants as well as the name and the address of the inventors that are listed in the patent application. However, what distinguishes PCT applications from the other patent applications is that, in most of the cases, they record both the residence and the nationality of the inventor. This is due to the fact that only nationals or residents of a PCT contracting State can file PCT applications. Consequently, in order to verify that the applicant fulfills at least one of the two requirements, the PCT application form asks for both nationality and residence (Miguelez and Fink, 2013). As a general rule, the PCT system only documents residence and nationality information for applicants and not inventors. However, U.S. patents application procedure, until recently, required that all inventors in PCT applications to be also listed as applicants. Thus, if a given PCT application included the U.S. as a country in which the applicant considered pursuing a patent, all inventors were listed as applicants and their residence and nationality information are, in principle, available.

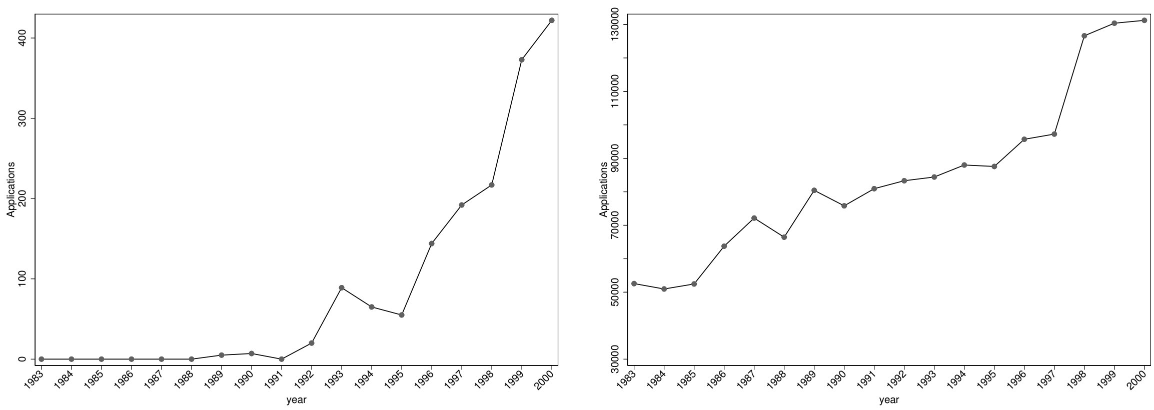


Figure 1: Distribution of ex-Soviet PCT patents (left panel) and U.S.patents (right panel) in the United States

From the PCT database we retrieve information regarding all PCT applications filed in the United States and granted during the period 1992 (right after the collapse of the Soviet Union) to

2000 with at least one inventor with a nationality in one of the 15 ex-Soviet Socialist Republics.[2] In particular, we retrieve information on the U.S. location (5-digit zip-code) where the inventor resided at the time the application was filed and regarding the different 4-digit IPC classes assigned to each application.

By drawing on the United States Patent Office database (USPTO), we next identify all the patents granted in the United States for the period 1983-2000 with at least one U.S. inventor residing in the United States. As in the previous case, we retrieve information about the residence of the inventor and the IPC classes assigned to each application.

Figure 1 outlines the distribution of ex-USSR PCT and USPTO patents over the period 1983-2000. It shows a constant increasing trend overtime for both PCT and USPTO patents, with almost no ex-USSR PCT patents before 1992.

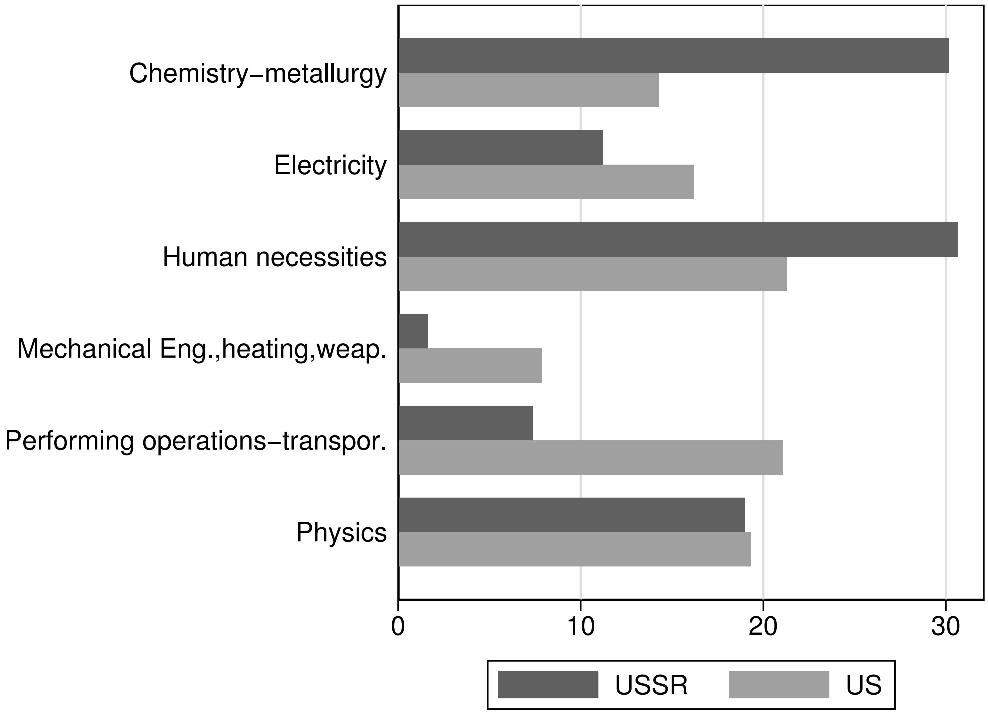


Figure 2: Distribution of ex-Soviet PCT and USPTO patents by field (IPC Sections)

Figure 2 presents the distribution of PCT and USPTO granted patents by the main area of technology.[3] Interestingly, the picture show a quite different technological specialization of Soviet Union inventors with respect to their U.S. counterparts. Indeed, Soviet Union inventors appear to be much more active than U.S. inventors in 'Human necessity' and 'Chemistry-metallurgy', while they invent less in comparative terms in the remaining fields and in particular in 'Mechanical Engineering and Lightning-Heating and weapons' and 'Electricity'. To further characterize the technological specialization of the Soviet Union inventors, Table 1 lists the top 20 4-digit IPC

[2]The Soviet Union (1917/22—1991) consisted of 15 Soviet Socialist Republics: Armenia, Azerbaijan, Belorussia (now Belarus), Estonia, Georgia, Kazakhstan, Kirgiziya (now Kyrgyzstan), Latvia, Lithuania, Moldavia (now Moldova), Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

[3]Notice that we exclude from the final sample all the applications field in the IPC technological fields 'Textile' and 'Fixed construction'. Indeed, the number of ex-Soviet Union inventors applying for patents in these fields in the United States is extremely negligible

classes for number of patents with at least on Soviet Union inventor. For comparison purposes, in the last two columns of Table 1, we report also the correspondent ranking per number of USPTO patents and PCT patents with at least one (non ex USSR) foreign-born inventor. Many technological classes, such as 'preparation for medical and dental purposes', 'electric digital data processing', and 'investigating and analysing materials' rank high also in the case of U.S. inventors and foreign born inventors (see last two columns of Table 1). However, others appear to have a much less relevant role in the United States innovative context. This is the case for example of 'micro-organisms or enzymes', 'peptides', 'semiconductor devices', 'measuring and testing processes involving enzymes', 'data processing systems or methods'.

Table 1: Distribution of ex-Soviet PCT patents by field (top 20 IPC sub-classes)

| *IPC code* | *IPC definition* | *IPC level* | *Freq.* | *Perc.* | *Rank-USSR* | *Rank-US* | *Rank-For.* |
|---|---|---|---|---|---|---|---|
| A61K | Preparations for med. dental pourp. | Hum.Nec | 329 | 20.70 | 1 | 2 | 1 |
| G01N | Investigating or Analysing Materials | Phy | 96 | 6.04 | 2 | 6 | 6 |
| C12N | Micro-organisms or Enzymes | Ch-Met | 87 | 5.48 | 3 | 17 | 4 |
| C07K | Peptides | Ch-Met | 78 | 4.91 | 4 | 45 | 3 |
| C07D | Heterocyclic Compounds | Ch-Met | 60 | 3.78 | 5 | 11 | 2 |
| A61B | Diagnosis, surgery, ientifications | Hum.Nec | 59 | 3.71 | 6 | 3 | 9 |
| C12Q | Measuring or test.proc.invol. enzy. | Ch-Met | 55 | 3.46 | 7 | 80 | 10 |
| H01M | Processes or Means, E.G. Batteries | Elec | 47 | 2.96 | 8 | 43 | 17 |
| G06F | Electric Digital Data Processing | Phy | 44 | 2.77 | 9 | 1 | 5 |
| C07C | Acyclic or Carbocyclic Compounds | Ch-Met | 41 | 2.58 | 10 | 7 | 8 |
| B01J | Chemical or Physical Processes | Op.Tr. | 35 | 2.20 | 11 | 26 | 20 |
| H01L | Devices using stimulated emission | Elec | 35 | 2.20 | 12 | 5 | 14 |
| H01S | Semiconductor devices | Elec | 35 | 2.20 | 13 | 65 | 42 |
| G02B | Optical Elements, Systems | Phy | 33 | 2.08 | 14 | 14 | 23 |
| C07H | Sugars; Derivatives Thereof | Ch-Met | 29 | 1.83 | 15 | 53 | 15 |
| H04N | Pictorial Communication, e.g. Television | Elec | 20 | 1.26 | 16 | 15 | 13 |
| G06K | Recognition/Presentation/Record of Data | Phy | 17 | 1.07 | 17 | 23 | 46 |
| G06Q | Data processing systems or methods | Phy | 17 | 1.07 | 18 | 558 | 11 |
| C23C | Coating met.materials | Ch-Met | 16 | 1.01 | 19 | 71 | 40 |
| H01J | Electric discharge tubes | Elec | 15 | 0.94 | 20 | 21 | 39 |

# 4 Empirical strategy

## 4.1 Regression framework

In line with the spatial correlation literature studying the economic effects of immigration in local labor market (see, among others Card, 2001), our empirical approach exploits variations across cities, technological fields and time in the number of immigrant inventors arriving to the U.S. from the former Soviet Union. Although, as pointed out by Feldman (2000), there is no general agreement regarding the appropriate unit of analysis for a geographical location in studies of localised knowledge flows, we follow the most common practice in the field and choose as administrative division the concept of Metropolitan Statistical Area (MSA).

In order to get evidence on our research question, we estimate the following regression model:

$$y_{c,j,t} = \delta_c + \delta_j + \delta_t + (\delta_j \times \delta_t) + \beta_1 \text{Number of USSR patents}_{\text{c,j}} \times \text{post}_{\text{t}} + \beta_2 \text{X}_{\text{c,j,t}} + \epsilon_{i,t}, \qquad (1)$$

Where the dependent variable $y_{c,j,t}$ identifies the number of patents granted to U.S. inventors in MSA $c$, 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 those U.S. patents with at least one ex-Soviet Union inventors.

As for the covariates, $\delta_c$ represents a vector of city (MSAs) fixed effects that control for unobservable geographical specificities that may cause variation in patenting across MSAs and constant over time, $\delta_j$ controls for technological specificities, while $\delta_t$ is a vector of year fixed effects that control for unobservable variation in patenting over time. Finally, $\delta_j \times \delta_t$ represents technological fields x year fixed effects, which controls for changes in the fields over time. This complete set of fixed effects will allow us to control for unobserved factors not related to the arrival of Ex-Soviet Union inventors that may have increased the patenting activity of incumbent inventors.

The variable Number of USSR $\text{patents}_{c,j}$ identifies the number of PCT patents with at least one ex-Soviet Union inventor residing in MSA $c$ and patenting in technological field $j$, while 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. First, we construct a variable identifying the 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. This is useful to control for possible unobservable factors, which might have influenced the patenting activity of U.S. inventors regardless the arrival of the ex Soviet Union inventors. Second, in order to control for variation in the speed of invention across the life cycle of a technology, we construct a variable measuring the years that have elapsed since the first patent was issued in technological class $c$ and its square.

### 4.2 Identification strategy

Our identification strategy is primary based on the comparison of two distinct groups of U.S. cities/technological fields. In particular, we identify a group of 'treated' and 'control' cities/ technological classes on the basis of the value taken by the variable Number of USSR $\text{patents}_{c,j}$. In this way we are able to make a comparison of cities/technological classes that have been affected by the ex Soviet Union inventors vis-á-vis those ones that were not affected by the influx of ex Soviet Union inventors. It is likely that U.S. native inventors not active in these particular cities and technological fields experienced a less pronounced influence from the influx of ex-Soviet Union inventors. Therefore, the basic idea of our identification strategy is that not all home-born inventors were equally affected by the Soviet immigration flow. This differential shock provides the method for determining the productivity impact of the collapse of the USSR on the level of innovation in the United States.

As can be imagined, the two treated and control cities/technological classes groups are far from to be homogeneous. In particular, the control group is much bigger, as there are many cities/technological classes without any USSR patents. In order to reduce the degree of heterogeneity between the two groups, we apply a nonparametric matching method, namely coarsened exact matching (CEM; Blackwell et al. 2009), to create matched control group for MSA and technological classes. The matching is carried out on two relevant pre-1991 characteristics, that is to say, total MSAs population on 1990 and MSAs IPC technological distribution. This matching procedure leads to a final sample made up of 39,225 control and 4,862 treated MSAs/technological classes.

Table 2: Distribution of ex-Soviet PCT patents by geographical location (top 20 MSAs)

| *MSA* | *Freq.* | *Perc.* | *Rank-USSR* | *Rank-US* | *Rank-For.* |
|---|---|---|---|---|---|
| New-York,NY | 480 | 30.21 | 1 | 1 | 1 |
| Brockton,MA | 280 | 17.62 | 2 | 3 | 2 |
| Oakland,CA | 136 | 8.56 | 3 | 4 | 3 |
| Gary-Hammond,IN | 110 | 6.92 | 4 | 2 | 4 |
| San-Diego,CA | 64 | 4.03 | 5 | 21 | 8 |
| Philadelphia,PA-NJ | 53 | 3.34 | 6 | 10 | 7 |
| San-Jose,CA | 51 | 3.21 | 7 | 6 | 5 |
| Stamford,CT | 40 | 2.52 | 8 | 7 | 14 |
| Brazoria,TX | 39 | 2.45 | 9 | 5 | 6 |
| Seattle,WA | 22 | 1.38 | 10 | 14 | 10 |
| Alton,Granite-City,IL | 21 | 1.32 | 11 | 11 | 12 |
| Cleveland,OH | 20 | 1.26 | 12 | 17 | 22 |
| Baltimore,MD | 18 | 1.13 | 13 | 29 | 24 |
| Omaha,NE-IA | 16 | 1.01 | 14 | 82 | 62 |
| New-Haven-Meriden,CT | 16 | 1.01 | 15 | 33 | 20 |
| Cincinnati,OH-KY-IN | 16 | 1.01 | 16 | 18 | 9 |
| Beaver-County,PA | 14 | 0.88 | 17 | 13 | 23 |
| Madison,WI | 13 | 0.82 | 18 | 48 | 37 |
| Tuscon,AZ | 13 | 0.82 | 19 | 49 | 41 |
| Minneapolis-St.-Paul,MN-WI | 12 | 0.76 | 20 | 15 | 21 |

Figure 3 shows the evolution of the number of U.S. patents distinguishing between MSA and IPC subclasses with and without ex-soviet union inventors. The depicted trend points to a visible increase in U.S. patents after 1992 in research fields and cities of Ex-Soviet Union inventors compared with control fields and cities.

Next, we design a specific strategy to correct for possible endogeneity issues. Indeed, as extensively discussed in Borjas (2003), one relevant empirical issue in our context is that immigrants do not choose their destination randomly. If unobserved factors have a role in determining both the choice of the immigrants and affecting the level of innovation at city level, there will be an endogeneity problem leading to a biased estimation of the coefficient $\beta_1$. This concern is somehow corroborated by the figures reported in Table 2, that lists the top 20 MSAs for number of residing ex Soviet Union inventors. It emerges that the most innovative cities per number of patents are also some of those with the highest number of Soviet Union inventors. This is the case of New York-Newark-Jersey City, NY-NJ-PA, San Jose-Sunnyvale-Santa Clara, CA Los Angeles-Long Beach-Anaheim, CA and Chicago-Naperville-Elgin, IL-IN-WI.

To deal with this endogeneity concern we follow the idea of the supply-push instrument proposed by Card (2001) by instrumenting the distribution across cities of USSR inventors after 1991 (captured by the variable Number of USSR patents$_{c,j}$) with the pre-1990 distribution of all USSR-born immigrants (see Cortes, 2008; Hunt and Gauthier-Loiselle, 2010; Ganguli, 2015; Gagliardi, 2015, for studies using similar strategies). Indeed, it is very likely that the current and historical immigrant communities 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. Historical accounts suggest that this factor might have been particularly important in the case of the ex-Soviet Union inventors migrating in the United States. As suggested by Ganguli (2015), ex-Soviet Union scientists that emigrated to the U.S. were, on average, credit constrained, often without a formal offer of employment, in many cases unable to fluently communicate in English and in general unacquainted with habits and life in the United States. Accordingly, we can plausibly claim that the broader immigration network, more than the professional one, represented a relevant factor driving the location decision of the ex-Soviet Union inventors in the United States.

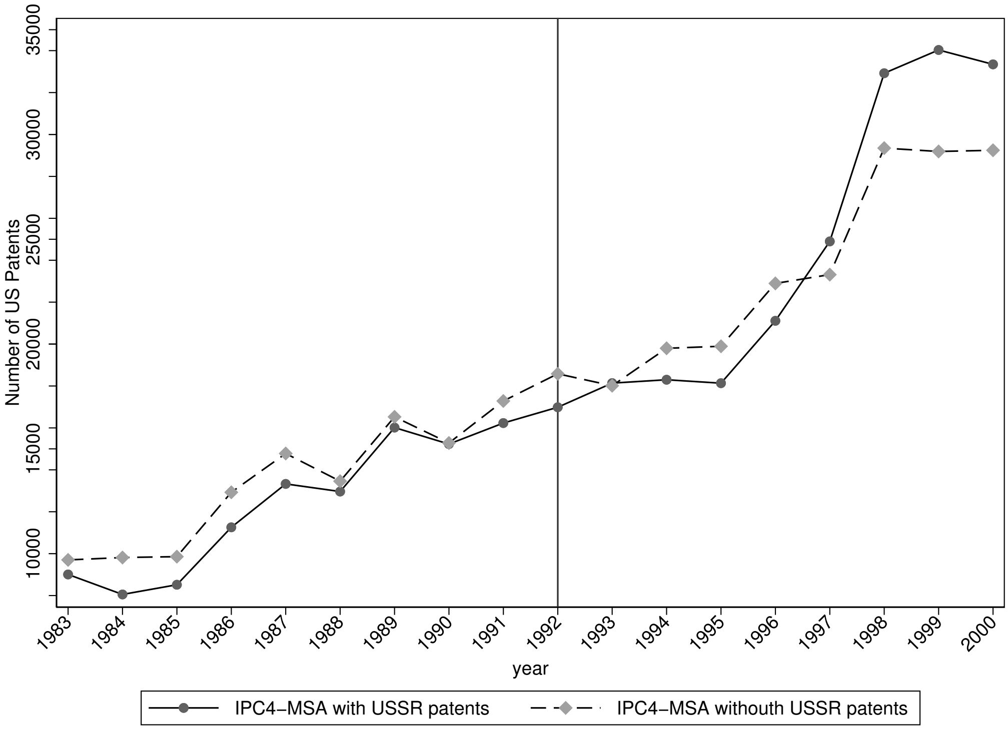


Figure 3: Number of US patents per Class MSA, Year by domestic US inventors

In order to construct the instrument, we retrieve information from the 1990 Public Use Microdata Sample-PUMS (State 5% sample) on the number of 15-65 years old individuals reporting a birthplace in the ex-Soviet Union and residing in a specific MSA in the 1990 and match them with all the MSAs in our dataset. By making use of this information, we construct a weighted measure of the inflow of USSR inventors across U.S. cities using the 1990 distribution of Soviet-born immigrants in the following way:

$$\frac{\text{Tot.USSR Migrants}_{c1990}}{\text{Tot.USSR Migrants}_{1990}} * \text{Migrant Inventors}_{jt}$$

where Tot.USSR $\text{Migrants}_{c1990}$/ Tot.USSR $\text{Migrants}_{1990}$ represents the share of all Soviet-born immigrants in the 1990 census in city $c$ and $MigrantInventors_{jt}$ is the total number of ex-Soviet Union inventors filing in filed $j$ in year $y$.

Table 3 shows a quite high degree of spatial concentration with respect to the historical migration flows of Soviet Union born, with New York-Newark-Jersey City, NY-NJ-PA and Los Angeles-Long Beach-Anaheim, CA reporting by far the largest shares of USSR migrants in 1990.

Table 3: Cities' share of 1990 ex-Soviet born immigrants

| *MSA* | *%* | *Rank Inv ex-USSR* |
|---|---|---|
| New-York,NY | 29.45 | 1 |
| Gary-Hammond,IN | 7.30 | 4 |
| Philadelphia,PA-NJ | 4.52 | 6 |
| Brockton,MA | 3.83 | 2 |
| Oakland,CA | 3.39 | 3 |
| Fort-Lauderdale-Hollywood-Pompano-Beach,FL | 2.58 | 25 |
| Detroit,MI | 2.13 | 30 |
| Daytona-Beach,FL | 1.91 | 112 |
| Cleveland,OH | 1.65 | 12 |
| Baltimore,MD | 1.40 | 13 |
| Seattle,WA | 1.10 | 10 |
| Minneapolis-St.-Paul,MN-WI | 1.04 | 20 |
| Monmouth-Ocean,NJ | 0.93 | 137 |
| Denver,CO | 0.87 | 41 |
| Vancouver,WA | 0.84 | 33 |
| Sacramento,CA | 0.82 | 26 |
| Tampa-St.-Petersburg-Clearwater,FL | 0.81 | 50 |
| Milwaukee,WI | 0.79 | 135 |
| Rochester,NY | 0.74 | 146 |
| San-Jose,CA | 0.71 | 7 |

# 5 Econometric results

Table 4 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. However, as previusly discussed, these results may be biased by endogenity. Accordingly, in Table 5 we present the IV estimations obtained using the instrument described in the previous section. First-stage regression estimates (columns 1-4) strongly confirm the validity of the chosen instrument, namely that the existing historical USSR immigrants enclaves considerably affect the location decision of ex-Soviet Union inventors. Indeed, the coefficient of the instrument is always highly significant and the value of the F-statistics on the excluded instrument is considerably high. The coefficients of the reduced form (columns 5-8) are also positive and highly significant. Interestingly, the IV estimates are much larger than the OLS estimates. This is at first surprising, since we predicted an upward bias of the OLS estimates. However, it is in line with the results found by Hunt and Gauthier-Loiselle (2010) and Ganguli (2015), who rely on similar IV approaches. Our speculative explanation is that ex-Soviet Union that made their location decision on the basis of existing immigrant enclaves are more likely to contribute to knowledge diffusion only through their mobility. On the other hand, immigrants who do not take into account existing immigrant networks in their location decisions would contribute to the transfer of knowledge even if they did not migrate. For example, immigrant scientists may be more likely to locate in cities with big research centers or universities but with smaller existing

USSR immigrant enclaves. These scientists would probably have an employment offer in advance, and the people with whom they interact would be probably already familiar with their past work. In a city with no such conditions, an ex-Soviet Union scientist would be more likely to be unknown to the natives upon arrival, and so the opportunity for him to transmit new knowledge to them would be much higher.

Table 4: 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.

Starting from these general findings, we carry out additional estimations with the aim of identifying some specific degree of idiosyncrasy at technological level. In particular, we estimate an modified version of equation 1 by interacting the main variable of interest with 6 dummies identifying the different technological fields depicted in Table 2. Results, reported in Table 8, show that the effect is mostly driven by USSR patents filed in Physics (omitted category) and to a less extent in Operation and transportation.

Table 5: First Stage and Reduced Form

| | First Stage | | | | Reduced form | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| USSR migrants 1990 | 1.089*** | 1.085*** | 0.722*** | 0.722*** | | | | |
| | (0.165) | (0.164) | (0.187) | (0.187) | | | | |
| *Number of USSR patents* x *post* | | | | | 47.105*** | 46.554*** | 38.183*** | 38.219*** |
| | | | | | (7.178) | (7.120) | (12.331) | (12.317) |
| Quadratic age subclass | No | No | No | Yes | No | No | No | Yes |
| (N. of foreign patents) | No | No | Yes | Yes | No | No | Yes | Yes |
| Year X Class fix. eff. | No | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Class fixed effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| MSA fixed effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Number of observations | 43,795 | 43,795 | 43,795 | 43,795 | 43,795 | 43,795 | 43,795 | 43,795 |
| Number of clusters | 6,302 | 6,302 | 6,302 | 6,302 | 6,302 | 6,302 | 6,302 | 6,302 |
| $R^2$ | 0.30 | 0.30 | 0.39 | 0.39 | 0.04 | 0.04 | 0.13 | 0.13 |
| F-Statistics | 43.78 | 43.87 | 14.97 | 14.98 | | | | |

*Notes:* In reduced-form regressions (columns 5-8) the dependent variable measures U.S. patents issued to U.S. inventors per MSA, IPC sub-class and year, excluding patents by ex-Soviet Union inventors. The dummy variable *Post* equals 1 for years after 1991. Standard errors are clustered at the level of MSA and IPC technological class.
***, ** and * indicate significance at 1%, 5% and 10% level, respectively.

Finally, we check the sensitivity of our results to the exclusions of some of the biggest historical enclaves of Soviet-born immigrants. Indeed, from Table 3 emerges clearly that for most MSAs, the shares of all Soviet-born immigrants in the 1990 census in city $c$ are quite small and are determined by few people in all but the largest cities. Accordingly, we re-estimate all the models, excluding New-York MSAs. Tables 6 and 7 present the results for the OLS and IV estimates. As can be seen, both the magnitude and the level of significance of the coefficients are largely in line with those presented in tables 4 5.

## 6 Conclusions

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.

This paper contributes to this literature by providing systematic evidence on the extent to which foreign-born inventors contribute to boost innovation in the host country through the diffusion and spread of new ideas and knowledge. Unlike most of the extant literature, our focus is on a specific category of skilled workers who contribute directly to the innovation capacity of a country, namely inventors. We draw on a recently developed, and largely underexploited, bilateral worldwide dataset which collects relevant information on the international mobility of inventors for both developed and developing economies. By making use of this novel and rich data source and by drawing upon the natural experiment provided by the end of the Soviet Union, we provide new empirical evidence on the actual role played by foreign-born inventors in bringing new ideas and in contributing to the diffusion of knowledge in the United States.

OLS estimates on a panel of U.S. patents at city, technological class and year level document a positive and significant contribution of ex Soviet Union immigrant inventors on the patenting propensity of native inventors. In order to correct for the potential endogenenity deriving from the fact that migrants inventors do not choose randomly their destination, we use the 1990 geographical distribution of Soviet-born immigrants to construct a suitable instrument for number of ex-Soviet union patent applications in a certain city and technological class. Results of the IV regression confirm that the influx of ex Soviet Union inventors in the United States has brought a substantial increase in the number of patents granted to native inventors. Furthermore, additional estimations show that the overall effect is mainly driven by those ex USSR inventors active in two specific technological fields, namely, physics and chemistry.

In the light of the discussion put forward in the introduction, these findings may imply interesting policy implications. Indeed, they seem to suggest that the migration of highly skilled worker, and in particular inventors, is beneficial for the host country economy because of the positive spillover effects on the native inventors. Also, the differences in the impact of immigrant inventors across scientific fields suggest that there might be some field specific conditions that render the diffusion of knowledge to the native inventors more or less effective.

# Appendix

Table 6: Ordinary Least Square Regressions (excluding New York MSA)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| *Number of USSR patents* x *post* | 17.939*** | 17.725*** | 3.639** | 3.639** |
| | (3.212) | (3.189) | (1.585) | (1.583) |
| 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 | 42,793 | 42,793 | 42,793 | 42,793 |
| Number of clusters | 6,199 | 6,199 | 6,199 | 6,199 |
| $R^2$ | 0.11 | 0.16 | 0.25 | 0.25 |

*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.

Table 7: First Stage and Reduced Form estimations (excluding New York MSA)

| | First Stage | | | | Reduced form | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| USSR migrants 1990 | 1.835*** | 1.838*** | 0.866*** | 0.869*** | | | | |
| | (0.669) | (0.685) | (0.244) | (0.245) | | | | |
| *Number of USSR patents* x *post* | | | | | 49.467*** | 48.197*** | 47.904*** | 47.847*** |
| | | | | | (8.143) | (7.924) | (10.756) | (10.713) |
| Quadratic age subclass | No | No | No | Yes | No | No | No | Yes |
| (N. of foreign patents) | No | No | Yes | Yes | No | No | Yes | Yes |
| Year X Class fix. eff. | No | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Class fixed effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| MSA fixed effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Number of observations | 42,793 | 42,793 | 42,793 | 42,793 | 42,793 | 42,793 | 42,793 | 42,793 |
| Number of clusters | 6,199 | 6,199 | 6,199 | 6,199 | 6,199 | 6,199 | 6,199 | 6,199 |
| $R^2$ | 0.17 | 0.17 | 0.36 | 0.36 | | | | |
| F-Statistics | 7.52 | 7.20 | 12.57 | 12.62 | | | | |

*Notes:* In first stage (columns 1-4) dependent variable is *N.USSR pat. x post.* In reduced-form regressions (columns 5-8) the dependent variable measures U.S. patents issued to U.S. inventors per MSA, IPC sub-class and year, excluding patents by ex-Soviet Union inventors. The dummy variable *Post* equals 1 for years after 1991. Standard errors are clustered at the level of MSA and IPC technological class.
***, ** and * indicate significance at 1%, 5% and 10% level, respectively.

Table 8: OLS estimations: by IPC categories

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| *Number of USSR patents* x *post* | -1.536 | -0.387 | -0.907 | -0.938 |
| | (1.263) | (1.279) | (1.459) | (1.466) |
| *Number of USSR patents*(Physics) x *post* | 39.631*** | 37.370*** | 32.791*** | 32.819*** |
| | (14.588) | (13.891) | (11.939) | (11.938) |
| *Number of USSR patents*(Hum Nec) x *post* | 30.274*** | 28.691*** | 5.783 | 5.811 |
| | (6.590) | (6.587) | (6.842) | (6.848) |
| *Number of USSR patents*(Chem.) x *post* | 11.859*** | 10.855*** | 3.147 | 3.175 |
| | (3.647) | (3.443) | (2.739) | (2.737) |
| *Number of USSR patents*(Mec.Eng.) x *post* | 1.132 | 1.205 | 1.768 | 1.802 |
| | (1.599) | (1.506) | (1.627) | (1.634) |
| *Number of USSR patents*(Elect.) x *post* | 7.302*** | 6.147** | 5.333* | 5.348* |
| | (2.767) | (2.698) | (3.009) | (3.014) |
| 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 |
| $R^2$ | 0.16 | 0.21 | 0.29 | 0.29 |

*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.

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