How Immigrants Invent

Evidence from Sweden

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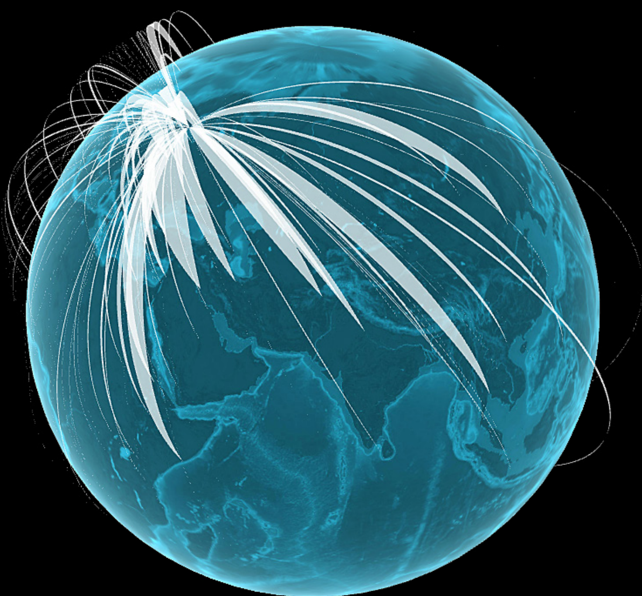

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Evidence from Sweden

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Abstract

This thesis investigates the inventive performance of immigrants in Sweden based on a special database which links inventors to the general population of the country from 1985 to 2007. It shows that the inventive performance of immigrants is influenced by immigrants' age at migration, region of origin, educational level, match between education and occupation and migration policy.

In general, first-generation immigrants are less likely to patent than native Swedes. The exception is the group working in the high-tech knowledge-intensive service (KIS) sector, where first-generation immigrants are more likely to patent than natives. This is mainly because in this sector, first-generation immigrants are educated to a higher level than their native peers; furthermore, their high and similar representation in high-skill occupations as natives enable them to have as high patenting rate as natives when other variables are held constant. In most sectors, however, the main barriers to first-generation immigrants' probability of patenting are their over-representation in low-skill occupations and their lower education-occupation match compared with natives. When the analysis is limited to inventors, first-generation immigrant inventors perform as well as their native counterparts.

Second-generation immigrants with a non-Nordic European background perform better than native Swedes, which appears to be because they have more highly educated parents than their native counterparts. Their performance may also be positively affected from having non-native parents who originated from regions with close geographic proximity to Sweden.

The findings also suggest that, the liberalization of migration after the inception of the European Economic Area (EEA) in 1994 had a negative effect on educational profile of new EU-15 immigrants to Sweden in the short run when compared with new immigrants from 'Other developed regions', but there is no such effect in the long run; moreover, the liberalization of migration also has no systemic effect on the EU-15 immigrants' probability of becoming an inventor both in the short and long run.

Key words: First-generation immigrants · Second-generation immigrants · Inventors · Patent · Children · Adults · Human capital · Selection · Sector · Age · Region of origin · Education · Occupation · Migration policy

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To my family: love you with all of my heart

致我最爱的家人

Content

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List of papers

I. Zheng, Yannu and Ejermo, Olof (2015). How do the foreign-born perform in inventive activity? Evidence from Sweden. *Journal of Population Economics*, 28(3): 659–695

II. Zheng, Yannu (2016). The inventive performance of second-generation immigrants in Sweden: differentiated by parents' region of origin. *Unpublished manuscript*.

III. Zheng, Yannu (2016). The inventive performance of immigrants across multiple sectors: the importance of education and occupation. *Unpublished manuscript*.

IV. Ejermo, Olof and Zheng, Yannu (2017). Liberalization of European migration and the immigration of skilled people to Sweden. *Unpublished manuscript*.

Introduction

Aims and objectives of the thesis

International migration has continued to increase over the last 30 years and is an important policy issue for most host countries, especially countries with a large and increasing inflow of immigrants (OECD, 2016; United Nations, 2016). The impact of immigration on the host country is a controversial issue both in research and political debate. There has been research on the impact of immigrants on a variety of economic and social outcomes in host countries (e.g. Storesletten, 2003; Rowthorn, 2008; Paserman, 2013), however, empirical evidence about the impact of immigrants on innovation, which is considered a main driver of economic progress and a potential way of meeting global challenges (OECD, 2007), is still scarce.

Immigrants usually bring knowledge and skills with them. Immigrants, especially highly skilled immigrants, are able to contribute directly to innovation in the host country by drawing on their human capital, or indirectly through knowledge spillover (Hunt & Gauthier-Loiselle, 2010; Ozgen et al., 2013). Therefore, many countries designed migration policies to attract highly skilled immigrants as this is considered an effective way of promoting innovation and economic growth (Paserman, 2013; Parrotta et al., 2014). To assess the benefits of immigration, it is important to study the effect of immigrants on innovation in the host country.

In recent years there has been increasing interest in the contribution of immigrants to innovation in host countries (e.g. Stephan & Levin, 2001; Hunt & Gauthier-Loiselle, 2010; No & Walsh, 2010; Hunt, 2011). Most of the extant studies are from the United States (US) but some are from European countries. Most focus on highly skilled immigrants and have found that highly skilled immigrants have a positive effect on innovation outcomes in the host country. This is mainly attributed to the positive (self-)selection of highly skilled immigrants (Chiswick, 1978; Borjas, 1987; Wadhwa et al., 2007; No & Walsh, 2010; Hunt, 2011; Nathan, 2014a). However, highly skilled immigrants constitute a special immigrant group as they are more qualified than immigrants in general. This difference is rarely acknowledged in empirical studies. Moreover, highly skilled immigrants are also over-represented in certain high-tech sectors compared with natives (Kerr, 2010). These factors mean that the innovation of highly skilled immigrants is not representative of the majority of immigrants, who are not high-skilled and do not work in high-tech sectors.

There have been some analyses of the innovative performance of immigrants in general, based on data aggregated at regional or country level. Both Ozgen et al. (2012) and Bratti & Conti (2014) find that neither the size of the general immigrant population nor the proportion of immigrants in the population affect the number of patent applications. This indicates that studies which only consider highly skilled immigrants should not be used to generalize about the innovative performance of immigrants in general. This is especially important for countries that attract large number of low-skilled immigrants, like Sweden, which has a tradition of focusing on humanitarian migration and paying little attention to its economic impact (Scott, 1999; Bevelander, 2000). However, aggregated data cannot reveal the real distribution and contribution of immigrants to innovation. It is also important to emphasize that innovation is not confined to the high-tech sectors but can be expected to occur to varying extents across multiple sectors, which differ in their requirements for knowledge and invention skills as well as differing markedly in inventive activity (Helmers & Rogers, 2011).

This thesis takes advantage of a new individual-level database that links inventors to the general population in Sweden between 1985 and 2007. I examine the direct inventive performance (as an indicator of innovation) of both immigrants in general and immigrant inventors. Immigrant inventors are considered and defined as a subgroup of highly skilled immigrants. Moreover, I examine the inventive performance of immigrants across four different sectors: (a) high-tech manufacturing (e.g. chemicals); (b) high-tech knowledge intensive service (KIS) (e.g. telecommunications); (c) ‘other KIS’ (e.g. health care and social services) and (d) low-tech (e.g. food industry).

Invention is a knowledge-intensive and creative activity. A person’s inventive performance can be related to his or her demographic or formal human capital characteristics such as gender, age and education (Hunt, 2011; Jung & Ejermo, 2014); it also depends heavily on unmeasured assets such as language skills, cultural and institutional knowledge and social networks (Agrawal et al., 2008; Nathan, 2014a). Lack of these informal factors, which is more likely to affect immigrants than natives, may hamper an individual’s inventive performance (Nathan, 2014a).

Age at migration and region of origin provide some indication of immigrants’ qualifications and integration into the host society and both these factors are thought to affect immigrants’ development of formal and informal human capital and their performance (Fuligni, 1997; Schaafsma & Sweetman, 2001; Böhlmark, 2008; Zimmermann et al., 2008). However, no previous study has looked at how age at migration and region of origin influence immigrants’ inventive performance. In particular, no study has examined how parents’ region of origin affects second-generation immigrants’ inventive performance through intergenerational transmission of human capital. Arguably, these factors contribute heavily to the extent to which immigrants integrate into the host society and the impact they have on its long-term development, especially if immigrants make up a large proportion of the population. Therefore, in this thesis I examine these issues by comparing the inventive performance of first-generation immigrants who migrated as children (under the age of 18 years) and as adults, and second-generation immigrants (Swedish born with at least one foreign-born (FB) parent) with that of natives.

The position of second-generation immigrants differs from that of both first-generation immigrants and natives. Although they are born and educated in the host country, their parents' immigration is likely to play an important role in the formation of their human capital (Chiswick & DebBurman, 2004). Parents' region of origin is also thought to influence children's human capital to some extent, through intergenerational transmission (Ermisch & Francesconi, 2001; Riphahn, 2003; Lundborg et al., 2014). Therefore, this thesis investigates how parents' region of origin affects second-generation immigrants' inventive performance by comparing different groups of mixed immigrants (i.e. Swedish born with one Swedish-born and one FB parent) and immigrants with two FB parents.

Education plays a crucial role in invention, and is usually seen as highly skilled immigrants' most important advantage compared with natives, especially in the fields of science and engineering (Hunt & Gauthier-Loiselle, 2010; No & Walsh, 2010; Hunt, 2011). However, high educational attainment does not guarantee that immigrants will find employment in a high-skill occupation, where patenting is more likely to occur. This is because education-occupation mismatches are more frequent amongst immigrants than natives, possibly due to lack of country-specific human capital or to discrimination (Battu & Sloane, 2002; 2004; Green et al., 2007; Ottaviano & Peri, 2012). Moreover, the mismatch can also vary across sectors (Battu & Sloane, 2002). Thus, I investigate the effects of both education and education-occupation match on immigrants' inventive performance across several sectors.

The profile of a country's immigrants is strongly affected by its migration policy (Borjas, 1987; Huber & Bock-Schappelwein, 2014). However, little is known about how Sweden's migration policy, which differs from that of the US and the United Kingdom (UK) (Cerna, 2011), has affected the skill profile of Swedish immigrants and their innovation. I aim, therefore, to improve understanding of how migration policy has affected the skill profile and inventive performance of Swedish immigrants. Specifically, I examine how liberalization of migration following the establishment of the European Economic Area (EEA) in 1994 has affected the skill profile of European Union (EU) immigrants to Sweden.

Sweden is a relatively small country which had a population of only 10 million in 2016 (Statistics Sweden, 2017a), yet it is a world leader in innovation (OECD, 2008; Dutta et al., 2015). Sweden has put a lot of effort into improving its capacity for innovation. For example, Sweden has a very high level of spending on research and development (R&D) relative to its gross domestic product (GDP) (OECD, 2017). The innovation output in Sweden is also very impressive. In 2105, the Global Innovation Index ranked Sweden as the third most innovative of 141 countries, close behind Switzerland and the UK (Dutta et al., 2015). Moreover, between 1975 and 2000 Sweden experienced steady growth in the number of patents per million inhabitants, which increased from around 100 patents per million inhabitants in 1975 to around 175 in 2000, putting Sweden in fifth place amongst the 14 world-leading countries (Porter & Stern, 2002). Some of these patents were contributed by immigrants. For instance, Guellec & de la Potterie (2001) report that for the 1993–1995 period, foreign residents owned 8.4% and 18.4% of all patent applications at European Patent Office (EPO) and United States Patent and Trademark Office (USPTO) that were based on work carried out in Sweden.

Immigrants are an important component of the Swedish population. In 2014 first-generation immigrants constituted 16.5% of the population and second-generation immigrants 12.3% (Statistics Sweden, 2015). In order to increase its competitiveness in innovation, it is important for Sweden to know and understand its immigrant population's potential capacity for innovation; this would help it to make better use of immigrants' human capital and promote innovation in Sweden.

In brief, therefore, the overarching purpose of this thesis is to provide insight into the inventive performance of first- and second-generation immigrants in Sweden and to determine how their skills and inventive performance is related to age at migration, region of origin, educational level, education-occupation match and migration policy. This is important for discussions about the effect of immigrants on the development of Sweden (Storesletten, 2003; Rowthorn, 2008). The findings of this study may also apply to other European countries, especially those hosting large numbers of immigrants. More specific research questions are explored in four related papers.

There are some advantages to using several variables to capture the inventiveness of immigrants. First, it gives an overall impression of the direct contribution of the immigrant population in general to the host country. Second, it highlights the contribution of immigrant inventors, i.e. those who have directly contributed to innovation in the host country. Third, it suggests that it is important to acknowledge the heterogeneity of immigrants, which can in efforts to develop targeted policies to enable different types of immigrants to realize their full potential for innovation.

Review of literature on migration and innovation

Throughout history migration has been an important mechanism for distributing knowledge and innovation. Although there are now more ways of communicating, it remains important today. This is because a lot of knowledge, such as tacit knowledge, needs to be transferred through face-to-face interaction and face-to-face interaction is also important for knowledge recombination and generation of new ideas. In historical terms, immigrants, especially skilled immigrants, play a very important role in disseminating advanced technology from their home country to the host country. They promote innovation in the host country by drawing on their human capital or by contributing to the host country's accumulation of human capital. For example, Gripshover & Bell (2012) find that between 1883 and 1939, 19% of the 81 inventors who patented in onion-related inventions in the US were immigrants and 30% were sons of immigrants. Research on European emigration to the US during the Age of Mass Migration (1850–1920) shows that during this period, European immigrants had a large, positive impact on US innovation, measured as patents per capita (Nunn et al., 2017). Hornung (2014) find that immigration of highly skilled Huguenots to Prussia had a positive long-term effect on the productivity of the Prussian textile industry.

International migration is increasing, in particular there is rapid growth in skilled migration to developed nations (Nathan, 2014b; OECD, 2016; United Nations, 2016) and there is increasing scholarly interest in the impact of recent immigrants on invention and innovation in the host country. The extant studies have largely focused on highly skilled immigrants in the US. For example, a study by Chellaraj et al. (2008) show that the presence of foreign graduate students (immigrants with student visas) have a positive impact on patenting in the US. No & Walsh (2010) report that foreign-born individuals are more likely to invent than people born in the US although this effect disappears after controlling for variance in technology class, education and time spent on inventing. However, patents filed by leading immigrant inventors tended to be higher. Hunt & Gauthier-Loiselle (2010) and Hunt (2011) also indicate that in general, US immigrants have better patenting performance than US natives, largely due to immigrants' higher educational level and the above average proportion with degrees in science and engineering. Stephan & Levin (2001) find that in the life sciences foreign-born and foreign-educated (baccalaureate degree) immigrants contributed disproportionately to highly cited patents (the top 3.5% during 1980 1991). However, skilled immigrants and immigrant inventors are more likely to be concentrated in particular high-tech industries such as information technology (IT), computers and pharmaceuticals (Saxenian, 2002; Kerr, 2010).

There are also some studies on other countries. For instance, based on UK patent data, Nathan (2014b) concludes increasing the diversity of inventor communities can promote patenting. Moreover minority ethnic inventors with a high patent rate, especially so-called patenting stars of East Asian origin, can raise overall patenting rates. Based on organization-level data from the Netherlands, Ozgen et al. (2013) conclude that firms employing relatively high numbers of immigrants are less innovative, but the effect is weaker or even absent in the case of second-generation immigrants. In addition, firms with a more diverse foreign workforce are more innovative, especially with respect to product innovation. The benefits of cultural diversity for innovation are more apparent in sectors which employ highly skilled immigrants than sectors which employ unskilled immigrants. Based on regional patent application data from Germany, Niebuhr (2010) finds that the differences in knowledge and capabilities of workers from diverse cultural backgrounds enhance performance of regional R&D sectors. Moreover, the benefits of cultural diversity for innovation (indicated by number of patents per capita) seem to outweigh the costs e.g. communication barriers. In addition, there have also been several studies investigating the relationship between migration and scientific performance based on the Global Science (GlobSci) survey of 16 countries (Franzoni et al., 2012; 2014; Van Noorden, 2012).

History of Swedish immigration

Sweden started to become an immigrant country in the 1930s and the numbers coming in have increased since World War II (see Figure 1). In 1940 immigrants constituted only 1% of the population but this figure had reached 16.5% (about 1.6 million) by 2014 (Ekberg, 2011; Statistics Sweden, 2015). Immigrants choose Sweden as their destination for a variety of political, economic and social reasons.

Sweden remained neutral during both two world wars, becoming a refuge for individuals from neighboring countries (Helgertz, 2010). Sweden's position during the World War II also translated into a very favorable economic situation following 1945. Swedish export industry flourished against the background of the reconstruction and economic boom in Western Europe in the years after the war and this led to labor shortages. Swedish companies recruited large numbers of workers from the other Nordic countries, Italy, Hungary and Western Germany to meet the high demand for labor (Bevelander, 2000; Westin, 2000; Helgertz, 2010). Relatively high wages and good employment opportunities for low-skilled workers were the main reason for immigrants to work in Sweden. During the same period the Swedish government implemented a number of measures to facilitate worker immigration. For example, the labor market authorities of Sweden made agreements with several European countries on the collective transfer of labor to Sweden. The Swedish government also abolished visa restrictions for several western European countries in 1947 (Helgertz, 2010).

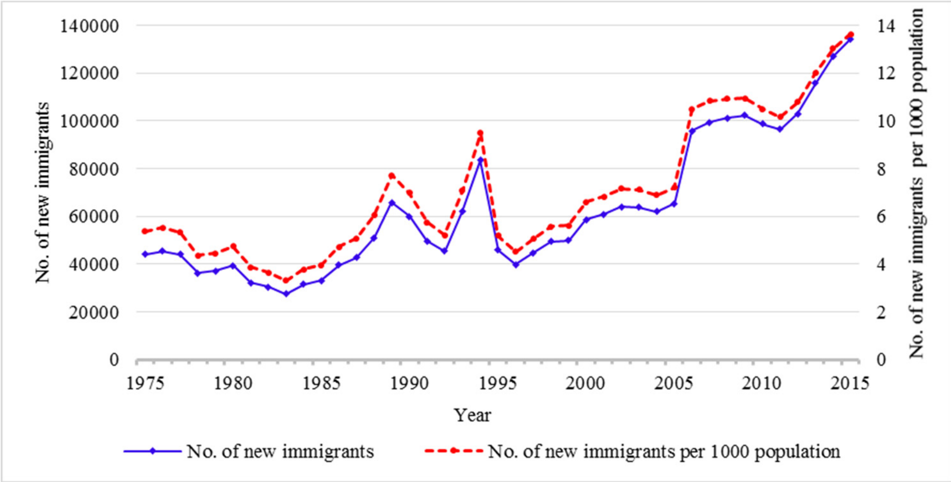

Figure 1 Number of new immigrants and number of new immigrants per 1000 population in Sweden, 1975−2015

Source: Statistics Sweden

In 1954 the five Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) signed an agreement to set up a common labor market that would allow their citizens to live and work freely in any Nordic country (no passport or visa control; no work or residence permit) (Bevelander, 2000; Stalker, 2002). This treaty enabled large-scale emigration from the other Nordic countries, particularly Finland, to Sweden (Westin, 2000; Helgertz, 2010). Immigration rates peaked in 1969 and 1970 mainly due to the high demand for foreign labor caused by a boom in the Swedish economy (Ekberg, 2011). In 1970 about 60% of Swedish immigrants were from the other Nordic countries (Denmark, Norway and Finland) and about 30% were from other European countries (Hammarstedt, 2004; Ekberg, 2011).

In the mid-1970s the structure of Swedish immigration changed. From 1968 onwards work-related immigration from non-Nordic countries was strictly controlled and it was stopped in 1972 (Klinthäll, 2003). This limitation on migration was due to the application of a new, restrictive migration policy which required immigrants to obtain work permits and housing before their arrival (Westin, 2000) and to the Swedish Trade Union Confederation's recommendation to reject all applications from non-Nordic citizens (Bevelander, 2000). The same period also saw a decreased in work-related immigration from other Nordic countries, especially Finland (Klinthäll, 2003).

The main reasons for the change of migration policy in 1968 were an increase in unemployment in Sweden and reduced demand for foreign labor, mainly caused by the economic recession of 1966 1967, which followed several years of low economic growth in the early, 1970s, and the impact of the international oil crisis of

1973. Moreover, the high inflow of immigrants in 1965 and 1966 and Swedish labor market unions' objections to the country's liberal migration policy led to even greater restrictions on immigration (Bevelander, 2000). This is because the influx of immigrants was seen as increasing competition in the labor market and keeping wages down and was thus inimical to the unions' pursuit of full employment and the requirement that immigrants be given equal rights (Bevelander, 2000).

Nevertheless between the 1970s and 2008, Sweden still allowed two types of labor migration: a) short-term employment (e.g. temporary hires, international exchange and seasonal workers) to meet demand that could not be met by local workers and b) permanent immigration, which was offered to immigrants in highly specialized occupations (Cerna, 2009; OECD, 2011).

Since the early 1970s immigration by refugees, asylum seekers and people seeking to join family members already in Sweden primarily from non-European and East-European countries increased significantly and dominated the inflow of immigrants to Sweden (Bevelander, 2000; Hammarstedt, 2004). This was mainly caused by the Swedish government's implementation of the Geneva Convention under which it became possible for political refugees to seek asylum and permission to work in Sweden (Bevelander, 2000). In addition, Sweden's friendly policy towards the Third World, a generous refugee policy and welfare benefits also make it an attractive country to the above groups of immigrants. A migration network based on interpersonal ties of kinship, friendship and shared origin plays an important role in this kind of immigration. Political events abroad also generated new flows of refugee immigrants to Sweden (Klinthäll, 2003). For example, the military coup in Chile in 1973 resulted in a large number of refugees coming to Sweden; the 1980s saw many refugees come in from Vietnam and Ethiopia and then later from Iran and Iraq as a result of the Iran-Iraq War. In the early 1990s the Yugoslavian civil war resulted in an unprecedented flow of refugees into Sweden (Klinthäll, 2003). In the mid-2000s and since 2012 many refugees have come from Somalia and Syria as a result of civil wars in these countries (Statistics Sweden, 2017b). The overall effect has been to increase the diversity of immigrants and culture in Sweden. At the end of 2015, the proportion of Swedish immigrants coming from other Nordic countries had fallen to 15%, 34% percent were from other European countries and 51% from non-European countries (Statistics Sweden, 2016). However, immigrants who come to Sweden as refugees and those immigrating under family reunification provisions are usually less skilled than those who come to work (Scott, 1999; Bevelander, 2000).

The EEA treaty of 1994 and Sweden's entry into the EU in 1995 allowed individuals from other EU/EEA countries to move freely to Sweden (Westin, 2000; Cerna, 2009). Sweden was also one of the few EU-15 members (the other two were the UK and Ireland) that chose not to impose any transitional controls on the movement of people from the countries that joined the EU in 2004 (Ruhs, 2015). Unlike in Germany or Austria, for instance, people from the new member countries were immediately allowed to travel and work in Sweden without applying for a work permit (Focus migration, 2009). This generous migration policy stimulated the flow of immigrants from other EU/EEA countries to Sweden: e.g. the number of new immigrants from Bulgaria and Romania increased dramatically when they entered the EU, from 221 in 2006 to 3264 in 2007 (Statistics Sweden, 2015).

In addition, unlike in many other developed countries such as the US and the UK, the labor market in Sweden is open to workers of all skill levels; Sweden does not discriminate between immigrants on the basis of their skills (Ruhs, 2015). In 2008 the Swedish government also changed the legislation that had restricted labor migration for more than 30 years, owing to the decrease in the size of the working-age population and labor shortages in certain industries (OECD, 2011). Currently employers can determine their need for labor and choose from where in the world they want to recruit (Emilsson, 2014). In order to attract and retain highly skilled immigrants, Sweden also enacted legislation making it easier, from July 2014, for immigrants with work permits and graduate study permits to obtain Swedish permanent residence (Sveriges Riksdag, 2014).

Until recently Sweden appeared to have the most open labor migration system of all OECD countries, given the absence of skill requirements, salary thresholds and visa restrictions as well as the renewability of permits (OECD, 2011; Emilsson, 2014), despite the fact that in June 2015 Sweden tightened its policy on admission of asylum seekers. Compared with the majority of other countries Sweden is very attractive to both highly skilled and less skilled immigrants, mainly because of its open migration policy, relatively good economic development, low unemployment rate, generous welfare benefits, high living standard, political freedom, friendly environment and the high degree of legal equality it offers to immigrants (Eger, 2010; Koopmans, 2010; Giulietti & Wahba, 2013; OECD, 2014; 2015).

Theoretical discussion

Theoretical linkages between immigration and innovation

As knowledge is largely tacit and embedded in individuals, migration plays an important role in the diffusion of knowledge internationally through interpersonal communication and interaction. Being able to draw on knowledge from diverse sources is considered to promote the generation of ideas and innovation (Franzoni et al., 2014). Migrants, especially highly skilled migrants, may influence innovation in the host country in various ways.

First, immigrants are expected to contribute directly to innovation in the host country by using the experiences and skills they bring with them. For example, relative to natives, highly skilled immigrants are over-represented in occupations where the requirements for country-specific human capital are small, but specific scientific or technical skills, such as science and engineering skills, are essential (Hunt & Gauthier-Loiselle, 2010), as these are the domains in which international knowledge transfer is easiest. As these occupations are directly related to the technology development, there is a high probability that immigrants will contribute to innovation in the host country. For instance, it has been shown that skilled immigrants directly increase innovation in the US due to their higher educational level and higher share of degrees in science and engineering compared with natives (Hunt & Gauthier-Loiselle, 2010; Hunt, 2011). However, unlike skilled immigrants, large proportions of immigrants who are low-skilled and concentrated in low-skilled sectors or occupations may not be able to contribute to innovation directly (Singer, 2012).

Second, immigrants with different backgrounds can contribute to cultural diversity and impact on innovation through knowledge spillovers in the host country. A diverse workforce may increase a country's human capital and generate spillovers that contribute to knowledge creation and innovation (Hunt & Gauthier-Loiselle, 2010; Ozgen et al. 2013). Specifically, compared with homogenous teams, diverse teams may be better at problem-solving and generating new ideas (Nathan, 2014b). This is due to the diversity of cultural backgrounds as the skills and qualifications of immigrants and natives may be different and complementary (Niebuhr, 2010). In addition, a culturally diverse labor force will have varied knowledge and abilities, which is beneficial to idea generation and innovation although heterogeneity may also hamper innovation because of e.g. communication barriers (Niebuhr, 2010).

This thesis compares immigrants' *direct* contribution to innovation in Sweden with that of their native counterparts as this is the most direct way to assess their contribution to innovation in the host country.

Determinants on immigrants' innovative performance

Immigrants come from diverse backgrounds and their background can influence their skills and inventive performance in several ways. This thesis mainly focuses on examining the effects of age at migration, region of origin, educational level, education-occupation match and migration policy on immigrants' inventive performance.

Effects of economic motivation and migration policy on selection of immigrants

Selection mechanisms, which can be strongly affected by economic motivation and migration policy, are expected to affect the skill profile of the immigrant population and its inventive performance (Borjas, 1987; Grogger & Hanson, 2011; Huber & Bock-Schappelwein, 2014).

Economic motivation on selection of immigrants

From an economic perspective, immigrants' self-selection is driven primarily by income differentials net of migration costs (Sjaastad, 1962; Lee, 1966; Becker, 1975; Borjas, 1987; Nathan, 2014a, b). Positive (self-)selection (i.e. people with above-average earnings and productivity in their home country choose to migration and they out-perform their native counterparts in the host country) is driven by the fact that the destination country offers a higher return on education and skills than the country of origin. However, negative self-selection occurs when the return on education is lower in the destination country than in the country of origin with higher income inequality (Borjas, 1987).

Sweden has relatively low income inequality, with a low Gini index and relatively high wages for unskilled workers (World Bank, 2014). This makes it an attractive country for relatively unskilled immigrants, presumably inducing negative self-selection. The low return on education and relatively high marginal income taxes (Quirico, 2012) may make Sweden less attractive to highly skilled immigrants compared with other developed countries like the US and the UK. Sweden could experience both positive and negative selection of highly skilled and low-skilled immigrants due to its relative good economic performance, generous welfare system and high living standards (Eger, 2010; Koopmans, 2010; Giulietti & Wahba, 2013).

Migration policy

The migration policy of a prospective destination country can have strong impact on the profile of its immigrants (Belot & Hatton, 2012), but data on the impact on the skill profile of immigrants is ambiguous. For example, some studies find that relaxing immigration restrictions actually increases the mean skill level of new immigrants (Kato & Sparber, 2013; Huber & Bock-Schappelwein, 2014), whereas others suggest that it decreases the skill levels of new immigrants (Chen, 2005; Beerli & Indergand, 2014).

International migration is costly in terms of the money (e.g. cost of visa application) and information required (e.g. time spent researching the visa application process) as well as the psychological and adoption costs (e.g. learning language in the host country) in the host country (McKenzie & Rapoport, 2010). These costs are likely to be negatively related to the individual's skills (Chiquiar & Hanson, 2005; Cuecuecha, 2005). For example, education can make it easier to find the necessary information and help to reduce the psychological cost. This means that more highly educated individuals are usually more 'efficient' at migration (Chiswick, 1999). If migration costs are large enough and credit constraints sufficiently tight, one would expect to see positive selection for education as less educated individuals would find migration too costly (McKenzie & Rapoport, 2010).

Migration quotas also play an important role in increasing migration costs (if implemented strictly). This is because competition for visas is high and potential immigrants will have to invest more time and effort in order to obtain one (Borjas, 1987). Hence, migration costs ensure that only those who think it is worthwhile to migrate will do it and thereby create a positive selection bias.

However, the existence of free migration within the Nordic countries (since 1954) and the EU/EEA countries (since 1994) has reduced migration costs as discussed above. It enables people from those countries to move to Sweden more easily, especially less educated people. This may mean that there is less positive selection of immigrants from other Nordic countries since 1954 and hence that they are less qualified than economic immigrants from other regions. One would expect the liberalization of migration within the EU/EEA in 1994 to have had a similar effect on the average skill level of EU immigrants.

Grogger & Hanson (2011) argue that destinations with liberal refugee and asylum policies draw relatively more low-skilled immigrants, all other factors being equal. Sweden can probably be described as such a country (Scott, 1999). Since 1968, setting aside free migration from other Nordic countries and other EU/EEA countries, Sweden's immigration policy has principally been focused on refugees and family reunification, with the result that the opportunity to migrate to Sweden is skewed towards less skilled rather than highly skilled immigrants. Clearly, this negative selection mechanism may reduce the average skill level and inventive performance of Sweden's immigrant population.

In some respects, however, Sweden has also tried apply a positive selection policy to immigrants. For example, although restrictions were imposed on labor migration from non-Nordic countries in the early 1970s, Sweden still allowed individuals in highly specialized occupations to work in Sweden (Cerna, 2009; OECD, 2011). Since 2001, Sweden has also provided tax exemptions for foreign nationals who work in high-skill occupations (Mahroum, 2001;

Forskarskattenämnden, 2013). All these migration policies help Sweden to attract and retain highly skilled immigrants.

Age at migration and region of origin

Both age at migration and region of origin can be used as approximate indicators of the qualification and integration of immigrants – factors which are expected to affect immigrants' inventive performance in the host country (Schaafsma & Sweetman, 2001; van Ours & Veenman, 2006; Böhlmark, 2008). Regarding region of origin, this thesis focuses on the effect of parents' region of origin on second-generation immigrants. This provides a long-term perspective on the effect of region of origin on integration of immigrants.

The effect of age at migration on qualification of immigrants

The selection mechanism can vary across immigrants who migrated at different ages. First-generation immigrants who migrated as adults are more likely to be (self-)selected than young immigrants; especially those highly skilled adult migrants and those who migrated to take up employment, who are likely to be (self-)selected in terms of their skills. However, first-generation immigrants who migrated as children and second-generation immigrants are usually not (self)-selected as their residence in the host country is due mainly to their parents.

Nonetheless, immigrants who migrated as adults may have a direct disadvantage in invention if they are refugees or family reunification migrants, as is frequently the case in Sweden since 1968. This is especially true of those who were born in or after 1961, who are available in my database. However, the situation may well be different for inventors who migrated as adults, as this subgroup is expected to be positively (self-)selected. This is because invention is a knowledge-intensive activity mainly carried out by highly skilled individuals.

There is a curvilinear relationship between age and inventive productivity (Giuri et al., 2007; Jones, 2010; Jung & Ejermo, 2014). The most productive age for invention is around 40 years old. Therefore, in terms of life cycle, individual who migrated as children spend their most productive years for invention in the host country; however individual who migrated as adults, especially those who migrated after the age of 50 years, are much less likely to invent in the host country.

The effect of region of origin on qualification of immigrants

Region of origin may be an approximate indicator of immigrants' human capital. Immigrants from the same region may share similar economic backgrounds and motivations for migration (Scott, 1999; Bengtsson et al., 2005; Helgertz, 2010). On average, immigrants from developed regions have higher human capital than those from developing regions.

Since 1968 quite a lot of adult immigrants to Sweden have been refugees or asylum seekers originating from developing countries. Consequently, among Sweden's immigrants who migrated as children and have been adults today, quite a large proportion of them are from developing regions. Among immigrants who migrated as children and aged 25–64 years between 1985 and 2007, 36% are from developing regions as shown in my database. These immigrants are generally less skilled than labor immigrants and are less likely to contribute to invention (Scott, 1999; Bevelander, 2000). However, most of the foreign-born parents of adult second-generation immigrants in Sweden are from European regions (97% in my database).

Parental human capital is likely to affect children's development through intergenerational transmission. Individuals with better-educated parents, especially those with a more educated mother, are more likely to have a higher educational attainment and better non-cognitive skills than those whose parents are less well educated (Ermisch & Francesconi, 2001; Riphahn, 2003; Lundborg et al., 2014). Therefore, compared with immigrants who migrated as children (a large proportion of whom have parents from developing regions), second-generation immigrants in Sweden (who tend to have relatively more highly educated parents from developed regions) are expected to have higher average human capital and better inventive performance (Hunt, 2011).

The parental educational level of second-generation immigrants also varies by region of origin. For mixed immigrants from intermarriage family, if their non-native parents originated from a region having geographical and cognitive (e.g. linguistic, cultural and institutional) distant to the host country, both of their native and non-native patents tend to be more highly educated than mixed immigrants whose non-native parents originated from a geographically and cognitively proximate region. This is because first, the former group's patents need higher educational level to compensate for the larger cultural distance to each other. Second, highly educated individuals are more likely to accept larger cultural distances than less educated individuals (Dribe & Lundh, 2008; Furtado, 2012). Third, in the marriage market there is general assortative mating with respect to education, such that well educated immigrants are more likely to select partners of similar educational level (see e.g. Mare, 1991; Kalmijn, 1998; Henz & Jonsson, 2003; Niedomysl et al., 2010). This may mean that the mixed immigrants having parents who are geographically and cognitively distant to each other tend to be more highly educated than those having parents who are geographically and cognitively closer to each other. However, unobserved strengths such as one's social network and institutional familiarity can also affect inventive activity (Agrawal et al., 2008; Nathan, 2014a), and this is where the former group may face disadvantages.

Often, parents of immigrants with two FB parents are from the same country of origin, since people simply seem to prefer a partner with the same ethnic background as them (positive assortative mating). Therefore, there is no need to compensate culture distance with educational level (Niedomysl et al., 2010).

Swedish migration policy treats different regions differently, which also affects the qualifications of immigrants. Free migration within the Nordic countries since 1954 is expected to have meant less positive selection of immigrants along with lower migration costs. Thus, parents of second-generation immigrants with other Nordic backgrounds will tend to be less qualified than those from other regions.

The effect of age at migration on immigrants' integration

Immigrants who arrived in the host country at a younger age tend to integrate better than those who arrived when they are older (Gonzalez, 2003; Bleakley & Chin, 2004; Chiswick & DebBurman, 2004; Beck et al., 2012). Second-generation immigrants are expected to be better integrated into the host country than first-generation immigrants who migrated as children, who are in turn better integrated than those who migrated as adults. This is because first, in terms of education, second-generation immigrants are usually educated entirely in the host country whereas first-generation immigrants who migrated as children may only receive part of their education in the host country and those who migrated as adults may receive some or no education in the host country. Immigrants' educational attainment in the host country is crucial to their performance and integration into mainstream society in their host country (Beck et al., 2012). Second-generation immigrants have most opportunity to integrate fully as they were born in the host country, next are immigrants who migrated as children and those who migrated as adults benefit least in terms of time and opportunities (Beck et al., 2012).

The effect of region of origin on immigrants' integration

Region of origin can be an approximate indicator of geographical or cognitive proximity to the host culture, which may affect immigrants' integration into the host society and innovative performance (Amin & Wilkinson, 1999; Boschma, 2005).

Culture is transmitted across generations (Borjas, 1992; Rooth & Ekberg, 2003; Nekby & Rödin, 2010). To some extent immigrants can be classified by region of origin, because people from the same region may share similar cultures, values and institutions, as people from the Nordic region do.

Individuals from regions that are geographically close to the host country are supposed to be able to communicate more easily with its native citizens, which may make interactive learning easier and open up more opportunities for them. The closer the sending regions and receiving countries are, the easier it is for migrants to integrate into the host society and furthermore ease of integration may be linked to personal outcomes.

Immigrants' experiences of discrimination may also vary according to their region of origin. Immigrants with a Nordic or Western European background are at low risk of being discriminated against on the basis of their ethnic background, but this risk is higher for immigrants with a Southern European or developing region background. This may be due to the difference in appearance (Rooth & Ekberg, 2003).

The discussion above suggests that second-generation immigrants and immigrants from regions in geographical proximity to the host country have better integration opportunities than immigrants from more distant regions. For immigrants who migrated as children and adults, as a large proportion of them originated from developing regions, the average integration level and then the inventive performance of the above two group may be negatively influenced.

The effect of educational level

Better educated individuals are usually more skilled and more likely to be active in invention than their less well educated peers. Education is especially important for immigrants as it is the most important signal of their skills and they are at a disadvantage in terms of country-specific human capital. Education has been shown to play a very important role in innovation activity, which seems to account for immigrants' more superior inventive performance than that of natives (Hunt & Gauthier-Loiselle, 2010; No & Walsh, 2010; Hunt, 2011). Therefore, this thesis also investigates the effect of education on immigrants' inventive performance in several ways.

The match of education and occupation

Immigrants usually find it more difficult to obtain employment than natives with matched education and experience, which may be due to discrimination and lack of country-specific human capital. However, if an individual's job does not make use of his/her skills and education, their effect on knowledge productivity will be diminished (Green et al., 2007). The educational attainment is considered independent from occupation for foreign labor force because of the frequency with which there is a mismatch between immigrants' actual educational level and the level required for their occupation: immigrants are often overeducated for the job they do (Green et al., 2007; Battu & Sloane, 2002; 2004). Moreover, the education-occupation mismatch for immigrants can also vary across sectors (Battu & Sloane, 2002). The mismatch is higher in sectors which need different types of workers with diverse skills than sectors where specialist skills are required. Therefore, I also investigate the effect of education-occupation match on immigrants' inventive performance across sectors.

Data

This thesis takes advantage of a special database which links inventors to the general population in Sweden from 1985 to 2007 (Jung & Ejermo, 2014; Zheng & Ejermo, 2015). For the purposes of this thesis, an inventor is defined as a person who is listed as an inventor on a patent application filed with the EPO between 1985 and 2007. Although patents have some shortcomings as indicators of innovation – they only relate to certain types of inventions and not all patents have commercial value (Giuri et al., 2007) – they remain the most commonly used measure of innovation output. The data on inventors and inventions were extracted from the Worldwide Patent Statistics (PATSTAT) database provided by the EPO. The EPO was selected as the source of patent information because, first, it is one of the most frequently used filing offices for inventors in Sweden; second, the patents are expected to have high quality on average for its large scale protection in multiple European countries and high cost of application; third, EPO patents provide inventors' street addresses, which is essential for identifying the inventors.

In total the database comprises 39,600 Swedish patent applications and 73,356 patent–inventor combinations[1] filed between 1985 and 2007. The matching was done in two stages. First, an inventor's social security number (SSN)[2] was identified by matching the name and address provided by the EPO with those offered by a commercial company or in the Swedish population directory in 1990. In the end I was able to identify 79.3%[3] of inventors' SSNs. Second, inventors and the general population were linked together through their SSNs. Detailed demographic information was also obtained from Statistics Sweden, which has data on all Swedish residents since 1985. Statistics Sweden provides access to information about individuals' age, gender, year of birth, educational level, high school GPA, field of study, size of the company for which they work, sector of work, region of work, employment status, number of children for an individual, region of origin (in the case of immigrants)[4], year of immigration and emigration (data is only available who migrated from 1961 and onwards).

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[1] Each inventor included in a patent generates a unique observation. If one patent has three inventors it will generate three unique observations. If an inventor contributes to four patents then s/he generates four patent-inventor combinations.

[2] All people legally resident in Sweden for at least one year are assigned a unique Swedish social security number.

[3] Zheng and Ejermo (2015) indicated that the 20.7% unidentified inventors are not different from the identified inventors with respect to immigration status.

[4] Country of origin for immigrants is not available in the database; immigrants are classified into 10 groups based on the data on region of origin: Sweden, other Nordic countries, EU-15, the rest of Europe, former Soviet Union, North America (including Central America and Caribbean countries), Oceania, South America, Asia and Africa.

The data used in this thesis have several advantages over survey data, case studies and data based on using name-matching techniques for ethnic identification (e.g. Kerr, 2008; No & Walsh, 2010; Hunt, 2011; Breschi et al., 2014; Nathan, 2014a). First, it covers almost all patent applications filed with the EPO between 1985 and 2007 by inventors in Sweden, which greatly reduces the risk of selection bias and allows the tracking of inventors over time. Second, it includes the entire Swedish adult population (age ≥ 16 years), which makes it possible to investigate inventive activity among the entire population. Third, the data includes detailed and very accurate demographic information.

In the first three papers, I focus on the population aged 25 to 64 years (mean age = 43.9 years), because this is the age range during which people are more likely to be working and patenting, and this means that the sample is more homogeneous (inventors outside this age range make a negligible to the full dataset). I use 76.5% of the inventor–patent combinations for which I was able to identify the inventor. Of these inventors, 10.9% are first-generation immigrants and 8.3% second-generation immigrants. First-generation immigrants are more active in the high-tech KIS sector than native Swedes (i.e. Swedish-born with two Swedish-born parents) but in high-tech manufacturing sector the opposite pattern is observed. However, in both the ‘other KIS’ sector and the low-tech sector, neither natives nor immigrants are very active in patenting and the difference between the two groups is very small. In the fourth paper, I focus on the impact of change of migration policy on first-generation immigrants’ educational level at the time of migration and their probability of becoming inventors after migration, so the analysis is limited to those who were aged between 18 and 64 years.

The descriptive analyses presented in papers I, II and IV cover both employed and unemployed individuals of all educational levels. Paper III considers only the employed population for whom information about sector of work is available. The empirical research on which the first three papers are based focused on employed individuals educated to at least secondary high school level (≥10 years of schooling). This is because data on the explanatory variables ‘field of study’ and ‘sector of work’ are only available for this group.[5] Compared with unemployed immigrants who have low-level education, immigrants included in empirical study are expected to be more qualified and more positively selected.

[5]The results still represent the majority of population aged between 25 and 64 years. For example, in Paper III the empirical regressions are based on data from 75% and 60% of the 2001–2007 native and immigrant populations respectively. The corresponding figures for native and immigrant inventors are 86% and 55% respectively.

Methods

Most of the comparisons between immigrants and natives are based on two indicators: (a) All four papers compare the probability of patenting or probability of becoming an inventor between immigrants and natives in each population using different methods;[6] (b) Paper IV also considers the effect of liberalization of migration on the educational level at the time of migration (low; middle; high) of new immigrants from the EU-15 by comparing this group of immigrants with immigrants from other regions.

Limiting the analysis to inventors, Papers I–III use number of forward citations (NFC) for patents to compare the quality of patents attributed to immigrants and natives. NFC is positively correlated with patent value (e.g. Harhoff et al., 2003; Hall et al., 2005; Gambardella et al., 2008). NFC is the most commonly used indicator of patent value and is considered the best predictor of patent value (Lanjouw & Schankerman, 1999). Paper I also examines another two indictors: (a) the total number of patents attributed to each inventor between 1985 and 2007 (this is used as a measure of inventive productivity) and (b) the probability of a patent being granted (another indicator of patent value) (Guellec & de la Potterie, 2000; 2002). These indicators are used in more detailed comparisons of the inventive performance of immigrants and natives. Table 1 summarizes the various indicators used in each paper, the comparison groups, data, estimation methods for each indicator, coding or type of data and the statistics reported.

[6] In analyses of the probability of patenting or the probability of becoming an inventor, I have used four different indicators, but the main idea and purpose are the same. I use different indicators to make the regressions reported in subsequent papers as simple as possible.

Table 1 Description of dependent variables in the four papers.

	Dependent variable	Comparison groups	Data	Estimation method	Coding or type of data	Statistic(s) reported
Population						
Paper I	Probability of patenting	First-generation immigrants vs. Swedish born (i.e. native Swedes+ second-generation immigrants)	Unbalanced panel data for 1985–2007	Random-effects probit regressions	Dummy variable: coded as 1 if an individual in Sweden has been listed as an inventor on at least one patent application in year *t* and 0 otherwise.	Marginal effects
Paper II	Probability of becoming an inventor	Second-generation immigrants vs. native Swedes (with two Swedish-born parents)	Pooled data: one observation per individual, 1985–2007	Probit regressions	Dummy variable: coded as 1 if an individual has been listed as an inventor on at least one patent application during 1985 and 2007 and 0 otherwise.	Marginal effects
Paper III	Patenting rate	First-generation immigrants vs. native Swedes	Unbalanced panel data from, 1985–2007	Random-effects negative binomial regressions	Count data: the number of patents for which an individual applied in year *t*	Incidence rate ratios
Paper IV	Probability of becoming an inventor after immigration	First-generation immigrants from the EU-15[a] vs. those from 'Other developed regions'[b] or all other regions[c] (excluding the rest of Europe and former Soviet Union)	Pooled data: One observation per individual, 1985–2007	Difference-in-differences (DiD) estimation	Dummy variable: coded as 1 if an immigrant has been listed as an inventor on at least one patent application between immigrating and the end of the study period (2007) and 0 otherwise.	Coefficient results
	Educational level at the time of migration (low, middle or high)				Dummy variable: coded as 1 if an immigrant has the educational level in question and 0 otherwise.	

Table 1 Continued

	Dependent variable	Comparison groups	Data	Estimation method	Coding or type of data	Statistic(s) reported
Inventors						
Paper I	Total number of patents attributed to each inventor	First-generation immigrants vs. Swedish born	Pooled data: one observation per inventor for 1985–2007	Negative binomial models	1. Count data 2. Widely overdispersed	Coefficient results
	Probability of a patent application being granted			Logit models	Dummy variable: coded as 1 if a patent application is granted and 0 otherwise.	Marginal effects
Papers I, II, III	NFC received by each inventor's patent	Paper I: first-generation immigrants vs. Swedish born Paper II: second-generation immigrants vs. native Swedes Paper III: first-generation immigrants vs. native Swedes	Unit: patent–inventor combination. An inventor can be observed several times per year during 1985–2007	Negative binomial models	1. Count data. Calculated for the five-year period after the patent is filed. 2. Highly overdispersed. 3. Around 50% of inventors filed more than one patent during 1985–2007 so I control for intra-inventor correlation by clustered robust standard errors on inventors.	Coefficient results

Notes: [a] *The EU-15 includes*: Austria, Belgium, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, and the UK. Sweden, Finland, and Denmark are excluded as they are part of the Nordic country, where free movement policy enacted in 1954; [b] *'Other developed regions'* includes: the other Nordic countries (Finland, Denmark, Norway, and Iceland), North America (Canada, the US, Central America, and the Caribbean countries), and Oceania; [c] *'All other regions'* (excluding the rest of Europe and the former Soviet Union): this group includes 'Other developed regions' as well as Asia, Africa, and South America.

In each paper different estimated models are used for different purposes. It provides an overall impression of the inventive performance of different immigrant groups and also reveals the factors that affect their performance.

Paper I compares the inventive performance of several groups of first-generation immigrants: (a) immigrants in general, (b) immigrants who migrated as children and (c) immigrants who migrated as adults (two groups: educated in Sweden; educated abroad). As the main interest is to compare the performance of different immigrant groups relative to that of native counterparts, all the control variables (see Table 2) are held constant in the regressions. The paper also examines the relationship between high school performance – used as an indicator of ability – and the inventive activity of immigrants who migrated as children.

Paper II examines several groups of second-generation immigrants: (a) immigrants in general, (b) mixed immigrants and immigrants with two FB parents and (c) seven sub-groups of second-generation immigrants based on parents' region of origin. First, I compare each group with native Swedes without including any control variables to get a picture of their overall performance. Second, I examine the effect of educational level on the inventive performance of seven sub-groups of immigrants. This analysis is carried out because average educational level can differ a lot between immigrants from different regions and it has an especially strong influence on inventive performance (Dustmann & Theodoropoulos, 2010; Hunt, 2011). Finally, I carry out separate regressions for each group, including the control variables, to examine the extent to which the control variables (individual background variables; patent characteristics; see Table 2) account for observed group differences in inventive performance.

Paper III focuses on the inventive performance of first-generation immigrants in four sectors and considers the effects of educational level and occupation in the various sectors. First, immigrants are compared with natives after controlling for certain basic variables (see Table 2). Second, building on the first model, I examine the independent effects of educational level and occupation in order to assess their importance in each sector. Finally, a full model including all control variables, educational level and occupation is calculated.

Paper IV examines the effects of the liberalization of migration following the establishment of the EEA in 1994 on the skill profile of immigrants from the EU-15 to Sweden by comparing them with immigrants from other regions. I investigate the effect of change of migration policy on immigrants' educational attainment at the time of migration and their probability of becoming an inventor between migration and the end of the study period (2007) using the difference-in-differences (DiD) method. Analyses are carried out with and without control variables.

Table 2 presents an overview of the control variables and the variables of interest for each paper.

	Individual's background		Patent characteristics		
	Control variables	Variable of interest	Control variables		
			Total number of patents attributed to each inventor	*Probability of a patent application being granted*	*NFC per patent*
Paper I; II and III	Field of study; age and age squared; gender; firm size; region of work.				Technology classes; application year; number of inventors
Paper I	Educational level	High school GPA (migrated as children); Educated in Sweden or educated abroad (migrated as adults)	Technology class	Technology class; application year; number of inventors	
Paper II	Educational level; birth cohort; sector of work; parental educational level; number of children for each parent	Educational level (seven second-generation groups)			Numbers of inventors per patent for each of the following groups: native Swedes; mixed immigrants; immigrants with two FB parents; first-generation immigrants
Paper III	Industry	Educational level; Occupation			
Paper IV	Gender; age and age squared; dummy for marital status, whether having a child at the time of migration; weighted human capital in region of origin	Migration date (before or after 1994)			

Summary of papers and main results

My main findings on the inventive performance of immigrants and its determinants are presented in four related papers.

Paper I: How do the foreign-born perform in inventive activity? Evidence from Sweden

First, this paper compares the inventive performance of first-generation immigrants with the Swedish-born. Second, it compares immigrants who migrated as children and as adults with their native Swedish counterparts. Third, it examines the effect of education on inventive performance in two ways. (a) In the case of immigrants who migrated as children and were educated in Sweden, we examine high school GPA, which is used as an indicator of ability, and its association with inventive performance. (b) In the case of immigrants who migrated as adults, we examine whether immigrants used to have education in Sweden or only have it abroad affects their inventive performance.

The results show that when other variables are held constant, first-generation immigrants are generally less likely to patent than Swedish born. Nonetheless, immigrant inventors in general, especially those who migrated as adults, perform as well as native inventors in terms of number of patents per inventor, NFC per patent and probability of patents applications being granted. The inventive performance of immigrants who migrated as children is lower than that of Swedish born, perhaps due to their lack of Sweden-specific human capital and perhaps partly because of their lower qualifications. In the case of immigrants who migrated as adults, their inventive performance does not seem to be affected by whether they received at least post-secondary high school education (≥13 years of schooling) in Sweden or not.

Paper II: The inventive performance of second-generation immigrants in Sweden: differentiation by parents' region of origin

This paper compares the inventive performance of second-generation immigrants with that of native Swedes and considers how this relates to their parents' region of origin.

The results show that second-generation immigrants with non-Nordic European backgrounds perform better than native Swedes. Their superior performance is related to having more highly educated parents than native Swedes, combined with their non-native parents' region of origin being geographically close to Sweden. The study indicates that either disadvantage in educational attainment or lack of geographical or cognitive proximity of non-native parents' region of origin to

Sweden can hamper second-generation immigrants' inventive performance. This is the case for second-generation immigrants with other Nordic backgrounds and mixed immigrants whose non-native parent is from a developing region. The former group perform less well than native Swedes is mainly because of their lower educational level, which is further related to their parents' lower educational level than natives, despite their non-native parents having geographical and cognitive proximity to Sweden. The latter group tend to have best educated parents and as a group they have the best educational performance of all groups; however the large cultural distance originated from their non-native parent seems to impede their performance. These results suggest that there are interactions between educational attainment and the geographical or cognitive proximity of non-native parents' region of origin to the host country, which affect second-generation immigrants' inventive performance through intergenerational transmission of human captial.

Paper III: The inventive performance of immigrants across multiple sectors: the importance of education and occupation

This paper investigates the distribution and inventive performance of first-generation immigrants across four sectors with different skill requirements and different probabilities of patenting. The paper also examines how important education-occupation match is to immigrants' inventive performance in various sectors.

The results clearly indicate that immigrants and natives have different probabilities of patenting in all sectors. In the high-tech KIS sector, immigrants are more likely to patent than natives, mainly because immigrants are educated at a higher level than natives; furthermore, immigrants' high and similar representation in high-skill occupations as natives enable them to have as high patenting rate as natives when all other variables are held constant. The reason for immigrants' high education-occupation match in the high-tech KIS sector may be that work in this sector requires very specialist knowledge that transfers relatively easily across countries because it is not highly dependent on country-specific human capital. In the high-tech manufacturing, low-tech and 'other KIS' sectors, especially in the former two sectors, immigrants are less likely to patent than natives, largely because immigrants are over-represented in low-skill occupations. Overall, the lower match between education and occupation in immigrants reduces their probability of patenting in the above three sectors. Immigrant inventors perform as well as natives in terms of NFC received for the inventor's patent.

Paper IV: Liberalization of European migration and the immigration of skilled people to Sweden

This paper explores how the liberalization of migration following the establishment of the EEA in 1994 affected the skill profile of Swedish immigrants from the EU-15. It examines how the liberalization of migration affected new EU-15 immigrants' educational level at the time of migration and their probability of becoming an inventor between migration and the end of the study period (2007) by comparing them with those from other regions using DiD regressions.

The results show that when compared with immigrants from 'Other developed regions', the liberalization of migration after the inception of the EEA in 1994 had a negative effect on educational profile of new EU-15 immigrants in the short run, but there is no such effect in the long run; moreover, the liberalization of migration also has no systemic effect on the EU-15 immigrants' probability of becoming an inventor both in the short and long run. These patterns are consistent with the theoretical notion that the reduction in migration costs brought about by Sweden's EEA membership mainly stimulated migration from the lower end of the education distribution.

Discussion

This thesis investigates the direct distribution, skill profile and inventive performance of several groups of first- and second-generation Swedish immigrants with varying characteristics and backgrounds. It contributes to the literature on how age at migration, region of origin, educational level, education-occupation match and migration policy affect immigrants' inventive performance.

The empirical analyses in this thesis compare immigrants and natives who are employed and educated to at least secondary high school level. Even this relatively highly qualified group of first-generation immigrants − especially those who migrated as adults − has a lower probability of patenting than the equivalent native group. This could be related to the nature of Sweden's migration policy from 1968 and onwards, which has favored refugees, asylum seekers and immigration for family reunification. As many of the immigrants who entered Sweden as adults are less well educated and less skilled than their native peers (Scott, 1999; Bevelander, 2000), the average human capital of immigrants who entered Sweden as adults has been decreasing (Bevelander, 2000). This also affects the inventive performance of first-generation immigrants.

This thesis finds that first-generation immigrants' lower probability of patenting is mainly attributable to their over-representation in low-skill occupations and to their lower education-occupation match, relative to natives, in most sectors. This indicates that it is very important to improve immigrants' education-occupation match so that better use is made of their skills. These results may well be applicable to other countries besides Sweden, which suggests that it is important to improve immigrants' host country-specific skills by e.g. (a) improving their language skills, especially of those working in sectors where good language skills are required; (b) building stronger ties between immigrant groups and native communities. It is also important to reduce discrimination.

However, highly skilled immigrants working in the high-tech KIS sector or in high-skill occupations in the high-tech manufacturing and 'other KIS' sectors are more likely to patent as natives because of their higher level of education than natives. Moreover, immigrant inventors, especially those who migrated as adults, also perform similarly to their native counterparts when other variables are held constant. These results indicate that highly skilled immigrants contribute better or similar to invention in Sweden as highly skilled natives. Highly skilled immigrants are therefore the group to which Sweden should pay most attention if it wants to improve the skill profile and inventive capacity of its immigrant population. In order to achieve this Sweden could, for example, (a) extend preferential entry policies to include skilled adult migrants, especially those in the high-tech sectors and high-skill occupations, where international knowledge transfer is easier; (b) make it easier for highly skilled immigrants from non-EU/EEA countries and their families to settle in Sweden.

The results also suggest that it is important to consider the long-term impact of immigrants. Even if in general first-generation immigrants are not as highly educated as natives, cannot perform as well as natives in innovative, and may even have some negatively economic and social impact on the host country (Rodríguez-Pose & Von Berlepsch, 2014; Zheng and Ejermo; 2015), their children may make good contribution to the innovation development of the host country.

The results show that first-generation immigrants who migrated as children, 36% of whom originated from developing regions, have a lower inventive performance than natives. Second-generation immigrants, who have less educated non-native parents (i.e. those with other Nordic backgrounds) or have non-native parents with large cultural distance between their regions of origin and the host country (i.e. mixed immigrants whose non-native parent is from a developing region) also cannot perform as well as natives. However, second-generation immigrants, who have highly educated non-native parents originated from non-Nordic European regions, tend to be more highly educated than those of natives and show better inventive performance. These results suggest that both having highly skilled immigrants and immigrants' geographical or cognitive proximity to Sweden is important. The above two factors will not only affects the inventive performance of immigrants themselves, but also that of their children. It seems that parents' human capital can affect their children's human capital and inventive performance through intergenerational transmission. Moreover, the government should pay more attention to developing child immigrants' human capital, including adopting more effective education and integration policies.

The thesis has some limitations. First, the database does not include data on country of origin, which limits the investigation of cultural effects. Second, despite the richness of the data, it is not possible to make inferences about the environment in which children of immigrants grow up − for example their linguistic environment (Nekby & Rödin, 2010; Schüller, 2015), or their upbringing environment (Nielsen et al., 2003; Åslund et al., 2011) − and such factors may affect their human capital and inventive performance in adulthood. This is because individual data are only available from 1985 onwards. Third, because of space and time limitations, this thesis has not examined the effect of region of origin on first-generation immigrants' inventive performance, nor the effect of age at migration on the inventive performance of first-generation immigrants who migrated as children. It would be interesting to explore how parental background and age at migration affect first-generation child immigrants' integration and inventive performance and compare this group with second-generation immigrants. These are topics for future research.

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Paper I

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ORIGINAL PAPER

How do the foreign-born perform in inventive activity? Evidence from Sweden

Yannu Zheng · Olof Ejermo

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Abstract Using a new database that matches patent applications by Swedish residents with demographic information from 1985 to 2007, we examine differences in inventive performance by individuals of foreign and domestic origins, in terms of quantity (probability of patenting, total number of patents per inventor) and quality (forward citations, probability of grant) of patents. We further compare adult and child immigrants with their Swedish-born counterparts. Holding other variables constant, we find that the immigrants are generally less likely to patent than the Swedish-born. Nonetheless, the general group of immigrant inventors, including those who migrated as adults, performs as well as the native inventors and therefore seems more positively selected. Compared with the Swedish-born, the immigrants who migrated as children are disadvantaged in both quantity and quality of patents, which may be linked to a lack of Sweden-specific human capital. Whether education was received in Sweden does not seem to make a difference for the immigrants who migrated as adults. In summary, this study provides an initial impression of the inventive performance, contribution and challenges of distinct groups of immigrants who have differing characteristics and backgrounds.

Keywords Immigrants · Inventors · Children · Adults

JEL classification J15 · J24 · N30 · O31

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1 Introduction

Augmenting the number of highly skilled immigrants can boost workforce diversity, idea development, innovation, productivity and ultimately economic growth (Goldin et al. 2011; Ozgen et al. 2013; Paserman 2013; Nathan 2014a; Parrotta et al. 2014). In recent years, scholars and policymakers have paid increasing attention to the contribution of the foreign-born to technological development and innovation in their host countries (e.g. Stephan and Levin 2001; Hunt and Gauthier-Loiselle 2010; No and Walsh 2010; Hunt 2011). Most of these studies are based on survey data or case studies from the USA (e.g. No and Walsh 2010; Hunt 2011), but little evidence has been collected for European countries, which differ substantially from the USA, particularly in the origin of immigrants.[1] Unlike the USA, which attracts highly skilled emigrants from different origins (Franzoni et al. 2012), European nations mainly receive highly skilled migrants from neighbouring countries (Breschi et al. 2014).[2]

The US studies indicate that the most innovative and dynamic high-tech industries, such as software, computer science and engineering, have high concentrations of talented immigrants (Goldin et al. 2011) and that these individuals make significant contributions to advancing technology and boosting innovation (Kerr 2010; Hunt and Gauthier-Loiselle 2010; No and Walsh 2010; Hunt 2011). Sweden shares similarities with the USA in certain respects: it has a comparable and increasing proportion of immigrants[3] (Ekberg 2011) as well as a good reputation for openness, advanced technology and strong innovation capability (OECD 2008). Sweden, however, not only possesses positive traits similar to the USA but also has specific conditions which may negatively affect innovation. For instance, the migration policies in Sweden, historically targeted at refugees, asylum seekers and tied movers (family-reunification policy)—groups that are usually less educated and skilled (Scott 1999; Bevelander 2000)—can lead to a more negative selection with respect to the skills needed for innovation.

In this paper, we aim to obtain a better understanding of the effect of positive and negative migrant selection on inventive performance through the study of different migration groups in Sweden, which has not been studied before. The results of this study may broaden the understanding of immigration's effects on inventive capability and better characterize the situation of European countries in this respect.

Our study is the first to compare the differences in the inventive performance of immigrants who moved as children (raised in Sweden, migrated under the age of 18) and adults with that of the Swedish-born. Those who migrated as children can differ

[1] The US immigrants originate mainly from South and East Asian countries as well as Latin America (Pew Research Center 2014). The origins of European immigrants vary substantially between countries (Eurostat 2011).

[2] This may be a result of geographic, linguistic and cultural proximity as well as established institutional regimes, such as those existing in the Nordic countries and the European Union/European Economic Area (EU/EEA), where free movement of member citizens is allowed between member countries, but movement of non-member citizens is restricted (Koslowski 1998). Citizens from other Nordic countries are allowed to live and work freely in Sweden because of the agreements signed between the Nordic countries in 1954 (Stalker 2002). Free mobility has also been allowed for individuals from other EU/EEA countries, since the EEA treaty in 1994 and Sweden's entry into the EU in 1995 (Westin 2000; Cerna 2009).

[3] From 1960 to 2013, the proportion of foreign-born residents increased from 4.0 to 15.9 % (Statistics Sweden 2014a).

significantly from both adult migrants and the natives in terms of migrant selection and upbringing experiences. While immigrants who migrated as adults may, to some extent, be (self-)selected, the children usually do not positively self-select but mainly follow their parents. They may also suffer from a double burden of adaption. First, they usually have to reconcile their home environment with the different culture and language of the host society. Second, they have to attain a Swedish education aligned with the values and educational objectives of the host society (Westin 2003). Immigrants who migrated as adults, on the other hand, may have a direct disadvantage in invention if they are refugees or tied movers, as is the frequent case in Sweden. In some cases, however, they may be more positively selected, for instance, if they were handpicked to work on inventions in one of Sweden's multinational and technologically advanced enterprises.

We also examine the effect of education on inventive performance in two ways. First, for immigrants who migrated as children and obtained an education in Sweden, we examine whether their performance is affected by school performance, measured as final secondary school grade average (high school GPA), which is used as an indicator of ability. Second, for immigrants who migrated as adults, we examine differences in inventive performance between those educated in Sweden and those educated abroad. This distinction is relevant because it may pick up differences in the quality of education, the transferability of education acquired abroad to the Swedish context and country-specific human capital obtained in the destination country (Chiswick and Miller 1994).

Our investigation uses a unique data set that contains almost all records of inventors with a Swedish address (i.e. both Swedish-born and foreign-born inventors residing in Sweden at the time of filing) found in European Patent Office (EPO) applications from 1985 to 2007. The social security number (SSN),[4] which is identified for the vast majority of these inventors (Jung and Ejermo 2014), allows us to link them to demographic and education information housed at Statistics Sweden.

We examine two dimensions of inventive performance: (a) inventive productivity, indicated by the probability of patenting and the total number of patents attributed to each inventor and (b) the quality of the patents, indicated by the number of forward citations (NFC) to the patents and the probability of the patent applications being granted.

As this is mainly a descriptive paper, no causal links for the difference between immigrants and natives in inventive performance are explored here. Even so, this study makes several important contributions to our knowledge. First, our results show that there are no general positive 'migrant effects' on invention in Sweden, in contrast to the results found for the USA and the UK (No and Walsh 2010; Hunt 2011; Nathan 2014b).[5] Instead, the immigrants are found to be less likely to patent than the Swedish-

[4] The Swedish social security number is a unique identification number for each resident in Sweden, including foreigners with a valid residence permit for at least 1 year. Therefore, foreign-born inventors who reside in Sweden for less than 1 year have no Swedish SSN.

[5] The comparison of inventive performance between the immigrants and natives in our study sometimes differs from earlier studies. We compare the foreign-born (first-generation immigrants) and the native-born, the same type of comparison as in Hunt and Gauthier-Loiselle (2010), Hunt (2011) and No and Walsh (2010). In studies by e.g. Kerr (2008a) and Nathan (2014b), the comparison is made between the ethnic inventor communities following name-based approaches, where minority ethnic inventors also include second- and third-generation immigrants.

born, though the difference is quite small. This difference is greater for the immigrants born in or after 1961 (≥1961) and primarily for those who migrated as adults, which is a reflection of how the distinctive geography, institutional regimes, migration history and selection of immigrants affect the overall inventive activity of the immigrants in Sweden. Second, this is the first study to compare the inventive performance of the immigrants who migrated as children, those who migrated as adults and the native born. For those who are inventors, the general group of immigrants, including those who migrated as adults, performs as well as those of the Swedish-born and therefore seems to be more positively selected. However, the immigrants who migrated as children generally perform more poorly than the natives in both the quantity and quality of patents. Their poorer inventive performance may be linked to a lack of Sweden-specific human capital; poorer high school performance explains a minor part of their lower probability of patenting. Third, we also contribute to the literature on whether obtaining an education in the host country is a factor in the immigrants' inventive performance. Looking at the immigrants who migrated as adults, we find that those who were educated in Sweden and those educated abroad have similar inventive performance. In summary, this study provides an initial impression of the inventive performance and contribution of, as well as challenges for, distinct groups of immigrants who have differing characteristics and backgrounds.

The paper is structured as follows: Section 2 summarizes the existing literature on the importance and contribution of foreign-born inventors to their destination countries and the factors that affect their inventive performance. Section 3 discusses the theoretical background used to formulate our hypotheses. Section 4 presents the databases and descriptive statistics. Section 5 contains the methodology and the factors that influence inventive performance. Section 6 reports the results of the empirical analysis. The final section concludes the study with a discussion of the results.

2 Literature review

In recent years, more and more researchers have begun to explore the contribution of highly skilled immigrants to invention and innovation in their host country. Extant studies have largely focused on the USA. For example, Wadhwa (2009) finds that foreign nationals living in the USA contribute to a great many of its international patent applications. No and Walsh (2010) find that according to a national survey of the 'triadic' patents of more than 1900 US-based inventors, almost 30 % of the leading inventors in the US are non-US-born, a significant overrepresentation compared with the total foreign-born population (about 11 %) and the foreign-born proportion of the college-educated science and engineering (S&E) workforce (about 22 %). Kerr (2008a) indicates that there is a growing contribution by ethnic minorities to US domestic patents. Immigrants of Chinese and Indian ethnicity especially have become an integral part of US invention in high-tech sectors. Similarly, Stephan and Levin (2001) reveal that a disproportionate number of highly cited patents (the top 3.5 % from the period 1980–1991) in the life sciences were contributed by the foreign-born (17.6 %) and foreign-educated (baccalaureate degree) immigrants (11.1 %). Chellaraj et al. (2008) find that the presence of foreign graduate students (immigrants with student visas) has a significant and positive effect on both future patent applications and future patent grants awarded to American universities and firms. The presence of skilled immigrants also has a positive, but smaller, impact on patenting. A study by No and Walsh (2010) shows that foreign-born individuals are more likely to invent than the US-born. After controlling for technology class, education and time spent on inventing, though, this difference disappears. Nevertheless, the quality of patents filed by leading inventors born outside the US is higher on average. Hunt and Gauthier-Loiselle (2010) and Hunt (2011) also indicate that immigrants in the USA generally perform better than the US-born when it comes to patenting, largely because they are more highly educated and more likely to study S&E.

Research on the impact of immigrants on innovation activity in non-US countries is very sparse. We are aware of only a few studies on immigration and patenting outcomes outside the US; these include two regional-level studies by Niebuhr (2010) (German regions) and Ozgen et al. (2012) (across 12 EU countries), as well as some pilot studies based on individual data. For instance, Nathan (2014b), analyzing new UK patent data, finds that increased diversity of inventor communities can help promote individual patenting and suggests that high-patenting minority ethnic inventors, especially patenting 'stars' of East Asian origin, drive overall patenting rates. Based on patents filed with the EPO, preliminary results by Breschi et al. (2014) indicate that immigrant inventors contribute significantly to innovation not only in the USA but also in selected European countries. Some studies based on the Global Science (GlobSci) survey of 16 countries have also investigated the relationship between migration and scientific performance (Franzoni et al. 2012, 2014; Van Noorden 2012).

In summary, as shown in almost all of the literature, immigrants seem to make a significant and positive contribution to innovation in their destination country, and their positive self-selection is usually considered the basis for their superior performance (Chiswick 1978; Borjas 1987; Wadhwa et al. 2007; No and Walsh 2010; Hunt 2011; Nathan 2014b).

3 Hypotheses

3.1 Positive and negative forces of immigration and their impact on invention

Inventive performance depends not only on demographic or formal human capital characteristics such as gender, age and education (Hunt 2011; Jung and Ejermo 2014), but also on informal and largely unmeasured assets such as language skills, culture, institutional familiarity and social networks (Agrawal et al. 2008; Nathan 2014b). A lack of these informal qualities may hamper an individual's development. For instance, patents with more inventors (indicative of larger networks) have been found to be of higher quality (Ejermo and Jung 2011), and inventing teams may stretch across different regions (Ejermo and Karlsson 2006). Thus, inventive activity requires cooperation and network relationships across individuals as well as across organizations. However, immigrants tend to be disadvantaged with respect to these human capital resources, which are country specific in many cases. Language barriers, discriminatory attitudes towards immigrants, limited social networks and unfamiliarity with the host country's culture and institutions might decrease inventive activity in immigrants (Nathan 2014b).

From an economic perspective, migration is an investment with associated costs and benefits for the individual (Sjaastad 1962; Lee 1966; Becker 1975; Borjas 1987; Nathan 2014a, b). The potential migrant who decides to move does so if the benefits of moving exceed the costs (Borjas 1987; Bevelander 2000). Such immigrants are therefore positively self-selected compared with non-migrants in their country of origin and may perform better than the average comparable native population in their destination country (Borjas 1987). However, Borjas (1987, 1991) maintains that immigrants can be negatively self-selected under some conditions, where people with below-average earnings and productivity in their home country are more likely to migrate. This occurs if the income distribution in the home country is more unequal than that in the destination country. Compared with the majority of other countries, incomes are much more evenly distributed in Sweden. For example, in 2000, the Gini index[6] in Sweden was the lowest of 47 reporting countries in that year (World Bank 2014). It follows that Sweden is a very attractive destination country for relatively *unskilled* persons from other countries, inducing negative self-selection. In addition, equal and relatively low payment (compared with other developed countries) for highly skilled workers, as well as relatively high marginal income taxes[7] (Quirico 2012), may make Sweden less attractive to highly skilled immigrants.

Furthermore, the migration policy of a prospective destination country may sway the selection of immigrants (Belot and Hatton 2012). Tied movers, who migrate for family reasons, and refugees or asylum seekers, who may be politically oppressed, are not primarily selected for their skill advantages. They may therefore be negatively selected with respect to their abilities to engage in inventive activity, at least compared with immigrants picked for a specific job. Such a skill bias seems to characterize the situation in Sweden (Scott 1999; Bevelander 2000). Since 1968, except for the free migration of immigrants from the other Nordic countries, which has been extended to the other EU/EEA countries since 1995 as well, immigration policy in Sweden for other countries has principally been focused on immigrants who migrate as refugees or for reasons of family reunification, with the result that the opportunity to migrate to Sweden is skewed towards low rather than high-skilled immigrants from those counties. Clearly, such a negative selection mechanism, and its implications for skill and education levels, may also reduce the average inventive capability of Sweden's immigrant population.

Considering immigrants' disadvantage in terms of Sweden-specific human capital and the negative selection mechanism (the Sweden-specific economic feature and migration policy) applied in Sweden, as discussed above, we formulate the following:

> *Hypothesis 1*. On average, the immigrants to Sweden are less likely to become inventors than the Swedish-born.

[6] The Gini index measures the income distribution of a nation's residents. A Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality.
[7] Sweden's highest marginal rates of personal income tax ranked fourth (after Aruba, Curaçao and Denmark) and second (after Aruba) in the world in 2005 and 2010, respectively (see KPMG 2012).

3.2 Inventors' inventive performance

Although Sweden faces challenges in attracting highly skilled immigrants,[8] many still find it an appealing destination country for several reasons. First, in general, Sweden has shown an impressive economic performance since the Second World War and has enjoyed relatively low unemployment rates compared with other developed countries, especially before 1992 (OECD 2014). Since the mid-1970s, the Swedish economy has experienced a structural change in which it has gradually shifted from heavy industry to a service economy with investment in new branches of production and innovation (Scott 1999; Bevelander 2000; Schön 2010). This transformation has increased the need for highly skilled workers (Edin and Topel 1997; Cerna 2012), providing job opportunities for skilled immigrants. Second, Sweden stands out as one of the most humanitarian, egalitarian and democratic countries in the world (Eger 2010) and, furthermore, offers generous welfare benefits, devoting around 30 % of its GDP to social expenditures (Eger 2010; Giulietti and Wahba 2013; OECD 2015). The Swedish social welfare system may be an important positive factor in the choice of destination country for immigrants, including the highly skilled ones, who want to minimize the risks of migration. Residents in Sweden can enjoy a high standard of living, a good work–life balance, universal health care, free education[9] and generous parental and unemployment benefits (Eger 2010). Third, Sweden offers a very friendly environment and a high degree of legal equality to immigrants—the best among eight European countries in a recent assessment (Koopmans 2010). Fourth, developed links between Sweden and other European countries (especially other Nordic countries), such as fewer linguistic and cultural obstacles, networks based on a shared history and free mobility of institutional regimes, as well as short physical distances, play important roles in migration (Belot and Ederveen 2012) and help attract highly skilled immigrants to Sweden.

Highly skilled immigrants may be much more positively self-selected compared with other immigrants, as they are usually more rational in their decision to migrate (Peixoto 1999). They may even be more skilled than the natives if judged by formal human capital indicators like level of education, an important reason for the better patenting performance of immigrants in the USA (Hunt 2011). On the other hand, since the economic structural transformation that has taken place in Sweden, and the resulting rising demand for informal qualifications, highly skilled immigrants can also be somewhat disadvantaged in comparison with the past (Klinthäll 2003). For example, the disadvantage of foreign-born inventors regarding informal qualifications, for instance, a social network in the destination country, may impede their development (Agrawal et al. 2006; Kerr 2008a). Therefore, considering both the advantages and disadvantages of foreign-born inventors, most of whom can be

[8] For example, among the Swedish population aged 25 to 64 in 2006, 13 % of people engaged in science and technology in Sweden were foreign-born, compared with 16 % of total immigrants in the Swedish population (OECD 2008; Statistics Sweden 2014a; b).

[9] Sweden introduced undergraduate and master's programs tuition fees for students from non-EU/EEA/Switzerland countries in August 2011.

considered and defined as a subgroup of highly skilled immigrants,[10] we expect the following:

> *Hypothesis 2.* Among inventors, the immigrants to Sweden perform as well as the Swedish-born in invention, in terms of both quantity and quality of patents.

3.3 Differences between immigrants who migrated as children and adults

Some immigrants come to Sweden as children[11] and some as adults. These two groups can have different characteristics and expectations of inventive performance compared with natives. The following hypotheses (3–7) could therefore be seen as qualifications of hypothesis 1 and hypothesis 2.

3.3.1 Immigrants who migrated as children

Immigrants who migrated as children can be considered a special group for several reasons.

First, in contrast to adult immigrants, who may be (self-)selected, children who migrate to Sweden are not usually positively self-selected based on their knowledge, ability or skills but generally follow their parents as tied immigrants.

Second, they may suffer a double burden during their youth. On the one hand, they inherit characteristics from their parents and tend to be raised in families with languages, cultures and social networks that differ from the native families and host society. This may lead to a smaller social network, discrimination and cultural and linguistic shocks that result in difficulties integrating into Swedish society. On the other hand, they usually attend schools organized in accordance with the values and educational objectives of the host society (Westin 2003). Schooling can help the immigrant children improve their Swedish language skills, interact with native residents, acquire a wider social network and gain Sweden-specific human capital. Notwithstanding, the language problem, culture shock, conflicting values between family and school, and social marginalization may impede their school performance, damage their self-confidence (Westin 2003) and hamper their development as innovative individuals.

Third, the advantage of foreign-born children in having characteristics of both immigrants and natives can also become a disadvantage, because these may create difficulties in defining their social role among foreigners and natives and thus establishing well-developed social networks, which is important for inventive performance (Owen-Smith and Powell 2003; Kerr 2008a). Several studies suggest that knowledge flows, such as those that stem from patent citations, follow social networks (Agrawal et al. 2006; Kerr 2008a), which may be channelled partially through ethnic networks (Agrawal et al. 2008). Thus, if immigrants raised in Sweden find it difficult to define

[10] In our data, 80 % of the identified foreign-born inventors have a long or PhD education and 20 % have a short education (see definitions of 'education level' in Table 3). The corresponding figures for the identified Swedish-born inventors are 70 and 30 %, respectively.

[11] Among the general population of immigrants in Sweden in 2000, 10.7 % were younger than 18. The corresponding figures were 9.1 % in 2007 and 9.9 % in 2013 (Statistics Sweden 2014b).

their social role, resulting in a lack of good social networks with both co-ethnic people and natives, their inventive performance may be affected.

Based on these disadvantages with respect to the acquisition of human capital for the immigrants who migrated as children, our next hypothesis becomes the following:

> *Hypothesis 3*. Immigrants who migrated as children perform more poorly in invention than natives, both in quantity and quality of patents.

A person's school performance may also affect his/her inventive performance. It is reasonable to assume that those with better school performance have better knowledge and ability and then are able to have better inventive performance. For immigrants who migrated as children and obtained a high school education in Sweden, their high school GPA, which is used as a proxy for ability, can possibly be observed in our data. However, a high school GPA can only indicate part of a lack of formal human capital. Sweden-specific human capital, such as social networks, which immigrants who migrated as children may be lacking, is not necessarily reflected in grades. Thus, even after controlling for grades, we still expect immigrants who migrated as children to suffer from a poorer inventive performance compared with their Swedish-born counterparts. We therefore formulate the following:

> *Hypothesis 4*. Immigrants who migrated as children are expected to perform worse than the Swedish-born in invention even after controlling for school performance.

3.3.2 Immigrants who migrated as adults

Adult immigrants are more likely to be (self-)selected than young immigrants. Nonetheless, from 1968 and onwards, migration policy in Sweden has favoured refugees, asylum seekers and tied movers, so that many of those who migrated as adults are less educated and skilled (Scott 1999; Bevelander 2000). Hence, the average level of the human capital for immigrants who migrated as adults in Sweden has been decreasing (Bevelander 2000). Because of the date limitations in the available immigration data,[12] in looking at immigrants who migrated as adults, we only include those born in or after 1961. We formulate the following:

> *Hypothesis 5*. Immigrants who migrated to Sweden as adults are less likely to become inventors compared with the Swedish-born.

On the other hand, the situation may well be different for inventors who migrated as adults. In this subgroup, we are more likely to encounter a positively (self-)selected

[12] Data on the date of immigration on the individual level is only available from 1961 onwards. For those born before 1961, our data on date of immigration may be not their first entry date. To ensure that the date of immigration is the first entry date for immigrants, which can be used to identify their age of immigration correctly, we only keep immigrants who were born in or after 1961 when we study those who migrated as children and adults in model 4 and model 5.

type of immigrant rather than, for example, refugee immigrants, as invention is a knowledge-intensive activity in which mainly highly skilled individuals participate. Therefore, the level and quality of invention contributed by inventors who migrated as adults may be equal to or even better than those of natives.

> *Hypothesis 6*. Inventors who migrated as adults perform at an equal level or even better in invention than natives.

The inventive performance of immigrants may be affected by whether they have obtained an education in the host country or abroad. First, the quality of education can vary across countries and further affect individual knowledge, skills and ability. Compared with many other countries, the quality of education in Sweden, especially that of university education, is relatively high: five universities in Sweden rank among the top 200 universities in the world (Ranking Web of Universities 2014). Second, it is difficult to fully transfer immigrants' education acquired abroad to the Swedish context. Third, immigrants who obtain an education in the destination country are more likely to acquire host country-specific human capital to augment the skills that they bring with them (Chiswick and Miller 1994), and this may enhance their individual inventive performance. We will examine the effects of education on immigrants who migrated as adults and expect the following result:

> *Hypothesis 7*. Among immigrants who migrated as adults, those with a Swedish education perform better in invention than those without a Swedish education.

4 Data and descriptive statistics

4.1 Summary of data

We use to good advantage a unique database that combines demographic information with patent applications filed with the EPO by Swedish residents from 1985 to 2007 (Jung and Ejermo 2014). The base data set contains information on inventors and inventions extracted from the Worldwide Patent Statistics (PATSTAT) database[13] provided by the EPO. The EPO was selected as the source of patent information for several reasons. First, it is one of the most frequently used filing offices for inventors in Sweden, along with the Swedish Patent and Registration Office (PRV) and the US Patent and Trademark Office (USPTO). Figure 1 shows that there is an artificial downward trend forming at the PRV, but a growing trend for patent applications to the EPO by Swedish residents in the past two decades. Second, as EPO patents cover protection in multiple European countries and impose substantial filing costs on an applicant, the projected returns (either strategic or sales) for a patent need to be higher and of better average quality than, for example, those filed only with the PRV. Third, EPO patents are highly useful for the identification of inventors, since they provide inventors' street addresses, while USPTO records only indicate names and cities. Full addresses have been essential for reaching a high match precision.

[13] This material uses patents and inventors from the April 2010 version, later supplemented and updated with information from the April 2011 version.

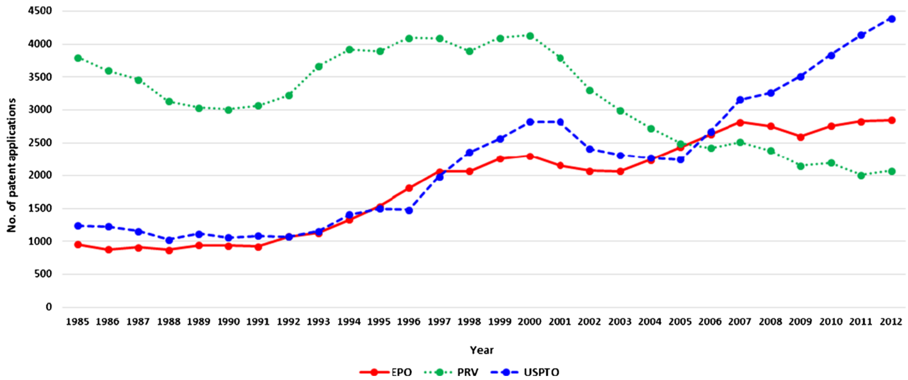

Fig. 1 Number of patent applications by Swedish residents in EPO, PRV and USPTO. Sources: EPO (2014), PRV (2014) and USPTO (2014). Number of patent applications in EPO is calculated by inventor's country of residence; in PRV, it is calculated by the applications that have at least one applicant residing in Sweden; in USPTO, it is calculated by the residence of the first-named inventor

In total, our database comprises 39,600 Swedish patent applications and 73,356 patent–inventor combinations[14] filed from 1985 to 2007. In brief, the matching was done in two stages. First, after cleaning the data, the inventor's SSN was added by a commercial company according to his/her name and address.[15] Eventually, 66 % of the records were thus matched or could be determined from matches found by the company. Nevertheless, the match rate was much higher for later patenting years. In order to go further, all remaining inventors were searched for in a complete address directory of the whole Swedish population in 1990.[16] This raised the match ratio substantially to 79.3 %, especially for the 1980s and 1990s, and removed most of the differences in matching over time (Jung and Ejermo 2014). Appendix 1 reports on our investigations to verify that the 20.7 % unidentified inventors were not subject to bias with respect to immigrant or native background.

Next, inventor records were sent to Statistics Sweden, who subsequently matched them with detailed population directory data using the unique SSN provided.[17] In this way, we gained access to demographic information for inventors, which was combined with patent information to constitute our rich database. In addition, the inventors were matched with the *entire* Swedish population by the unique SSN.

The data used in this paper has several advantages over survey data, case studies and data that uses name-matching techniques for the ethnic identification of inventors (e.g. Kerr 2008b; No and Walsh 2010; Hunt 2011; Breschi et al. 2014; Nathan 2014b). First,

[14] Patent–inventor combination means that each inventor in a patent is listed as one observation with demographic and patent information for that application year. For example, if one patent has three inventors, then there are three observations of patent–inventor combinations. If one inventor contributed to N patents, then he/she is shown *N* times and contributes to *N* observations.

[15] The commercial company holds all addresses of Swedish residents for the past 3 years. As the establishment of our database was in 2011, only the inventors whose addresses in the patent file are the same as they had between 2009 and 2011 can be matched.

[16] In the 1990 directory, the whole Swedish population was included with their addresses and birth dates. The full SSN was derived by checking birth date in accordance with existing matches and by contact with the Swedish tax authority.

[17] Statistics Sweden has very detailed information that includes demographic and education information for all residents in Sweden from 1985 onwards. Any resident living in Sweden for more than 1 year has an SSN. If the SSN in Statistics Sweden can be matched with the SSN identified by the commercial company for the inventors, then the inventor's detailed personal information can be matched.

our data comprises almost all patent applications filed with the EPO by inventors in Sweden from 1985 to 2007, which greatly reduces the risk of selection bias and allows us to track inventors over extended periods of time. Second, the data is complemented with demographic information, which is usually only accessed from complementary survey data but is measured here with very high precision. Third, the data on the entire Swedish population is available, which allows us to investigate the inventive activity among the whole population.

We focus on inventors aged 25 to 64 (mean age 43.9)[18], in other words, the working age for the majority of people living in Sweden. People are more likely to work and patent at these ages, which makes our sample more coherent. Finally, we use the 76.5 % of inventor–patent combinations where inventors are identified[19] (see Table 1). Among the identified inventors, 10.9 % or 2176 individuals are foreign-born and are attributed with 11.6 % (by fractional count) of the identified Swedish patent applications.[20] On average, each foreign-born inventor is attributed slightly more patents (by fractional count) than each Swedish-born inventor (1.5 vs. 1.4).

4.2 Component and growing trends among foreign-born inventors

Of the identified foreign-born inventors (see Table 2), 27.3 % of them came from other Nordic countries, 23.3 % from EU-15 (excluding Sweden, Denmark and Finland), 24.3 % from the rest of Europe (including the former Soviet Union), 16.3 % from Asia, 4.2 % from North America[21] or Oceania and 4.6 % from South America or Africa. The proportion of identified inventions (by fractional count) contributed by each group is almost identical.

Figure 2 presents the population shares of foreign-born inventors against the shares of their contributions to inventions and the shares of immigrants in the entire Swedish population aged 25 to 64. The population shares of foreign-born inventors are between 7.5 and 13.4 % from 1985 to 2007. Except for the shares in 1985 and 1986, they are much lower and more fluctuant than the shares of immigrants in the entire Swedish population, which rose stably from 11.0 to 17.0 % between 1985 and 2007. In general, the shares of inventions contributed by foreign-born inventors are slightly higher than their population shares over the whole period.[22]

[18] Inventors younger than 25 are excluded from our data as their contribution to Swedish invention is negligible. Those aged 16 to 24 only contributed 0.29 % of identified patent–inventor combinations that were contributed by inventors aged 16 to 64, which is less than the contribution by the inventors at any other single age. For example, the corresponding figure for the inventors aged 25 is 0.35 %.

[19] Please see Appendix 1 for the check of unidentified inventors.

[20] Fractional count means that each co-patent is counted as a fraction, depending on how many inventors contributed to one patent. For example, if one patent has three co-inventors, then each inventor is attributed one third of the patent.

[21] North America includes Central America and the Caribbean countries. According to data from Statistics Sweden, 66.3 % of immigrants from North America were from Canada or the USA in 2000 (59.8 % in 2008).

[22] Figure 2 shows a temporary decline in the share of immigrants' inventions in 1993 and 1994 and an increase in 1995, after which the trend is steadier. There may be several reasons for this dip and rebound. For example, (a) the economic depression in Sweden at the beginning of the 1990s may have affected immigrants differently (Ekberg 2011), (b) Sweden's entry into the EU may also have led to an increased inflow of skilled migrants from other EU countries from 1995 onwards and (c) labor migration from non-EU/EEA countries tends to be strictly selected in the form of experts and key personnel, who are more likely to participate in invention (Ministry of Justice 2001; Cerna 2009).

Table 1 Number and share (%) of identified inventors in Sweden aged 25–64 and patent applications that they contributed to, 1985–2007

	Foreign-born	Swedish-born	Total	Unidentified/ excluded by age[a]	Total
Total no. of patent–inventor combinations	6457	49,745	56,102	17,254	73,356
Share of all combinations	8.8 %	67.7 %	76.5 %	23.5 %	100 %
Share of all identified combinations	11.5 %	88.5 %	100 %	–	–
No. of identified inventors	2176	17,839	20,015	–	–
Share of all identified inventors	10.9 %	89.1 %	100 %		
No. of identified applications (fractional count)	3254	24,853	28,107	–	–
Share of all applications	11.6 %	88.4 %	100 %		
Average no. of patents contributed to	1.5	1.4	1.4	–	–

Sources: Statistics Sweden and CIRCLE data on inventors

[a] 'Unidentified/excluded by age' includes 15,183 (20.7 %) unidentified patent–inventor combinations and 2071 (2.8 %) combinations where inventor's age is less than 25, more than 64 or unknown

The descriptive analyses suggest two key points. First, foreign-born inventors in Sweden appear to be substantially different from foreign-born inventors in American and British populations. Compared with immigrants' shares in the workforce population in the host countries, the minority ethnic inventors in the USA and the UK are overrepresented in terms of patents (No and Walsh 2010; Nathan 2014b), while our figures reveal that foreign-born inventors in Sweden are underrepresented. Moreover, in the USA, minority ethnic inventor communities are mainly from South and East Asian countries such as China (including Taiwan and Hong Kong) and India (Kerr 2008a, b; Wadhwa 2009; No and Walsh 2010), which are also important regions of origin for foreign-born inventors in the UK (Nathan 2014b). By contrast, the majority of foreign-born inventors in Sweden are from European countries, with other Nordic countries as the most important sources of inflow. This reflects how geographic location, migration institutional regime and migration history in Sweden affect its constituent of foreign-born inventors. Second,

Table 2 Number and share (%) of foreign-born inventors aged 25–64 and inventions that they contributed to (fractional count) by region of origin, 1985–2007

Region of origin	No. of inventors	Share (%) of inventors (1)	No. of inventions	Share (%) of inventions (2)	Gap=(2)−(1) (%)
Other Nordic countries	595	27.3	854	26.2	−1.1
EU-15 excl. SE, DK and FI	507	23.3	783	24.1	0.8
Rest of Europe[a]	528	24.3	825	25.3	1.1
Asia	354	16.3	526	16.2	−0.1
North America + Oceania	92	4.2	151	4.6	0.4
South America + Africa[b]	100	4.6	116	3.6	−1.0
Total	2176	100	3255	100	

Sources: Statistics Sweden and CIRCLE data on inventors

[a] Includes the former Soviet Union

[b] Includes one inventor whose region of origin is unknown and who filed 1.7 inventions by fractional count

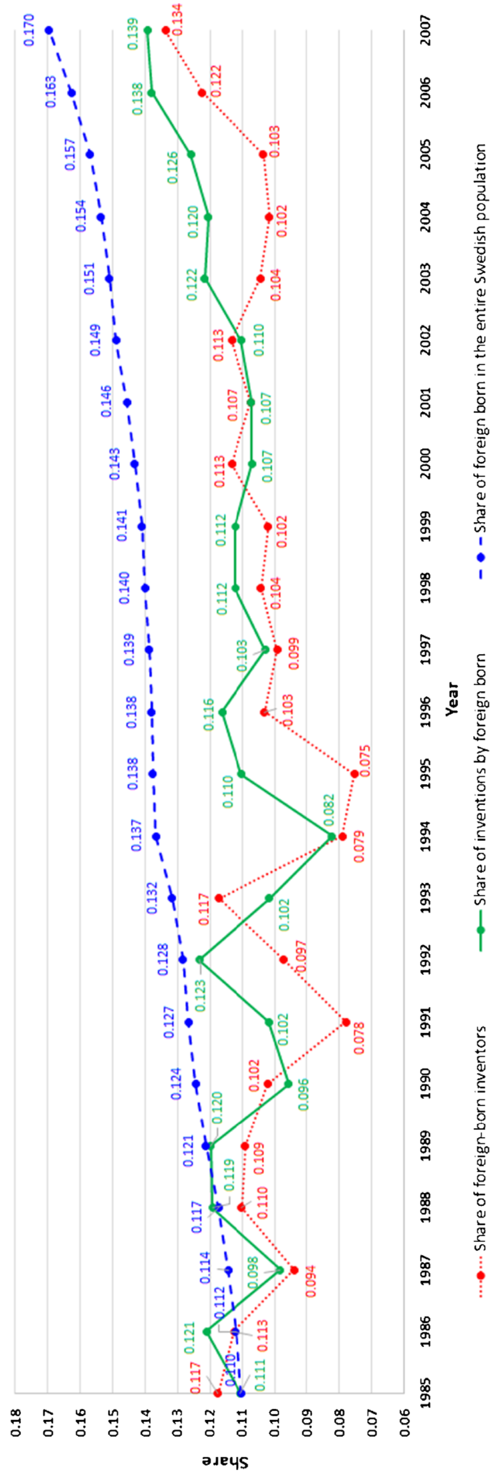

Fig. 2 Share of foreign-born inventors, their contribution of inventions (fractional count) and foreign-born in the entire Swedish population aged 25–64, for each year 1985–2007. Sources: Statistics Sweden and CIRCLE data on inventors

foreign-born inventors are, on average, slightly more productive than Swedish-born inventors, in terms of the average number of patents per inventor.

5 Methodology

5.1 Estimated models

We now turn to examining how inventors' backgrounds affect inventive performance in terms of both quantity and quality analysis. For our *quantity* investigations, the unit of analysis is the individual. The level of inventive performance is investigated in two ways. First, we examine the probability of patenting for *all* immigrants compared with all natives based on unbalanced panel data for the entire Swedish population from 1985 to 2007. Second, among the inventors, we examine the total number of patents attributed to each of them from 1985 to 2007. The *quality* of inventive performance is also measured in two ways for those who are inventors, namely, the NFC for each patent and the probability of a patent being granted. In these cases, the unit of analysis is the unique patent–inventor combination.

Each dependent variable is examined in five different models.

In model 1, we compare the probability of patenting for all immigrants with the probability for all natives. For the subgroup of immigrants made up of inventors, we compare their contribution to the total number of patents, the NFC received per patent and the probability of their patents being granted with the corresponding figures for native-born inventors. We use this model to test hypotheses 1–2.

In model 2, we compare the same indicators for immigrants *raised* in Sweden with those for natives. To do this, we retain only individuals whose high school GPAs between 1973 and 1996 are available.[23] We use this model to estimate hypothesis 3. In total, 48.2 % of the inventors in Sweden are found to have a high school GPA. Immigrants who have received a high school education in Sweden are assumed to have been raised in Sweden because the usual graduating age in Sweden is 18–19.[24] Students usually enter secondary school at the age of 16–17.

In model 3, building on model 2 for each indicator, we add a variable, high school GPA, as a proxy for ability. We include this variable to represent the otherwise unobservable effect of individual ability,[25] which may correlate with inventive

[23] Grade data are complete between 1973 and 1996 but unobserved before 1973 and not comparable with earlier years from 1997 on.

[24] We cannot find other higher-quality information to indicate whether immigrants were raised in Sweden for the *entire* population in the whole examined period. We believe that it is reasonable to assume that those attending high school in Sweden are likely to have been raised in Sweden. Of all inventors in Sweden, 61.5 % graduated before the age of 19 and 93.5 % before the age of 20. The corresponding figures for foreign-born inventors are 56.2 and 86.4 % (please see footnote 12 for the reason why we do not use data here, such as the date of immigration, to identify whether immigrants have been raised in Sweden or not).

[25] Individual ability could also correlate with the choice to migrate, which may lead to a self-selection problem. To test for endogeneity caused by self-selection, we use the variable *child_migrant* (migration occurred as children) as the instrument variable for *foreign-born* (omit: Swedish-born), a strategy similar to the one used by Franzoni et al. (2014). According to the ivpoisson control function model and generalized method of moments (GMM) on total number of patents and NFC to patents (see dependent variables below), we find that the variable *foreign-born* is not endogenous.

performance. The absence of an individual ability proxy may result in correlation between the explanatory variables and the error term, which leads to potentially biased and inconsistent estimates (Franzoni et al. 2014). High school GPA can be considered a reasonable proxy for ability because those with higher grades are assumed to have higher ability. The unified evaluation standard for high school GPA between 1973 and 1996 in all high schools in Sweden makes it possible to compare different individuals. This model is used to test hypothesis 4.

In model 4, we compare the same indicators for immigrants raised in Sweden, those who immigrated as adults[26] and the Swedish-born. We only include individuals born in or after 1961 due to date limitations in the available immigration data. In total, we find that 38.1 % of the inventors in Sweden were born in or after 1961. We employ this model to test hypothesis 3 and hypotheses 5–6.

In model 5, building on model 4, we divide immigrants who migrated as adults into two groups: those who obtained their education in Sweden and those who acquired it abroad. We do this to ascertain that whether either source of education affects inventive performance. In this model, all the Swedish-born and immigrants who migrated as children are assumed to have been educated in Sweden, regardless of their level of education.[27] Model 5 is used to test hypothesis 7.

Models 1–3 have three submodels each. Each first submodel includes all population/inventors without restricting the sample by birth year. Each second submodel includes only population/inventors born before 1961 (<1961), and each third submodel only includes those born in or after 1961. This age split for the first three models facilitates comparison with model 4 and model 5, for which only immigrants born in or after 1961 are available.

Only people with an education level equal to or higher than secondary school, and who were employed, are included in the regressions, as the data on explanatory variables of 'field of study' in Sweden and 'sector of work' (see discussion in Table 3) is only available for this group.[28]

5.2 Dependent variables and estimation methods

5.2.1 Inventive productivity

Probability of patenting First, we compare the probability of patenting between the entire populations of immigrants and the Swedish-born. The dependent variable is set up as a dummy variable, coded as 1 if an individual in Sweden has at least one patent application in year *t* and 0 otherwise. Random-effects probit regressions with observed

[26] Of those born in or after 1961, 71.4 % of foreign-born inventors and 69.9 % (2000) and 71.7 % (2007) of all immigrants migrated as adults.

[27] Among the identified inventors born in or after 1961, we find that 97.2 % of the Swedish-born and 93.5 % of immigrants who migrated as children have received an education in Sweden at secondary school or higher levels according to their study records in Statistics Sweden; 26.2 % of immigrants who migrated as adults obtained an education in Sweden.

[28] Among the identified inventors, only 3.8 % have an education at primary school level. Of these, 91.5 % are Swedish-born and 8.5 % are foreign-born. The distribution is similar for inventors who have an education level equal to or higher than secondary school, 89.4 and 10.6 %, respectively. Only 3.6 % of the identified inventors are unemployed. Of these, 75.9 % are Swedish-born and 24.1 % are foreign-born. The distribution among employed inventors is 89.6 and 10.4 %, respectively.

information matrix (oim) standard errors are applied in the analysis,[29,30] (Gibbons and Hedeker 1994).

Total number of patents attributed to each inventor Among inventors who attributed with at least one patent application, we consider the total number of patent applications by each inventor to examine differences in patent productivity between the foreign-born and native-born. The number of patents per inventor is widely overdispersed: more than half (53.6 %) of the inventors have only one patent application, and the standard deviation (4.1) of the total number of patents per inventor is larger than the mean value (2.8). Therefore, we apply negative binomial models with robust standard errors rather than Poisson models (Cameron and Trivedi 2010) for the analysis.

5.2.2 Quality of patents

It is difficult to assess the value of patents, since the value distribution is highly skewed (Harhoff et al. 2003; Acemoglu et al. 2014). Numerous researchers have approximated patent value with various indicators, such as market value of patents, NFC, patent scope, opposition procedure, family size,[31] number of claims, renewal data and the probability that a patent application is granted (e.g. Trajtenberg 1990; Lerner 1994; Lanjouw et al. 1996; Harhoff et al. 2003). In this paper, we use the NFC and probability of a patent application being granted as our dependent variables to measure the quality of patents.

NFC received by each patent We use NFC as one of our indicators of patent quality because, virtually, all studies on patent value have demonstrated that it has a significant and positive correlation with the value of a patent (e.g. Harhoff et al. 2003; Hall et al. 2005; Gambardella et al. 2008). Although these studies admit that the relationship is quite noisy (Harhoff et al. 1999) and the best possible approximation of patent value is unlikely to be obtained by using forward citation counts alone (Gambardella et al. 2008), NFC retains its role as the most common indicator and is even considered the strongest predictor of patent value compared with other indicators (Lanjouw and Schankerman 1999; Sapsalis et al. 2006). Moreover, it is also considered a proxy for effective use or importance of a patent to new inventions (Sapsalis et al. 2006).

The NFC is calculated within a 5-year interval after filing the original patent or one of its family members, using the International Patent Documentation Center

[29] When the dependent variable is a dummy variable (probability of patenting and probability of a patent application being granted) and both probit and logit model are applicable, or when the dependent variable is count data (total number of patents per inventor and NFC received by each patent) and any of the negative binomial, Poisson, and zero inflow models are applicable, we always choose the model which has the higher log pseudolikelihood, smaller Akaike's information criterion (AIC) and Schwarz's Bayesian information criterion (BIC) after comparison.

[30] This method is appropriate because it takes into account that the probability of patenting for an individual is a series of correlated binary outcomes, in which a person who patented previously is also more likely to patent later on.

[31] Roughly, number of countries of patent protection (see Martínez 2011).

(INPADOC) extended family size definition (Martínez 2011). Again, negative binomial models are preferred because the NFC is both count data and highly overdispersed (zero citations: 50.2 %, standard deviation: 2.8, mean: 1.4). Since 46.4 % of inventors have patented more than one invention, we employ negative binomial regression models with clustered robust standard errors to control for intra-inventor correlation.

Probability of a patent application being granted The granting of a patent application is interpreted as a signal of the invention's value. Granted patents are likely to have a higher value than rejected or withdrawn patents for two related reasons. The one is related to the technological value and the granting process.[32] The other is related to the legal rights conferred to the patentee, in which the grant provides an exclusive right to the exploitation of the invention, leading to a potentially higher return than generated by a non-protected invention (i.e. the grant generates value) (Guellec and van Pottelsberghe de la Potterie 2000, 2002).

Patent grant years are observed from 1987 to 2011.[33] On average, it takes 5.1 years for a patent to be granted, with a minimum of 0.9 years, a maximum of 19.6 years and a standard deviation of 1.9 years in our data. Of all patent applications, 55 % are granted within 5 years and 90 % within 7.7 years. A dummy variable is used, coded as 1 if a patent application is granted and 0 otherwise. Logit models with robust standard errors are used to investigate the probability of a patent application being granted.

The logit model is written as follows:

$$P(\text{grant} = 1) = \frac{e^{X\beta}}{1 + e^{X\beta}} \tag{1}$$

where P is the probability of a patent application being granted, X is a vector of explanatory variables and β is a vector of estimated model parameters.

5.3 Independent variables

Foreign-born is our main variable of interest for each dependent variable. We compare the inventive performance of different groups of foreign born with the corresponding groups of Swedish-born (reference groups). The dummy variable here is assumed to capture a mixture of observed and unobserved effects of foreign-born in the models.

We include the following control variables for each estimated dependent variable: *highest education level* at the time of the examined year, *high school GPA*, *field of study*, *age and age*^{2}, *gender*, *firm size*, *sector of work* and *region of work*. We also include *technology classes* when we examine the total number of patents for each inventor, the NFC for patents and the probability of a patent application being granted, as they are likely to be influenced by the number of patents in different technology

[32] Three main criteria must be fulfilled during the search and examination procedures for a patent application to be granted: the invention must (a) be novel in terms of the published state of the art (new), (b) be industrially applicable (useful) and (c) exhibit a sufficient 'inventive step' (be non-obvious).

[33] As our data were collected in early 2011, the information on grants in 2011 is incomplete. There are only 171 observations in 2011 compared with 2216 in 2010.

sectors. *Application year* and *number of inventors*, which are related to patent quality, are only included when we examine the NFC for patents and the probability of a patent being granted. An overview of the reasons for including these control variables is given in Table 3.

6 Empirical results

6.1 Do different groups of immigrants perform as well as the Swedish-born in invention?

After including control variables, the random-effects probit regressions in model 1 (Table 4) show that the immigrants in Sweden are significantly less likely to patent than the Swedish-born, for those born both before and in or after 1961, which strongly supports hypothesis 1. Model 1.1 shows that an immigrant has a 0.0003 % ($p<0.01$) lower probability of patenting than a Swedish-born. This means that, holding other variables constant, the probability of observing an inventor drops by about 0.5 % (=1−(0.000579−0.000003)/0.000579, 0.000579 is the average share of Swedish-born inventors in the Swedish-born population sample used in model 1.1) if the individual is foreign-born. Compared with their Swedish-born counterparts, immigrants born in or after 1961 are even less likely to patent (−0.0005 %, $p<0.01$, model 1.3) than those born before 1961 (−0.0002 %, $p<0.01$, model 1.2). This could be the result of two underlying factors. First, the negative selection of immigrants became a more dominant feature from the 1970s onwards, when migration policy increasingly favoured refugees and asylum seekers over relatively skilled labour (Scott 1999; Bevelander 2000). Second, Sweden's economic structural transition into post-industrial society (Schön 2010) raised the requirement for Sweden-specific skills, such as the ability to speak and write Swedish and other cognitive abilities, which could decrease immigrants' chances to participate in inventive activity.

Generally, the total number (model 1 in Table 5) and quality of patents (model 1 in Tables 6 and 7) filed by foreign-born inventors, both those born before and in or after 1961, do not differ significantly from those of Swedish-born inventors, except for the finding that the patents of foreign-born inventors born before 1961 are less likely to be granted ($p<0.1$, model 1.2 in Table 7). This means that hypothesis 2 is broadly supported. It is therefore quite possible that the selection mechanism works in two ways. Seen as a whole, immigrants may be negatively selected in terms of invention. However, the selected group that does invent is more positively selected and similar to corresponding groups in, for example, the USA.

Broadly speaking, immigrants raised in Sweden perform more poorly in invention than natives, both in quantity and quality of patents (model 2 in Tables 4, 5, 6 and 7), which supports hypothesis 3. Nonetheless, those born before and in or after 1961 perform differently depending on the dimension considered when compared with their Swedish-born counterparts. Immigrants raised in Sweden, especially those born before 1961, are less likely to patent than the Swedish-born (model 2, Table 4). Conditional on being inventors (model 2.1 in Tables 5, 6 and 7), immigrants raised in Sweden also file fewer patents per inventor (especially those born before 1961, model 2.2 in Table 5), have lower quality of patents as indicated by NFC (especially those born in or after 1961, model 2.3 in Table 6) and are granted fewer patents (both born before and in or after 1961, model 2

Table 3 Control variables: rationale for inclusion and categorization

Control variable	Rationale	Categories
Highest education level at the time of the examined year	Studies indicate that better patenting performance of immigrants to the USA can largely be attributed to their higher education levels (Hunt and Gauthier-Loiselle 2010; No and Walsh 2010; Hunt 2011).	Three education levels: 1. Less than 3 years of post-secondary education[a] (short education); 2. At least 3 years of post-secondary education but below PhD level (long education, reference group); 3. Any PhD education (also unfinished).
High school GPA	Grades are used as a proxy and a control for individual ability. Used to check the robustness of our results compared with leaving it out.	Continuous variable
Field of study	Earlier studies suggest that the type of education is an important factor for the patenting performance of immigrants in the USA (Hunt and Gauthier-Loiselle 2010; Hunt 2011).	Four categories: 1. Engineering, manufacturing and construction (reference category); 2. Science, mathematics and computing; 3. Health and welfare; 4. Other fields.
Age and age^2	Inventive productivity varies with the age of individuals and has a curvilinear relationship (Mariani and Romanelli 2006; Jones 2010; Jung and Ejermo 2014; Simonton 2000). These variables also reflect variations in patent productivity and quality related to birth cohort and how recently a person acquired education.	Discrete data
Gender	There are well-documented gender differences in patenting performance (e.g. Ding et al. 2006; Azoulay et al. 2007), which can be attributed to personal characteristics, structural positions, organizational reasons and marital status (Xie and Shauman 1998). Women are less likely to patent than men (Azoulay et al. 2007; Huang et al. 2011) because of e.g. their lower probability of holding an S&E degree (Garant et al. 2012) or a preference for devoting more time to family and children than men. Whittington and Smith-Doerr (2005), however, find that the patents filed by women have equal or better citation rates than patents filed by men.	Dummy variable: Male (reference group); Female.
Firm size	Small firms may be more constrained in their propensity to patent and thus might focus only on the most valuable inventions (No and Walsh 2010). Large firms are more likely to patent and can also be expected to produce higher-quality patents, as they usually have more ample resources for invention and can afford to hire employees with greater innovation skills.	Three categories: 1. Small firms, coded 1 for 1–99 employees, 0 otherwise); 2. Medium firms (reference category, coded 1 for 100–499 employees, 0 otherwise; 3. Large firms, coded 1 for 500 employees or more, 0 otherwise.
Sector of work	Inventive activity can vary across different sectors. Patenting activity can be higher in manufacturing sectors than agriculture and	Four categories following Swedish Standard Industrial Classification (SNI92, see Appendix 2):

Table 3 (continued)

Control variable	Rationale	Categories
	service sectors (Nathan 2014b). Employees in the public service sector may perform more poorly than employees in other sectors as their work rarely involves competing for technology in markets.	1. Agriculture, hunting, forestry and fishing; 2. Industry (reference category); 3. Private service; 4. Public service.
Region of work[b]	Larger cities often offer agglomeration economies stemming from thick markets, knowledge spillovers, openness, job opportunities and cultural diversity. This leads to more developed markets, specialized inputs and other resources used in innovation, as well as greater opportunities for innovators to learn from one another, than smaller cities (Orlando and Verba 2005).	Three categories[c]: 1. Metro regions; 2. Urban areas; 3. Rural regions (reference group).
Technology classes	In some technology classes, inventions are more likely to be applied for as patents (No and Walsh 2010). Moreover, technologies with many patents are likely to have a higher NFC than those with fewer patents (No and Walsh 2010; Ejermo and Kander 2011). Meanwhile, technological convergence—that is, the blurring of boundaries across technological fields—may increase the probability of a patent being granted (Guellec and van Pottelsberghe de la Potterie 2002).	Five categories (Schmoch 2008): 1. Electrical engineering (reference group); 2. Instruments; 3. Chemistry; 4. Mechanical engineering; 5. Other fields.
Application year	We include them to control for differences in citation behaviour over time and possible differences in the accumulation of citations over time (Sapsalis et al. 2006), although this is largely dealt with by counting citations within 5 years after application. We also include them when we examine the probability of a patent being granted, as patents are not granted immediately after being filed.	23 time dummy variables
Number of inventors	To some extent, this controls for the level of resources devoted to the research project leading up to a patent, which should therefore affect the quality of a patent (Sapsalis et al. 2006).	Discrete data

[a] This includes secondary education and less than 3 years of post-secondary education. Education levels are grouped according to the International Standard Classification of Education 97 (ISCED 97)

[b] We have also run regressions using regional fixed effects dividing Sweden into five regions: (a) Stockholm, (b) around Stockholm (including the provinces of Uppsala, Södermanlands and Västmanlands), (c) Västra Götalands, (d) Skåne and (e) other regions. We find no substantial differences from the reported results

[c] The definition of metro/urban/rural regions is from the Swedish Board of Agriculture. Storstadsområden (e.g. Stockholm, Malmö and Gothenburg) are metro regions, Stadsområden (other cities in Sweden, e.g. Linköping) are urban areas, and Landsbygd (small towns and villages) are rural regions

in Table 7). Results in Tables 4 and 5 show that immigrants born in or after 1961 and who migrated as children (a) are generally as likely to patent as the Swedish-born (model 3.3 and model 4), (b) perform relatively better than immigrants born before 1961 (compare

Table 4 Random-effects probit regressions on the probability of patenting for immigrants among the *entire* population aged 25–64, 1985–2007

	1			2			3			4	5
	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3	4	5
	All	All_be61	All_af61	Chi_all	Chi_be61	Chi_af61	Chi_all_2	Chi_be61_2	Chi_af61_2	Adu_chi_af61	Edu_SE
Foreign-born (omit: Swedish-born)											
All foreign-born	−0.000003***	−0.000002***	−0.000005***								
	(0.000000)	(0.000000)	(0.000001)								
Migrated as children				−0.000003***	−0.000006**	−0.000002*	−0.000002*	−0.000006*	−0.000001	−0.000002	−0.000002
				(0.000001)	(0.000003)	(0.000001)	(0.000001)	(0.000003)	(0.000001)	(0.000001)	(0.000001)
Migrated as adults										−0.000007***	
										(0.000001)	
Migrated as adults and edu. in SE											−0.000006***
											(0.000001)
Migrated as adults and edu. abroad											−0.000008***
											(0.000001)
Education level (omit: long education)											
Short education	−0.000011***	−0.000009***	−0.000012***	−0.000020***	−0.000028***	−0.000016***	−0.000012***	−0.000021***	−0.000009***	−0.000013***	−0.000013***
	(0.000001)	(0.000001)	(0.000001)	(0.000002)	(0.000003)	(0.000002)	(0.000001)	(0.000002)	(0.000001)	(0.000001)	(0.000001)
PhD	0.000444***	0.000388***	0.000419***	0.000572***	0.000741***	0.000464***	0.000278***	0.000447***	0.000199***	0.000432***	0.000431***
	(0.000023)	(0.000026)	(0.000037)	(0.000042)	(0.000085)	(0.000044)	(0.000022)	(0.000055)	(0.000021)	(0.000038)	(0.000038)
High school GPA							0.000000***	0.000000***	0.000000***		
							(0.000000)	(0.000000)	(0.000000)		
Field of study (omit: engineering, manufacturing and construction)											
Science, mathematics and computing	−0.000007***	−0.000004***	−0.000008***	−0.000011***	−0.000011***	−0.000010***	−0.000011***	−0.000010***	−0.000010***	−0.000008***	−0.000008***
	(0.000000)	(0.000001)	(0.000001)	(0.000000)	(0.000002)	(0.000001)	(0.000001)	(0.000002)	(0.000001)	(0.000001)	(0.000001)
Health and welfare	−0.000010***	−0.000007***	−0.000011***	−0.000015***	−0.000018***	−0.000013***	−0.000017***	−0.000020***	−0.000014***	−0.000011***	−0.000011***
	(0.000000)	(0.000000)	(0.000001)	(0.000001)	(0.000002)	(0.000001)	(0.000001)	(0.000002)	(0.000001)	(0.000001)	(0.000001)
Other fields	−0.000011***	−0.000009***	−0.000012***	−0.000017***	−0.000022***	−0.000014***	−0.000019***	−0.000024***	−0.000015***	−0.000012***	−0.000012***

Table 4 (continued)

	1			2			3			4	5
	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3	4	5
	All	All_be61	All_af61	Chi_all	Chi_be61	Chi_af61	Chi_all_2	Chi_be61_2	Chi_af61_2	Adu_chi_af61	Edu_SE
	(0.000001)	(0.000001)	(0.000001)	(0.000001)	(0.000002)	(0.000001)	(0.000001)	(0.000002)	(0.000001)	(0.000001)	(0.000001)
Age	0.000002***	0.000002***	0.000007***	0.000007***	0.000008***	0.000009***	0.000008***	0.000009***	0.000011***	0.000007***	0.000007***
	(0.000000)	(0.000000)	(0.000001)	(0.000000)	(0.000001)	(0.000001)	(0.000000)	(0.000001)	(0.000001)	(0.000001)	(0.000001)
Age^2	−0.000000***	−0.000000***	−0.000000***	−0.000000***	−0.000000***	−0.000000***	−0.000000***	−0.000000***	−0.000000***	−0.000000***	−0.000000***
	(0.000000)	(0.000000)	(0.000000)	(0.000000)	(0.000000)	(0.000000)	(0.000000)	(0.000000)	(0.000000)	(0.000000)	(0.000000)
Gender (omit: male)	−0.000013***	−0.000013***	−0.000014***	−0.000020***	−0.000029***	−0.000017***	−0.000025***	−0.000035***	−0.000021***	−0.000014***	−0.000014***
	(0.000001)	(0.000001)	(0.000001)	(0.000001)	(0.000003)	(0.000001)	(0.000002)	(0.000003)	(0.000002)	(0.000001)	(0.000001)
Firm size (omit: medium (100–499 employees)											
Small (1–99 employees)	−0.000001***	−0.000001***	−0.000001***	−0.000002***	−0.000004***	−0.000001***	−0.000002***	−0.000004***	−0.000001***	−0.000001***	−0.000001***
	(0.000000)	(0.000000)	(0.000000)	(0.000000)	(0.000001)	(0.000000)	(0.000000)	(0.000001)	(0.000000)	(0.000000)	(0.000000)
Large (500+ employees)	0.000001***	−0.000000	0.000003***	0.000003***	0.000000	0.000004***	0.000003***	0.000000	0.000004***	0.000003***	0.000003***
	(0.000000)	(0.000000)	(0.000000)	(0.000000)	(0.000001)	(0.000001)	(0.000001)	(0.000001)	(0.000001)	(0.000000)	(0.000000)
Sector of work (omit: industry)											
Agriculture, hunting, forestry and fishing	−0.000014***	−0.000014***	−0.000011***	−0.000019***	−0.000031***	−0.000015***	−0.000023***	−0.000035***	−0.000017***	−0.000011***	−0.000011***
	(0.000001)	(0.000001)	(0.000002)	(0.000001)	(0.000003)	(0.000002)	(0.000002)	(0.000004)	(0.000002)	(0.000002)	(0.000002)
Private service	−0.000010***	−0.000010***	−0.000009***	−0.000014***	−0.000022***	−0.000011***	−0.000016***	−0.000025***	−0.000013***	−0.000009***	−0.000009***
	(0.000001)	(0.000001)	(0.000001)	(0.000000)	(0.000002)	(0.000001)	(0.000001)	(0.000003)	(0.000001)	(0.000001)	(0.000001)
Public service	−0.000015***	−0.000015***	−0.000014***	−0.000021***	−0.000032***	−0.000017***	−0.000025***	−0.000037***	−0.000020***	−0.000015***	−0.000015***
	(0.000001)	(0.000001)	(0.000001)	(0.000001)	(0.000003)	(0.000001)	(0.000002)	(0.000004)	(0.000002)	(0.000001)	(0.000001)
Region of work (omit: rural regions)											
Metro regions	0.000004***	0.000003***	0.000006***	0.000008***	0.000009***	0.000007***	0.000008***	0.000009***	0.000007***	0.000006***	0.000006***
	(0.000000)	(0.000000)	(0.000001)	(0.000001)	(0.000001)	(0.000001)	(0.000001)	(0.000001)	(0.000001)	(0.000001)	(0.000001)
Urban areas	0.000001***	0.000001***	0.000001***	0.000002***	0.000002**	0.000002***	0.000002***	0.000002**	0.000002***	0.000001***	0.000001***
	(0.000000)	(0.000000)	(0.000000)	(0.000000)	(0.000001)	(0.000000)	(0.000000)	(0.000001)	(0.000000)	(0.000000)	(0.000000)

Table 4 (continued)

	1			2			3			4	5
	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3	4	5
	All	All_be61	All_af61	Chi_all	Chi_be61	Chi_af61	Chi_all_2	Chi_be61_2	Chi_af61_2	Adu_chi_af61	Edu_SE
No. of observations	60,722,211	39,909,384	20,812,827	25,438,112	8,931,753	16,506,359	25,438,112	8,931,753	16,506,359	20,789,157	20,789,157
No. of individuals	4,790,529	2,603,142	2,187,456	1,843,162	443,248	1,399,917	1,843,162	443,248	1,399,917	2,185,171	2,185,171
Wald χ^2	28,779	17,572	12,134	16,058	5884	10,590	15,931	5888	10,394	12,128	12,128
Log likelihood	−185,198	−119,191	−65,139	−89,044	−32,712	−56,093	−88,449	−32,555	−55,690	−65,035	−65,034
Pseudo R^2	0.198	0.212	0.171	0.183	0.192	0.176	0.181	0.190	0.174	0.172	0.172

Robust standard errors in parentheses. Sources: Statistics Sweden and CIRCLE data on inventors. Marginal effects are reported. Sensitivity of quadrature approximation has been checked for each regression by quadchk, and the results are reliable, as the largest relative difference for each variable is smaller or around 0.01 % when we use intpoints (32). Pseudo $R^2 = 1 - \log$ likelihood (full model)/log likelihood (constant-only model). Model 1 was run on the entire populations. Models 2 and 3 were only run on the population whose high school GPA between 1973 and 1996 was available. In each submodel of models 1–3, we compare all populations, those born before and in or after 1961. Models 4 and 5 were only run on the population born in or after 1961

***p<0.01; **p<0.05; *p<0.1

Table 5 Negative binomial regressions on total number of patents per inventor aged 25–64, 1985–2007

	1			2			3			4	5
	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3	4	5
	All	All_be61	All_af61	Chi_all	Chi_be61	Chi_af61	Chi_all_2	Chi_be61_2	Chi_af61_2	Adu_chi_af61	Edu_SE
Foreign-born (omit: Swedish-born)											
All foreign-born	−0.045	−0.070	−0.042								
	(0.033)	(0.044)	(0.046)								
Migrated as children				−0.128**	−0.357***	−0.053	−0.113*	−0.340***	−0.039	−0.081	−0.081
				(0.060)	(0.093)	(0.070)	(0.059)	(0.092)	(0.069)	(0.065)	(0.065)
Migrated as adults										−0.027	
										(0.057)	
Migrated as adults and edu. in SE											−0.021
											(0.073)
Migrated as adults and edu. abroad											−0.032
											(0.081)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−0.529***	−1.603***	−0.931	−1.707***	−4.959***	−0.822	−2.509***	−5.495***	−1.486*	−0.923	−0.924
	(0.191)	(0.457)	(0.609)	(0.376)	(0.943)	(0.754)	(0.394)	(0.979)	(0.761)	(0.609)	(0.609)
No. of observations	16,471	9399	7072	8918	2876	6042	8918	2876	6042	7072	7072
Wald χ^2	1802	1280	1071	1077	640	871	1156	651	886	1071	1073
Log pseudolikelihood	−35,208	−20,499	−14,435	−18,797	−6,200	−12,467	−18,745	−6192	−12,430	−14,435	−14,435
Pseudo R^2	0.038	0.039	0.052	0.044	0.051	0.049	0.046	0.053	0.052	0.052	0.052

Robust standard errors in parentheses. Sources: Statistics Sweden and CIRCLE data on inventors. Coefficient results are reported. The results for control variables are omitted to save space. The control variables included here are three dummies for education level and high school GPA (only included in model 3); four dummies for field of study, age, age^2 and gender; three dummies for firm size; four dummies for sector of work; three dummies for region of work; and five dummies for technology field. Pseudo R^2 =1−log likelihood (full model)/log likelihood (constant-only model). Model 1 was run on all inventors. Models 2 and 3 were only run on inventors whose high school GPA between 1973 and 1996 was available. In each submodel of models 1–3, we compare all inventors, those born before and in or after 1961. Models 4 and 5 were only run on inventors born in or after 1961. It is the same for Tables 6 and 7

***p<0.01; **p<0.05; *p<0.1

Table 6 Negative binomial regressions on number of forward citations for foreign-born inventors aged 25–64, 1985–2007

	1			2			3			4	5
	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3	4	5
	All	All_be61	All_af61	Chi_all	Chi_be61	Chi_af61	Chi_all_2	Chi_be61_2	Chi_af61_2	Adu_chi_af61	Edu_SE
Foreign-born (omit: Swedish-born)											
All foreign-born	−0.035	−0.024	−0.034								
	(0.051)	(0.068)	(0.068)								
Migrated as children				−0.251***	−0.202	−0.262***	−0.243***	−0.200	−0.248***	−0.251***	−0.251***
				(0.077)	(0.151)	(0.087)	(0.076)	(0.149)	(0.086)	(0.084)	(0.084)
Migrated as adults										0.032	
										(0.079)	
Migrated as adults and edu. in SE											0.049
											(0.107)
Migrated as adults and edu. abroad											0.016
											(0.108)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.955***	−0.185	1.449	1.050*	−2.989**	1.923*	0.493	−3.242**	1.315	2.620***	2.614***
	(0.283)	(0.483)	(0.891)	(0.570)	(1.411)	(1.023)	(0.564)	(1.461)	(1.003)	(0.848)	(0.847)
No. of observations	49,949	30,231	19,718	26,356	9144	17,212	26,356	9144	17,212	19,718	19,718
No. of inventors	16,752	9630	7122	8993	2909	6084	8993	2909	6084	7122	7122
Wald χ^2	3179	1520	1993	2137	722	1797	2167	728	1829	2006	2047
Log pseudolikelihood	−78,135	−47,515	−30,490	−41,677	−14,726	−26,889	−41,661	−14,725	−26,873	−30,485	−30,485
Pseudo R^2	0.039	0.032	0.054	0.046	0.034	0.054	0.046	0.034	0.055	0.054	0.054

Robust standard errors in parentheses. Sources: Statistics Sweden and CIRCLE data on inventors. Coefficient results are reported. The results for control variables are omitted to save space. The control variables included here are three dummies for education level and high school GPA (only included in model 3); four dummies for field of study, age, age^2 and gender; three dummies for firm size; four dummies for sector of work; three dummies for region of work; five dummies for technology field, number of inventors and dummies for application year. Pseudo R^2 =1−log likelihood (full model)/log likelihood (constant-only model). The results for the foreign-born are robust if using data from 1985 to 2004, 1985 to 2005 and 1985 to 2006

***p<0.01; **p<0.05; *p<0.1

Table 7 Logit regressions on the probability of a patent application being granted for foreign-born inventors aged 25–64, 1985–2007

	1			2			3			4	5
	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3	4	5
	All	All_be61	All_af61	Chi_all	Chi_be61	Chi_af61	Chi_all_2	Chi_be61_2	Chi_af61_2	Adu_chi_af61	Edu_SE
Foreign-born (omit: Swedish-born)											
All foreign-born	−0.008	−0.021*	0.015								
	(0.009)	(0.011)	(0.015)								
Migrated as children				−0.094***	−0.100***	−0.092***	−0.095***	−0.099***	−0.093***	−0.084***	−0.084***
				(0.022)	(0.037)	(0.026)	(0.022)	(0.037)	(0.026)	(0.025)	(0.025)
Migrated as adults										0.049***	
										(0.016)	
Migrated as adults and edu. in SE											0.042*
											(0.024)
Migrated as adults and edu. abroad											0.054**
											(0.021)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	49,949	30,231	19,715	26,356	9144	17,209	26,356	9144	17,209	19,715	19,715
No. of observations granted	25,665	17,642	8023	12,110	4931	7179	12,110	4931	7179	8020	8020
No. of inventors	16,752	9630	7122	8993	2909	6084	8993	2909	6084	7122	7122
Wald χ^2	5802	3082	2403	3268	1237	2099	3272	1239	2107	2402	2402
Log pseudolikelihood	−28,797	−17,582	−11,152	−15,066	−5278	−9751	−15,066	−5277	−9750	−11,136	−11,136
Pseudo R^2	0.168	0.144	0.163	0.171	0.164	0.166	0.171	0.164	0.166	0.164	0.164

Robust standard errors in parentheses. Sources: Statistics Sweden and CIRCLE data on inventors. Marginal effects are reported. The results for control variables are omitted to save space. The control variables included here are the same as those in Table 6. The results for the foreign-born are robust if using data from 1985 to 2004, 1985 to 2005 and 1985 to 2006, except for those in model 1.1 (all foreign-born) and model 5 (migrated as adults and educated in SE)

***p<0.01; **p<0.05; *p<0.1

model 2.2 with model 2.3) and (c) are more likely to patent than (model 4 in Table 4)[34] and file a total number of patents per inventor (model 4 in Table 5) similar to those who migrated as adults. This may be attributed to the integration policy in Sweden. Since 1975, the policy has aimed for better integration of immigrants into Swedish society through improvement of their Sweden-specific human capital, which in turn promotes their ability to invent. Immigrants enjoy the same social and educational rights as natives without restriction, and the government and society pay more attention to their education and growth, such as providing intensive training courses in Swedish (Westin 2003). It is more likely for immigrants raised in Sweden and born in or after 1961 to benefit from this policy than those born before 1961 or who migrated as adults, because of their age and immigration background. However, in contrast to foreign-born inventors born before 1961, the NFC for patents filed by those born in or after 1961 is lower than that of their Swedish-born counterparts. This may be because the establishment and accumulation of social networks through which patent citations flow (Agrawal et al. 2006; Kerr 2008a) are more limited for young immigrants.

Generally speaking, after controlling for high school GPA, the results in model 2 for each indicator persist (model 3, Tables 4, 5, 6 and 7), although the significance of the lower probability of patenting for immigrants raised in Sweden declines (model 3.1 and model 3.2, Table 4) or even disappears (model 3.3, Table 4). This means that the poorer performance of immigrants raised in Sweden cannot be well explained by their grades and that other unexplained human capital, such as social networks or unmeasured abilities, could be the main explanatory factor. This aligns with hypothesis 4.

Model 4 in Table 4 shows that immigrants born in or after 1961, who migrated as adults, are less likely to patent than the Swedish-born, which confirms hypothesis 5. However, as shown in model 4 in Tables 5, 6 and 7, conditional on being inventors, their total number of patents per inventor and NFC is similar to that of natives, and their patents are more likely to be granted, which supports hypothesis 6. This suggests that inventors who migrated as adults could be a more positively selected group.

However, contrary to the expectations of hypothesis 7, whether education was obtained in Sweden or abroad has no significant effect on inventive performance for immigrants who migrated as adults (model 5, Tables 4, 5, 6 and 7). This suggests that high school education in Sweden is not an important factor for this group. It is reasonable to believe that adult immigrants who have a foreign education and are active in invention are relatively skilled. The ability to obtain Sweden-specific human capital may therefore not be as important a factor for these two groups of immigrants.

6.2 Control variables

The control variables largely confirm our expectations. Education level has mainly a significant positive effect on inventive performance: the higher a person's education level, the more productive he/she is in invention and the greater the NFC received for a patent he/she files. However, the quality of patents is not higher for inventors with a

[34] Compared with model 2.3, the significance of the results in model 4 and model 5 for immigrants who were born in or after 1961 and raised in Sweden is different. The reason is that in model 2.3, we only include individuals with a recorded high school GPA between 1973 and 1996, while in models 4 and 5, we also include individuals without a recorded GPA.

PhD education compared with those with a long education. This may be because inventors with a PhD education are more likely to invent as an adjunct to scientific work, but their inventions are less likely to be granted patents. In the event of being granted patents, they would be less likely to be cited.

High school GPA has a significantly positive effect on the productivity of individuals in invention and the NFC that a patent receives. However, it has no significant effect on the probability of a patent being granted.

Individuals who studied in different fields perform differently in invention. Those who studied engineering, manufacturing and construction are significantly more likely to patent, and their patents are more likely to be granted, than those who studied in any other field. However, the patents of those who studied in the fields of science, mathematics and computing or health and welfare are more likely to be cited than those who studied engineering, manufacturing and construction.

As we expected, a curvilinear relationship is found for age and age squared, and the effect differs when comparing quantity and quality. We find that the higher the age of an individual, the higher his/her cumulative productivity in invention. However, we also find that the higher the age of the inventor, the lower the NFC to his/her patents. Generally, age does not significantly affect the probability of a patent being granted.

Women are significantly less productive in invention than men, and their patents are also significantly less likely to be granted than those of men. Still, no significant difference is found when we investigate the NFC.

Generally, individuals working in smaller firms are less productive in invention than employees in larger firms. This result is similar to the probability of their patents being granted. However, the patents of inventors from small or large firms receive a higher NFC than the patents of inventors from medium-sized firms.

Individuals who work in non-industry sectors are significantly less likely to patent than those who work in industry sectors. In addition, individuals who work in the public service sector file fewer patents per inventor and have lower-quality patents. This most likely reflects the lesser tendency of public employees to work in commercial activities. The results are similar for individuals who work in agriculture, hunting, forestry and fishing, except that the NFC for their patents is not significantly different from that of inventors who work in industry sectors. Inventors who work in private services perform similarly to or even better than those working in industry sectors with regard to the number of patents per inventor and quality of patents.

Generally, individuals who work in metro regions perform better in inventive activity than those who work in rural regions, both in quantity and quality of invention. Individuals who work in urban regions are more likely to patent, and their patents have a higher NFC, but they have no advantage in the number of patents per inventor and the probability of patents being granted compared with individuals who work in rural regions. As is well established in the literature, the results generally reflect that better opportunities for innovation exist in large regions (e.g. Orlando and Verba 2005).

7 Discussion and conclusion

The results of this paper show that holding other variables constant, immigrants in Sweden are, in general, significantly less likely to patent than the Swedish-born, though the difference is quite small. This difference is greater for immigrants born in or after 1961 and is mainly because of those who migrated as adults. This can be related to immigrants' lack of Sweden-specific human capital and the negative selection mechanism (Sweden-specific economic features and migration policy) applied in Sweden. On the other hand, conditional on being inventors, the immigrants at large, including those who migrated as adults, perform as well as natives and therefore seem to be more positively selected. Immigrants who migrated as children normally perform more poorly than the Swedish-born, in terms of both quantity and quality of patents. However, those born before and in or after 1961 can perform differently when different dimensions are considered. The worse inventive performance of immigrants raised in Sweden may be attributed to their lack of Sweden-specific human capital. However, whether education was obtained in Sweden does not seem to have a significant effect for immigrants who migrated as adults.

In contrast to most prior studies, especially those in the USA, which show that immigrants tend to outperform in invention and innovation compared with natives (e.g. Chellaraj et al. 2008; No and Walsh 2010; Hunt 2011), we find that immigrants in Sweden do not outperform the Swedish-born when it comes to invention. The difference in inventive performance between immigrants in Sweden and those in other developed countries, especially the USA, may be attributed to several factors.

First, as discussed in Sect. 3.1, the high and evenly distributed income in Sweden, compared with many other countries in the world, makes it attractive for unskilled persons from other countries and may favour a negative selection of immigrants. In addition, wages for highly skilled workers in Sweden are relatively low compared with other developed countries, such as the USA and the UK, as a result of Sweden's even income distribution and high marginal taxes (Quirico 2012). This makes it more difficult for Sweden to attract highly skilled immigrants.

Second, except for the other Nordic countries since 1968, as well as the other EU countries since 1995, migration policies in Sweden have favoured refugees, asylum seekers and tied movers. This may have swayed the selection of immigrants in Sweden towards low-skilled rather than high-skilled immigrants. In addition, and in contrast to the strict selection of highly skilled immigrants in the USA (e.g. the H-1B visa[35]) and the UK (e.g. the 'Highly Skilled Migrant Programme', a point-based system for attracting the 'best and brightest' talent in the world) (Cerna 2011), the free migration between the Nordic and other EU/EEA countries leads to less positively selected immigrants.

Third, the origin of immigrants in Sweden and the USA differs. There is no doubt that the USA is one of the most attractive countries for the best talent; it is the dominant destination for highly skilled emigrants in most countries (Franzoni et al. 2012). In contrast, the majority of highly skilled immigrants in Sweden are refugees, asylum seekers or tied movers when they arrive (Gaillard 2002).

[35] H-1B is a type of temporary work visa in the USA given to people in specialty occupations with at least a bachelor's degree (or equivalent).

Fourth, the relative inventive performance of natives and immigrants differs between countries like the USA and Sweden, which may be due to the relative quality and skills of natives and immigrants. For example, the average quality of US-born individuals choosing to get doctorates in S&E has declined, as bright native students more often choose lucrative careers in business, law and medicine (Stephan and Levin 2001). However, in Sweden, many natives still choose to study S&E. For instance, in 2010/2011, 75 % of the Swedish-born PhDs under the age of 65 graduated in the S&E field, while the corresponding figure for foreign-born PhDs was 80 % (Statistics Sweden 2013).

Finally, language is less of an obstacle for immigrants in the USA and UK than for immigrants to Sweden, as English is much more widely used in the world than Swedish.

The Swedish government has realized that there is a shortage of skilled labour. Recently, Swedish policies put into effect a more positive selection that may help to improve Sweden's competitive advantage in technology and innovation (Mahroum 2001; Shachar 2006; Sveriges Riksdag 2014). Since 2001, Sweden has provided tax exemptions on the first 25 % of income for up to 5 years for foreign nationals who work in highly skilled occupations (Mahroum 2001; Forskarskattenämnden 2013). Notwithstanding, Sweden could still do much more if it wants to attract and retain more highly skilled immigrants and improve its inventive performance, for example, (a) making it easier for highly skilled immigrants from non-EU/EEA countries and their families to settle in Sweden, (b) developing programs such as a skill-based points system like those in Canada and Australia to actively and broadly attract and select highly skilled immigrants and (c) expanding preferential policies to skilled adult migrants. The government also needs to do more for immigrants who migrated as children to help them improve their human capital accumulation, including offering more effective education and integration policies. Our results may well be applicable to other countries, suggesting the need in Sweden and elsewhere to improve on immigrants' host country-specific skills by e.g. building stronger ties between ethnic groups and domestic communities.

This study certainly makes contributions to the literature, but there are limitations which call for further research. First, we need to better understand what drives our research results. Causal effects on the difference in inventive performance between immigrants (including those who migrated as adults and children) and natives are not explored in this paper. Second, despite the richness of our data, we do not consider the commercialization of patents or other activities such as publication because of limited available data. Moreover, we cannot rule out the possibility that there may be biases in that 20.7 % of the inventors, who cannot be identified as either immigrant or native. The tests based on name inspections of inventors (see Appendix 1) suggest no indication of such biases, even though these tests also capture second- and third-generation immigrants. Third, the effect of parental background on immigrants is not investigated here because such data are not available. Finally, for reasons of space, we do not compare the intra-group differences among the foreign-born by country of origin, the impact of the motivation to immigrate (e.g. those who migrated as labour migrants, tied movers, students and refugees), the effect of changes in migration policy (e.g. those of 1968 and 1995) and economy (e.g. 1991), or the influence of diversity and networks on invention. We plan to explore these dimensions in future research.

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Appendices

Appendix 1. Selection bias of unidentified inventors

As 20.7 % of the patent–inventor combinations are still unidentified, one might suspect it to be more difficult to find the SSN of foreign-born inventors in Sweden, as they are likely to be more mobile and less 'sticky' in the registers. Thus, we initially looked for sample selection bias as to whether foreign-born inventors might be overrepresented among unidentified inventors by randomly choosing 15 % of unidentified combinations per year from 1985 to 2007. Eyeballing inventors' names, we found 17.6 % to have names that could be characterized as 'foreign', which is slightly higher than the share of inventions by identified foreign-born inventors (11.5 %). This may be because some foreign-born inventors had resided in Sweden for less than 1 year and thus had no Swedish SSN. Also, our classification of names as foreign may be overstated, as many individuals (including inventors) are second- and third-generation immigrants (see Fig. 3 in Appendix 3) who are likely to have foreign names but were born in Sweden.

We also used the Onomap software[36] to classify inventors' surname–forename combinations as Swedish or non-Swedish. Among the unidentified inventors, Onomap matched 96.9 % of the names (3.1 % are unclassified), and among the matched names, 51.2 % were found to be Swedish. To examine whether Onomap's result was robust or not, we also used Onomap to classify identified inventors. Among the identified inventors, Onomap matched 96.2 % of the names, of which 49.0 % were Swedish names. This proportion is much lower than that of the identified Swedish-born inventors in terms of our data (89.1 %). Several reasons may account for it. First, we used 'UK' as the origin country of our data, as the other countries in Onomap are not currently working. Thus, we found quite a high percentage of inventors with English/Scottish/Welsh/Irish names (14.4 and 11.6 % among unidentified and identified inventors, respectively). Second, many Swedes have names popular in other Nordic countries and Germany, which makes it difficult to differentiate origin among these countries. Third, as mentioned above, many Swedish natives have foreign names. Nevertheless, Onomap shows that among identified and unidentified samples, the proportion of inventors with Swedish names is roughly similar.

Both the eyeballing of inventors' names and the Onomap test cannot directly identify the share of 'foreign-born inventors' as in our identified data, since they only

[36] See Nathan (2014b) for a detailed introduction to the Onomap system.

show the share of minority ethnic inventors, which can also capture second- and third-generation immigrants. Nevertheless, both tests show that it seems unlikely that there is any large sample selection issue in our data with respect to foreign participation.

Appendix 2. Sector of work by SNI 1992

1. Agriculture, hunting, forestry and hunting
   A Agriculture, hunting and forestry: 01–02
   B Fishing: 05
2. Industry
   C Mining and quarrying: 10–14
   D Manufacturing: 15–37
   E Electricity, gas and water supply: 40–41
   F Construction: 45
3. Private service
   G Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods: 50–52
   H Hotels and restaurants: 55
   I Transport, storage and communication: 60–64
   J Financial intermediation: 65–67
   K Real estate, renting and business activities: 70–74
   P Activities of households: 95
4. Public service
   L Public administration and defence; compulsory social security: 75
   M Education: 80
   N Health and social work: 85
   O Other community, social and personal service activities: 90–93
   Q Extra-territorial organizations and bodies: 99

Appendix 3

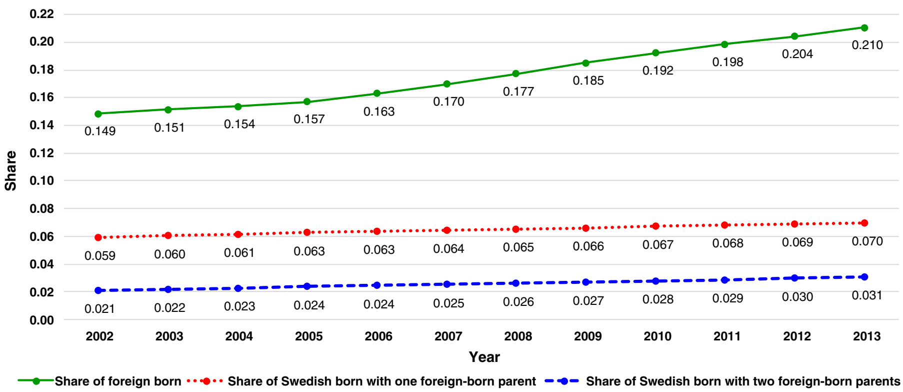

Fig. 3 Share of foreign-born, Swedish-born with one foreign-born parent and Swedish-born with two foreign-born parents among Swedish population aged 25–64, for each year 2002–2013. Source: Statistics Sweden

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Paper II

The inventive performance of second-generation immigrants in Sweden, differentiated by parents' region of origin

Yannu Zheng

Abstract

The development of children of immigrants is influenced by their parents' foreign background, which can affect their assimilation, school and innovative performance. In this respect, the geographical or cognitive proximity of the parents' region of origin to the host society is important. This paper examines the inventive performance of second-generation immigrants (with at least one foreign-born parent) compared with native Swedes (with two native-born parents), and explores how it is related to their parental backgrounds in terms of their region of origin. The study is based on a new Swedish database, which links inventors to the general population between 1985 and 2007. The results show that, second-generation immigrants with a non-Nordic European background perform better than natives in terms of the probability of becoming an inventor and the number of forward citations to the inventor's patents. This immigrant group's better performance is found to be linked to a tendency that they have more highly educated parents than their native counterparts. Their performance may also be positively affected from having non-native parents who originated from regions with close geographic proximity to Sweden. However, either disadvantage in educational attainment or lack of geographical or cognitive proximity of non-native parents' region of origin to Sweden can hamper second-generation immigrants' inventive performance.

Keywords Native Swedes · Foreign-born · Innovation · Human capital

JEL classification I21 · J24 · O14 · O31

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1 Introduction

Attracting highly-skilled immigrants is a priority for many countries aiming to be competitive in the global market. Immigrants' performance and contributions to invention, innovation, productivity and economic growth have attracted increasing scholarly interest in recent years (Ozgen et al., 2013; Paserman, 2013; Parrotta et al., 2014). Most extant studies which investigate the innovativeness of immigrants focus on comparing the differences between foreign-borns (first-generation immigrants) and native-borns (No & Walsh, 2010; Hunt, 2011; Zheng & Ejermo, 2015), or between different ethnic groups according to name-based approaches (Kerr, 2008; Nathan, 2014). However, no previous study has examined the differences that can exist between native-born individuals with different parental backgrounds. Arguably, such differences may be important driving forces for a country's long-term development, and may have implications for the integration of immigrants in the host society.

This paper contributes to ongoing research by exploring whether differences in innovative performance exist between children of immigrants and children of native-born parents, by comparing their performance in terms of patents. The study is based on a unique and rich database that contains nearly all patent applications filed by Swedish residents to the European Patent Office (EPO) between 1985 and 2007 (Zheng & Ejermo, 2015). I divide the native-born population into three groups, according to their parents' region of origin[1]:

(a) native Swedes: Swedish-born with two Swedish-born parents.[2]

(b) mixed second-generation immigrants: Swedish-born with one Swedish-born and one foreign-born (FB) parent; and

(c) second-generation immigrants with two FB parents.

For ease of reference, I term groups (b) and (c) as *mixed immigrants* and *immigrants with two FB parents*, respectively. These two groups are both made up of second-generation immigrants. In total, the above three groups constitute 89% of all inventors in Sweden (see Table 1 and Zheng & Ejermo, 2015).

Differences in innovation activity may exist between individuals who were born and raised in the same country and who experience similar education systems. This is because of differences in ethnicity (and this may relate to discrimination),

[1] Data on specific countries of origin for immigrants is not available in the database and the most detailed data available on regions of origin has been categorized into 10 groups. They are: Sweden, other Nordic countries, EU-15, the rest of Europe, former Soviet Union, North America (including Central America and Caribbean countries, 66% of the immigrants to Sweden from North America were from Canada and the United States (US) in 2000), Oceania, South America, Asia and Africa.

[2] The category of Swedish-born parents includes second- or even earlier generations of immigrants, but their impact can be ignored because of their small number.

ethnic identity (the degree of acculturation identity),[3] culture and other country-specific human capital, which can be driven by their parents' region of origin to some extent. These factors are believed to have important effects on the development of an individual's human capital (Fuligni, 1997; Ermisch & Francesconi, 2001; Zimmermann et al., 2008; Nekby & Rödin, 2010, Lundborg et al., 2014; Schüller, 2015), which are expected to have a further impact on an individual's inventive behaviour (Hunt & Gauthier-Loiselle, 2010; Hunt, 2011).

For second-generation immigrants, the environment in which they are brought up and their experiences within it are usually more complex and challenging than those of natives. For example, they usually have ambiguous ethnic identifications, and are more likely to experience discrimination or segregation (Kristen, 2008). However, they may also be more ambitious than their native peers, in order to improve their lives (Fuligni, 1997), and more open to different cultures and social networks. All of these factors may affect an individual's innovative performance after reaching adulthood.

Zheng & Ejermo (2015) find that first-generation immigrants who migrated to Sweden as children (under the age of 18) perform worse in terms of patenting performance, compared with their native-born counterparts. This may be linked to their lower qualifications and lack of Sweden-specific human capital than native born, e.g. a native social network. This paper compares the inventive performance between second-generation immigrants and native Swedes. This study adds to the literature which find that children's ages at the time of immigration significantly impact their assimilation, school and their labour outcome performance in the host country (Schaafsma & Sweetman, 2001; van Ours & Veenman, 2006; Böhlmark, 2008).[4] As compared with highly skilled first-generation immigrants, especially those who immigrated as teenagers or adults and who are usually highly mobile, second-generation immigrants are often more likely to stay in the host country for the whole of their lives and are a more reliable backbone force for the long-term development of the host country.

This paper also compares the inventive performance of mixed immigrants, immigrants with two FB parents, and native Swedes. The experiences of second-generation immigrants may also be different due to differences in their parental

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[3] Ethnicity is assigned to an individual either by birth or by others on the basis of ethnic background or phenotype (Phinney & Ong, 2007). Ethnic identity is defined as a part of social identity and can be chosen by individuals themselves (Tajfel, 1981; Phinney & Ong, 2007; Schüller, 2015).

[4] Studies find that immigrants who arrived at a younger age assimilate more quickly than those arriving in their teenage years (Gonzalez, 2003; Bleakley & Chin, 2004; Chiswick & DebBurman, 2004; Beck et al. 2012). Child immigrants who arrived before the age of 7 are found to perform substantially better in school than those who migrated after the age of 7 (Böhlmark, 2008).

background. Compared with those who have two FB parents, mixed immigrants should have an advantage in obtaining host-country specific human capital, as they have one native-born parent.

In addition, the paper considers the effects of the parents' region of origin on inventive performance of second-generation immigrants. The parents' region of origin is intended to capture differences in geographical or cognitive (e.g. linguistic, cultural and institutional) proximity to Sweden and Swedish culture to some extent. Such differences may affect an individual's opportunities of integrating into the host society and benefiting from interactive learning to develop their own innovativeness (Amin & Wilkinson, 1999; Boschma, 2005). Moreover, the criteria of the parents' region of origin is also intended to capture the educational level of immigrants, which can further impact on their children's human capital through intergenerational transmission (Ermisch & Francesconi, 2001; Riphahn, 2003; Lundborg et al., 2014). This can have an impact on innovative performance in the long-term (Hunt, 2011).

Sweden has seen a rise in immigration since the World War II. Accompanying the increase in the size and diversity of the foreign-born population (constituting 1.6 million individuals, or 16.5% of the entire population), has been a corresponding rise in the number and proportion of mixed immigrants and immigrants with two FB parents, which reached 7.3% and 5.0% of the entire Swedish population, respectively, in 2014 (see Figure A1 in Appendix 2). Although second-generation immigrants now constitute a large proportion of the population in Sweden, to my knowledge, this is the first study which considers their innovative contribution. Studying the inventive performance of children of immigrants with parents from different regions of origin may help to broaden the understanding of both intergenerational incorporation as well as the long-term effects of migration and migration policy on a host country's innovation and development.

Based on the unique database of inventors linked to the general population in Sweden, this paper enables to compare the inventive performance of the different groups of native-born Swedes with different parental backgrounds by two indicators: (a) the probability of becoming an inventor among the corresponding general population and (b) the number of forward citations (NFC) received per patent. Although patents have some shortcomings as indicators of innovation output (e.g., they only apply to certain types of inventions and do not necessarily have commercial value), they are still the most common output measure of innovation (Giuri et al., 2007).

The results show that, in terms of both indicators, second-generation immigrants with non-Nordic European backgrounds perform better than native Swedes. Their better performance is related to the fact that they are positively affected from having more highly educated parents compared to their native counterparts and the close geographic proximity of their non-native parents' region of origin to Sweden. The study indicates that either disadvantage in educational attainment or lack of geographical or cognitive proximity of non-native parents' region of origin to the host country can hamper second-generation immigrants' inventive performance. This is the case for second-generation immigrants with other Nordic backgrounds – they have close geographic proximity to the host country but are lower educated than natives, and those whose native parent intermarried a non-native parent originated from a developing region – they are more highly educated than natives but have larger cultural distance of non-native parent's region of origin to the host country. Although this is primarily a descriptive analysis and no causal effect has been explored regarding determinants on discrepancy of inventive performance of different groups of native-born Swedes, this paper still provides an initial impression of each group's innovative contribution and the influence of their parents' region of origin on their inventive performance.

The paper is structured as follows: Section 2 summarizes previous studies about second-generation immigrants, as well as the difference between this study and prior studies. Section 3 discusses the theoretical background. Section 4 presents the databases and descriptive statistics. Section 5 contains the methodology. Section 6 reports the results of the empirical analysis. The final section concludes the study, with a discussion of the results.

2 What do we know about second-generation immigrants?

The performance of second-generation immigrants has attracted considerable research interest from scholars across disciplines (Chiswick, 1977; Carliner, 1980; Chiswick & Miller, 1985; Borjas, 1993; Borjas, 1994; Maani, 1994; Gang & Zimmermann, 2000; Nielsen et al., 2003; Riphahn, 2003; van Ours & Veenman, 2003). Earlier studies have focused largely on educational and labour market outcomes, and find that differences exist between second-generation immigrants whose parents are from different countries or regions of origin (Fuligni, 1997; Rooth & Ekberg, 2003; Ramakrishnan, 2004; Behrenz et al., 2007; Ekberg et al., 2010). However, the results of the different studies vary. For example, Ramakrishnan (2004) indicate that mixed immigrants in the US are more successful as regards educational attainment and income than both third-generation immigrants with two native-born parents and second-generation immigrants with two FB parents. Fuligni (1997) also report that mixed second-generation adolescents received higher grades in mathematics and English than their peers from native families. Moreover, he finds that students with East Asian parents received significantly higher grades than those with European parents. Nevertheless, Riphahn (2003) shows that the schooling success of German-born children of immigrants (with foreign citizenship) still lags behind that of native Germans (including second-generation children with German citizenship). She also indicates that the lower educational attainment of second-generation immigrants in Germany is significantly related to their country of origin, and differences exist between immigrants from different countries of origin.

Dustmann & Theodoropoulos (2010) find that although British-born ethnic minorities are, on average, more highly educated than their British-born white peers, their employment probabilities are lower. Algan et al. (2010) show that, on average, labour market performance in terms of earnings and employment for most groups of second-generation immigrants in France, Germany and the UK is worse than their native counterparts. However, substantial heterogeneity across different immigrant groups is found in both of the above two studies. Rooth & Ekberg (2003) indicate that, compared with native Swedes, second-generation immigrants with a Nordic or western or eastern European background have similar prospects in terms of earnings or being unemployed, while those with either a southern European or a non-European background fare much worse. The outcome is more favorable for those with one Swedish-born parent than those whose parents were both born abroad. Behrenz et al. (2007) show that, compared with Swedish "twins" (i.e. people whose parents have the same age, gender, occupational status and county of residence as parents of immigrants), second-generation immigrants are more disadvantaged in obtaining employment, and their performance in the Swedish labour market differs depending on their parents' regions of origin. Hammarstedt (2009) find that there is no significant difference in the relative earnings between second-generation immigrants and native Swedes in the years 1980 and 1985. However, he reports a downward trend in immigrants' relative earnings across generations, and his results indicate that ethnicity-based differences in earnings are likely to occur even after several generations spent in the host country; that is to say, the problem of immigrant assimilation may last for several generations.

The causal reason as to why second-generation immigrants perform differently in terms of educational achievement and labour market outcome is difficult to investigate. The selection of immigrants as a result of different migration policies (e.g., migration policy in the US is more selective than in Sweden and Germany) may be a reason for the differing performances of second-generation immigrants when compared with natives of various countries (Christensen & Stanat, 2007; Dustmann et al., 2012). In addition, many studies indicate that the different performance of native-born immigrants can be related to their ethnic background (Borjas, 1992; Gang & Zimmermann, 2000; Riphahn, 2003), which may affect their accumulation of human capital, preference and ethnic identity (Gang & Zimmermann, 2000; Lundborg & Rödin, 2010). These factors are thought to have an impact on immigrant children's educational attainment and their labour market outcome (Gang & Zimmermann, 2000; Nekby & Rödin, 2010; Schüller, 2015). Borjas (1992) also indicates that "ethnic capital", which is the average human capital of the ethnic group in the parents' generation, can work as an externality in the process of accumulating human capital, and can be transmitted across generations. In the literature, ethnicity effects are usually indicated by country or region of origin (Gang & Zimmermann, 2000; Riphahn, 2003; Nekby & Rödin, 2010).

However, it is not yet known whether the above applies to innovation performance between different groups of second-generation immigrants and natives. Compared with the attainment of education, employment and income, invention is a more knowledge-intensive and creative activity. The increasing dominance of and propensity for high-educated or skilled individuals to work in invention or inventive industries implies that demand for educational level and skills is increasing be an inventor (Jung & Ejermo, 2014). The development of children's human capital is achieved mainly through the educational system, plus their family, which is in turn highly determined by parental human capital and input (Borjas, 1992; Haveman & Wolfe, 1995; Rooth & Ekberg, 2003). Therefore, for a person to become an inventor, significant demands may be made on the human capital and input of that person's parents, as well as their "ethnic capital", which can be very different between parents who are from different regions of origin (Gang & Zimmermann, 2000). For example, the capability of obtaining host country-specific human capital can be very different between groups whose parents are from different regions of origin. Moreover, the migration policy in Sweden differs a lot for immigrants from different regions of origin, which can affect the selection and human capital level of immigrants from different regions (Zheng & Ejermo, 2015). Studying the inventive performance of children of immigrants can help us to better understand and predict the long-term impact of a selective migration policy on a country's future innovative performance, as ethnic differences and parents' human capital can be transmitted to succeeding generations (Borjas, 1992) – although potential cohort differences among immigrants, even those from the same country, may make this prediction very difficult (Borjas, 1994).

3 Theoretical discussion

3.1 Positive and negative forces on second-generation immigrants and their impact on invention

A person's inventive performance depends not only on demographic or formal human capital characteristics such as gender, age and education (Hunt, 2011; Jung & Ejermo, 2014), but also largely on unmeasured assets such as cultural and institutional knowledge as well as social networks (Agrawal et al., 2008; Nathan, 2014). A lack of these informal qualities, which is more likely to be the case for immigrants than natives, may hamper an individual's inventive performance (Nathan, 2014).

The living environment of immigrants and their children is usually more complex and more challenging than that of native Swedes. For children of immigrants, immigrant influences through migrant parents likely affect the formation of their human capital, both formal and unmeasured assets, which are expected to have an impact on their assimilation, school performance and subsequent innovative performance (Chiswick & DebBurman, 2004). On the one hand, children of immigrants' distinct appearance, and the differing cultures, values and norms of their family life and those of their school or society may put them at risk of discrimination, lower their self-confidence and affect their educational performance. Moreover, foreign-born parents often retain their home language and culture and reside in areas that are segregated from the native-born population and have a high concentration of immigrants with a similar ethnic background. They may also have problems in fully integrating into the host society (Bayer et al., 2004). These factors can all affect their children's school achievement (Åslund et al., 2011; Dustmann et al., 2012) and put their children at a disadvantage in obtaining host country-specific human capital (such as accessing a native social network and getting familiar with the host country's culture and institutions), which is a very important factor in inventive performance (Agrawal et al., 2006; Kerr, 2008). For example, Kristen (2008) indicates that Turkish children in Germany are more likely to enter a school which has a relatively large proportion of foreign nationals than children of a German background; this is a pattern that in the aggregate seems to contribute to increasing ethnic separation at the school level, mainly due to immigrant parents' unfamiliarity with the German elementary school system. However, the boundary between immigrants and natives can fade gradually over time, and it is possible for immigrants and their children to become highly assimilated in their host country (Borjas, 1992; Alba & Nee, 2009).

On the other hand, the environments that children of immigrants grow up in can also become an important source of motivation to push them to become more ambitious than their native peers. They may have stronger aspirations to study or work harder, and they may pay more attention to improving their knowledge and skills, believing that these are the most significant ways to improve their status in life. For example, Fuligni (1997) find that the greater academic achievement of second-generation immigrants in the US compared to their native peers is largely attributable to their parents' expectations and aspirations, as well as their own stronger academic attitudes. Second-generation immigrants are also more likely to be open to different cultures and social networks on account of their dynamic racial or ethnic identification. For example, they can co-invent with people from both their home and host countries with less of a communication cost. Moreover, their diverse cultural background may increase their creativeness and innovativeness (Niebuhr, 2010).

It is difficult to have *a priori* expectations about the relative strengths of positive and negative forces on second-generation immigrants' innovative performance. This paper tries to investigate this issue by studying their inventive performance.

3.2 Differences between mixed immigrants and immigrants with two FB parents compared with native Swedes

Mixed immigrants can be distinguished from immigrants with two FB parents and natives (Ramakrishnan, 2004). First, compared with immigrants with two FB parents, mixed immigrants with one native-born parent can have certain advantages. They have an advantage in obtaining host country-specific human capital. Their link to the native-born population gives them a better chance of participating in social networks which include other native Swedes, and then they might have a higher probability of residential assimilation, and overall a better chance of integrating into the host society. All of these factors can have a positive effect on their ethnic self-identification as natives, as well as on their development of human capital (Ramakrishnan, 2004; Nekby & Rödin, 2010).

Second, the foreign-born parents of mixed immigrants are likely to be more highly educated than the parents of immigrants with two FB parents (and their education may even be better than the parents of natives) (Ramakrishnan, 2004).[5] Individuals with more highly educated parents, especially those with a more educated mother,[6] are not only more likely to have higher educational attainment, but are also more likely to have better non-cognitive skills than those whose parents are less educated (Ermisch & Francesconi, 2001; Riphahn, 2003; Lundborg et al., 2014). This is because better educated parents are more likely to provide a better cultural environment for their children (e.g., they might have more books at home) and are more likely to invest in the development of their children's human capital (Ermisch & Francesconi, 2001). Some studies find that the higher educational level obtained by immigrants is an important reason for their better inventive performance than natives (Hunt & Gauthier-Loiselle, 2010; No & Walsh, 2010; Hunt, 2011).

[5] This is because educated immigrants are more likely both to move out of ethnic enclaves and to accept prospective partners with different ethnic origins (Furtado & Theodoropoulos, 2011; Furtado, 2012). Moreover, as there is a general assortative mating pattern regarding education in the marriage market (see e.g. Mare, 1991; Kalmijn, 1998; Henz & Jonsson, 2003; Niedomysl et al., 2010), better-educated immigrants are more likely to find partners who have an education at equal or similar level, and who are willing to trade similarities in ethnicity for similarities in education (Dribe & Lundh, 2008; Niedomysl et al., 2010; Furtado, 2012). Often, parents of immigrants with two FB parents are from the same country of origin, since people simply seem to prefer a partner with the same ethnic background as them (positive assortative mating). Therefore, there is no need to compensate culture distance with educational level (Niedomysl et al., 2010). Table 6 shows a positive association between the parents' average years of school. Part B of Table 6 shows that such marriage matches on education also exist for mixed marriages.

[6] This is because mothers usually put more time and effort into children's development than fathers. Better-educated mothers lead to substantially greater income and more "bargaining power" in the family, and they can also put more weight on investing in children's human development (Ermisch & Francesconi, 2001; Lundborg et al., 2014).

Therefore, mixed immigrants are expected to have both cognitive (e.g. educational attainment) and non-cognitive advantages, which could improve their inventive performance.

Third, mixed immigrants may also benefit from the mixed cultural and ethnic backgrounds of their families and communities as compared with native Swedes and immigrants with two FB parents. Cognitive distance and diversity among family members may have a positive impact on children's knowledge creation (Boschma, 2005). Mixed ethnicity might also broaden their social network to include people with both foreign and native backgrounds. Native Swedes usually have identical culture and ethnic backgrounds, and this may also be the case for immigrants with two FB parents, if their parents are from the same country of origin (Niedomysl et al., 2010). Cultural diversity can help to improve the generation of new ideas and innovation as it involves variety in abilities and knowledge (Alesina & La Ferrara, 2005; Niebuhr, 2010; Nathan, 2014). Some studies find that knowledge dissemination, such as patent citations, follow social networks (Agrawal et al., 2006; Kerr, 2008), which may be partially channelled through ethnic networks (Agrawal et al., 2008). Thus, the diverse ethnicity and culture that mixed immigrants have may broaden their social network and make a positive impact on their inventive performance (Owen-Smith & Powell, 2003; Kerr, 2008; Niebuhr, 2010; Nathan, 2014).

Based on the advantages discussed above for mixed immigrants, as compared with native Swedes and immigrants with two FB parents, mixed immigrants are expected to have a better inventive performance than native Swedes, who in turn have a better performance than immigrants with two FB parents.

3.3 Differences among second-generation immigrants with parents from different regions of origin

Parents' ethnic backgrounds have been found to affect second-generation immigrants identity formation (Nekby & Rödin, 2010), linguistic acculturation (Rooth & Ekberg, 2003) and structural assimilation, since ethnic differences in skills can be transmitted across generations (Borjas, 1992). Individuals' ethnic backgrounds can be classified to some extent by their regions of origin, since people from the same region may share similar languages, cultures, values and institutions. They may even share economic backgrounds and motivations for migration, which imply to some extent the human capital of immigrants (Scott, 1999; Bengtsson et al., 2005; Helgertz, 2010).

Individuals from regions that are geographically close to the host country are supposed to have less communication problems with natives, which can facilitate their interactive learning opportunities and capabilities. The more proximate the sending regions and receiving countries are, the easier it can be for those individuals' children to integrate into the host society. This can have an impact on their personal outcomes. For example, Nekby & Rödin (2010) find that, of people who immigrated to Sweden at a young age (before age 16), or who were born in Sweden with immigrant parents, the likelihood of being separated and marginalized rather than assimilated (according to their self-perceived ethnic identity) from the majority Swedish society is higher for those with non-Nordic European backgrounds than those with Finnish backgrounds, which is even higher for those with non-European backgrounds. Therefore, even among mixed immigrants and immigrants with two FB parents, differences can exist if their parents are from different regions of origin. From this, mixed immigrants with a foreign-born parent from regions that are close – geographically and cognitively – to Sweden, such as other Nordic countries, are easier to integrate into the Swedish society and obtain Sweden-specific human capital than those whose non-native parent is from a non-European country, especially those from a developing region. The result is similar for immigrants with two FB parents; for example, individuals with two parents from other Nordic countries can expect to find it easier to accumulate Sweden-specific human capital than those with two parents from another region, such as southern Europe.

Moreover, experiences of discrimination against second-generation immigrants can vary depending on their parents' region of origin. The risk of being discriminated against based on ethnic background is expected to be low for second-generation immigrants with Nordic or western European backgrounds. However, the risk can be higher for those who are from southern European or developing regions. This may be driven by their different appearance (Rooth & Ekberg, 2003). The context of the reception from the host society, which may be affected by an individual's parental background, can affect that individual's assimilation, school and innovative performance in the long term.

In an attempt to take into account the importance of the geographical and cognitive proximity of foreign-born parents' region of origin to Sweden, second-generation immigrants are divided into seven groups. These are:

Mixed immigrants whose non-native parent is from

(a) another Nordic country;

(b) the EU-15 (excluding Sweden, Denmark and Finland; for ease of reference, I term these countries the EU-15);

(c) the rest of Europe (including the former Soviet Union);

(d) North America or Oceania; or

(e) a developing region (i.e. South America, Asia or Africa).

Immigrants with two FB parents, where

(f) at least one parent is from another Nordic country (82% of inventors in this group have parents who are both from other Nordic countries); and

(g) both parents who are from non-Nordic European countries (i.e. the EU-15 + the rest of Europe).

I exclude second-generation immigrants with both parents who are foreign-born and at least one parent has a non-European background in all regressions, since they represent only a very small percentage of inventors.

However, the educational level for parents of second-generation immigrants in Sweden can differ by region of origin. This may also affect the development of their children's human capital through intergenerational transmission (Phalet & Schönpflug, 2001; Bauer & Riphahn, 2007). The larger the cultural distance between immigrants and natives from the intermarriage family, the higher the educational level both immigrants and natives are expected to have. This may be because they need greater educational assets to compensate for the larger cultural distances to their partner; in addition, more highly educated individuals are more likely to accept larger ethnic and cultural distances than lower-educated individuals (Dribe & Lundh, 2008; Furtado, 2012). Therefore, for mixed immigrants, their non-native parents who are from a non-European region are more likely to be higher educated than those who are from other Nordic countries. Moreover, the Swedish migration policy to immigrants from different regions of origin is very different. The agreement establishing the free movement of citizens between Nordic countries, in place since 1954 (Stalker, 2002), which has reduced the cost of migration such as visa application cost, may also have reduced the possibility of having highly educated and skilled immigrants from the other Nordic countries in Sweden. Therefore, parents of second-generation immigrants from other Nordic countries are likely to be less educated and skilled than parents from other regions, following self-selection theory.

As discussed in Section 3.2, parental human capital can affect their children's cognitive and non-cognitive development through intergenerational transmission (Phalet & Schönpflug, 2001; Bauer & Riphahn, 2007). Compared with second-generation immigrants who have non-native parent from regions with closer geographic and cognitive proximity to Sweden, those who have non-native parents with larger distance to Sweden are expected to be higher qualified, e.g., they have a higher level of education, which can positively influence their innovative performance (Hunt, 2011). However, unobserved skills such as social network and institutional familiarity can also affect inventive activity (Agrawal et al., 2008; Nathan, 2014), and this is where the latter group may face disadvantages. Therefore, greater distance of this type can also impede immigrants' inventive performance.

Considering both the advantages and disadvantages when parents' region of origin are geographically or cognitively close to Sweden, and the potential impact of this on the human capital of immigrants, it becomes difficult to have a *priori* expectations about the innovative performance for each group. I will explore this issue by studying each group's inventive performance by comparing them with native Swedes.

4 Data and descriptive statistics

4.1 Summary of data

Based on the database as introduced in Zheng & Ejermo (2015) (for a detailed introduction of the data, see Section 4 of that paper) – which matches patent applications filed with the EPO by Swedish residents between 1985 to 2007 with demographic information – I added further information relating to individuals' parental backgrounds. Two steps are required for this. Firstly, I matched individuals' social security numbers (SSNs)[7] with their parents' SSNs, as provided by Statistics Sweden (SCB). Secondly, I added detailed demographic information (e.g. region of origin, educational level, number of children and year of birth) for parents by using their SSNs. SCB provides detailed demographic information for all residents in Sweden from 1985 onwards. If an individual's parent died or left Sweden before 1985, then that parent's demographic information cannot be matched. In total, I matched 74.0% the Swedish-born population's mother's SSNs, and 63.8% of their fathers' SSNs. The corresponding figures for inventors are 87.8% and 76.9%, respectively. SCB also provides basic information about whether an individual's parent is Swedish-born or foreign-born. I consider an inventor to be a person who has been listed as an inventor on a patent application filed with the EPO between 1985 and 2007.

Table 1 shows that, among the identified inventors in Sweden aged between 25 and 64 years (mean age: 43.9),[8] 6.25% (or 1,251 individuals) are mixed immigrants and 2.09% (or 419 individuals) are immigrants with two FB parents. They contribute 6.39% and 1.93% respectively of overall inventions (fractional count for inventions[9]) in Sweden. On average, first-generation immigrant inventors have the highest number of patents per inventor (1.49), followed by mixed immigrant inventors (1.43), native inventors (1.39) and immigrant inventors with two FB parents (1.29). However, mixed immigrants have the highest proportion of inventors among the corresponding population (0.36%; i.e. on average, there are 36 inventors

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[7] The Swedish social security number (SSN) is a unique identification number for each resident in Sweden, including foreigners who have a valid residence permit for at least one year.

[8] I focus on inventors aged 25 to 64 because this is the age range in which people are most likely to be working and patenting. Therefore, restricting the sample in this way makes it more homogeneous (inventors outside this age range made a negligible contribution to overall inventions). In total, 76.5% of the identified observations of patent–inventor combinations (see definition in footnote 13) are used in this paper. Regarding unidentified inventors, Zheng & Ejermo (2015) suggest that it is unlikely to be a large issue in terms of sample selection regarding immigrant status.

[9] Fractional count means that each co-patent is counted as a fraction, depending on how many inventors contributed to one patent. Each patent is summed as one. For example, if one patent has three co-inventors, then the invention for each inventor is one third.

per 10,000 mixed immigrants), followed by immigrants with two FB parents (0.32%), native Swedes (0.29%) and first-generation immigrants (0.17%).

These results suggest that first- and second-generation immigrants display opposite results in terms of their contribution of inventions per inventor and the proportion of inventors among the corresponding population. That is to say, compared with the first-generation, the second-generation contribute a smaller number of patents per inventor but, by contrast, have a higher proportion of inventors among its population as a whole. Compared with native Swedes, both second-generation groups have a higher proportion of inventors among their populations, and mixed immigrant inventors also contribute, on average, a higher number of patents per inventor. Although the non-native parents of second-generation immigrants investigated in this paper are predominately unskilled manual labourers (especially the parents of immigrants with two FB parents[10]), who have lower human capital than the parents of native Swedes (e.g., they had a lower educational level and language skills), when compared with their population as a whole, their children are still more likely to become inventors than native Swedes.

4.2 Growing trends for native-born inventors

Figures 1 and 2 compare the proportion of population for two second-generation immigrant groups and native Swedes in the Swedish population, the proportion of their inventors in the Swedish inventor population and their percentage contribution to overall inventions in Sweden. In contrast with Figure 1, which shows that for all of the above three indicators, native Swedes have decreasing trends over the study period, Figure 2 shows that two immigrant groups have growing trends. The figures show that both of immigrant groups and native Swedes are over-represented in their inventor populations and contribution to inventions relative to their representation in the overall population in Sweden.

[10] For immigrants (inventors) with two FB parents, 89% (85%) and 88% (73%) respectively of their non-native mothers and fathers have an education ends up at secondary level (i.e. ≤12 years of schooling); the corresponding figures for native Swedes (inventors) are 86% (69%) and 83% (65%); for the non-native mothers and fathers of mixed immigrants (inventors) are 85% (69%) and 80% (58%).

Table 1 Number and share (%) of different groups of identified inventors in Sweden aged 25–64 years and the inventions that they contributed to, for 1985–2007

Different groups of residents in Sweden	Native Swedes	Mixed immigrants	Immigrants with two FB parents	First-generation immigrants	Total
No. of identified inventors	16,169	1,251	419	2,176	20,015
Share of all identified inventors	80.78%	6.25%	2.09%	10.87%	100%
No. of population	5,546,209	347,990	131,001	1,274,029	7,299,229
Share of inventors in the population	0.29%	0.36%	0.32%	0.17%	0.27%
No. of identified applications (fractional count)	22,513	1,797	542	3,254	28,106
Share of all identified applications	80.10%	6.39%	1.93%	11.58%	100%
Average no. of patents per inventor	1.39	1.44	1.29	1.49	1.40

Source (for all table and figures): Statistics Sweden and CIRCLE data on inventors.

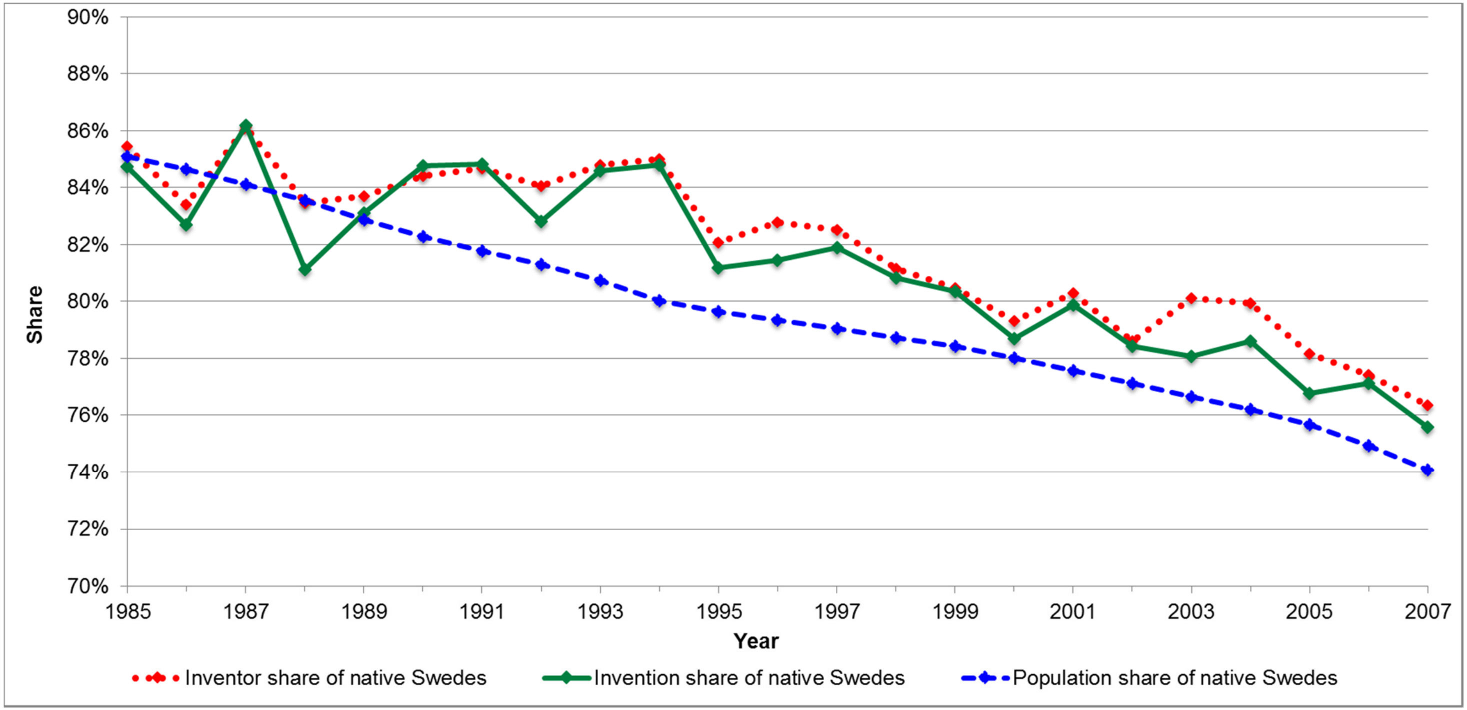

Figure. 1 Native inventors as a percentage of the Swedish inventor population and their percentage contribution to inventions, native population as a percentage of the general population in Sweden aged 25–64 years; annual data for 1985–2007.

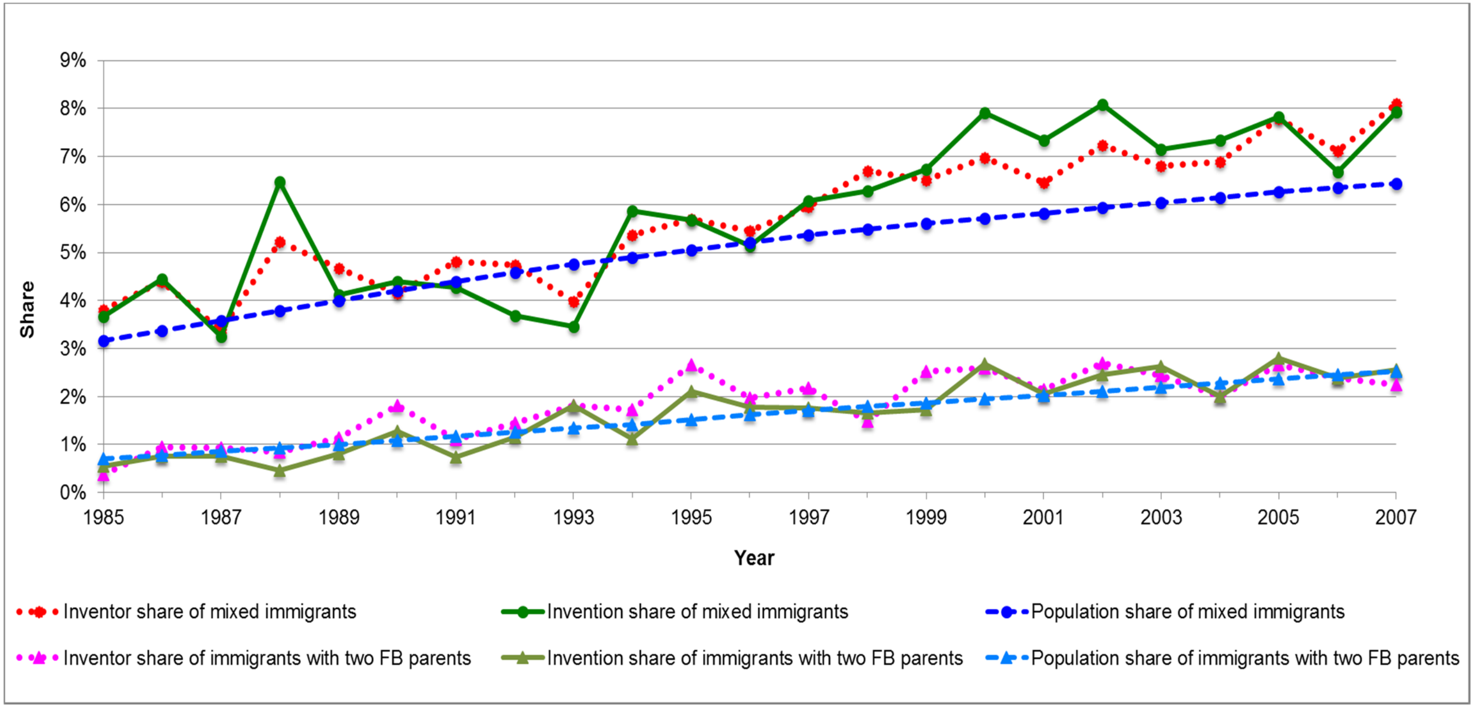

Figure. 2 Mixed immigrants and immigrants with two FB parents as a percentage of the Swedish inventor population and their percentage contribution to inventions, their population as a percentage of the general population in Sweden aged 25–64 years; annual data for 1985–2007.

5 Methods

I compare the inventive performance of second-generation immigrants and native Swedes using two indicators. First, I examine (a) the probability of becoming an inventor among the entire corresponding population from 1985 to 2007.[11] Each individual aged 25 to 64 only shows once in the data. Second, for inventors, I investigate (b) the NFC for their patents, to compare the quality of patents attributed to each group of native-born inventors. Studies have indicated that the NFC is positive correlated with patent value (e.g. Harhoff et al., 2003; Hall et al., 2005; Gambardella et al., 2008). It is used as the most common indicator and is considered the best predictor of patent value (Lanjouw & Schankerman, 1999). Moreover, it is considered a proxy for the effective use or importance of a patent to new inventions (Sapsalis et al., 2006). Figure A2 also shows that patents that received higher NFC are also more likely to be granted, and more likely to receive opposition[12] in the data. The above two indicators are also used to indicate the value and quality of patents in the literature (Guellec & de la Potterie, 2000; Harhoff et al., 2003). Table A2 presents the descriptive statistics of each dependent variable. The unit of analysis for probability of becoming and inventor is the individual whereas for NFC it is the

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[11]Two main robustness checks have been made. First, I have tried to examine the dynamics over time by dividing the data into two periods, 1985–1997 and 1998–2007. The results are very similar to using the whole period of data 1985–2007. This implies that that there is no significant dynamic effect over time. Second, I have also tried to use the indicator of *the probability of patenting*, which is based on unbalanced panel data (as individuals can enter in different years, die or move out, or retire) for the entire Swedish-born population from 1985 to 2007 (the same indicator used in Zheng & Ejermo, 2015). This is because the control variables used in the regressions (see Table A1) for the same person – such as age, educational level, field of study and sector of work – can vary across the years. The dependent variable is set up as a dummy variable, coded as 1 if an individual has at least one patent application in year *t* and 0 otherwise. The results are similar to using the indicator of *the probability of becoming an inventor*. I report the results of the above indicator as the marginal effects for *the probability of patenting* are very small. That is because in each year, only a small number of individuals patent among the entire population. For example, in 2000, only 2,180 individuals patented among a population of 4.7 million.

[12] The opposition system in EPO is effective in weeding out weak patents and can be helpful in assessing the value of patent rights (van der Drift, 1989; Merges, 1999). As the cost of an opposition procedure can be substantial and expensive for the attacker, valuable patents are more likely to be opposed (see more discussion in Harhoff et al., 2003). Figure A2 shows that, only 1.4% of patents which had 0 forward citations received opposition; however, this increases to 6.5% among patents which had 5 or more forward citations.

patent–inventor combination[13] since the NFC varies within inventors. Table 2 presents an overview of the estimation methods for each indicator and the reasons for using each method.

Table 2 Dependent variables and estimation methods

Dependent variable	Estimation method[a]	Rationale of estimation method
(a) Probability of becoming an inventor	Probit regressions with observed information matrix (oim) standard errors	Dummy variable: coded as 1 if an individual has been listed as an inventor in a patent application at least once during 1985 to 2007 and 0 otherwise.
(b) NFC received by each inventor's patent	Negative binomial models with clustered robust standard errors.	1. Count data. This is calculated for the five-year period following the filing of the patent. 2. Highly overdispersed (zero citations: 49.3%, standard deviation: 3.0, mean: 1.5). 3. As 48.5% of inventors have filed more than one patent, I control for intra-inventor correlation by clustered robust standard errors on inventors.

Notes: [a] I have compared between probit and logit models for indicator (a) and negative binomial, Poisson and zero inflow models for indicators (b). I find that the models used here have the higher log pseudolikelihood, a smaller Akaike's information criterion (AIC) and Schwarz's Bayesian information criterion (BIC) than their model counterparts.

Mainly three models are used to examine the patenting performance of second-generation immigrants. Model 1 combines all second-generation immigrants together when compared with native Swedes (the reference group in all regressions). This model is used to examine the overall positive and negative forces on second-generation immigrants' inventive performance as discussed in Section 3.1. Model 2 divides second-generation immigrants into two groups – mixed immigrants and immigrants with two FB parents, and compare each with native Swedes. This model is used to test the discussion in Section 3.2. Similarly, model 3 divides second-generation immigrants into seven groups by their parents' region of origin, as described in Section 3.3.

Model 1 and model 2 have two specifications, and model 3 has three specifications. The first specification in each model compare different groups of second-generation immigrants with native Swedes without including any control variable. The second specification in model 3 control for variance in the highest educational level (at the time of the examined year), to investigate its effect on the

[13] For example, a patent filed jointly by three inventors generates three patent-inventor observations. An inventor who contributed to four patents generates four patent-inventor observations.

inventive performance of each group. This is because educational level can vary considerably among different immigrant groups, and are expected to have especially strong effect on inventive performance (Dustmann & Theodoropoulos, 2010; Hunt, 2011). The second specification in models 1 and 2, and the third specification in model 3 for both dependent variables, I control for variance in: *highest educational level; field of study; age* and *age^2; birth cohort; gender; firm size; sector of work* (use *high-tech industry* instead when do robust check on the high-tech sectors); *region of work; educational level of mother/father; number of children of mother/father*. When studying the probability of becoming an inventor, an individual's personal information, which can vary within a person across years, is randomly selected in year *t* between 1985 and 2007. The analyses of NFC also control for variance in *technology fields; application year; total number of inventors in a paten*; and *numbers of inventors per patent for each of the following groups: native Swedes, mixed immigrants, immigrants with two FB parents, first-generation immigrants*. All of these factors are related to patent quality. Table A1 provides brief rationales for the inclusion of each control variable and an explanation of their structures. I control for the above variables in order to examine to what extent they can account for any observed discrepancy between different native-born groups in invention.

Patenting activity can vary across different sectors. The high-tech sectors can be more active in patenting than other sectors, and they can work as key drivers of innovation and economic growth for a country (Helmers & Rogers, 2011). In order to reduce unobserved heterogeneity in the underlying patenting activity of various sectors, I also restrict the sample to a cohort of individuals who work in the *high-tech sectors*.[14] The high-tech sectors in this paper include high-tech and medium high-tech manufacturing, and high-tech knowledge-intensive service (KIS) sectors. This is because these sectors are the ones most likely to have the chance of patenting (that is, in principle all their inventions should be patentable) (Arundel & Kabla, 1998; Helmers & Rogers, 2011). In total, 70.6% of the inventors in Sweden work in these high-tech sectors at the year when they patented. Moreover, to compare those who work in the high-tech sectors, I also investigate the other sectors (see 3.2 in Appendix 3) by comparing the seven subgroups of immigrants with native Swedes after adding control variables (model 4 in Tables A3, model 6 in Table A4).

As immigrants originated from different regions can be concentrated in different technology fields (Kerr, 2010), when studying the NFC for patents in the

[14] High-tech sectors are grouped based on the three-digit codes of the Swedish Standard Industrial Classification (SNI92) system. The detailed codes and names of each sector is shown in 3.1, Appendix 3. I combine the different high-tech sectors together but have not examined each sub-sector separately, in order to retain an adequate number of observations for each group of second-generation immigrants when I divide them into seven groups, which makes the statistical analysis more meaningful.

high-tech sectors, the subgroups of immigrants are compared with native Swedes in different technology fields. Among the investigated inventors, 39% of them have patents in electrical engineering, which is the most important technology field for patenting for Swedish companies like Ericsson (WIPO, 2011). Therefore, when comparing the seven subgroups of immigrants with native Swedes, first, I investigate the NFC for patents in electrical engineering (model 4 in Table A4), and then in other technology fields as a whole (model 5 in Table A4). The technology fields are classified according to International Patent Classification (IPC) codes (Schmoch, 2008). Patents belonging to multiple technology fields are randomly assigned to one field.[15]

The empirical research only focus on employed individuals educated to at least secondary school level or the equivalent (≥10 years of schooling) as the data on the explanatory variables for 'field of study' in Sweden and 'sector of work' are only available for this group.[16]

6 Empirical results

6.1 Probability of becoming an inventor

Table 3 shows that for second-generation immigrants, both mixed immigrants and immigrants with two FB parents, are significantly more likely to become an inventor than native Swedes, although the size of this difference is small (models 1 and 2). Model 2.2 shows that, when holding other variables constant, a mixed immigrant and an immigrant with two FB parents are 0.03 % ($p<0.05$) and 0.07% ($p<0.01$) more likely to become an inventor than native Swedes. This means that, given the number of population, mixed immigrants have 7.6% (= (0.00397+0.0003)/ 0.00397−1, where 0.00397 is the average proportion of native inventors amongst the sample of native population used in model 2.2) more inventors in their midst than among native Swedes. The corresponding figure for immigrants with two FB parents is 17.6% (= (0.00397+0.0007)/0.00397−1). However, there is no significant difference between mixed immigrants and immigrants with two FB parents ($p>0.1$ by T-test, model 2).

The better performance of mixed immigrants is mainly attributed to those whose non-native parent is from the EU-15, North America or Oceania; for immigrants with two FB parents, it is mainly linked to those with two parents from

[15] Among the patents, 61% belong to only one technology field and 30% belong to two fields. Among the patents which are classified as being in the category of electrical engineering, 64% of them are categorized as electrical engineering only, and 29% of them belong to two fields. Therefore, it seems unlikely that there is any major issue with respect to the classification of the technology field if a patent belongs to multiple fields.

[16] Among all of the identified inventors, only 3.8% have an education that ends at the primary school level, and only 3.6% are unemployed.

non-Nordic European countries (model 3.1). Compared with native Swedes, immigrants with other Nordic backgrounds are less likely to become inventors, although the result is not significant for those with at least one parent from other Nordic countries (model 3.1).

Compared with native Swedes, the higher or lower probability of becoming an inventor for each group of immigrants is largely due to their higher or lower educational levels. When controlling for variance in educational level (model 3.2), the advantage for immigrants with non-Nordic European, North American and Oceanian backgrounds becomes smaller (17–75% of the original size in model 3.1). However, the disadvantage for immigrants whose non-native parent is from a developing region increases by 11 times (=–0.0011/–0.0001), and becomes significant (p<0.5). Moreover, controlling for variance in educational level reverse the direction of the discrepancy between natives and immigrants with other Nordic backgrounds; mixed immigrants whose non-native parent is from another Nordic country become as likely to be inventors as natives.

When controlling for variance in other variables, the advantage and disadvantage for mixed immigrants whose non-native parent is from North America or Oceania and a developing region disappear (model 3.3). However, the marginal effects are similar for other groups regardless of whether or not the other control variables are included in the models. Finally, mixed immigrants whose non-native parent is from the EU-15 and immigrants with two FB parents from non-Nordic European countries are 0.13 % (p<0.01) and 0.12% (p<0.01) respectively more likely to become inventors than native Swedes. This means that among the same population, the above two groups have 32.7% and 30.2% more inventors in their midst than native Swedes. This implies that the above two immigrant groups have advantages in some unobservable characteristics compared with native Swedes, such as higher non-cognitive skills or abilities.

For individuals who work in the high-tech sectors (Table A3 in Appendix 1), both groups of second-generation immigrants are as likely to become inventors as native Swedes (models 1 and 2). However, the results for the comparison of seven subgroups of immigrants and native Swedes are similar to those discussed above (model 3, Table 3). The main differences are as follows. First, in general, the marginal difference in probability of becoming an inventor between each group of immigrants and native Swedes is much higher in the high-tech sectors than that of looking at all sectors together (increased by 3–17 times, model 3 in Table 3 vs. model 3 in Table A3). This is because compared with natives, second-generation immigrants are more likely to concentrate in the high-tech sectors (12.1% of natives vs. 13.2% of immigrant employees work in this sector), where is more likely to produce inventions. This may be because the skills required in this sector rely less on institutional or cultural knowledge (Hunt & Gauthier-Loiselle, 2010). Second, the negative difference between native Swedes and immigrants with at least one FB parent from other Nordic countries becomes significant (p<0.1, model 3.1). Third, educational level plays a more important role in explaining the differences between native Swedes and each immigrant group (model 3.2). Fourth, the better performance of immigrants with both FB parents from non-Nordic European countries is not significant any more in the high-tech sector when all control variables are held constant (model 3.3), but it is positively significant at 10% level in other sectors (model 4). Mixed immigrants whose non-native parent is from the EU-15 are still more likely to become inventors than natives in other sectors, although the advantage is not as large as that in the high-tech sectors (model 4).

6.2 NFC for patents per inventor

On average, a patent filed by second-generation immigrant inventors receive 0.098 ($p<0.05$) more forward citations than native inventors (model 1, Table 4), when holding other variables constant. This is mainly due to the contributions of mixed immigrant inventors (model 2), especially those whose non-native parent is from the EU-15 or the rest of Europe (i.e. non-Nordic European countries) (model 3). However, patents filed by immigrants whose non-native parent is from a developing region have significantly lower NFC (0.33–0.43) than native inventors. Only a small proportion of the differences in the NFC for patents between the above immigrant groups and natives can be explained by our observable variables; their main differences can be attributed to some unobservable characteristics. No significant differences are found for the NFC for patents filed by immigrant inventors with two FB parents and native inventors, regardless of where immigrant inventors originated from (models 2 and 3).

The above results are also held when only study on those who work in the high-tech sectors (models 1–3, Table A4 in Appendix 1). The only difference is that the lower NFC for patents filed by immigrant inventors with at least one FB parent from other Nordic countries becomes significantly negative compared to those filed by native Swedes ($p<0.1$, model 3.1). This can be mainly attributed to the former group's lower educational levels (model 3.2), 40% of whom just had a secondary education or less than three years of post-secondary education (henceforth, termed as "medium education", coef: –0.34, $p<0.01$), which is twice the proportion seen in the other groups. Compared with native Swedes, The better performance of mixed immigrants with non-Nordic European background is attributed to those who filed patents in high-tech electrical engineering (model 4). The patents filed by the above immigrant group are more likely to be cited, may be because of their higher quality, as they were fielded by the "best and brightest" inventors who patented in electrical engineering (they have the top three average high school GPAs among all of the groups – see Table 5). Compared with individuals who have lower grades, those who have higher grades are likely to be more creative and knowledgeable (Zheng & Ejermo, 2015), and to produce a higher quality of patents (high school GPA have a significantly positive effect on the NFC, $p<0.01$, see note [b] in Table A1).

Table 3 Probit regressions on the probability of becoming an inventor for second-generation immigrants (omit: native Swedes) among the general employee population aged 25–64 years, 1985–2007

Different groups of second-generation immigrants	1		2		3		
	1.1	1.2	2.1	2.2	3.1	3.2	3.3
	1g_sim	1g_con	2g_sim	2g_con	6g_sim	6g_edu	6g_con
All second-generation	0.0004***	0.0004***					
	(0.0001)	(0.0001)					
Mixed immigrants (1)			0.0004**	0.0003**			
			(0.0002)	(0.0001)			
Immigrants with two FB parents (2)			0.0006**	0.0007***			
			(0.0003)	(0.0003)			
Mixed immigrants whose non-native parent is from							
−Another Nordic country					−0.0004**	0.0000	0.0001
					(0.0002)	(0.0002)	(0.0002)
−The EU-15					0.0020***	0.0013***	0.0013***
					(0.0004)	(0.0003)	(0.0003)
−The rest of Europe					0.0006	0.0001	−0.0001
					(0.0004)	(0.0004)	(0.0003)
−North America/Oceania					0.0030***	0.0017**	0.0009
					(0.0010)	(0.0008)	(0.0007)
−A developing region					−0.0001	−0.0011**	−0.0006
					(0.0007)	(0.0005)	(0.0006)
Immigrants with two FB parents							
−≥1 parent(s) from other Nordic countries					−0.0002	0.0005	0.0004
					(0.0003)	(0.0003)	(0.0003)
−2 parents from non-Nordic European countries					0.0024***	0.0018***	0.0012***
					(0.0006)	(0.0005)	(0.0005)
Educational level	No	Yes	No	Yes	No	Yes	Yes
Other control variables	No	Yes	No	Yes	No	No	Yes
No. of observations	2,634,159	2,634,159	2,634,159	2,634,159	2,634,159	2,634,159	2,634,159
Wald χ^2	10	47,754	10	47,756	76	15,142	47,776
Log likelihood	−68,276	−44,404	−68,276	−44,403	−68,243	−60,710	−44,393
Pseudo R^2	0.000	0.350	0.000	0.350	0.001	0.111	0.350
T-test (1)=(2) (p-value)			0.458	0.178			

Robust standard errors in parentheses. ***p<0.01; **p<0.05; *p<0.1. Notes: (1) Marginal effects are reported. (2) The other control variables included here are: age, age^2, gender; number of children for mother/father; dummies for field of study, birth cohort, firm size, sector of work, region of work, and educational level for mother/father

However, the result for immigrant inventors with at least one FB parent from other Nordic countries is entirely the opposite. No significant difference is found between each second-generation immigrant group and native Swedes when investigating other technology fields as a whole (model 5).

Table 5 shows that all of the "best and brightest" individuals among native Swedes, and mixed immigrants whose foreign-born parent is from European countries, filed their patents in electrical engineering. This could be because it is the most important and promising technology field in Sweden, and people are attracted by famous multinational companies like Ericsson. In this case, the groups above who have a 'better' Swedish background – compared to those who have a larger cultural distance from Sweden– could find it easier to get a job in this technology field. Compared with the "best and brightest" native Swedes who work in electrical engineering, the "best and brightest" mixed immigrants with non-Nordic European backgrounds may have higher human capital. This can be because the above immigrant group may also have been positively affected from having more highly educated parents than natives. The "best and brightest" individuals without European backgrounds may be "crowded out" by the above groups, and chose to work and patent in other technology fields which have less competition and less requirements for Sweden-specific human capital. The better performance of mixed immigrants with non-Nordic European backgrounds is mainly driven by those who work in high-tech sectors, but not by those who work in other sectors (model 6).

Table 4 Negative binomial regressions on the NFC for second-generation immigrant inventors (omit: native inventors) aged 25–64 years, 1985–2007

Different groups of second-generation immigrant inventors	1		2		3		
	1.1	1.2	2.1	2.2	3.1	3.2	3.3
	1g_sim	1g_con	2g_sim	2g_con	6g_sim	6g_edu	6g_con
All second-generation	0.118**	0.098**					
	(0.055)	(0.045)					
Mixed immigrants (1)			0.146**	0.121**			
			(0.062)	(0.050)			
Immigrants with two FB parents (2)			0.010	0.013			
			(0.093)	(0.095)			
Mixed immigrants whose non-native parent is from							
−Another Nordic country					0.081	0.111	0.098
					(0.100)	(0.099)	(0.072)
−The EU-15					0.243**	0.229**	0.178**
					(0.099)	(0.096)	(0.089)
−The rest of Europe					0.322***	0.292**	0.194**
					(0.117)	(0.117)	(0.093)
−North America/Oceania					0.012	0.038	0.120
					(0.175)	(0.210)	(0.282)
−A developing region					−0.381*	−0.427**	−0.329*
					(0.214)	(0.215)	(0.184)
Immigrants with two FB parents							
−≥1 parent(s) from other Nordic countries					−0.085	−0.023	−0.076
					(0.106)	(0.103)	(0.104)
−2 parents from non-Nordic European countries					0.107	0.067	0.103
					(0.142)	(0.139)	(0.151)
Educational level	No	Yes	No	Yes	No	Yes	Yes
Other control variables	No	Yes	No	Yes	No	No	Yes
Constant	0.399***	1.179***	0.399***	1.177***	0.399***	0.441***	1.182***
	(0.021)	(0.409)	(0.021)	(0.409)	(0.021)	(0.030)	(0.407)
No. of observations	31,002	31,002	31,002	31,002	31,002	31,002	31,002
No of inventors	10,576	10,576	10,576	10,576	10,576	10,576	10,576
Wald $\chi2$	5	2703	6	2,710	18	109	2,748
Log pseudolikelihood	−50,829	−48,495	−50,828	−48,494	−50,817	−50,657	−48,487
Pseudo R^2	0.000	0.046	0.000	0.046	0.000	0.004	0.046
T-test (1)=(2) (p-value)			0.207	0.306			

Robust standard errors in parentheses. ***$p<0.01$; **$p<0.05$; *$p<0.1$. Notes: (1) Coefficient results of clustered robust standard errors on inventors are reported, same as Table A4. (2) In addition to the control variables in Table 3, here, I also control for dummies for technology field and application years; the total number of inventors in a patent; numbers of inventors per patent for each of the following groups: native Swedes, mixed immigrants, immigrants with two FB parents, first-generation immigrants. (3) Pseudo $R^2 = 1 - \text{log pseudolikelihood (full model)}/\text{log pseudolikelihood (constant-only model)}$. (4) The results for different groups of second-generation immigrant inventors are robust, based on comparisons with analyses of data from 1985 to 2004, 1985 to 2005 and 1985 to 2006. The exception is model 3.3.

Table 5 Average high school GPA for different groups of inventors who patented in different high-tech technology fields

Different groups of Swedish-born inventors	Electrical engineering		All four other fields		*Instruments*		*Chemistry*		*Mechanical engineering*		*Other fields*	
	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.
Native Swedes	403	6,849	379	8,644	390	2,358	388	2,313	368	3,619	371	354
Mixed immigrants whose non-native parent is from												
−Another Nordic country	405	288	364	415	369	107	373	124	356	171	343	13
−The EU-15	422	183	381	246	378	53	382	68	381	118	373	7
−The rest of Europe	409	152	350	128	331	33	363	45	352	34	349	16
−North America/Oceania	365	14	442	27	444	10	453	8	430	9	-	-
−A developing region	414	50	395	34	376	8	446	10	369	15	433	1
Immigrants with two FB parents												
−≥1 parent(s) from other Nordic countries	367	71	372	182	350	39	407	65	362	69	300	9
−2 parents from non-Nordic European countries	393	70	383	126	400	27	388	52	371	43	326	4

Note: Mean = Mean high school GPA; No.= Number of patent–inventor combinations

6.3 Discussion

In terms of both indicators, the results in model 1 show that, second-generation immigrants in general have better inventive performance than native Swedes. This indicates that the positive forces on second-generation immigrants discussed in Section 3.1 generally overcome the negative forces. When investigating the inventive performance of mixed immigrants and immigrants with two FB parents, the results in model 2 strongly support part of the expectations of Section 3.2, which is that mixed immigrants are expected to perform better than native Swedes. However, immigrants with two FB parents are more likely to patent than native Swedes, and their patents receive equally high NFC as those of native Swedes. Therefore, some of the expectations in Section 3.2, which assumes that native Swedes would perform better than immigrants with two FB parents, are rejected. Moreover, no significant difference is found between the above two immigrant groups. This indicates that, in contrast to expectations, immigrants with two FB parents in Sweden are capable of overcoming their disadvantages, integrating well into Swedish society, and performing as well as or even better than their native counterparts in terms of patenting. This may be due to the geographical or cultural proximity between Sweden and other European countries, as discussed, which helps them to integrate into Swedish society.

Model 3 shows that the lower inventive performance for second-generation immigrants with other Nordic backgrounds than native Swedes can mainly be attributed to their lower levels of education (models 3.2 in Tables 3, A3 and A4, high school GPA in Table 5). It is further related to their parents' low educational level, which is the lowest among all immigrant groups. Tables 6 and 7 show that children's educational performance is positively correlated with their parents' education. The lower educational level of parents from other Nordic countries seems to negatively affect the development of their children's human capital through intergenerational transmission, which in turn impede their children's inventive performance.

In general, second-generation immigrants with non-Nordic European backgrounds, especially mixed immigrants whose non-native parent is from the EU-15, have better inventive performance than native Swedes. This is likely because they have benefited from having more highly educated parents than natives, which positively influenced their educational attainment (see Tables 6 and 7). The above immigrant group's higher level of education than natives is part of the reason for their better inventive performance, especially for those who work in the high-tech sectors. Moreover, it is also reasonable to expect that parents' educational levels may be positively correlated with their children's non-cognitive skills (Ermisch & Francesconi, 2001), which can affect inventive performance as well (Agrawal et al., 2006; Kerr, 2008). In addition, compared with native Swedes – who may experience too much cognitive proximity in family, society and work – second-generation immigrants with non-Nordic European backgrounds may benefit from only being a short distance away from Sweden in terms of their geographical and cultural background. Studies indicate that too much proximity between actors could be detrimental to their interactive learning and knowledge creation potential, because of the problem of lock-in (Boschma, 2005; Fornahl et al., 2011). It is less likely to generate new ideas and innovation if actors' knowledge bases are too similar than dissimilar knowledge are merged (McEvily & Zaheer, 1999; Fornahl et al., 2011). By contrast, a certain distance (not too much or too little) between actors can help to increase the diversity of culture and knowledge (Boschma, 2005), to generate new ideas through re-combination, and to promote the novelty of their patents.

However, for mixed immigrants whose non-native parent is from a developing region, the large geographical and cultural distance of non-native parents' region of origin from Sweden seems to impede their children inventive performance. Consistent with the above immigrant group having the best educated parents among all of the groups (Table 6), this group also has the best educational performance (see Tables 6 and 7). However, their inventive performance is not better than native Swedes, especially after controlling for variance in their educational level. This implies that this group can be disadvantaged in some unobserved form of human capital, for example by lacking social networks or having large culture distances from other actors (e.g., family members or co-inventors), which may hamper their inventive performance. This is likely because too little cognitive proximity between actors can harm an individual's interactive learning with others, which in turn affects his or her inventive performance by generating communication problems. Social and cultural proximity is necessary for actors to have a sufficient absorptive capacity to identify, interpret and exploit the knowledge of other actors (Fornahl et al., 2011). Therefore, a complicated upbringing with large distances between family members and the rest of society could induce the above group to suffer more discrimination, narrower social networks and more problems in integrating with the host society than those with European backgrounds. This may be driven by their different appearance and ambiguous ethnic identity.

The control variables largely confirm the expectations (results are available upon request), and Appendix 4 reports the detailed discussion.

Table 6 Descriptive statistics of parents' average years of schooling and secondary high school GPAs for each group of Swedish-born population/inventors who graduated between 1973 and 1996 and were aged 25–64 years, 1985–2007

Part A

Different groups of Swedish-born	Population					Inventors				
	Ave. years of schoolinga		School GPAs for population	No. of obs.	Share (%)	Ave. years of schooling		school GPAs for inventors	No. of obs.	Share (%)
	Mother	Father				Mother	Father			
All native Swedes	10.6	10.8	326	1,381,569	89.4	11.7	12.5	376	6,842	87.9
All second-generation	10.5	11.0	323	163,447	10.6	11.5	12.6	371	942	12.1
Mixed immigrants whose non-native parent is from	10.7	11.2	325	122,175	7.9	11.8	13.0	372	731	9.4
−Another Nordic country	10.4	10.6	321	69,991	4.5	11.2	12.1	367	352	4.5
−The EU-15	11.3	11.8	331	27,643	1.8	12.2	13.2	374	225	2.9
−The rest of Europe	11.0	11.6	328	16,849	1.1	12.1	13.8	376	99	1.3
−North America/Oceania	11.4	12.2	337	3,365	0.2	12.8	14.1	398	28	0.4
−A developing region	12.2	13.1	340	4,327	0.3	13.4	16.0	387	27	0.3
Immigrants with two FB parents	10.0	10.4	319	41,272	2.7	10.5	11.6	369	211	2.7
−≥1 parent(s) from other Nordic countries	9.7	9.9	317	28,137	1.8	10.3	11.4	366	127	1.6
−2 parents from non-Nordic European countries	10.5	11.2	322	13,135	0.9	10.7	11.9	373	84	1.1
All Swedish-born	10.6	10.8	326	1,545,016	100	11.7	12.5	375	7,784	100

Table 6: Part B

Mixed immigrants whose non-native parent is from	Population								Inventors							
	Native mother, foreign father				Foreign mother, native father				Native mother, foreign father				Foreign mother, native father			
	Ave. years of schooling		GPA_pop	No. of obs.	Ave. years of schooling		GPA_pop	No. of obs.	Ave. years of schooling		GPA_inv	No. of obs.	Ave. years of schooling		GPA_inv	No. of obs.
	Mo_N	Fa_F			Mo_F	Fa_N			Mo_N	Fa_F			Mo_F	Fa_N		
−Another Nordic country	10.4	10.7	320	26,587	10.3	10.6	321	43,402	11.5	12.6	366	128	11.0	11.8	367	224
−The EU-15	11.4	12.0	331	15,262	11.0	11.6	330	12,380	12.3	13.3	375	124	12.2	13.1	371	101
−The rest of Europe	10.9	11.7	326	10,630	11.1	11.6	331	6,218	11.9	13.6	373	51	12.3	14.0	378	48
−North America/Oceania	11.4	12.2	335	1,916	11.4	12.2	340	1,449	13.0	14.4	411	16	12.5	13.7	375	12
−A developing region	12.2	13.1	338	3,049	12.4	13.1	346	1,277	13.2	15.6	393	17	13.9	16.6	379	10

Note: [a] I use average years of schooling instead of educational level for parents, for an easy comparison with high school GPAs.

Table 7 Descriptive statistics of educational level for each group of Swedish-born population/inventors aged 25–64 years, 1985–2007

Different groups of Swedish-born	Population					Inventors				
	Medium edu. (%)	Long edu. (%)	PhD (%)	Sum (%)	No. of obs.	Medium edu. (%)	Long edu. (%)	PhD (%)	Sum (%)	No. of obs.
All native Swedes	77.2	22.1	0.7	100	2,379,152	26.2	46.9	26.9	100	27,739
All second-generation	78.4	20.8	0.8	100	255,007	26.0	52.2	21.7	100	3,263
Mixed immigrants whose non-native parent is from	77.4	21.8	0.8	100	195,754	25.3	53.6	21.1	100	2,537
−Another Nordic country	80.6	18.8	0.6	100	116,389	31.0	53.3	15.7	100	1,262
−The EU-15	73.6	25.3	1.1	100	39,453	23.7	47.7	28.6	100	646
−The rest of Europe	74.2	24.9	1.0	100	25,923	13.6	63.2	23.2	100	397
−North America/Oceania	71.9	26.7	1.4	100	6,624	33.3	25.0	41.7	100	120
−A developing region	64.3	34.5	1.3	100	7,365	3.6	86.6	9.8	100	112
Immigrants with two FB parents	81.7	17.5	0.7	100	59,253	28.7	47.5	23.8	100	726
−≥1 parent(s) from other Nordic countries	84.3	15.2	0.5	100	40,394	38.6	46.5	14.9	100	383
−2 parents from non-Nordic European countries	76.3	22.6	1.1	100	18,859	17.5	48.7	33.8	100	343
All Swedish-born	77.3	21.9	0.7	100	2,634,159	26.1	47.5	26.4	100	31,002

7 Conclusion

The paper shows that, in terms of both indicators, second-generation immigrants with non-Nordic European backgrounds have better inventive performance than native Swedes. Holding other variables constant, among the same size of population, compared with native Swedes, there are 32.7% more inventors among mixed immigrants whose non-native parent is from the EU-15, and 30.2% more inventors among immigrants with two FB parents from non-Nordic European countries. Moreover, the patents filed by mixed immigrants receive 0.12 more forward citations than those from native Swedes. This is mainly on account of the inventors with non-Nordic European backgrounds who patented in the high-tech electrical engineering sector. Their patents may be of higher quality, and therefore more likely to be cited, than those of native Swedes. This is because they were filed by the "best and brightest" immigrants from that group, who are also the "best" among all groups patenting in this field. The above results also hold, in the main, when studying just individuals who work in high-tech sectors.

The study indicates that there are interactions between educational levels and the geographical or cognitive proximity of non-native parents' region of origin to the host country on second-generation immigrants' inventive performance through intergenerational transmission. Moreover, the influence of the above two factors varies depending on where their non-native parents originated from. First, for second-generation immigrants with non-Nordic European backgrounds, they have better inventive performance than natives could be linked to the tendency that they have more highly educated parents and their non-native parent originated from region with close geographic proximity to Sweden, both of which seems positively affect the development of their human capital through intergenerational transmission and inventive performance. Second, for second-generation immigrants with other Nordic backgrounds, although their non-native parents have more of geographical and cognitive proximity to Sweden, their lower educational attainment, which is related to their relatively low-educated parents, reduce their inventive performance. Third, for mixed immigrants whose non-native parent is from a developing region, even though they have the best educational performance among all groups as their parents, they still cannot perform as well as natives, especially after controlling for their advantage in educational level. This may be related to the large cultural distance between their non-native parents' region of origin and Sweden, which hamper their assimilation to the host society and their inventive performance.

This study also suggests that it is important to consider the long-term impact of immigrants on a country. Contrary to the findings by Zheng & Ejermo (2015), which shows that, generally, first-generation immigrants in Sweden are under-represented in the inventor population and contribution to invention relative to their representation in the general population, second-generation immigrants (especially mixed immigrants) are overrepresented. The better inventive performance of second-generation immigrants with non-Nordic European backgrounds than native Swedes also suggests that ethnic and cultural diversity may stimulate an individual's innovativeness, which in turn help promote the innovative capability of a country. Therefore, even if in general first-generation immigrants are not as highly educated as natives (see footnote 10), do not perform as well as natives in innovation, and may even have some negative economic and social impact on the host country (Rodríguez-Pose & Von Berlepsch, 2014; Zheng and Ejermo, 2015), their children may make good contribution to the innovation development of the host country. Thus, for those who worried about the cost of immigration to the host country (Ekberg, 1999; Storesletten, 2003; Rowthorn, 2008), it is important for them and for the government to have a long-term perspective on the impact of immigrants.

However, as discussed above, the study indicates the importance of having highly skilled immigrants. This is because it will not only affect the performance of immigrants themselves, but also their children's performance. The reason for this is the human capital of migrant parents can strongly affect the formation of their children's human capital through intergenerational transmission. The empirical results show that the parents' educational level, especially at university education or higher, is positively correlated with their children's inventive performance. This effect is more significant for mothers than fathers.

Moreover, the geographical and cognitive proximity of an immigrants' region of origin to Sweden is also very important. For immigrant who originated from regions that are distant to the host country in these ways, even second-generation immigrants, it is important to improve their host country-specific human capital, e.g. offering better integration policies to reduce discrimination and improving the social network of the immigrants. Therefore, the educational attainment of immigrants and their geographical and cognitive proximity to the host country will not only affect their own innovative performance (Zheng & Ejermo, 2015), but also that of their children in the long-term, which can influence a country's future innovation performance and international competitiveness.

This study certainly makes contributions to the literature, but there are some limitations which need to be explored further. First, although I have tried to explore the reasons for the difference in patent performance between different groups of native-born Swedes, the results are mainly descriptive. Second, the data on specific country of origin for immigrants are not available in the database, which is detrimental to the study of cultural effects. Geographical and cultural proximity to Sweden can vary across immigrants who may come from the same region but from different countries within that region. Third, despite the richness of the data, I cannot track the upbringing environment of individuals, as individual data are only available from 1985 onwards. For example, I do not have data on the work and income status of individuals' parents, the age at migration for non-native parent(s) (which indicates to some extent the level of integration), ethnic identity, language skills (Nekby & Rödin, 2010; Schüller, 2015), attitudes and expectations regarding the achievements of both their parents and themselves (Fuligni, 1997), or their place of upbringing (Nielsen et al., 2003; Åslund et al., 2011). All of these factors may have an impact on individuals' obtainment of human capital and future inventive performance. Fourth, the detailed collaboration patterns between different native-born groups (e.g., whether mixed immigrant inventors whose non-native parent is from another Nordic country are more likely to co-invent with individuals with the same parental background), which may influence their inventive performance, have not been studied in this paper. Finally, I cannot determine who cited the patents, and so cannot examine any ethnic effect on citation. For example, the preference for self-citation by different groups of inventors may affect the results of the NFC for patents, although I could not find any literature to show that such differences in preference exist.

Appendices

Appendix 1

Table A1 Control variables: rationale for inclusion and categorization

Control variable[a]	Rationale	Categories
Highest educational level	Studies indicate educational level has a positive effect on patenting performance (Hunt & Gauthier-Loiselle, 2010; No & Walsh, 2010; Hunt, 2011).	Three educational levels: (a) Secondary or <3 years of post-secondary education (medium education); (b) ≥3 years of post-secondary education but below PhD level (long education, reference); (c) Any PhD education (also unfinished).
Field of study[b]	Patenting activity can vary according to fields of study (Hunt & Gauthier-Loiselle, 2010; Hunt, 2011), e.g. those who studied science and engineering (S&E) are more likely to patent than those who have studied business.	Four categories: (a) Engineering, manufacturing, and construction (reference); (b) Science, mathematics, and computing; (c) Health and welfare; (d) Other fields.
Age and age^2	Inventive productivity has a curvilinear relationship with age (Simonton, 2000; Jung & Ejermo, 2014).	Discrete data.
Birth cohort	Individuals who were born in different periods can have different upbringing and social environments, which can affect their integration and inventive behaviour (Riphahn, 2003).	Four categories by birth year: (a) 1921–1945 (reference); (b) 1946–1955; (c) 1956–1965; (d) 1966–1982.
Gender	Gender differences exist in patenting performance (e.g. Ding et al., 2006). Women are less likely to patent than men (Azoulay et al., 2007) but patents filed by women have equal or better citation rates than those by men (Whittington & Smith-Doerr, 2005).	Dummy variable: (a) Male (reference); (b) Female.
Firm size	Small firms may be more constrained in their propensity to patent and thus might focus only on the most valuable inventions (No & Walsh, 2010). Large firms are more likely to patent and can also be expected to produce higher-quality patents, as they usually devote more resources for invention and can afford to hire employees with greater innovation skills.	Three categories: (a) Small firms, coded 1 for 1–99 employees, 0 otherwise; (b) Medium firms, coded 1 for 100–499 employees, 0 otherwise (reference); (c) Large firms, coded 1 for 500 employees or more, 0 otherwise.
Sector of work	Inventive activity can vary across different sectors. For instance, it can be higher in manufacturing sectors than agriculture and service sectors (Nathan,	Four categories following SNI92: (a) Agriculture, hunting, forestry and fishing;

Control variable[a]	Rationale	Categories
	2014). Employees in the public service sector may perform more poorly than those in other sectors as their work rarely involves competing for new technology in markets.	(b) Industry (reference); (c) Private service; (d) Public service.
High-tech industry of work	Inventive activity can vary across specific high-tech industries (Helmers & Rogers, 2011). I include industry fixed effects to account for unobserved industry-specific effects when studying on the *high-tech* sectors.	12 categories following SNI92: See the detailed names of each category in 3.1, Appendix 3. 32 Manufacture of radio, television and communication equipment and apparatus (reference).
Region of work	Larger cities often offer agglomeration economies, which lead to more developed markets, resources and greater opportunities for innovation, than are available in smaller cities (Orlando & Verba, 2005).	Three categories: (a) Metro regions; (b) Urban areas; (c) Rural regions (reference).
Educational level for mother/father	Parents' educational level, especially the mother, have a positive effect on their children's outcome, not only on educational attainment, but also on non-cognitive skills (Ermisch & Francesconi, 2001; Riphahn, 2003; Dustmann et al., 2012; Lundborg et al., 2014), which may impact their children's innovative performance.	Four categories: (a) ≤Primary education; (b) Secondary high school education (reference); (c) <3 years of post-secondary high education; (d) ≥3 years of post-secondary high education (university or above education).
Number of children for mother/father	Having more siblings may have a negative effect on a child's outcome because of resource dilution (both money and time) (Black et al., 2005), or a positive effect because they learn how to compete or cooperate with others.	Discrete data.
Technology fields	Patents in technological fields in which many patents exist are likely to have a higher mean NFC than patents filed in sparsely patented fields (No & Walsh, 2010; Ejermo & Kander, 2011).	Five categories (Schmoch 2008)[a]: (a) Electrical engineering (reference); (b) Instruments; (c) Chemistry; (d) Mechanical engineering; (e) Other fields.
Application year	Used to control for differences in citation behaviour over time and possible differences in the accumulation of citations over time (Sapsalis et al., 2006), although this is largely dealt with by counting citations over the five-year period after filing.	23 time dummy variables.
Total number of inventors in a patent	Used to control for the level of resources devoted to the research project which generates the patent,	Discrete data.

Control variable[a]	Rationale	Categories
	which is expected to be related to the quality of the patent (Sapsalis et al., 2006).	
Numbers of inventors per patent for each of the following groups: native Swedes, mixed immigrants, immigrants with two FB parents, first-generation immigrants.	Used to measure the cognitive diversity of inventors in a patent. Cognitive diversity may benefit a group if it is associated with greater diversity in ideas and perspectives and thus offers benefits in terms of problem-solving, generation of idea and patent quality (Nathan, 2014). Ethnic or cultural diversity may be a good proxy for cognitive diversity (Hong & Page, 2004).	Discrete data.

Notes: [a] I have also tried to control for individuals' secondary high school GPA (results are available upon request). This is used as a proxy for unobserved ability, which may correlate with inventive performance. However, these data are only complete between 1973 and 1996, but unobserved before 1973 and not comparable with earlier years from 1997 onwards. Therefore, it deducts quite a lot from the observations. The regression results do not change much regardless of including or excluding the high school GPA, although it have a positively significant effect on inventive performance. Thus, in order to retain an adequate number of observations for each group of second-generation immigrants when I divide them into seven groups, which makes the statistical analysis more meaningful, the main results reported here exclude this variable.

[b] fields of study for mother and father have been examined as well, and no substantial differences are found from the reported results.

[c] Only identified inventors in a patent are calculated here. Zheng & Ejermo (2015) indicate that it seems unlikely that there is any large sample selection issue in the data for unidentified inventors regarding immigrant status.

Table A2 Descriptive statistics of dependent variables: probability of becoming an inventor and NFC for patents, 1985–2007

Different groups of Swedish-born	Probability of becoming an inventor					NFC				
	Mean	S.D.	Max	No. of obs.	Share (%)	Mean	S.D.	Max	No. of obs.	Share (%)
All native Swedes	0.0039	0.0626	1	2,379,152	90.3	1.49	2.97	60	27,739	89.5
All second-generation	0.0043	0.0658	1	255,007	9.7	1.68	3.14	46	3,263	10.5
Mixed immigrants	0.0043	0.0654	1	195,754	7.4	1.73	3.25	46	2,537	8.2
whose non-native parent is from										
−Another Nordic country	0.0036	0.0596	1	116,389	4.4	1.62	2.94	46	1,262	4.1
−The EU-15	0.0059	0.0768	1	39,453	1.5	1.90	3.73	44	646	2.1
−The rest of Europe	0.0045	0.0670	1	25,923	1.0	2.06	3.71	31	397	1.3
−North America/Oceania	0.0069	0.0830	1	6,624	0.3	1.51	2.69	16	120	0.4
−A developing region	0.0038	0.0615	1	7,365	0.3	1.02	2.01	11	112	0.4
Immigrants with two FB parents	0.0045	0.0671	1	59,253	2.2	1.51	2.73	25	726	2.3
−≥1 parent(s) from other Nordic countries	0.0037	0.0606	1	40,394	1.5	1.37	2.56	24	383	1.2
−2 parents from non-Nordic European countries	0.0063	0.0792	1	18,859	0.7	1.66	2.91	25	343	1.1
All Swedish-born	0.0040	0.0629	1	2,634,159	100	1.51	2.99	60	31,002	100

Notes: (1) Minimum values for indicators of probability of becoming an inventor and NFC are 0; (2) S.D.=standard deviation

Table A3 Probit regressions on the probability of becoming an inventor for second-generation immigrants (omit: native Swedes) among the general employee population who work in high-tech and other sectors aged 25–64 years, 1985–2007

Different groups of second-generation immigrants	High-tech							Other
	1		2		3			4
	1.1	1.2	2.1	2.2	3.1	3.2	3.3	4
	1g_sim	1g_con	2g_sim	2g_con	6g_sim	6g_edu	6g_con	6g_other
All second-generation	−0.0001	0.0003						
	(0.0008)	(0.0008)						
Mixed immigrants (1)			−0.0002	−0.0001				
			(0.0009)	(0.0009)				
Immigrants with two FB parents (2)			0.0001	0.0016				
			(0.0016)	(0.0016)				
Mixed immigrants whose non-native parent is from								
−Another Nordic country					−0.0040***	−0.0019	−0.0015	0.0002
					(0.0011)	(0.0012)	(0.0011)	(0.0001)
−The EU-15					0.0065***	0.0036*	0.0033*	0.0009***
					(0.0023)	(0.0020)	(0.0019)	(0.0003)
−The rest of Europe					0.0021	0.0001	0.0001	−0.0002
					(0.0025)	(0.0023)	(0.0022)	(0.0002)
−North America/Oceania					0.0141**	0.0095*	0.0022	0.0006
					(0.0064)	(0.0056)	(0.0044)	(0.0005)
−A developing region					0.0005	−0.0050	−0.0036	−0.0003
					(0.0048)	(0.0037)	(0.0038)	(0.0004)
Immigrants with two FB parents								
−≥1 parent(s) from other Nordic countries					−0.0034*	0.0009	0.0002	0.0002
					(0.0018)	(0.0021)	(0.0019)	(0.0002)
−2 parents from non-Nordic European countries					0.0070**	0.0060**	0.0039	0.0006*
					(0.0032)	(0.0030)	(0.0026)	(0.0003)
Educational level	No	Yes	No	Yes	No	Yes	Yes	Yes
Other control variables	No	Yes	No	Yes	No	No	Yes	Yes
No. of observations	321,669	321,669	321,669	321,669	321,669	321,669	321,669	2,312,490
LR χ^2	0	20,690	0	20,691	38	6,993	20,698	14,939
Log likelihood	−33,018	−22,673	−33,018	−22,672	−32,999	−29,521	−22,669	−19,693
Pseudo R^2	0.000	0.313	0.000	0.313	0.001	0.106	0.313	0.275
T-test (1)=(2) (p-value)			0.886	0.329				

Robust standard errors in parentheses. ***p<0.01; **p<0.05; *p<0.1. Notes: (1) Marginal effects are reported. (2) The other control variables included here are the same as those of Table 3 except here using dummies for the high-tech industries instead of sector of work in Table 3.

Table A4 Negative binomial regressions on the NFC for second-generation immigrant inventors (omit: native inventors) who work in the high-tech and other sectors aged 25–64 years, 1985–2007

	High-tech									Other
Different groups of second-generation immigrants	1		2		3			4	5	6
	1.1	1.2	2.1	2.2	3.1	3.2	3.3	4	5	6
	1g_sim	1g_con	2g_sim	2g_con	6g_sim	6g_edu	6g_con	6g _co_ee	6g_co_ot	6g_other
All second-generation	0.117*	0.103*								
	(0.069)	(0.054)								
Mixed immmigrants (1)			0.160**	0.127**						
			(0.077)	(0.059)						
Immmigrants with two FB parents (2)			−0.054	0.008						
			(0.126)	(0.122)						
Mixed immmigrants whose non-native parent is from										
−Another Nordic country					0.072	0.079	0.072	0.023	0.087	0.126
					(0.130)	(0.124)	(0.089)	(0.136)	(0.091)	(0.098)
−The EU-15					0.301**	0.274**	0.211**	0.331*	0.121	0.102
					(0.128)	(0.124)	(0.114)	(0.186)	(0.116)	(0.102)
−The rest of Europe					0.323***	0.300**	0.211*	0.248*	0.121	0.116
					(0.120)	(0.121)	(0.104)	(0.129)	(0.143)	(0.185)
−North America /Oceania					0.120	0.211	0.432	−0.182	0.430	−0.375**
					(0.227)	(0.260)	(0.356)	(0.333)	(0.350)	(0.167)
−A developing region					−0.469**	−0.514**	−0.372**	−0.312	−0.199	−0.131
					(0.220)	(0.221)	(0.188)	(0.279)	(0.270)	(0.496)
Immmigrants with two FB parents										
−≥1 parent(s) from other Nordic countries					−0.238*	−0.160	−0.230	−1.113***	0.075	0.243**
					(0.144)	(0.141)	(0.145)	(0.260)	(0.127)	(0.122)
−2 parents from non-Nordic European countries					0.125	0.096	0.209	0.315	0.058	−0.101
					(0.181)	(0.176)	(0.192)	(0.335)	(0.181)	(0.137)
Educational level	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Other control variables	No	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes
Constant	0.469***	1.175**	0.469***	1.171**	0.469***	0.510***	1.200***	−0.094	−0.823*	1.101*
	(0.026)	(0.457)	(0.026)	(0.457)	(0.026)	(0.035)	(0.454)	(1.863)	(0.481)	(0.584)
No. of observations	21,875	21,875	21,875	21,875	21,875	21,875	21,875	8,614	13,261	9,127
No. of inventors	7,230	7,230	7,230	7,230	7,230	7,230	7,230	2,595	5095	4,092
Wald $\chi 2$	2.903	2560	4.637	2558	21	72	2173	2993	1681	997
Log pseudolikelihood	−36,750	−34,723	−36,747	−34,722	−36,735	−36,640	−34,944	−14,292	−20,104	−13,393
Pseudo R^2	0.000	0.055	0.000	0.055	0.001	0.003	0.049	0.068	0.054	0.040
T-test (1)=(2) (p-value)			0.136	0.379						

Robust standard errors in parentheses. ***p<0.01; **p<0.05; *p<0.1. Notes: (1) Coefficient results are reported. (2) The other control variables included here are the same as those of Table 4 except here using dummies for the high-tech industries instead of the sector of work in Table 4. (3) Pseudo R^2 =1−log pseudolikelihood (full model)/log pseudolikelihood (constant-only model)

Appendix 2

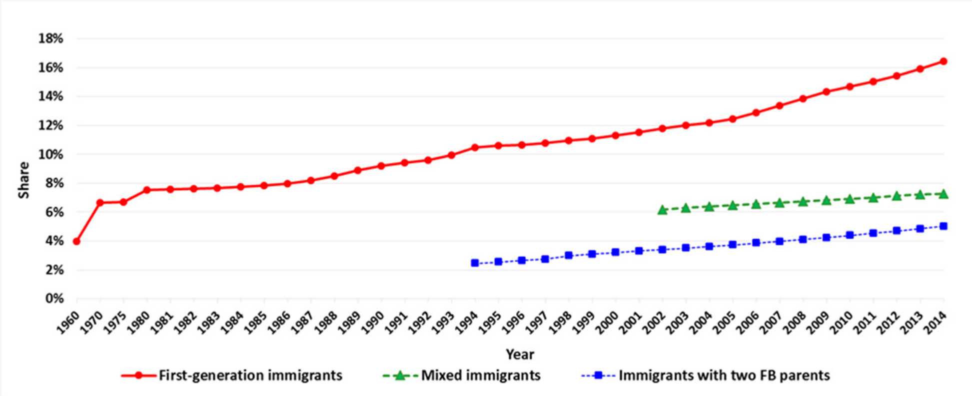

Figure A1. Percentage of first-generation immigrants, mixed immigrants and immigrants with two FB parents of the entire Swedish population at all ages; annual data for 1960–2014

Source: Statistics Sweden (2015)

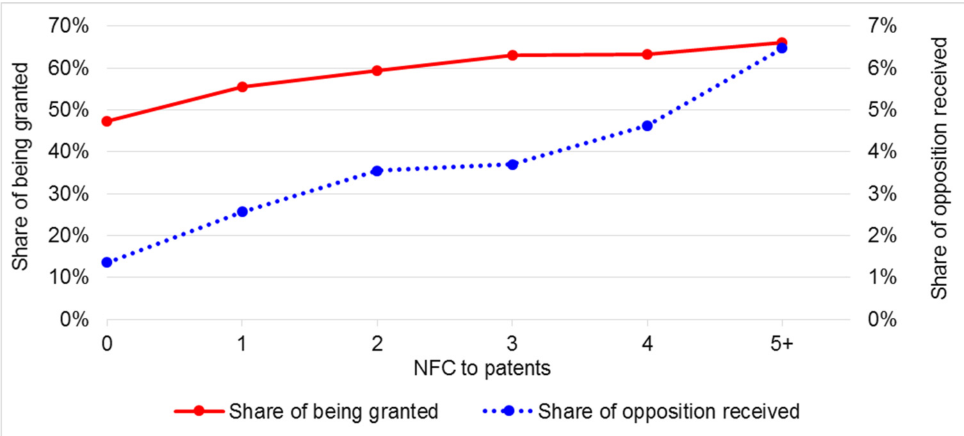

Figure A2. Relationship of the NFC for patents, the share of being granted and the share of opposition received.

Source: CIRCLE data on inventors

Appendix 3

The codes and names of grouped based on the three-digit codes of SNI92 system, and the inventor proportion (%) in each sector in the entire inventor population in Sweden

3.1 High-tech sectors

3.1.1 High-tech and medium high-tech manufacturing sectors (51.76%)
23x (excluding 231) Refined petroleum products and nuclear fuel 0.24%
24x Chemicals and chemical products 6.81%
29x Machinery and equipment 10.49%
30x Office machinery and computers 0.86%
31x Electrical machinery and apparatus 4.03%
32x Radio, television and communication equipment and apparatus 14.24%
33x Medical, precision and optical instruments, watches and clocks 7.02%
34x Motor vehicles, trailers and semi-trailers 6.73%
35x (excluding 351) Other transport equipment 1.36%

3.1.2 High-tech KIS sector (18.80%)
64x Post and telecommunications 1.34%
72x Computer and related activities 5.26%
73x Research and development 12.19%

3.2 Other sectors include:
(a) Primary sectors and low-tech, medium low-tech manufacturing sectors 11.25%
(b) KIS market and other sectors 13.35%
(c) Low KIS market and other sectors 4.84%

Appendix 4

Results of the control variables

Educational level is positively associated with both probability of becoming an inventor and NFC per patent. However, the patents filed by inventors with a PhD education and inventors with only a first stage of tertiary education (i.e. long education) have similar NFC.

Individuals who have studied in different fields perform differently in the world of invention. Those who studied engineering, manufacturing and construction are significantly more likely to be an inventor than those who studied in other fields. However, the patents of those who studied in the fields of science, mathematics and computing, or health and welfare are more likely to be cited than those who studied engineering, manufacturing and construction.

A curvilinear relationship is found for age and age squared. The higher the age of an individual is, the lower their probability of becoming an inventor, and the lower the NFC for their patents.

Individuals of different birth cohorts have different inventive performance. In general, the younger the birth cohort is, the better their inventive performance is. The only exception is that the marginal effect of becoming an inventor for those born between 1966 and 1982 is smaller than that of those born between 1946 and 1965. This may be because the former group of individuals are still too young to become inventors.

Women are significantly less likely to become inventors than men. However, no significant difference is found in the NFC for the different genders.

Generally, individuals who work in larger firms are more likely to become an inventor than those who work in smaller firms. Nevertheless, the patents of inventors from both small and large firms receive more NFC than the patents of inventors from medium-sized firms.

Individuals who work in non-industry sectors are significantly less likely to become inventors than those who work in industry sectors. The NFC for patents filed by inventors who work in the public services sector is significantly lower than for patents filed by inventors who work in the industrial sector. However, no significant difference is found when the figures are compared with those who work in agriculture, hunting, forestry and fishing, as well as in private service sectors.

Compared with those who work in rural regions, inventors who work in metro regions perform better in invention in terms of both indicators. Individuals who work in urban regions are also more likely to become inventors and their patents have more NFC, but the advantage is not as large as for those who work in metro regions.

Educational levels for both parents have significantly positive effects on the probability of their children becoming an inventor. Though when considering the NFC for patents, in general, the educational level for patents does not matter, except that the NFC for patents filed by inventors with mothers who have university-education level or above are larger than those with mothers who have secondary high school education. In general, the mother's educational level has a more significant and important effect than the father's.

In general, the number of children born to mother or father has no significant effect on their children's inventive performance, except that the more children a mother has, the lower the probability is that her child would become an inventor. This may be because there is an offset between the positive and negative effects of growing up in this environment.

The total number of inventors in a patent has a significantly positive effect on the NFC.

The number of co-inventors who are native Swedes has a significantly negative effect on the NFC (coef. −0.046, $p<0.01$), which can be contrasted with the number of co-inventors who are first-generation immigrant inventors (coef. 0.067, $p<0.05$). This may be because the cognitive proximity between native Swedes in the same group hampers the generation of new ideas and high-quality patents (Hong & Page, 2004; Boschma, 2005). First-generation immigrant inventors, who usually have larger cognitive distance from native-born inventors, and who may have been "pre-selected" on the basis of their skill – especially if they migrated as adults – may help to bring greater cultural diversity to the group (Nathan, 2014; Zheng & Ejermo, 2015). This may in turn help to improve patent quality, as well as helping to extend international social networks for patent citation flows by the co-ethnicity effect (Agrawal et al., 2008; Parrotta et al., 2014). The number of co-inventors who are in any group of second-generation immigrants has no significant effect on the NFC.

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Paper III

The inventive performance of immigrants across multiple sectors: the importance of education and occupation

Yannu Zheng

Abstract

This is the first study on the distribution and inventive performance of immigrants across multiple sectors based on individual-level data, which links inventors to the general population in Sweden from 1985 to 2007. It also investigates the extent to which the match between education and occupation influences immigrants' inventive performance. The results clearly indicate that immigrants and natives have different probabilities of patenting in different sectors. In the high-tech knowledge-intensive service (KIS) sector, immigrants are more likely to patent than natives, which is mainly because immigrants have a higher educational level than natives; furthermore, immigrants' high and similar representation in high-skill occupations as natives enable them to have as high patenting rate as natives after controlling for variance in other variables. In the high-tech manufacturing, low-tech and 'other KIS' sectors, especially in the former two sectors, immigrants are less likely to patent than natives, largely because immigrants are over-represented in low-skill occupations. Overall, the lower match between education and occupation in immigrants reduces their probability of patenting in the above three sectors. Immigrant inventors perform as well as natives in terms of number of forward citations for the inventor's patents.

Keywords Patent · Innovation · High-tech · Low-tech · Industry · Sweden

JEL classification I21 · J24 · O14 · O31

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1 Introduction

Recently there has been a lot of interest in immigrants' contribution to technological innovation and economic growth in the host country, from both scholars and policymakers (e.g. Stephan & Levin, 2001; Hunt & Gauthier-Loiselle, 2010; No & Walsh, 2010; Hunt, 2011; Parrotta et al., 2014; Zheng & Ejermo, 2015). Studies have shown that immigrants, especially highly skilled immigrants working in high-tech industries such as software, computer science and engineering, have contributed significantly to technological advances and innovation (e.g. Kerr, 2010; Goldin et al., 2011; Hunt, 2011). It is important to emphasize, however, that innovation is not confined solely to high-tech sectors but can be expected occur to varying degrees across all sectors (Helmers & Rogers, 2011). Moreover, immigrants may be over-represented in innovation in certain high-tech sectors relative to natives (Kerr, 2010). It is also important to underscore that highly skilled immigrants in the high-tech sectors constitute a special group of immigrants who are usually more highly qualified than immigrants in general and so their level of innovation performance is unlikely to be representative of immigrants in other sectors. This paper argues that more attention needs to be paid to the heterogeneity of immigrants as focusing on one specific group may preclude generalizations about immigrants' innovativeness and restrict implementation of policies designed to ensure that immigrants fulfil their potential for innovation.

There has not been any previous research into the innovation of immigrants across multiple sectors, using individual-level data. This is the first study compares inventive performance of first-generation immigrants[1], hereafter immigrants, and natives (i.e. native-born with two native-born parents) in different sectors. It also looks at the combined effect of education and occupation on immigrants' inventive performance, which has not been done before. The rationale for this analysis is that both educational level and occupation are expected to influence innovation performance and previous research had shown that in several sectors immigrants tend to differ from natives with respect to education and occupation (Saxenian, 2002; Hunt & Gauthier-Loiselle, 2010; No & Walsh, 2010; Hunt, 2011; Bosetti et al., 2012; Singer, 2012). There is more likely to be a mismatch between actual and required education in the case of immigrants than natives. Immigrants tend to be employed in different roles from natives with similar education and experience (Battu & Sloane, 2002, 2004; Green et al., 2007; Ottaviano & Peri, 2012).

This research is possible because I have access to a specialized database, which links inventors to the general population in Sweden between 1985 and 2007 (Jung & Ejermo, 2014; Zheng & Ejermo, 2015). I consider an inventor to be a Swedish

[1] Second-generation immigrants who have at least one foreign-born patent are excluded in this paper as they share characteristics with both natives and immigrants and perform differently from both these groups (Zheng and Ejermo, 2015; Zheng, 2016).

resident who has been listed as an inventor on a patent application filed with the European Patent Office (EPO). The innovativeness of immigrants and natives is compared using two indicators: (a) the patenting rate for the employed population; (b) the number of forward citations (NFC) received per patent.[2] The database makes it possible to measure the direct distribution and inventive performance of immigrants in the sector in which they are employed. Sectors are categorized into four groups based on the three-digit codes of the Swedish Standard Industrial Classification (SNI92) system: (a) high-tech manufacturing sector (e.g. chemicals); (b) high-tech KIS sector (e.g. telecommunications); (c) 'other KIS' sector (e.g. health care and social services) and (d) low-tech sector (e.g. food industry).[3] Work in the high-tech KIS sector is more likely to generate patents than work in the 'other KIS' sector. The empirical research focuses on employed individuals educated to at least secondary school level or the equivalent.[4]

This study provides clear evidence that immigrants and natives have different probabilities of patenting in most sectors. In the high-tech KIS sector, immigrants are more likely to patent than natives, which is mainly because immigrants are more highly educated than natives; moreover, immigrants' high and similar representation in high-skill occupations as natives enables them have similar probabilities of patenting as natives when holding all variables constant. In the high-tech manufacturing, low-tech and 'other KIS' sectors, especially in the former two sectors, however, immigrants are less likely to patent than natives. This is largely because immigrants are more concentrated in the low-skill occupations, despite their average educational level being higher than that of natives. Overall, possibly due to lack of country-specific human capital or discrimination, the match between the education and occupation is much lower for immigrants than for natives and this appears to be the main reason for the lower patenting rate for immigrants working

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[2] Although patents have some shortcomings as indicators of innovation (they only apply to certain types of invention and do not necessarily have commercial value; see Giuri et al., 2007), they are still the most common output measure of innovation.

[3] (a) *High-tech manufacturing sector* includes: manufacture of refined petroleum products and nuclear fuel (code 23x excluding 231); chemicals and chemical products (24x); machinery and equipment (29x); office machinery and computers (30x); electrical machinery and apparatus (31x); radio, television and communication equipment and apparatus (32x); medical, precision and optical instruments, watches and clocks (33x); motor vehicles, trailers and semi-trailers (34x); other transport equipment (35x excluding 351). (b) *High-tech KIS sector* includes: postal and telecommunication services (64x); computing and related activities (72x) and research and development (73x). (c) *Other KIS sector* includes such as water transport (61x); air transport (62x); real estate activities (70x); financial intermediation (65x, 66x); education (80x), health care and social services (85x). (d) *Low-tech sector* includes: primary sector (e.g. agriculture hunting and forestry); low- and medium-tech manufacturing sector (e.g. food industry) and low KIS sector (e.g. hotels and restaurants).

[4] Because data on the explanatory variable 'field of study' is only available for this group. Overall, the empirical regressions represent 75% and 60% respectively of the 25-64-year-old native and immigrant populations during 2001 to 2007 (see Table 6). The corresponding figures for native and immigrant inventors are 86% and 55% respectively (see Table 7).

in the above three sectors. Immigrant inventors perform similar as native inventors in terms of NFC per patent.

The rest of the paper is structured as follows. Section 2 summarizes relevant previous research and section 3 provides the theoretical background. Section 4 describes the databases and sets out descriptive statistics. Section 5 discusses the methods employed. Section 6 reports the empirical results. The final section presents conclusions from the study.

2 Literature review

Innovation is considered one of the most important driving forces behind advanced economies for most developed countries, many of which are experiencing increasing immigration (OECD, 2007, 2016). It is little wonder, therefore, that increasing attention is being paid to the innovation performance and contribution of immigrants to their host countries. Previous researches, however, mainly focused on highly skilled immigrants working in special high-tech sectors (e.g. Stephan & Levin, 2001; Chellaraj et al., 2008; Kerr, 2008; Hunt & Gauthier-Loiselle, 2010; No & Walsh, 2010; Hunt, 2011). Although previous literature has provided valuable insight into the contribution of immigrants, most studies to date have been small-scale and based on case studies or survey data. The findings usually show highly skilled or highly educated immigrants positively influence the innovation outcomes in the host country, but it is not clear to what extent the results are generalizable to the general population of immigrant employees. This is because not all immigrant employees have a high level of education. It is important to bear in mind that immigrant populations are very heterogeneous in terms of skills and education and distributed across all economic sectors in host countries.

Some studies have, however, explore the link between the general immigrant population and innovation using data aggregated at regional or country level. For example, Bratti & Conti (2014) use regional data on Italian provinces to show that the overall stock of immigrants do not appear to have an effect on the number of patent applications. Their results do suggest that there is a difference between low-skilled and high-skilled immigrants; an increase in the share of low-skilled migrants in the population would reduce patent applications whereas, highly skilled immigrants have a positive effect on patent applications. Based on panel data in 170 European regions, Ozgen et al. (2012) showe that the proportion of immigrants in the population do not affect the number of patent applications. Based on the evidence available so far, the effect of immigrants on innovation appears to be different when including low-skilled immigrants in compared with when only considering highly skilled immigrants (No & Walsh, 2010; Hunt, 2011). This means that excluding low-skilled immigrants from analyses may produce a misleading picture of the overall impact of immigration on innovation. This issue is especially important for countries that attract large numbers of low-skilled immigrants. For example, Sweden, the setting for this research, has a tradition of focusing on humanitarian migration and paying little attention to the economic impact of immigrants (Scott, 1999; Bevelander, 2000).[5] In such cases, immigrants are expected to have a lower potential for innovation in the host country compared with countries that have immigration policies more geared towards economic development.

Considering immigrants in the aggregate does not, however, reveal anything about how the distribution and performance of immigrants varies across sectors. This is important because it is well-known that innovation activity varies significantly between sectors (Helmers & Rogers, 2011). If immigrants are concentrated in certain sectors, if they are just more likely to live in innovative regions like large cities but are not employed in innovative sectors, or if their skills do not match to their roles, looking at the aggregate effect of immigration on innovation can be misleading (i.e. ecological fallacy). Examining the distribution and innovation of immigrants across sectors would improve understanding of how and where immigrants actually contribute to the host society.

It is well-known that immigrant employment tends to be concentrated in particular sectors. Fertig & Schmidt (2001) find that first-generation immigrants to Germany are more likely than natives to work in the manufacturing sector. Constant (2005) shows that in France immigrants are concentrated in labour-intensive and low-skill industries. Singer (2012) reveals that in the USA immigrants are over-represented in both high- and low-skill sectors. In particular, immigrants are prominent in high-tech sectors such as information technology (IT) and high-tech manufacturing sector (see also Saxenian, 2002; Kerr, 2010), but they are also over-represented in low-tech sectors such as agriculture, construction, food service and accommodation. In addition, within a sector the educational level and occupation profile of immigrants and natives are different. In high-tech industries such as healthcare, high-tech manufacturing, IT and life sciences, immigrants are more likely than natives to have a high level of education and are clustered in high-skill occupations (e.g. professionals) (Saxenian, 2002; Singer, 2012). However, in low-tech industries, the proportion of low-skill workers (without a high school diploma) is typically higher amongst immigrants than natives and immigrants are also more likely to cluster in low-skill occupations (Singer, 2012). Dustmann & Frattini (2011) report that in the UK immigrants tend to be over-represented in the most highly skilled occupations in the public sector, but in recent years the share of immigrants in low-skill sectors and occupations appears to have been growing rapidly (Rienzo, 2015).

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[5] Note, however that on 21 June, 2015, the Riksdag (the Swedish parliament) decided to tighten the criteria for obtaining asylum in Sweden because the large inflow of refugees have generated serious social and financial problems, but even with the new restrictions in place Sweden still attracts large numbers of refugees.

Very few studies have examined the relationship between immigrants' inventive activity and the sector in which they work. The knowledge required to innovate can vary dramatically between sectors, as does the skill level of immigrants (Breschi et al., 2000; Singer, 2012). To date only Fassio et al. (2015a, b) have explored this relationship. Using industry-level survey data from France, Germany and the UK, they show that the effect of migrants on total factor productivity (TFP) growth varied across sectors. The effect of migrants on TFP growth is stronger in manufacturing than in the service sector, and much stronger in high-tech manufacturing. They also find immigrants with tertiary education have a positive effect on the rate of increase in productivity in high-tech manufacturing and to a lesser extent in service sector, whilst immigrants with a medium or low level of education have a small positive effect in the manufacturing sector (Fassio et al., 2015b). Within the manufacturing sector, generally the effect of migrants on innovation varies across sub-sectors; highly skilled immigrants have a positive effect on innovation (indicated by the number of patents and patent citations per 1000 employees) that is specific to the high-tech manufacturing sector (Fassio et al., 2015a); whereas low-skill immigrants have a negative impact on innovation in both high- and low-tech manufacturing sectors, particularly in the latter sector.

In summary, immigrants are distributed differently from natives and there is quite a lot of variance in their skills, educational level and occupation. This is the first study to consider how all these factors affect immigrants' inventiveness across multiple sectors based on individual-level data. This provides a more accurate picture of the distribution and innovation contribution of immigrants than data aggregated at regional, country or even industry level.

3 Theoretical background

Sweden is an attractive country for both low-skilled and high-skilled immigrants. The relatively high payment to unskilled workers in Sweden makes it an attractive country for low-skilled immigrants, while its relative good economic performance, generous welfare system and high living standards make it attractive for both groups of immigrants (Eger 2010; Koopmans 2010; Giulietti & Wahba 2013).

The skills of immigrants can vary widely between sectors; educational level and occupation can be used as indicators of skill (Bosetti et al., 2012). Immigrants working in the high-tech sector are more likely to be highly skilled compared with those who work in the low-tech sector. Moreover, the recruitment process may also be more rigorous in the high-tech sector than in the low-tech sector. In the low-tech sector, recruitment is usually based on capacity for physical or manual work and there is a relatively low requirement for human capital such as education and communication skills; this means that often it does not make much difference whether a position is filled by a native or by an immigrant. It is different in the high-tech sector; the cost of labour and the requirement for human capital is usually higher and this may make employers more cautious about employing immigrants.

It is usually more difficult for immigrants to obtain positions for which a particular level of education or country-specific human capital is required, even if they have similar education and experience to natives in these roles. Immigrants are more likely to face discrimination and lack language skills and relevant social networks. To compete successfully with their native counterparts, immigrants must usually have a skill advantage, such as higher education, to compensate for their disadvantage in country-specific human capital (Green et al., 2007). This is more likely in the high-tech sector, where the requirement for knowledge is generally greater than in the low-tech sector. Educational level plays a very important role in innovation, which seems to explain why immigrants are more innovative than natives in some studies (Hunt & Gauthier-Loiselle, 2010; No & Walsh, 2010; Hunt, 2011). One might expect, therefore, that for a given role, Swedish immigrants are more highly educated than native employees and the education has a stronger effect on immigrants than on natives for inventive activity. This effect may be especially pronounced in the high-tech sector.

The effect of skills and education on knowledge creation and economic productivity is likely to be lower if an individual's role fails to utilize his or her skills (Green et al., 2007). Educational attainment is treated as independent from occupation in the case of the foreign labour force, because there is often a mismatch between immigrant employees' educational level and the level required for their roles such that immigrants are often overeducated for their roles (Battu & Sloane, 2002, 2004; Green et al., 2007). Ottaviano & Peri (2012) report that there are differences in the occupational profile on immigrants and natives with similar levels of education and experience. Moreover, the mismatch between education and occupation for immigrants can also vary across sectors (Battu & Sloane, 2002). The mismatch tends to be higher in sectors where there is high variance in the skills required (e.g. Volve) than in sectors where specialist skills are required (e.g. Ericsson). As Bosetti et al. (2012) have argued, immigrants' occupation may be a better indicator of their contribution to the creation of new knowledge than their educational level, because highly educated immigrants are not always employed in the high-skill occupations that generate patents at a higher rate. I therefore investigate the association between immigrants' occupation and inventiveness across sectors.

4 Data and descriptive analysis

4.1 Summary of data

This paper is based on a rich database which links inventors to the general population in Sweden from 1985 to 2007 (Jung & Ejermo, 2014; Zheng & Ejermo, 2015). The data on inventors and inventions were extracted from the Worldwide Patent Statistics (PATSTAT) database provided by the EPO. Inventors' social security numbers (SSNs)[6] were identified by matching the names and addresses provided by the EPO to those offered by a commercial company or a 1990 Swedish population directory. Finally, inventors were linked to the entire population in terms of their SSNs. Detailed demographic information on inventors was obtained from Statistics Sweden, which has collected such information for all Swedish residents from 1985 onwards.

This paper only deals with employees for whom information on work sector is available. The descriptive analyses shown in Table 1 and Figures 1 and 2 cover all employees, regardless of their educational level. Panel data are used in the statistical analyses presented in this paper as an individual's work sector can vary from year to year. The analyses are also restricted to people aged between 25 and 64 years (mean age 43.9 years), because this is the age range in which people are most likely to be working and patenting and so restricting the sample in this way makes it more homogeneous (inventors outside this age range make a negligible contribution to overall inventions). Overall, Table 1 and Figures 1 and 2 represent 68% and 88% respectively of Swedish immigrants and natives aged between 25 and 64 years (i.e. the table and figures exclude unemployed population). The distribution of employees across sectors is roughly similar for natives and immigrants throughout the study period. A slightly higher proportion of immigrants are employed in the high-tech manufacturing sector (on average, 2.8% higher) and the 'other KIS' sector (on average, 1.3% higher).

Table 1 shows that patenting activity varies considerably across sectors. Of the four sectors investigated, high-tech manufacturing is the most active in patenting. Employees in this sector constitute only 7.3% of the employee population, yet they account for 43.4% of inventors and 44.1% of inventions (fractional count for inventions[7]) in Sweden. It is hardly surprising that this sector has the highest proportion of inventors (0.25%; i.e. on average there are 25 inventors per 10,000 workers), followed by the high-tech KIS sector (0.16%), the 'other KIS' sector (0.02%) and the low-tech sector (0.01%). On average there are 18.7, 11.0, 1.2 and 1.4 inventions per 10,000 employees (include both natives and immigrants) respectively in the above four sectors.

[6] The Swedish social security number is a unique identification number for each resident in Sweden, including foreigners with a valid residence permit for at least one year.

[7] Fractional count means that each co-patent is counted as a fraction, depending on how many inventors contributed to one patent. Each patent is summed as one. For example, if one patent has three co-inventors, then the invention for each inventor is one third.

Table 1 Data by sector for proportion (%) of Swedish population aged 25−64 years identified as inventors (panel data), proportion of inventions (fractional count) they contributed to and employee population (panel data) grouped by immigration status, for 1985−2007.

	High-tech manufacturing			High-tech KIS			Other KIS			Low-tech sector			Share of natives and imm. in the Swedish pop.	Total no. of obs.[a]
	Nat	Imm	SuT	Nat	Imm	SuT	Nat	Imm	SuT	Nat	Imm	SuT		
Percentage of the inventor pop.	38.6	4.8	43.4	12.2	2.1	14.3	13.9	2.0	15.9	16.4	1.6	18.0	91.6	37,548
Percentage of inventions	38.8	5.4	44.1	11.5	2.1	13.7	12.8	2.0	14.8	17.3	1.8	19.1	91.7	27,050
Percentage of the general employee pop.	6.2	1.1	7.3	3.5	0.4	3.9	33.6	4.6	38.2	38.9	4.8	43.6	93.1	87,841,866
Percentage of general pop. who are inventors	0.27	0.18	0.25	0.15	0.24	0.16	0.02	0.02	0.02	0.02	0.01	0.02		0.04

Sources (for all table and figures): Statistics Sweden and CIRCLE data on inventors.

Notes: (1) Nat=Natives; Imm=First-generation immigrants, same as in tables below; SuT=Sub-total; pop.=population. (2) [a] Second-generation (2nd-gen) immigrants are included in the calculations.

Table 1 also shows that within a given sector patenting activity differs between natives and immigrants; this is especially true in high-tech manufacturing and high-tech KIS. In the high-tech manufacturing sector, the proportion of inventors is higher amongst native employees (0.27%) than immigrant employees (0.18%); the opposite applies in the high-tech KIS sector (0.15% vs. 0.24%). In the 'other KIS' sector and the low-tech sector, neither natives nor immigrants are very active in patenting and the difference between the groups is very small.

4.2 Growing trends for immigrants by sector

I also compare the proportion of immigrant employees in the Swedish employee population, the proportion of immigrant inventors in the Swedish inventor population and their percentage contribution to inventions as a whole (Figure 1) and in each sector (Figure 2).

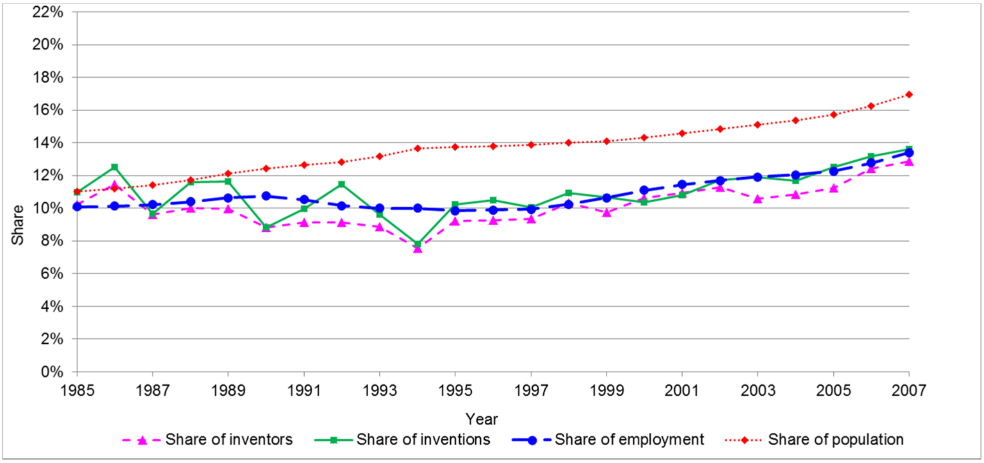

Figure 1 Immigrant inventors as a percentage of the Swedish inventor population (share of inventors) and their percentage contribution to inventions (share of inventions), immigrant employees as a percentage of the Swedish employee population (share of employment) for *all sectors* and immigrants as a percentage of the general Swedish population (share of population) aged 25–64 years; annual data for 1985–2007.

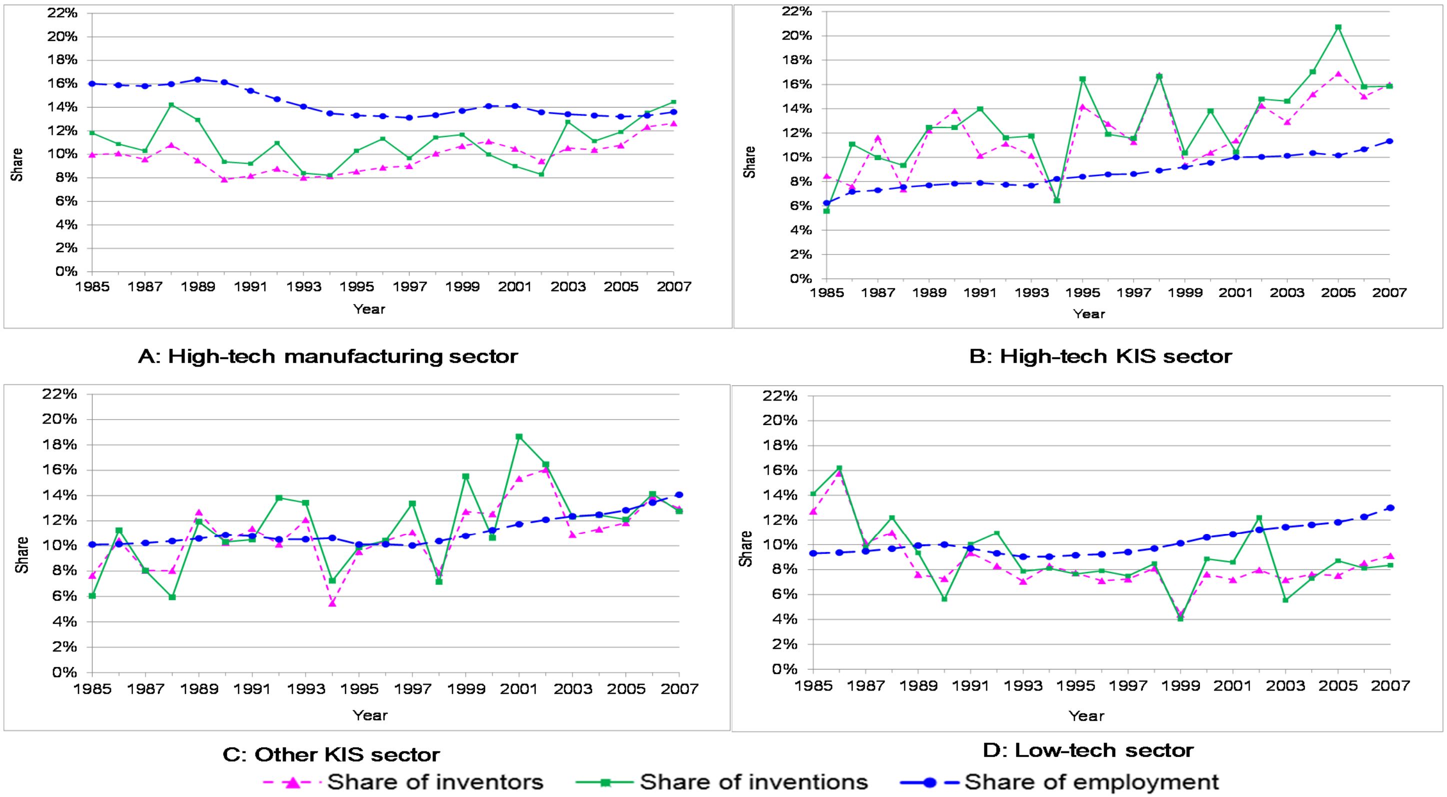

Figure 2 Immigrant inventors as a percentage of the Swedish inventor population (share of inventors) and their percentage contribution to inventions (share of inventions) and immigrant employees as a percentage of the Swedish employee population (share of employment) aged 25–64 years in *each sector*; annual data for 1985–2007.

Figure 1 shows that, in general, immigrants are under-represented in the employee population. The proportion of jobs taken by immigrants decreased rapidly during the financial crisis of the early 1990s. Although it improved a little after the crisis (from 1997 onwards), as the Swedish economy recovered (Helgertz, 2010), it has not yet returned to the pre-crisis level when compared with the proportion of immigrant population in general Swedish population.[8] Throughout the study period, immigrants are under-represented in the inventor population relative to their representation in the employee population, with the exception of the years 1986 and 1998. Immigrants account for a greater proportion of inventions than one would expect given their proportion of inventors.

Moreover, the proportions of inventors, inventions and employment attributable to immigrants vary considerably across sectors (see Figure 2, graphs A–D). In the high-tech manufacturing sector (graph A), immigrants account for smaller proportions of both inventors and inventions than one would expect given their representation in the workforce; however throughout the study period, immigrant inventors are generally a little more productive (in terms of no. of patents per inventor) than their native counterparts. The growing trends in the low-tech sector are similar to those in the high-tech manufacturing sector, except during part of the early period (graph D). In the high-tech KIS sector, however, immigrants account for higher proportions of inventors and inventions than one would expect from their representation in the workforce (graph B). In the 'other KIS' sector, immigrants' representation in the inventor population and inventions vary across its proportion of workforce over the study period (graph C).

4.3 Educational level and occupational profiles amongst natives and immigrants

As expected that Sweden is attractive for both low- and high-skilled immigrants, immigrants are over-represented in the groups educated to primary school level and university education, regardless of whether the analysis is limited to employees (see Table 2). Table 2 also shows that individuals with only primary education are more

[8] Immigrants were struck harder than natives because, first, immigrants were overrepresented in the primary and manufacturing sectors which were most negatively affected by the recession. This put immigrants at a higher risk of unemployment during the recession (Arai and Vilhelmsson, 2004; Ekberg, 2011). Second, there was large inflow of refugees from the early 1990s, for instance, refugees from former Yogslovia, Iran and Iraq. These newly arrived immigrants usually have problems to enter into labor market due to lack of human capital in some areas. Third, discrimination and the barriers to immigrants, especially those from non-European countries, can also increase when jobs are scarce in a recession (Ekberg, 2011). Finally, Sweden's economic structural transition into post-industrial society (Schön, 2010) increases the demand of Sweden-specific knowledge (e.g. proficiency in Swedish) for labor market success, which puts immigrants at a disadvantage.

likely to be unemployed than those with higher education, regardless of immigration status. Table 3 shows that amongst employees with the equivalent of at least secondary education (≥10 years of schooling), the proportion with a university education[9] is higher amongst immigrants than natives in all sectors, especially high-tech KIS, regardless of whether the analysis is limited to inventors or includes the entire employee population. In all sectors, inventors tend to be more educated than employees generally.

Four occupation categories based on the Swedish Standard Classification of Occupations (SSYK 96), which is based on the International Classification of Occupations (ISCO-88), are used in the analysis. The following occupations are considered highly skilled as they usually require a high level of education or experience (Bosetti, 2012; International Labour Organization, 2012): legislators, senior officials and managers (code 1); professionals (code 2); technicians and associate professionals (code 3). All other occupations (codes 0, 4–8) are considered low-skill occupations. Table 4 shows that in three sectors immigrants are much less likely to work in high-skill roles than natives; the exception is the high-tech KIS sector, where the proportion of immigrants working in a professional role (48.0%) is higher than the corresponding proportion of natives (42.6%). When the analysis is limited to inventors, immigrants are more likely to be employed in professional roles than natives in all sectors except the ‘other KIS’ sector. Moreover, in the ‘other KIS’ sector, the proportion of immigrants employed as legislators, senior officials and managers (18.1%) is higher than the corresponding proportion of natives (14.3%), which is the opposite pattern to the other three sectors. The proportion of inventors employed in a professional role (52.6–86.9%) is around 1–5 times higher than for the employee population as a whole.

Table 5 shows the correlations between educational level and occupation for the general employee population and for inventors specifically. In the case of employees in general, the correlation between educational level and occupation is lower for immigrants than for natives in all sectors. The discrepancy between immigrants and natives is the highest in the low-tech sector, followed by ‘other KIS’, high-tech manufacturing and finally high-tech KIS. In the case of inventors the picture is slightly different. In high-tech manufacturing and high-tech KIS, the education-occupation correlation is slightly higher for immigrant inventors than for native inventors. In the ‘other KIS’ and low-tech sectors, the correlation is still slightly lower for immigrant inventors than for native inventors, but the discrepancy of education-occupation correlation between immigrant and native inventors is smaller than for that of the general immigrant and native employee population.

[9] Around 30% of inventors in this sample have a PhD education, so for the purposes of the regression analyses, individuals with a university education are divided into those with long education (i.e. ≥3 years of post-secondary education but below PhD level) and those with a PhD as this makes it clear how important PhD education is for invention.

Table 2 Percentage (%) distribution of educational level for the general population aged 25–64 years for 1985–2007, grouped by immigration status (panel data).

	General population		Employee population		Employee population educated to at least secondary level		Unemployed population	
	Natives	Imm	Natives	Imm	Natives	Imm	Natives	Imm
Primary education	26.5	30.7	23.8	26.3	–	–	44.9	40.6
Secondary education	46.1	42.5	46.8	44.6	61.4	60.5	41.3	37.9
<3 years of post-secondary education	12.7	11.3	13.5	12.1	17.7	16.4	7.4	9.6
University education[a]	14.7	15.5	16.0	17.1	20.9	23.1	6.4	12.0
Total	100	100	100	100	100	100	100	100

Note: [a] University education is defined as ≥3 years of post-secondary education, i.e. a bachelor's degree, master's degree, doctorate or equivalent.

Table 3 Educational profile of immigrants and natives, expressed as percentages (%) of the employee population and inventor populations aged 25–64 years for 1985–2007 and grouped by sector.

	All sectors		High-tech manufacturing		High-tech KIS		Other KIS		Low-tech sector	
Population	Natives	Imm	Natives	Imm	Natives	Imm	Natives	Imm	Natives	Imm
Medium	78.6	75.9	83.4	82.9	74.0	58.5	70.3	68.7	87.4	84.8
Long	20.3	21.8	15.4	15.0	22.1	30.7	28.3	28.5	12.3	14.5
PhD	1.1	2.3	1.2	2.1	3.8	10.8	1.4	2.7	0.3	0.7
Total	100	100	100	100	100	100	100	100	100	100
No. of obs.	50,762,634	5,345,282	3,847,847	546,771	2,685,012	239,870	23,132,544	2,492,074	21,097,231	2,066,567
Inventors										
Medium	30.6	20.1	30.7	22.0	15.9	11.4	26.6	12.2	48.6	38.0
Long	42.8	33.2	46.7	35.4	43.9	25.2	32.0	33.3	39.6	37.9
PhD	26.6	46.7	22.6	42.6	40.2	63.4	41.4	54.5	11.8	24.1
Total	100	100	100	100	100	100	100	100	100	100
No. of obs.	40,178	5,314	20,444	2,660	6,899	1,115	5,969	892	6,866	647

Notes: (1) Medium=Medium education (secondary or <3 years of post-secondary education); Long=Long education (≥3 years of post-secondary education but below PhD level). (2) The data on number of observations are the data used in the regressions reported in Tables A3 and A4. The educational profiles of natives and immigrants are similar to those based on data from 2001–2007. (3) For all tables, No. of obs.= Number of observations.

Table 4 Occupational profile of immigrants and natives, expressed as percentages (%) of the employee population and inventor populations aged 25–64 years for 1985–2007 and grouped by sector.

	All sectors		High-tech manufacturing		High-tech KIS		Other KIS		Low-tech sector	
Population	Natives	Imm	Natives	Imm	Natives	Imm	Natives	Imm	Natives	Imm
Low-skill occupations	48.0	59.0	49.0	64.4[a]	27.3	28.4	40.9	51.9[b]	58.4	70.8[c]
Legislators, senior officials & managers	6.9	3.9	8.3	4.0	7.1	4.8	4.6	2.4	9.1	5.6
Technicians & associate professionals	22.6	16.3	27.2	18.9	23.0	18.8	24.2	18.1	19.9	13.0
Professionals	22.6	20.9	15.4	12.7	42.6	48.0	30.3	27.7	12.7	10.5
Total	100	100	100	100	100	100	100	100	100	100
No. of obs.	16,581,136	1,971,968	1,208,341	174,608	924,455	96,323	7,576,495	957,429	6,871,845	743,608
Inventors										
Low-skill occupations	1.8	2.6	1.2	2.2	0.4	0.8	2.0	2.5	5.4	8.7
Legislators senior officials & managers	15.4	11.5	13.8	9.8	16.6	9.3	14.3	18.1	20.2	12.5
Technicians & associate professionals	17.0	11.7	21.8	15.9	5.2	3.0	12.0	8.1	21.8	21.2
Professionals	65.8	74.2	63.2	72.1	77.8	86.9	71.7	71.3	52.6	57.7
Total	100	100	100	100	100	100	100	100	100	100
No. of obs.	18,596	1,938	9,351	874	3,930	497	2,497	359	2,818	208

Notes. (1) The data for number of observations are the data used in the regressions reported in Tables 6 and 7. (2) [a] Compared with natives, the over-representation of immigrants in low-skill occupations in the high-tech manufacturing sector is mainly attributable to their over-representation in the following roles: craft and related trade roles (13.9% vs.14.5%), plant and machine operators and assemblers (8.3% vs. 24.5%) and elementary occupations (2.7% vs. 4.5%). In the 'other KIS' sector [b] and low-tech sector [c] their over-representation in low-skill occupations is attributable to their over-representation in the following roles: service workers and shop sales workers, plant and machine operators and assemblers and elementary occupations.

Table 5 Correlation of educational level and skill level of occupation.

	All			High-tech manufacturing			High-tech KIS			Other KIS			Low-tech sector		
Kendall’s tau-b	All	Natives	Imm	All	Natives	Imm	All	Natives	Imm	All	Natives	Imm	All	Natives	Imm
Population	0.55	0.56	0.48	0.54	0.55	0.49	0.49	0.50	0.47	0.61	0.62	0.55	0.43	0.44	0.34
Inventors	0.36	0.36	0.37	0.39	0.39	0.41	0.21	0.21	0.25	0.38	0.39	0.34	0.28	0.28	0.26

Notes: (1) Kendall’s tau-b, which can be used to measure the correlation between ordinal variables, is applied here (Gadermann, 2012). (2) Data on number of observations are the data used in the regressions reported in Tables 6 and 7. (3) The four skill levels of ***occupation*** (ordinal variable) are derived from the ten major ISCO-88 occupation groups. *Level 1* covers elementary occupations (code 9). *Level 2* covers basic administrative roles (code 4), service workers and shop and market sales workers (code 5), skilled agricultural and fishery workers (code 6), craft and related trades workers (code 7), plant and machine operators and assemblers (code 8) and armed forces (code 0). *Level 3* covers technicians and associate professionals (code 3). *Level 4* covers legislators, senior officials and managers (code 1) and professionals (code 2). (4) ***Educational level*** (ordinal variable) is divided into four levels here: *level 1* represents completion of secondary school; *level 2* represents < 3 years of post-secondary education; *level 3* represents ≥3 years of post-secondary education but below PhD level; *level 4* represents PhD education (also unfinished).

5 Methods

Two indicators are used to compare the patenting performance of immigrants and natives. First, I examine the patenting rate, based on unbalanced panel data for the general Swedish population between 1985 and 2007. The dependent variable is the number of patent applications per individual in year *t*. Random-effects negative binomial regressions with observed information matrix (oim) standard errors are applied in the regressions. Second, for inventors, I examine NFC for their patents in order to compare the quality of patents contributed by immigrants and natives. NFC is positively correlated with patent value (e.g. Harhoff et al., 2003; Hall et al., 2005; Gambardella et al., 2008) and it is the mostly commonly used indicator of patent value and is considered by some to be the best predictor of patent value (Lanjouw & Schankerman, 1999). NFC is calculated for the five-year period following the filing of the patent. Negative binomial models are used because NFC is both a count variable and highly over dispersed (zero citations: 49.3 %, standard deviation: 2.8, mean: 1.5). Since 46.4 % of inventors have been listed in more than one patent application, I control for intra-inventor correlation using clustered robust standard errors for inventors (Zheng & Ejermo, 2015). Table A2 presents the descriptive statistics for both dependent variables. The unit of analysis for the patenting rate is the individual whereas for NFC it is the patent–inventor combination[10] since the NFC varies within inventors.

Four models are used to examine the inventiveness of immigrants in all sectors on the basis of 2001–2007 data, as this is the period for which occupation data is available. Model 1 compares immigrants with natives whilst controlling for variance in *field of study*; *age*; *age^2*; *gender*; *firm size*; *industry of work*; *region of work*.[11] The analyses of NFC also control for variance in *technology field*; *application year*; *number of inventors per patent; number of inventors per patent for each of the following groups: native Swedes, mixed second-generation immigrants with one native and one non-native parent (*henceforth *mixed second-generation immigrants), second-generation immigrants with two foreign-born parents, first-generation immigrants*. Models 2 and 3 also include the variable *highest educational level* and *highest occupation,* which are expected to have especially strong effects on patenting and can vary considerably between natives and immigrants and across sectors (Battu & Sloane, 2002; Hunt, 2011). Model 4 is the

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[10] For example, a patent filed jointly by three inventors generates three patent-inventor observations. An inventor who contributed to four patents generates four patent-inventor observations.

[11] I also examine the effect of *years of residence* (data only available from 1961 onwards) on immigrants' probability of patenting in the various sectors (see Table A5). Overall, immigrants' probability of patenting increases with years of residence in Sweden.

full model, controlling for variance in educational level, occupation and all other control variables. Table A1 provides brief rationales for the inclusion of each control variable and an explanation of their structures. To check the robustness of the analysis I carry out a parallel analysis of data from the 1985–2007 period using the same models 1 and 2 as above but without including occupation (occupational data is not available for the period before 2001).

6 Empirical results

Table 6 compares the patenting rates of immigrants and natives. An incidence-rate ratio (IRR) greater than 1 indicates that immigrants are more likely to patent than natives; IRRs less than 1 that natives are more likely to patent than immigrants. The results show that, when variance in other variables is controlled, immigrants are less likely to patent than natives, but patenting varied considerably across sectors (see models 1 for all-sector and per sector). Immigrants' lower patenting rate is mainly attributed to data from the high-tech manufacturing sector and the low-tech sector, where immigrants are respectively 24.8% (p<0.01, model 2.1) and 33.1% (p<0.01, model 5.1) less likely to patent than natives. In the 'other KIS' sector, the patenting rate for immigrants is 6.3% lower than that of natives, although this result is not significant at 10% level (model 4.1). Controlling for variance in occupation results in reversal of the direction of the discrepancy in the above three sectors, which indicates that immigrants' occupational disadvantage is the main reason for their lower patenting rates (models 2.3, 4.3 and 5.3). This is because immigrants are concentrated in low-skill occupations where they are less likely to be involved patenting (Table 4); this is especially true for those working in the high-tech manufacturing sector.[12] In all above three sectors, controlling for variance in educational level increases the discrepancy between immigrants' and natives' IRRs by 9.9–15.2% (models 2.2, 4.2 and 5.2), which indicates that without an advantage in educational level, immigrants are even less likely to patent than natives. The full models, in which all control variables are held constant, show that immigrants working in the high-tech manufacturing and low-tech sectors have patenting rates that are respectively 10.7% (p<0.1, model 2.4) and 18.3% (p<0.05, model 5.4) lower than those of natives. The patenting rate for immigrants working in the 'other KIS'

[12] The robustness of this finding is checked by analyzing data from individuals only in high-skill occupations in the high-tech manufacturing, other 'other KIS' and low-tech sectors (results are available upon request). The results show that, when holding other variables constant, the patenting rates for immigrants in the above three sectors are respectively 13.9% (p<0.05), 19.2% (p<0.05) and 15.4% (not significant at the 10% level) higher than that of natives. When controlling for variance in educational level, however, immigrants in the high-tech manufacturing and 'other KIS' sectors become as likely to patent as natives, whereas immigrants in the low-tech sector have a patenting rate that is 18.2% (p<0.05) lower than that of natives.

is 3.6% lower than natives, but the difference is not significant at 10% level (model 4.4).

However, when holding other variables constant, the patenting rate for immigrants in the high-tech KIS sector is 16.7% ($p<0.05$) higher than that of natives (model 3.1). Controlling for variance in educational level reverses the direction of the discrepancy between immigrants and natives, and decreases the IRR by 21.1% and the significant difference between natives and immigrants disappears (model 3.2). This strongly indicates that immigrants have a better patenting rate than that of natives is mainly due to their superior educational level. Occupation does not appear to have had strong impact on the patenting activity of immigrants working in the high-tech KIS sector (model 3.3) since immigrants are highly concentrated in high-skill occupations as natives (Table 4) and the discrepancy in education-occupation match between immigrants and natives is fairly low in this sector (Table 5). This may be because the scientific and engineering knowledge required for working in the high-tech KIS sector is very specialized, which needs high match between education and occupation. Moreover, it is easy to be transferred across countries as it is not dependent on institutional or cultural knowledge and or on good language skills (Hunt & Gauthier-Loiselle, 2010). For example, Ericsson needs employees who are highly educated in engineering to work as technicians or professionals, but it does not matter much whether the employee is a native or an immigrant. With all control variables held constant, immigrants in the high-tech KIS are as likely to patent as their native counterparts (models 3.4).

The robustness of the analyses of patenting rate has been checked using data from a longer period, 1985–2007, which only examine the effect of education (see Table A3). The results are very similar to those obtained for 2001–2007 (compare models 1 and 2 in Table 6 and Table A3). This implies that the results for comparison of the patenting rate of immigrants and natives are robust both in short and long periods.

Table 7 shows that in most sectors, the NFC is similar for patents filed by immigrants and natives; the exception is the ‘other KIS’ sector (models 4.1–4.5) where immigrants’ patents have a higher mean NFC ($p<0.1$). These results are the same regardless of whether or not the control variables are included in the models and indicate that neither educational level nor occupation accounts for differences between natives and immigrants with respect to NFC per patent.

The robustness of the results has been checked by analyzing data from 1985–2007. The results are similar to those for the 2001–2007 data when using the same models (Table A4). In the high-tech manufacturing and low-tech sectors, immigrants and natives have similar NFC. The only difference is in the case of the ‘other KIS’ sector, where over the longer time period, the difference in favour of immigrants is no longer significant (compare models 4.1 and 4.2 in Table A4 and Table 7). In the high-tech KIS sector, the mean NFC is lower for immigrants’ patents than for those of natives (models 3.1–3.2 in Table A4). Over the longer period, educational level still does not account for differences between natives and immigrants.

The results relating to the control variables largely conform to expectations (detailed results are available upon request). Both educational level and occupation have a significantly positive effect on patenting performance, but the effect is much stronger on the patenting rate than that on the NFC per patent. Educational level is positively associated with both patenting rate and NFC per patent. However, patents filed by inventors with PhD education and inventors with only a first stage of tertiary education (i.e. long education) have similar NFC in all sectors. In the high-tech manufacturing and low-tech sectors, the patenting rates are higher for professional roles than other roles. However, in the high-tech KIS sector, legislators, senior officials and managers have a higher patenting rate than professionals, whereas in the ‘other KIS’ sector, no significant difference is found from the above two roles. When the analysis is limited to inventors, however, in each sector, occupation has small effect on NFC per patent and the difference between professionals and other occupations is small.

Table 6 Random-effects negative binomial regressions on the patenting rate of immigrants (omit: natives) among the general employee population aged 25–64 years, 2001–2007.

	All				High-tech manufacturing				High-tech KIS			
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4
	All_sim	All_edu	All_occ	All_full	HM_sim	HM_edu	HM_occ	HM_full	HK_sim	HK_edu	HK_occ	HK_full
Immigrants	0.863***	0.710***	1.165***	0.933*	0.752***	0.653***	1.093	0.893*	1.167**	0.956	1.198**	1.000
	(0.032)	(0.026)	(0.043)	(0.036)	(0.045)	(0.039)	(0.066)	(0.055)	(0.088)	(0.074)	(0.090)	(0.077)
Educational level	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Occupation	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes
Other control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.006***	0.007***	0.018***	0.017***	0.004***	0.017***	0.017***	0.042***	0.005***	0.001***	0.011***	0.002***
	(0.001)	(0.002)	(0.004)	(0.004)	(0.002)	(0.005)	(0.006)	(0.014)	(0.002)	(0.000)	(0.005)	(0.001)
Wald χ2	16,610	22,765	20,363	23,003	2,717	5,297	4,165	5,086	3,246	3,800	3,253	3,672
Log likelihood	−96,583	−91,751	−91,252	−88,917	−35,969	−34,398	−33,828	−33,204	−17,440	−16,998	−17,180	−16,878
No. of obs.	18,553,104				1,382,949				1,020,778			
No. of individuals	3,337,267				318,908				261,054			

Table 6 continued.

	Other KIS				Low-tech sector			
	4.1	4.2	4.3	4.4	5.1	5.2	5.3	5.4
	OK_sim	OK_edu	OK_occ	OK_full	LT_sim	LT_edu	LT_occ	LT_full
Immigrants	0.947	0.831**	1.159*	0.964	0.669***	0.517***	1.052	0.817**
	(0.077)	(0.068)	(0.095)	(0.080)	(0.059)	(0.043)	(0.086)	(0.070)
Educational level	No	Yes	No	Yes	No	Yes	No	Yes
Occupation	No	No	Yes	Yes	No	No	Yes	Yes
Other Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.000***	0.003***	0.002***	0.009***	0.000***	0.003***	0.001***	0.013***
	(0.000)	(0.002)	(0.001)	(0.005)	(0.000)	(0.001)	(0.001)	(0.006)
Wald $\chi 2$	3,635	4,978	3,827	4,819	3,170	5,470	5,482	6,342
Log likelihood	−17,257	−16,231	−16,741	−16,062	−25,212	−23,671	−23,253	−22,558
No. of obs.	8,533,924				7,615,453			
No. of individuals	1,805,230				1,654,857			

Robust standard errors in parentheses. ***p<0.01; **p<0.05; *p<0.1. Notes: (1) incidence-rate ratios are reported. (2) There are three dummies for educational level and four dummies for occupation, the same in Tables 7, A3 and A4. (3) The other control variables included here are: age; age^2; gender; dummies for field of study, firm size, region of work and industry of work.

Table 7 Negative binomial regressions on NFC for immigrant inventors (omit: natives) aged 25–64 years, 2001–2007.

	All				High-tech manufacturing				High-tech KIS			
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4
	All_sim	All_edu	All_occ	All_full	HM_sim	HM_edu	HM_occ	HM_full	HK_sim	HK_edu	HK_occ	HK_full
Immigrants	0.022	0.013	0.021	0.011	−0.048	−0.050	−0.050	−0.053	−0.100	−0.104	−0.095	−0.095
	(0.073)	(0.070)	(0.073)	(0.070)	(0.070)	(0.070)	(0.070)	(0.070)	(0.113)	(0.110)	(0.114)	(0.111)
Educational level	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Occupation	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes
Other control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.979***	0.934***	0.978***	0.887***	0.908*	0.894*	0.810*	0.713	−0.157	−0.292	−0.074	−0.212
	(0.346)	(0.336)	(0.356)	(0.344)	(0.468)	(0.469)	(0.471)	(0.471)	(0.551)	(0.559)	(0.548)	(0.557)
Wald $\chi 2$	3,390	3,381	3,403	3,398	2,215	2,205	2,233	2,215	713	711	715	713
Log pseudolikelihood	−27,872	−27,862	−27,871	−27,859	−13,349	−13,348	−13,347	−13,343	−6,491	−6,488	−6,485	−6,483
Pseudo R^2	0.050	0.050	0.050	0.050	0.053	0.053	0.053	0.053	0.067	0.067	0.068	0.068
No. of obs.	20,532				10,223				4,427			
No. of inventors	8,348				3,910				1,833			

Table 7 continued.

	Other KIS				Low-tech sector			
	4.1	4.2	4.3	4.4	5.1	5.2	5.3	5.4
	OK_sim	OK_edu	OK_occ	OK_full	LT_sim	LT_edu	LT_occ	LT_full
Immigrants	0.213*	0.203*	0.211*	0.207*	−0.165	−0.190	−0.163	−0.190
	(0.128)	(0.121)	(0.125)	(0.119)	(0.139)	(0.137)	(0.139)	(0.137)
Educational level	No	Yes	No	Yes	No	Yes	No	Yes
Occupation	No	No	Yes	Yes	No	No	Yes	Yes
Other control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.267*	1.067	1.304*	1.093	0.622	0.797	0.642	0.786
	(0.681)	(0.684)	(0.673)	(0.677)	(0.777)	(0.766)	(0.782)	(0.778)
Wald $\chi 2$	1,190	1,056	1,057	1,046	241	249	265	268
Log pseudolikelihood	−4,083	−4,081	−4,079	−4,077	−3,760	−3,754	−3,755	−3,751
Pseudo R^2	0.041	0.041	0.042	0.042	0.035	0.036	0.036	0.037
No. of obs.	2,856				3,026			
No. of inventors	1,565				1,490			

Robust standard errors in parentheses. ***p<0.01; **p<0.05; *p<0.1 Notes: (1) Coefficient results of clustered robust standard errors on inventors are reported. (2) The other control variables are: age; age^2; gender; dummies for field of study, firm size, industry of work, region of work, technology field and application years; the total number of inventors in a patent; number of inventors per patent for each of the following groups: native Swedes, mixed second-generation immigrants, second-generation immigrants with two foreign-born parents, first-generation immigrants. (3) Pseudo R^2 =1−log pseudolikelihood (full model)/log pseudolikelihood (constant-only model).

7 Conclusion

This study provides an overall picture of the distribution and inventiveness of immigrant employees as well as looking at the effects of educational level and occupation on inventive performance across multiple sectors. The results show that in general immigrants are less likely to patent than natives. This is mainly due to the contribution of immigrants working in the high-tech manufacturing and low-tech sectors, where their patenting rates are respectively 24.8% and 33.1% lower than that of natives. The patenting rate for immigrants working in the 'other KIS' sector is 5.3% lower than natives, but the difference is not significant. The main reason that immigrants in the above three sectors, especially in the former two, are less likely to patent than natives is because immigrants are concentrated in low-skill roles where involvement in patenting activity is less likely; This is the case despite immigrants' average educational level is higher than that of natives, which has a positive effect on decreasing the discrepancy of patenting rates between natives and immigrants. However, the patenting rate for immigrants working in the high-tech KIS sector is 16.7% higher than natives and this is largely attributable to the fact that they tend to be more highly educated than their native counterparts. Moreover, in the high-KIS sector, immigrants' high and similar concentration in high-skill occupations as natives enable them to have as high patenting rate as natives when other variables are held constant. Overall, immigrants' higher educational level increases their patenting rates by 11.6–21.1% relative to that of natives in each sector, but immigrants' high representation in low-skill roles reduces their patenting rates by 21.2–38.3% in each sector except in the high-tech KIS sector. In general, however, immigrants' and natives' patents are of similar quality in terms of NFC – although there is a small difference in the 'other KIS' and high-tech KIS sectors in short and long study periods, respectively. This is because both native and immigrant inventors tend to be highly educated and employed in high-skill roles. Therefore, there is only a small discrepancy between native and immigrant inventors with respect to education-occupation match. Compared with the general immigrant employee population, immigrant inventors are more highly educated and tend to be employed in roles requiring a higher level of skill.

The study indicates that the average educational level for immigrants working in the high-tech KIS sector is higher than immigrants working in other sectors (see Table 3) and the discrepancy between immigrants' and natives' education-occupation match is lower in the high-tech KIS sector than in other sectors (see Tables 4 and 5). This may be because working in the high-tech KIS sector usually requires special knowledge and skills, which are easier to be transferred across national boundaries than those in other sectors as they have lower requirement on country-specific human capital.

The lower patenting rate of immigrants (after controlling for variance in educational level) in all sectors except the high-tech KIS sector implies that immigrants are disadvantaged in terms of some unobserved form of human capital or that discrimination reduces their inventive productivity. It indicates even relatively high-educated immigrant employees (i.e. with at least secondary education or equivalent) have problems finding opportunities to make full use of their education and skills, which reduce their productivity in the host country. This conclusion is corroborated by the observed mismatch between educational attainment and occupation in the immigrant population. It is important to emphasize that failing to realize the full potential of immigrants damages the competitiveness of Swedish companies: they have not got the most out of the human capital their employees represent. Improving the match between immigrants' education and occupation would be a good way of ensuring that their skills are used more effectively. One way of doing this would be for governments, companies and immigrants to place more emphasis on increasing immigrants' country-specific human capital, such as language skills, especially in the case of those working in sectors that place a premium on such skills; another would be to reduce discrimination.

Appendix

Table A1 Control variables: rationale for inclusion and categorization.

Control variable	Rationale	Categories
Highest education level	Studies indicate that educational level has a positive effect on patenting performance (Hunt & Gauthier-Loiselle, 2010; No & Walsh, 2010; Hunt, 2011).	Three category variables : (a) Secondary or <3 years of post-secondary education (medium education); (b) ≥3 years of post-secondary education but below PhD level (long education, reference); (c) Any PhD education (also unfinished).
Occupation	Individuals in roles requiring a high level of skill are usually more knowledgeable and skilled than those in low-skill occupations and are therefore expected to show better patenting performance (Bosetti et al., 2012)	Four category variables : (a) Low-skill occupations; (b) Legislators, senior officials and managers; (c) Technicians and associate professionals; (d) Professionals (reference).
Field of study	Patenting activity can vary according to field of study (Hunt & Gauthier-Loiselle, 2010; Hunt, 2011), e.g. those who have studied science and engineering (S&E) are more likely to patent than those who have studied business.	Four category variables : (a) Engineering, manufacturing and construction (reference); (b) Science, mathematics and computing; (c) Health and welfare; (d) Other fields.
Age and age^2	Inventive productivity has a curvilinear relationship with age (Simonton, 2000; Jones, 2010; Jung & Ejermo, 2014).	Discrete data.
Gender	There are gender differences in patenting performance (e.g. Ding et al., 2006; Azoulay et al., 2007).	Dummy variable: (a) Male (reference); (b) Female.
Firm size	Small firms may be more constrained in their propensity to patent and may therefore focus on the most valuable inventions (No & Walsh, 2010). Large firms are more likely to apply for patents and are expected to produce higher-quality patents as they usually devote more resources to invention and can afford to hire employees with greater innovation skills.	Three category variables: (a) Small firms, coded 1 for 1–99 employees, 0 otherwise; (b) Medium firms, coded 1 for 100–499 employees, 0 otherwise (reference); (c) Large firms, coded 1 for 500 employees or more, 0 otherwise.
Industry of work	Inventive activity varies by industry (Helmers & Rogers, 2011). I include	38 categories following SNI92

Control variable	Rationale	Categories
	industry fixed effects to account for unobserved industry-specific effects.	
Region of work	Larger cities often offer economies of consolidation and hence more developed markets and more resources and opportunities for innovation than smaller cities (Orlando & Verba, 2005).	Three category variables: (a) Metro regions; (b) Urban areas; (c) Rural regions (reference).
Technology fields	Patents in technological fields in which many patents exist are likely to have a higher mean NFC than patents filed in sparsely patented fields (No & Walsh, 2010; Ejermo & Kander, 2011).	Five categories (Schmoch, 2008)[a]: (a) Electrical engineering (reference); (b) Instruments; (c) Chemistry; (d) Mechanical engineering; (e) Other fields.
Application year	Used to control for differences in citation behaviour over time and possible differences in the accumulation of citations over time (Sapsalis et al., 2006), although this is largely dealt with by counting citations over the five-year period immediately after filing.	Time dummy variables.
Total number of inventors in a patent	Used to control for the level of resources devoted to the research project which generates the patent, which is expected to be related to the quality of the patent (Sapsalis et al., 2006).	Discrete data.
Number of inventors per patent for each of the following groups: native Swedes, mixed second-generation immigrants, second-generation with two foreign-born parents, first-generation immigrants.[a]	Used to measure the cognitive diversity of inventors in a patent. Cognitive diversity may benefit a group if it is associated with greater diversity in ideas and perspectives and thus offers benefits in terms of problem-solving, generation of idea and patent quality (Nathan, 2014). Ethnic or cultural diversity may be a good proxy for cognitive diversity (Hong & Page, 2004).	Discrete data.

Note: [a] Only inventors identified in the patent are included in these figures. Zheng & Ejermo (2015) suggests that it is unlikely that there is any large sample selection issue in the data for unidentified inventors.

Table A2 Descriptive statistics for the dependent variables, 2001–2007.

Patenting rate	All		High-tech manufacturing		High-tech KIS		Other KIS		Low-tech sector	
	Natives	Imm	Natives	Imm	Natives	Imm	Natives	Imm	Natives	Imm
Mean	0.0012	0.0015	0.0067	0.0060	0.0044	0.0078	0.0004	0.0005	0.0008	0.0008
S.D.	0.5358	0.0636	0.1225	0.1196	0.1074	0.1480	0.0253	0.0345	0.0450	0.0546
Maximum	21	17	17	13	20	12	8	11	21	17
No. of obs.	16,581,136	1,971,968	1,208,341	174,608	924,455	96,323	7,576,495	957,429	6,871,845	743,608
NFC										
Mean	1.10	1.19	1.06	1.09	1.33	1.31	1.12	1.54	0.88	0.72
S.D.	2.11	2.33	2.19	2.12	2.45	2.78	1.79	2.59	1.46	1.17
Maximum	44	44	26	20	44	44	21	21	14	7
No. of obs.	18,596	1,938	9,351	874	3,930	497	2,497	359	2,818	208

Notes: (1) S.D.=Standard deviation; (2) Minimum=0 for each indicator and sector.

Table A3 Random-effects negative binomial regressions on patenting rate for immigrants (omit: natives) among the general employee population aged 25–64 years, 1985–2007.

	All		High-tech manufacturing		High-tech KIS		Other KIS		Low-tech sector	
	1.1	1.2	2.1	2.2	3.1	3.2	4.1	4.2	5.1	5.2
Immigrants	0.844***	0.733***	0.660***	0.612***	1.133**	0.975	0.944	0.848***	0.683***	0.588***
	(0.023)	(0.020)	(0.027)	(0.025)	(0.070)	(0.061)	(0.056)	(0.051)	(0.044)	(0.036)
Educational level	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Other control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.001***	0.000***	0.001***	0.001***	0.001***	0.000***	0.000***	0.002***	0.000***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Wald χ2	30,621	39,233	5,952	10,364	5,413	6,305	7,770	9,811	5,397	8,471
Log likelihood	−205,634	−198,616	−84,975	−82,194	−30,920	−30,197	−38,883	−37,252	−51,522	−49,311
No. of obs.	56,107,916		4,394,618		2,924,882		25,620,558		23,167,858	
No. of individuals	4,412,723		591,04		435,772		2,721,420		2,670,918	

Robust standard errors in parentheses. ***p<0.01; **p<0.05; *p<0.1. Notes: (1) incidence-rate ratios are reported. (2) The other control variables included here are the same as in Table 6.

Table A4 Negative binomial regressions on NFC for immigrant inventors (omit: natives) aged 25–64 years, 1985–2007.

	All		High-tech manufacturing		High-tech KIS		Other KIS		Low-tech sector	
	1.1	1.2	2.1	2.2	3.1	3.2	4.1	4.2	5.1	5.2
	All_sim	All_edu	HM_sim	HM_edu	HK_sim	HK_edu	OK_sim	OK_edu	LT_sim	LT_edu
Immigrants	−0.003	−0.013	0.019	0.018	−0.199***	−0.205***	0.163	0.144	−0.119	−0.139
	(0.050)	(0.047)	(0.048)	(0.048)	(0.072)	(0.071)	(0.117)	(0.108)	(0.098)	(0.093)
Educational level	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Other control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.015***	1.108***	1.451***	1.509***	−0.360	−0.363	1.166**	1.278**	−0.169	0.058
	(0.259)	(0.259)	(0.365)	(0.367)	(0.502)	(0.505)	(0.557)	(0.565)	(0.529)	(0.526)
Wald $\chi 2$	3,980	4,005	2,247	2,272	1,154	1,161	617	609	537	544
Log pseudolikelihood	−70,383	−70,333	−35,494	−35,478	−13,642	−13,634	−10,563	−10,557	−10,377	−10,361
Pseudo R^2	0.044	0.045	0.049	0.050	0.051	0.052	0.032	0.032	0.034	0.035
No. of observations	45,492		23,104		8,014		6,861		7,513	
No. of inventors	15,262		7,663		2,994		3,214		3,316	

Robust standard errors in parentheses. ***p<0.01; **p<0.05; *p<0.1. Notes: (1) Coefficient results of clustered robust standard errors on inventors are reported. (2) The other control variables included here are the same as in Table 7. (3) Pseudo R^2 =1−log pseudolikelihood (full model)/log pseudolikelihood (constant-only model). (4) The results for immigrant inventors are robust, based on comparisons with analyses of data from 1985 to 2004, 1985 to 2005 and 1985 to 2006. The exception is model 5.2.

Table A5 Odds ratios for the probability of patenting for the general employee immigrants (omit: natives) aged 25–64 years, grouped according to the duration of their residence in Sweden and by sector, 1985–2007.

Years of residence for immigrants	All	High-tech manufacturing	High-tech KIS	Other KIS	Low-tech sector
0–4 years	0.557***	0.564***	0.633***	0.475***	0.459***
	(0.036)	(0.057)	(0.081)	(0.077)	(0.071)
5–9 years	0.742***	0.632***	1.012	0.839*	0.551***
	(0.034)	(0.048)	(0.089)	(0.087)	(0.062)
10–14 years	0.767***	0.631***	0.930	1.125	0.618***
	(0.034)	(0.045)	(0.089)	(0.102)	(0.062)
15–19 years	0.743***	0.632***	1.071	0.784**	0.691***
	(0.034)	(0.047)	(0.107)	(0.087)	(0.069)
20–24 years	0.771***	0.749***	1.038	0.809*	0.636***
	(0.038)	(0.054)	(0.122)	(0.095)	(0.072)
25+ years	0.859***	0.825***	1.106	0.997	0.700***
	(0.025)	(0.035)	(0.083)	(0.063)	(0.045)
No. of obs.	56,095,149	4,388,676	2,924,469	25,617,134	23,164,870
No. of individuals	4,410,826	353,932	204,857	1,949,620	1,902,417
Wald $\chi 2$	139,030	31,172	17,362	27,489	26,707
Log likelihood	−205,619	−81,849	−29,264	−39,129	−52,406
Pseudo R^2	0.253	0.160	0.229	0.260	0.203

Robust standard errors in parentheses. ***p<0.01; **p<0.05; *p<0.1. Notes: (1) odds ratios are reported. (2) The other control variables included here are the same as in Table 6. (3) Probability of patenting is set up as a dummy variable, coded as 1 if an individual has been listed as an inventor on at least one patent in year t and as 0 otherwise

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Paper IV

Liberalization of European migration and the immigration of skilled people to Sweden

Olof Ejermo and Yannu Zheng

Abstract

Migration policies can have a strong impact on the selection of immigrants, who in turn can affect the host country's innovation development. This paper examines the effects of the liberalization of migration on the skill composition of immigrants from the EU-15 to Sweden after the inception of the European Economic Area (EEA) in 1994. We examine its effect on immigrants' educational levels and probability of becoming an inventor, comparing immigrants from the EU-15 with those from other regions in difference-in-differences regressions. The results show that, when compared with immigrants from 'Other developed regions', the liberalization of migration had a negative effect on educational profile of new EU-15 immigrants in the short run, but there is no such effect in the long run; moreover, the liberalization of migration has no systemic effect on the EU-15 immigrants' probability of becoming an inventor both in the short and long run. These patterns are consistent with the theoretical implication that reduction in migration costs associated with the EEA mainly stimulated migration from the lower end of the education distribution.

Keywords Human capital · Immigration · Innovation · Selection · Skill level

JEL classification J15 · J24 · N30 · O31

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1 Introduction

Migration policies can have a strong impact on which immigrants choose to move to another country and their skill levels, whether intended or not (Bianchi, 2013). These policies can in turn affect innovation development in the country to which those immigrants move. For example, Kerr & Lincoln (2010) find that higher levels of entry by those holding an H-1B visa[1] , increases employment among immigrants in science and engineering as well as patenting by inventors with surnames that appeared to be Indian and Chinese. Although some researchers have tried to investigate the impact of changes of migration policy on the composition of skills among immigrants, most of them focus on the impact of specific policy changes and immigrant groups (Chen, 2005; Kato & Sparber, 2013). Empirical evidence on the impact of more general liberalization of migration policies is still scarce.

One of the biggest changes in migration policy history in Europe is the liberalization of migration through the European Economic Area (EEA) agreement between the European Union (EU) and the European Free Trade Association (EFTA) countries in 1994. The agreement, which originally involved 17 countries, has grown in importance with the large expansion of the EU. In short, the EEA allows for the free movement of individuals among its member countries. However, little is known about how the EEA has affected the skill composition of immigrants in the member countries. We only find one earlier study on this topic by Huber & Bock-Schappelwein (2014). In examining the case of Austria, they find that the EEA has a positive impact on the educational level of permanent migrants to Austria.

However, it is far from clear that the results in Austria can be generalized to other EEA countries. In particular, we examine the case of Sweden. At first glance, the similarities between Sweden and Austria are striking. They have a similar population size and proportion of foreign born as well as generous welfare benefits (OECD, 2016a; 2016b).[2] High welfare ambitions in both Austria and Sweden raise rewards to low-skilled workers for migrating to those countries over other countries. However, the countries also differ substantially in particular when it comes to the immigrants' country of origin.[3]

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[1] H-1B visa is a temporary work visa in the United States (US) for highly skilled immigrants with at least a bachelor's degree (or equivalent).

[2] In 2016, the population was 9.9 million in Sweden and 8.6 million in Austria (Countrymeters, 2016; Statitics Sweden, 2017); in 2013 the proportion of foreign born was 16.0% in Sweden and 16.7% in Austria (OECD, 2016a). In 2014, Sweden devoted 28.1% of its gross domestic product (GDP) to social expenditures; for Austria, the corresponding figure was 28.6% (OECD, 2016b).

[3] For example, by the end of 2011, immigrants in Austria originated mainly in Germany, the former Yugoslavia, and Turkey (MMWD & South East Europe, 2013). However, for Sweden, the countries that sent the most migrants are Finland, Iraq, Poland, and Iran

The effect of liberalization of migration has a theoretically ambiguous effect in terms of the selection of immigrants at different skill levels. Theory highlights the distribution of skills and rewards to skills in receiving and sending countries, as well as migration costs that in turn determine the self-selection behavior of migrating individuals under free migration (Borjas, 1987; Grogger & Hanson, 2011).

In this paper, we explore this issue based on a unique database that links register data in the general population to inventors in Sweden (Jung & Ejermo, 2014; Zheng & Ejermo, 2015). We examine the effect of the full liberalization of migration on the skill composition of immigrants in Sweden who originated in the EU-15. [4] We exclude Denmark and Finland from the treatment group, as they have been part of a free-labor mobility agreement among the Nordic countries since 1954. Sweden's accession to the EEA meant that all EU-15 citizens could move to Sweden freely. This is the first study to examine the change in migration policy for immigrants with different educational levels and its impact on immigrants' inventive performance. We use difference-in-differences (DiD) estimations to evaluate the impact of liberalization on the skill composition of immigrants. This method means that the treatment group (i.e. EU-15 citizens) is compared in terms of skill composition (education, probability of becoming an inventor) both against themselves before treatment and relative to the trend in the control groups.

The results of our study indicate that the EEA had short-term negative effects on the selection of immigrants from the EU-15 with respect to their educational level. This is manifested as both an increased probability that EU-15 immigrants had a low level of education and a decreased probability that they were highly educated. However, it is also clear that those effects are temporary, as estimated lead and lag models show the effect to be statistically significant only in the first years after the application of liberalization. With respect to patenting, we see no systemic effects in our main interested result that using 'Other developed regions' as the control group and after controlling for variance in other variables. Our results are consistent with the theoretical assumption that negative selection driven by reduction in migration costs mainly applies to low-skilled immigrants.

The rest of the paper is structured as follows. Section 2 summarizes Swedish migration history. Section 3 reviews previous studies examining the impact of migration policy on the selection of immigrants. Section 4 discusses the theoretical background. Section 5 presents the databases and descriptive statistics. Section 6 describes the methods used. Section 7 reports the results of the empirical analysis. The final section concludes the results from the study.

(Statistics Sweden, 2016). In Austria, 89% of the foreign born originated in European countries, while the corresponding figure in Sweden was only 49% in 2015 (OECD, 2016c; Statistics Sweden, 2016).

[4] See the Appendix for a country list and descriptive information of EU-15 and EEA countries.

2 The Swedish migration experience

Immigration to Sweden started to take off after World War II. In the 1950s and 1960s, highly economic growth led to large inflow of immigrants for work reasons, who mainly originated in Nordic and Southern European countries (Bevelander, 2000). In 1954, the five Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden) enacted free movement in the entire area (Bevelander, 2000; Stalker, 2002). This treaty allowed large-scale emigration from the other Nordic countries to Sweden, and especially Finns emigrated (Westin, 2000; Helgertz, 2010). However, labor migration from non-Nordic countries came to a halt in the mid-1970s following an economic slowdown, and refugee migration started to dominate immigration flows to Sweden, a trend that continued until recently.[5] The European integration process started to change this, first with the implementation of the EEA in 1994, a free trade agreement that allows free mobility between the EFTA and the EU member countries; then with Sweden's membership in the EU along with Finland and Austria in 1995. The EEA can be characterized as a mark of change in policy toward more labour immigration, reinforced through EU membership.

Although total intra-EU migration comprised a small share (less than 2 percent) of total migration in the 1990s and 2000s (Cerna, 2009), the free movement agreement may still have changed the composition of immigrants in member countries. This seems plausible in the case of Sweden because the composition of immigration may have changed as immigration policies in Sweden before 1995 mainly favored refugees and family-reunification movers. In Sweden, immigrants from the EU-15 accounted for 8–12 percent of all new immigrants between 2000 and 2015 (Statistics Sweden, 2016).

This trend toward a more integrated European labor market has continued with the enlargement of the EU to include Eastern European countries beginning in 2004 (EU-27) and special expert tax systems in Sweden aimed at attracting highly skilled labours (Mahroum, 2001; Forskarskattenämnden, 2013). In 2004 the EU expanded dramatically, with 10 new member countries, and Sweden was one of the few EU-15 countries (the other two were the UK and Ireland) that allowed free immigration for the new member countries (Ruhs, 2016). This, however, had only a modest effect on immigration, as, according to Gerdes & Wadensjö (2008), about 10,000 migrant workers came to Sweden from the new EU member states.

[5] The Swedish government has tighten the criteria for obtaining asylum in Sweden since June, 2015 because the large inflow of refugees had generated serious social and financial problems. However, even with the new restrictions in place, Sweden still attracts large numbers of refugees.

3 Literature review

Many studies examine how changes in migration policies have induced migration shifts and the results are very ambiguous. For example, Mayda (2010) find that migration quotas matter because they mitigate supply-side effects. Giordani & Ruta (2010) argue that restrictive immigration policies tend to worsen the skill composition of immigrants. Djajic (1989) indicates that, by relaxing qualitative restrictions (i.e. admission is based largely on skills) on immigration, the labor-importing country may in fact improve the quality of its labor force and reduce the flow of migrants across the border. Kato & Sparber (2013) find that restrictive immigration policy (tightening of H-1B visa grants for prospective undergraduate students) disproportionately discourages high-ability international students from pursuing education in the US. By contrast, Chen (2005), based on a survey of Chinese graduate students, find that master-degree students who intended to migrate to the US are likely to be negatively self-selected in a less restrictive migration regime and positively self-selected in a more restrictive regime. Borjas (1993) argues that the Canadian point system does not help in attracting more highly skilled workers from a particular source country compared with the US, which does not use this kind of migration policy. However, it alters the national-origin mix of the immigrant flow, which reduces the proportion of immigrants from regions that generate flows of those who are low skilled. This explains why, on average, immigrants in Canada are more highly skilled than those in the US.

However, empirical evidence on how liberalization of migration affects the skill composition of immigrants is very sparse. We are aware of only two studies on European migration. The first example is on Austria. Based on survey data on immigrants who arrived between 1988 and 2002, Huber & Bock-Schappelwein (2014) find that after Austria became a member of the EEA in 1994, the share of permanent migrants from the EEA to Austria with low educational levels dropped compared to the change in the share of low-educated permanent migrants from other countries. They therefore argued that liberalizing migration may be an effective way to improve the skill structure of immigrants in countries that have a high share of low-skilled immigrants. By contrast, in the second example, Beerli & Indergand (2014) find that the abolition of quotas for workers from European countries through a bilateral agreement with the EU in 2002 had a small but negative effect on the educational quality of immigrants to Switzerland. They attribute this decline in educational attainment for immigrants to more selective immigration policies before 2002, which in turn stem from higher returns to education in Switzerland. In sum, the differing experiences of the two countries reveal that pre-reform migration patterns are quite important for understanding how liberalization changes migration flows.

4 Theories on immigration

The workhorse model for understanding selection patterns in immigration flows is Borjas's (1987) model of self-selection of migrants. In its basic construction, this model assumes that the costs of migration are positively related to the skill level. The model predicts that immigrants who move for work reasons will tend to move to a country (henceforth, host or destination country) that offers wages above those of their country of origin (henceforth, home country) corresponding to their skill levels, if the host country positively selects individuals, and if moving costs are low. The two other cases analyzed by Borjas (1987) are probably more in line with how we tend to think of Sweden as a country of immigration. Negative selection for work reasons is likely to occur, at least in part, because low-skilled people are (generally) rewarded more generously in Sweden than in the other EU-15 countries. Negative selection requires immigrants to be from the lower end of the distribution in both countries. In the third case, called refugee sorting, immigrants are from the lower end of the distribution in their home countries but end up at the higher end in the destination country. In other words, refugees may well be highly educated in their home country but are rewarded badly there, and they would be rewarded better in their destination country. At least two objections can be raised to the Borjas (1987) model. Let us first discuss why we think that the process of "refugee sorting" is not relevant in the way that Borjas discussed with regard to Sweden and then the critical assumption of moving costs that increase according to the skill level.

The "sorting" of refugees to Sweden is arguably not based primarily on an evaluation of different alternatives, including potential income distributions, among which a refugee chooses. Instead, most refugees have to accept whatever possibility they are offered. For instance, tens of thousands of Chileans fleeing their country after the military coup in 1973 were allowed permanent residency in faraway Sweden. It is a priori not clear that this type of selection draws from either the top or bottom of the income distribution. Moreover, importantly for the case of EU-15 countries, refugee immigration was nonexistent in our study period.

With respect to our assumptions on the cost of immigration, we first need to recognize that the Swedish income distribution is more compressed than that of the majority of other countries in the world, including the EU-15 countries. Therefore, negative selection of immigrants to Sweden seems to be the main theoretical implication of the Borjas' (1987) model, given an assumption of increasing costs by skill level and free mobility. However, this assumption about costs is debatable. Let us further discuss our view on this.

The nature of the cost of migrating to Sweden and its relation to skills before and after the EEA are important because they influence the payoff involved in moving. The distribution of the cost of moving for different skill levels before the EEA and the change in the distribution of the cost reductions implied by the EEA may differ by skill level and is important for the outcome. We can divide the cost of moving into the actual moving costs, cost in terms of social relationships and networks in the home country, and the cost of adapting to a new country, including learning the language.[6] For citizens from the EU-15, it is hard to see that actual moving costs and social relationship costs are systematically related to the skill level. By contrast, learning Swedish is probably easier for people in the highly skilled part of the distribution; English-language skills, which usually suffice to get around in Swedish society, are also generally positively related to skills. Those costs are, if anything, negatively related to skills. However, highly skilled work also often demands knowledge about institutions and may require more investment in education to adapt to the new country. Such institutional costs are likely to increase by skill level. Total adaptation costs may not be fully known before someone moves but surely play a role in the decision to move. Whether language and institutional costs on balance net out may vary from one individual to another. On the whole, it seems plausible that migration costs to Sweden are not systematically related to skills.

Importantly, the implication that costs rise with the skill level also seems to be at odds with generally observed migration patterns. They tend to show that selection is overall positive, even in cases where one would observe more negative selection patterns, according to empirical data on world migration flows reported by Grogger & Hanson (2011). Grogger & Hanson (2011) develop an alternative model in which moving costs are considered fixed and unrelated to the skill level. The model distinguishes between low-skilled (*L*) and highly skilled (*H*) workers, where wages (w) are specified as:

$$\ln w_k^L = \mu_k, \tag{1}$$
$$\ln w_k^H = \mu_k + \delta_k, \tag{2}$$

where μ_k is a constant and δ_k is the wage premium associated with high skills in country k. L means low-skilled and H means high-skilled. The fixed cost of moving from home country 0 to k is C_{0k}. In the model, utility is linearly and positively dependent on net income, such that for skill level $j = L, H$:

$$U_{i0k}^j = \alpha\left(w_k^j - C_{0k}\right) + \varepsilon_{i0k}^j. \tag{3}$$

[6] We note that such adaptation or assimilation costs could be part of the story or not, depending on the length of time an immigrant spends in the destination country. Note that the opportunity cost of losing a job is already incorporated in the net benefit calculation of the model and is not part of the "costs" as such.

Assuming that the error terms ε_{i0k}^{j} are independent and identically distributed (i.i.d.) with an extreme value distribution, the (natural) log odds ratio of choosing country k over 0, following McFadden (1974), is

$$\ln \frac{p_{0k}^{j}}{1-p_{0k}^{j}} = \alpha\left(w_k^j - w_0^j\right) - \alpha C_{0k.} \tag{4}$$

The selection pattern is obtained as the difference in log odds ratios of Equation (4) among skill groups:

$$\ln \frac{p_{0k}^{H}}{1-p_{0k}^{H}} - \ln \frac{p_{0k}^{L}}{1-p_{0k}^{L}} = \alpha\left[\left(w_k^H - w_0^H\right) - \left(w_k^L - w_0^L\right)\right], \tag{5}$$

In Equation (5), fixed costs are eliminated. This means that positive selection takes place *if the absolute wage premium difference is positive*. If average wages are the same, there is positive selection if $\delta_k > \delta_0$, but Equation (5) can still imply positive selection even if $\delta_k \leq \delta_0$ if μ_k is much larger than μ_0. Equation (5) may somewhat realistically capture a *cross-sectional* perspective after the EEA.

In our empirical analyses, we implicitly evaluate a change in costs induced by EEA membership. Arguably, the effects of the EEA should be understood as increasing the possibility of going to Sweden without visa requirements. It can be argued that, before the EEA, obtaining a visa was relatively easier ("low cost") for highly skilled people than low-skilled ones who wanted to go to Sweden. This interpretation makes the Swedish case different from that of Austria. Austria seems to have had "low costs" in its attraction of low-skilled workers from the EU-15 before the accession to the EEA (Huber & Bock-Schappelwein 2014). The argument for why a rise in immigrants' skills followed from the EEA is Austria had a relative "saturation" of low-skilled immigration before the EEA. Based on the Borjas' (1987) model, one would expect a decline in the level of skills of immigrants in Sweden, because there was no such composition of low-skilled migration as in Austria, and because the costs probably fell more for the low skilled.

It seems likely that moving costs were lower for the highly skilled before the EEA (because of visa requirements that existed). We can easily accommodate this assumption by changing the cost structure in Equation (3) to

$$\bar{U}_{i0k}^{j} = \alpha\left(\bar{w}_k^j - \bar{C}_{0k}^j\right) + \bar{\varepsilon}_{i0k}^{j}, \tag{3'}$$

So that costs differ by j , denoted $\bar{C}_{0k}^{j}$, and we use a bar above variables to denote the pre-EEA situation and let the previously defined equations describe the post-EEA situation. We assume that $\bar{C}_{0k}^{L} > \bar{C}_{0k}^{H}$. Furthermore, Equation (5) is modified as:

$$\ln\frac{\bar{p}_{0k}^{H}}{1-\bar{p}_{0k}^{H}} - \ln\frac{\bar{p}_{0k}^{L}}{1-\bar{p}_{0k}^{L}} = \alpha\left[\left(\bar{w}_{k}^{H} - \bar{w}_{0}^{H} - \bar{C}_{0k}^{H}\right) - \left(\bar{w}_{k}^{L} - \bar{w}_{0}^{L} - \bar{C}_{0k}^{L}\right)\right]. \quad (5')$$

The difference between Equations (5) and (5’) shows the change in selection patterns:

$$\alpha[(w_{k}^{H} - w_{0}^{H}) - (w_{k}^{L} - w_{0}^{L})] - \alpha[(\bar{w}_{k}^{H} - \bar{w}_{0}^{H} - \bar{C}_{0k}^{H}) - (\bar{w}_{k}^{L} - \bar{w}_{0}^{L} - \bar{C}_{0k}^{L})] = \quad (6)$$

$$\alpha\{[(w_{k}^{H} - w_{0}^{H}) - (\bar{w}_{k}^{H} - \bar{w}_{0}^{H})] - [(w_{k}^{L} - w_{0}^{L}) - (\bar{w}_{k}^{L} - \bar{w}_{0}^{L})] + (\bar{C}_{0k}^{H} - \bar{C}_{0k}^{L})\} =$$

$$\alpha[\Delta W_{0k}^{H} - \Delta W_{0k}^{L} + (\bar{C}_{0k}^{H} - \bar{C}_{0k}^{L})],$$

Where ΔW_{0k}^{j} is the change in the wage differential for j-skilled workers following the reform and in comparison to other countries. This equation states that the change in selection is (more) positive if the wage differential for highly skilled workers becomes more pronounced in the destination country over time and if the returns to low-skilled workers decrease in the destination country relative to the home country over time. Although marginal taxes in Sweden fell in the early 1990s, they have risen somewhat since, such that Sweden has one of the highest marginal tax rates in the world (KPMG, 2012). This means that it is hard to argue that net wages for highly skilled workers (ΔW_{0k}^{H}) have generally increased for those who go to Sweden compared to other countries in the EEA. Equation (6) therefore indicates that $\Delta W_{0k}^{H} - \Delta W_{0k}^{L}$ either has gone down or is close to zero. That means that pre-EEA moving costs are critical to the results. Since we have argued that $(\bar{C}_{0k}^{H} - \bar{C}_{0k}^{L}) < 0$, this suggests a more negative selection change following the EEA.

Based on these arguments, we expect that the average skill level among immigrants from the EU-15 to Sweden declined after 1994, when Sweden became a member of the EEA.

5 Data and descriptive analysis

5.1 Variable construction

This paper takes advantage of a unique database that links the general population with inventors in Sweden from 1985 to 2007 (Jung & Ejermo, 2014; Zheng & Ejermo, 2015). We focus on those who migrated at the age of 18−64 in the period

1990−2007 (1985−2007 in the descriptive analysis) because they are potentially in the workforce. Table 1 shows the employment rate of immigrants who gained employment within two years after they migrated to Sweden (considered economic migrants) by their regions of origin and years of migration. It indicates that the employment rate for immigrants from the EU-15 is stable at around 62−66 percent within two years of migration.

Table 1 Employment rates (%) for immigrants who migrated at ages 18−64 and were employed within two years after they migrated to Sweden, by year of migration and region of origin.

	1990−1997		1985−2007	
Region of origin	1990−93	1994−97	1985−1993	1994−2007
EU-15	65.5	62.3	63.7	62.7
Other developed regions	68.1	52.8	61.6	58.3
All other regions	41.3	33.1	37.9	43.1
The rest of Europe + former SU	32.5	23.0	26.9	42.0

Source (for all table and figures): Statistics Sweden and CIRCLE data on inventors.

Notes: (1) immigrants who get employed within two years after migration are considered economic migrants. We use employment data on two years instead of one year after migration because the data on one year after migration are usually not well registered. Employment rate = No. of population in employment/Total no. of working-age (18−64) population. (2) former SU = former Soviet Union. (3) For all table and figures: includes only immigrants who migrated at ages 18–64.

We use education data to proxy for skills at the time of immigration. As data on immigrants' educational level at the time of migration are not well registered, we imputed the missing data as follows. First, if immigrants have not enrolled in any education in Sweden after they arrived, we assumed their educational levels at the time of migration are the same as the first record shown in later years. Second, if immigrants enrolled in secondary high school education in Sweden after they arrived, we assumed they had primary education before they arrived. Third, if immigrants enrolled in post-secondary high school (≥13 years of schooling) after they arrived, we expected that they had a secondary high school education (10−12 years of schooling) before they arrived. In total, we imputed 42 percent of data on educational level for immigrants at the time of migration.

We measure the skill composition of immigrants in two ways. First, we compare the education structure of immigrants before and after the liberalization on three educational levels. They are: (a) the low education: immigrants who arrived with education that ends up at primary school (≤ 9 years of schooling); (b) the middle education: those who arrived with a secondary school education; (c) the high education: those who arrived with a post-secondary school education. In addition, we also use inventor data to investigate the effect of the liberalization reform on skills, which has not been done before. In this way, we investigate the probability that an immigrant will become an inventor between the time of their immigration and the end of the study period (i.e. 2007). That is, if an immigrant is listed as an inventor on at least one patent application to the European Patent Office (EPO) at any time since the time of his/her migration until 2007, s/he is considered an inventor.

When it comes to data on origin of immigrants, we can only observe data on the broad regions of origin rather than the country. Knowing the region of origin would also have been useful in order to control for or examine region-specific effects. The division of region of origin and inflow of immigrants for each group are as follows:

(a) *The EU-15*. Finland, Denmark, and Sweden (the destination country) are excluded because they are part of the Nordic country, where free movement policy enacted in 1954. The EU-15 is our treatment group affected by the migration reform in 1994.
(b) '*Other developed regions*'. This includes the other Nordic countries (Finland, Denmark, Norway, and Iceland), North America (Canada, the US, Central America, and the Caribbean countries), and Oceania.
(c) '*All other regions*' (excluding the rest of Europe and the former Soviet Union (SU)). This group includes 'Other developed regions' (group b) as well as Asia, Africa, and South America.
(d) *The rest of Europe and the former SU*.

5.2 Trends in immigration group composition

Figure 1 shows number of immigrants over time by region of origin as defined above. We can observe that:

First, migration from the EU-15 to Sweden shows a stable increase over the whole period. This increase took place after 1995. In fact, immigration from the EU-15 more than doubled by 2006.

Second, the migration trend for the 'Other developed regions' is also quite stable and largely in line with that of the EU-15. The main difference is that during the period 1988−1990, a relatively large inflow of immigrants from Denmark and Norway occurred (Statistics Sweden, 1989: p.172–173; 1990: p.174–175; 1991: p148–149). We use this group as our benchmark comparison to that of the EU-15.

Third, migration from 'All other regions' shows a high level of fluctuation. Therefore, the group of 'All other regions' is not a good choice for comparison. However, we use it as a robustness check to compare with the results when we only use the 'Other developed regions' as a baseline. The line for 'All other regions' (which also includes 'Other developed regions') has an even sharper spike in 1989. This is because of a large inflow of refugees from developing countries, such as

Chile and Lebanon (Statistics Sweden, 1989: p.172–173; 1990: p.174–175; 1991: p148–149). The boom in 2006 is mainly due to large increases in refugees from countries such as Iran, Iraq, Lebanon, and Somalia (Statistics Sweden, 2016).

Finally, for the rest of Europe and the former SU we see that, as in Austria (Huber & Bock-Schappelwein, 2014), a massive inflow of immigrants took place in 1993 and 1994 because of the large number of refugees that resulted from the breakup of Yugoslavia and the ensuing wars. Immigrants from the former SU also doubled in 1991 compared with 1990 because of the breakup of the SU (Statistics Sweden, 2016). This influx of immigrants may have differed substantially from other immigrant flows in terms of motivation and education.[7] It is clear that refugee waves can distort the interpretation of policy reforms that we study. Therefore, we exclude this group in the regression analyses when compared with immigrants from the EU-15.[8]

Figure 2 shows the proportion of low-, middle- and high-education levels the year of immigration for each immigrant group by region of origin. For comparison, it also shows the proportion of each educational level for the Swedish-born population. Subgraph A shows that the share of the low educated drops markedly for all groups over time. It is clear that the developed regions have lower shares of the low educated. The EU-15 experienced a marked fall in the share of the low educated in the 1989−1993 period, followed by a small hike in the 1994−1995 period, seemingly corroborating our theoretical prediction. There is a similar trend for immigrants from the rest of Europe and the former SU in those years. It is possible that those changes are due to the refugee crisis in the former Yugoslavia, democratization of formerly communist regimes in Eastern Europe, and the loosening of emigration restrictions on those regions.

Like Graph A, Graph B shows declining trends with respect to the share of middle-educated immigrants for each immigrant group. By contrast, the trend in middle-educated Swedish born is rising. This is explained by the fact that nowadays almost every young person has had a secondary (gymnasium) education, which is now seen as almost a prerequisite for getting a job. Simultaneous with a large increase in immigrants in 1993 and 1994, the share of middle-educated immigrants in 1993 from the rest of Europe and the former SU experienced a spike. This group maintained a stable, relatively high level through 1998, before falling in 1999−2003, and then showed an increase. Among immigrants from ‘Other developed regions’ and ‘All other regions,’ the years 1992−1995 displayed a U-shaped pattern.

[7] Table 1 shows that immigrants from the rest of Europe and the former SU were less likely than other groups to be employed within two years after migration. Graphs A and B in Figure 2 show that the low- and middle-educated immigrants in this group increased rapidly in 1994.

[8] Results of robustness checks (available upon request) in which include migrants from the rest of Europe and the former SU do not change results substantially.

However, for the EU-15, the share consistently decreased until 2001, after which a slight increase can be observed.

Unlike Graphs A and B, Graph C shows generally growing trends in the shares of the highly educated in each group over the whole period. The share of the highly educated in each immigrant group was higher than for the Swedish population after 1990, seemingly reinforcing Grogger & Hanson's (2011) conclusion that emigrants generally draw from the highly educated part of the distribution. Again, the rest of Europe and the former SU showed a somewhat irregular pattern, increasing sharply in 1991−1992 and then dropping sharply in 1993 and 1994. The highest share of the highly educated immigrant group comes from the EU-15. Interestingly, this group showed a decline share of highly educated population in the period 1993−1995, but a decline is also observed for the 'Other developed regions' and 'All other regions' in the period 1994−1995. These patterns suggest that other things were going on at the period of observation and reinforces the need to control for underlying trends.

In sum, the descriptive analyses suggest that there is some correlation between the inflow of immigrants and their educational level to the migration policy to some extent. When the migration policy is less strict, more immigrants flow in, and, on average, immigrants' educational level seems to be lower. This can be seen in the EU-15 when a comparison is made of before and after its accession to the EEA in 1994, and it is similar for the rest of Europe and the former SU during 1993 and 1994 as well as for 'Other developed regions' and 'All other regions' in 1989.

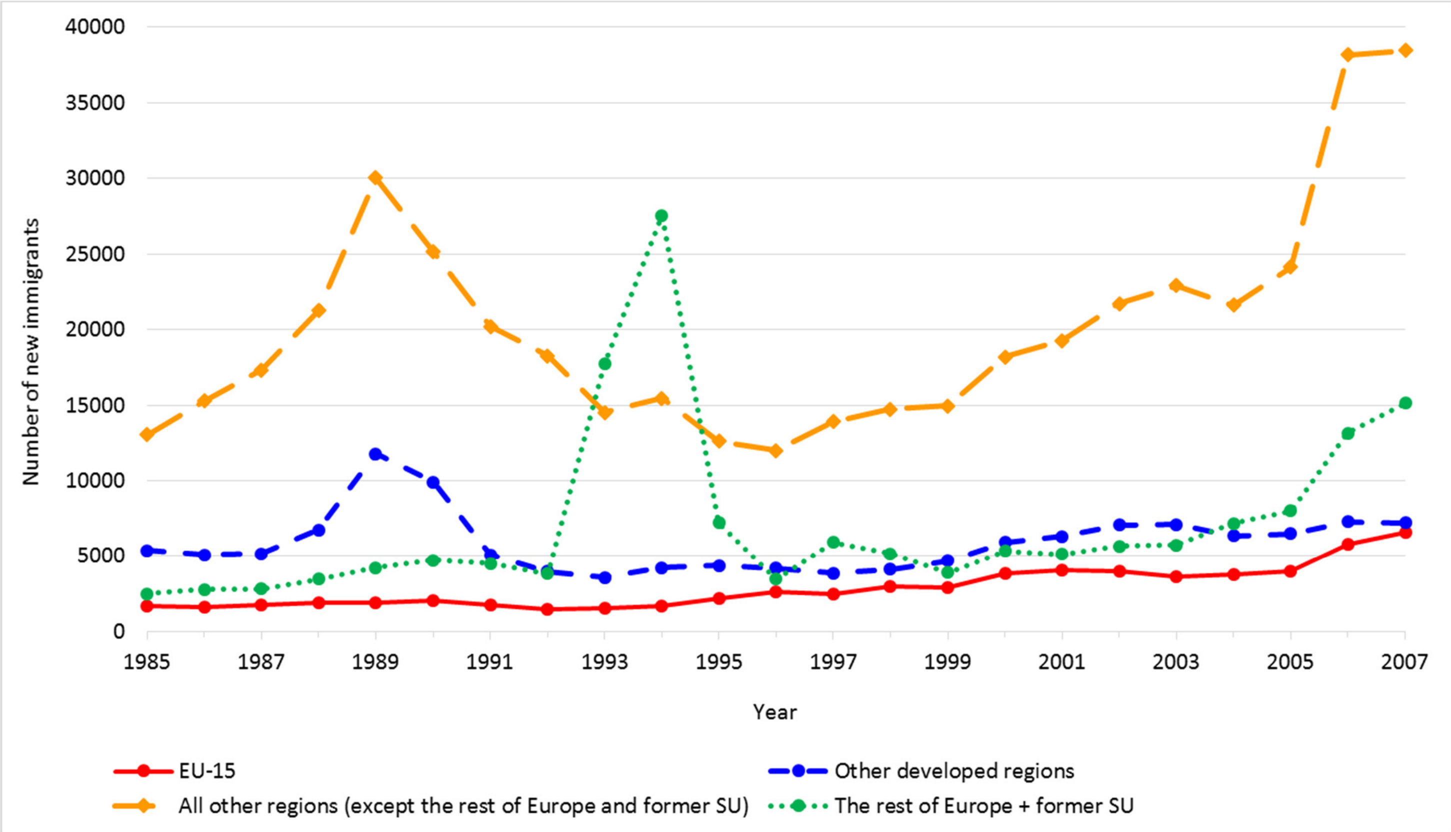

Figure 1 Foreign-born residents who migrated at ages 18−64 in Sweden by year of migration and region of origin.

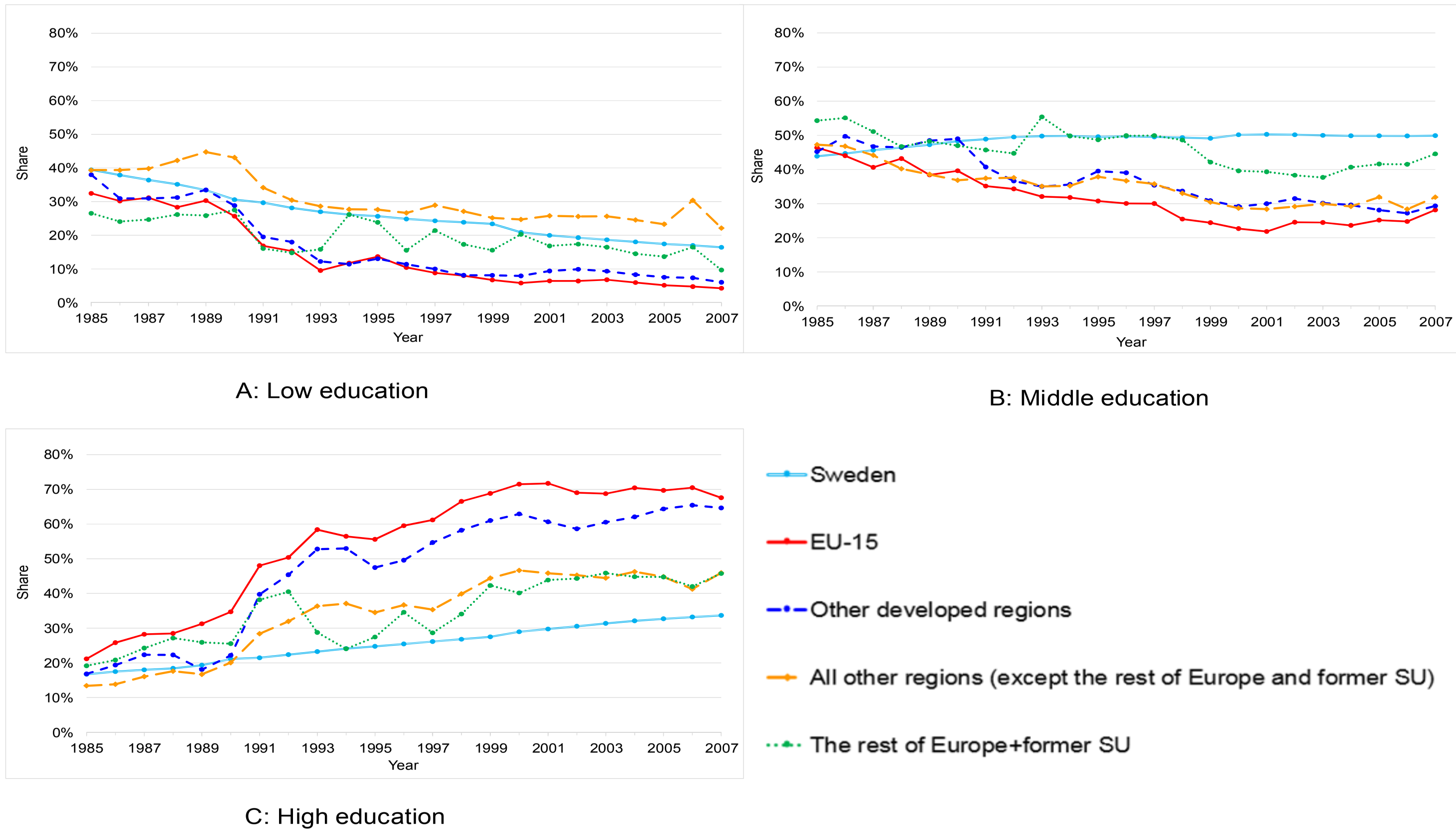

Figure 2 Share of population with low, middle, and high education among the general Swedish-born or immigrant population who migrated at ages 18−64 by year of migration and region of origin

6 Methods and empirical data description

A descriptive analysis shows that, after the EEA was formed in 1994, the number of immigrants from the EU-15 increased slightly, with an increase in the share of low-educated immigrants and decrease in the share of the middle and highly educated during 1994 to 1995. Additional evidence on the impact of this policy change on the skill structure of immigrants in Sweden from the EU-15 can be obtained using a DiD regression approach. Here, we exploit the fact that, in 1994, only immigration from the EU-15, but not from outside the EU-15, was affected by Sweden's accession to the EEA. We divide the data into a subset of region that was affected by the reform (the EU-15) and another subset that was not affected (the 'Other developed regions' or 'All other regions'). Our study period is 1990−1997, or alternatively 1990−2007, and we group the time period into a pre- (1990−1993) and a post-membership period (1994−1997 or 1994−2007). We start in 1990 due to the availability of data on control variables (marriage and children).[9] Moreover, inventor data in this dataset is complete until 2007. Extending the investigation period beyond 1997 allows us to distinguish whether any effects are short or long term.

We estimate the impact of the EEA accession on the EU-15 immigrants' skills in Sweden by studying the probability that an immigrant would be low, middle, or highly educated as well as the probability of his/her becoming an inventor after migration and until 2007. The DiD estimation can be described as:

$$y_{ijt} = \alpha D_{EU-15} \cdot D_{t \geq 1994} + \beta_t Y_{it} + \gamma_j D_j + \lambda X_i + \rho H_{jt} + \varepsilon_{ij}, \qquad (7)$$

Where y_{ijt} is a dummy variable indicating whether an immigrant (i) from region (j) at the time of migration (t) is low, middle, or highly educated or becomes an inventor after migration. Y_{it} is a set of migration year-fixed effects. These pick up influences stemming from, for example, business-cycle variations that may influence the skills of immigrants. D_j is a vector of dummy variables for each region of origin that captures unmeasured region-fixed effects. X_i is a set of individual characteristics at the time of migration that may affect the probability of observing a certain level of education or of being an inventor. X_i includes the variables female (1 = female, 0 = male), age, age^2, marital status (1 = married, 0 = unmarried), and children (1 = at least having one child, 0 = no children) at the time of migration. These are included to control for skill differences that stem from gender, life-cycle effects, and socioeconomic background. H_{jt} is an index of weighted human capital

[9] The results are robust both when using data for 1985−2007 (without data on marriage or children) and 1990−2007, regardless of whether we include or exclude marriage and children. See Tables 3 and 6 and Appendix Table A2.

based on the average number of years of schooling and estimated rates of return to education from the Penn World Tables (Feenstra et al. 2015).[10] This index controls for supply-side and trends in skills effects that influence the skill level of immigrants. $D_{t\geq 1994}$ is a dummy variable with a value of 1 if an immigrant migrated in 1994 or later. D_{EU-15} is a dummy variable with a value of 1 if an immigrant is from the EU-15. $\beta_t, \gamma_j, \lambda, \rho$ are parameters to be estimated, ε_{ij} is an error term. α is the central parameter of interest. This measures the average change in y_{ijt} on the treated relative to the untreated migrant groups. If α is statistically significantly different from zero, the examined skill for immigrants coming from the EU-15 in 1994 or later are found to be different from the EU-15 immigrants coming before 1994 and from immigrants from other regions.

Table 2 shows a descriptive analysis of dependent and control variables by period and region of origin. We compare within the EU-15, the 'Other developed regions' and 'All other regions' four years before and after the accession to the EEA in 1994 (1990−1993 vs. 1994−1997). For example, compared with before treatment, the mean value of low education for the EU-15 decreased by 0.07 percentage points after 1994. The same level of decline is observed for 'All other regions,' while for 'Other developed regions' it decreased by 0.12 percentage points, which is more than that of the EU-15. Both before and after the EEA, among immigrants from 'All other regions,' only 0.1 percent of them become inventors after they migrated to Sweden until 2007. This share is higher among immigrants from the 'Other developed regions' and is the highest among immigrants from the EU-15. In fact, this share increased from 0.6 percent for the EU-15 immigrants before the EEA to 1 percent after the EEA, whereas the increase in absolute terms was much smaller for immigrants from 'Other developed regions' (from 0.2 to 0.3 percent).

The immigrant age is very stable at around 29−30 years on average, both before and after 1994. Immigrants are roughly balanced by gender from the 'Other developed regions' both before and after 1994 and for immigrants from 'All other regions' before 1994, but a larger share (55 percent) are female from 'All other regions' after 1994. By contrast, male immigrants dominate strongly from the EU-15 both before and after 1994 (around 60 percent). Finally, it is much more common for immigrants from 'All other regions' to have a child than if they come from 'Other developed regions' and the EU-15, and the latter two groups have similar shares. A slowly declining share of immigrants have children in all immigrant groups.

Our regressions use two basic models for each dependent variable. The first model excludes all control variables X_i and weighted human capital. The second models includes all control variables X_i and weighted human capital, which are

[10] In order to create weighted human capital for each region, we multiply each country's value by country population size, and thereafter divide this weighted sum by the sum of all countries' population.

expected to affect the skill composition of immigrants. For simplicity, we use the linear probability model (rather than probit or logit models), as we are only interested in the average treatment effect of the EEA, and these are directly given by our estimated coefficient.

Table 2 Descriptive statistics for dependent and control variables by periods and region of origin.

Before treatment (1990−1993)	EU-15		Other developed regions		All other regions	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Low education	0.18	0.38	0.23	0.42	0.35	0.48
Middle education	0.36	0.48	0.44	0.50	0.37	0.48
High education	0.46	0.50	0.33	0.47	0.28	0.45
Inventor	0.006	0.076	0.002	0.045	0.001	0.036
Age	29.16	7.78	29.02	8.58	29.65	8.52
Female	0.40	0.49	0.49	0.50	0.48	0.50
Married	0.38	0.49	0.29	0.45	0.55	0.50
Children	0.24	0.43	0.25	0.43	0.38	0.49
No. of obs.	4,845		14,614		64,458	

After treatment (1994−1997)	EU-15		Other developed regions		All other regions	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Low education	0.11	0.32	0.11	0.32	0.28	0.45
Middle education	0.31	0.46	0.37	0.48	0.36	0.48
High education	0.58	0.49	0.51	0.50	0.36	0.48
Inventor	0.010	0.101	0.003	0.053	0.001	0.038
Age	30.36	7.87	29.92	8.59	29.58	8.26
Female	0.39	0.49	0.51	0.50	0.55	0.50
Married	0.35	0.48	0.33	0.47	0.61	0.49
Children	0.23	0.42	0.23	0.42	0.35	0.48
No. of obs.	6,156		9,651		41,852	

Note: S.D. = standard deviation; No. of obs.=Number of observations, same as for tables below.

7 Empirical results

7.1 Results for education

Table 3 shows the main results, where we use the period 1990−1997 in the regressions. We view the comparison with ‘Other developed regions’ as the most reliable control group to the EU-15 treatment group and ‘All other regions’ as a robustness check in the results. The probability that an immigrant from the EU-15 was low educated clearly increased compared to immigrants from ‘Other developed regions’ after Sweden’s accession to the EEA (models 1.1 and 1.2). However, the significance disappeared when compared to ‘All other regions’ (models 4.1 and 4.2).

The probability of observing that an immigrant from the EU-15 was middle educated decreased significantly ($p < 0.05$) relative to those from ‘Other developed regions’ without including control variables (model 2.1). However, when controlling for variance for other variables, the effect turns insignificant (model 2.2). Compared to immigrants from ‘All other regions,’ the probability that an immigrant from the EU-15 was middle educated decreased significantly ($p < 0.05$), regardless of whether including or excluding the control variables (models 5.1 and 5.2).

Finally, with respect to the probability of being highly educated, it shows that the probability that immigrants from the EU-15 were highly educated decreased significantly ($p < 0.05$) compared to those from ‘Other developed regions’ when control variables are held constant (model 3.2). However, when compared to ‘All other regions,’ we see that the probability increased significantly for immigrants from the EU-15 (model 6.1), but this effect becomes insignificant when we control for variance in other variables (model 6.2). In sum, the effect for the 1990−1997 period on the education composition of immigrants from the EU-15 after accession to the EEA follows our expectations when we use ‘Other developed countries’ as our baseline, but not when we use ‘All other regions’. The effects are also economically significant. Compared with ‘Other developed regions’, we see an average increase of 3.6 percent in the low educated (model 1.2) and a decrease of 3.7 percent (model 3.2) in the highly educated from the EU-15.

Table 3 Linear probability models for migrants aged 18−64 being low, middle, or highly educated at the time of migration, 1990−1997.

	Control: Other developed regions					
	1.1	1.2	2.1	2.2	3.1	3.2
	Dev_low1	Dev_low2	Dev_mid1	Dev_mid2	Dev_hig1	Dev_hig2
EU-15*1994−1997	0.021**	0.036***	−0.023**	0.001	0.001	−0.037**
	(0.008)	(0.011)	(0.011)	(0.016)	(0.011)	(0.016)
Age at migration		−0.040***		−0.043***		0.083***
		(0.002)		(0.002)		(0.002)
Age^2 at migration		0.001***		0.000***		−0.001***
		(0.000)		(0.000)		(0.000)
Female		−0.037***		0.030***		0.007
		(0.004)		(0.005)		(0.005)
Marriage		−0.024***		0.004		0.020***
		(0.005)		(0.006)		(0.006)
Children		0.110***		−0.037***		−0.073***
		(0.006)		(0.007)		(0.006)
Human capital		−1.184*		−1.113		2.297**
		(0.619)		(0.914)		(0.919)
Year of immigration FE	Yes	Yes	Yes	Yes	Yes	Yes
Region of origin FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	35,266	35,266	35,266	35,266	35,266	35,266
Adjusted R^2	0.206	0.233	0.407	0.434	0.501	0.535

Table 3 Continued

	Control: All other regions					
	4.1	4.2	5.1	5.2	6.1	6.2
	All_low1	All_low2	All_mid1	All_mid2	All_hig1	All_hig2
EU-15*1994–1997	0.007	0.008	−0.054***	−0.020**	0.047***	0.012
	(0.007)	(0.007)	(0.010)	(0.010)	(0.010)	(0.010)
Age at migration		−0.052***		−0.016***		0.069***
		(0.001)		(0.001)		(0.001)
Age^2 at migration		0.001***		0.000***		−0.001***
		(0.000)		(0.000)		(0.000)
Female		0.027***		0.008***		−0.036***
		(0.003)		(0.003)		(0.003)
Marriage		−0.020***		0.011***		0.009***
		(0.003)		(0.003)		(0.003)
Children		0.124***		−0.053***		−0.070***
		(0.003)		(0.003)		(0.003)
Human capital		−0.287**		1.367***		−1.080***
		(0.120)		(0.138)		(0.130)
Year of immigration FE	Yes	Yes	Yes	Yes	Yes	Yes
Region of origin FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	117,311	117,311	117,311	117,311	117,311	117,311
Adjusted R^2	0.351	0.377	0.371	0.387	0.377	0.420

Robust standard errors in parentheses. ***p<0.01; **p<0.05; *p<0.1. Note (for all regression tables): Coefficient results are reported.

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One of the critical aspects of the DiD approach is the validity of the so-called common trend or parallel trend assumption (Angrist & Pischke, 2009). Without parallel trends in the outcome variable before a reform, it is no longer clear that something that affected the outcome after the reform is not influenced by trends that existed before the liberalization reform. Table 4 tests the common trend assumption with another set of regressions. Those regressions are based on the idea that the addition of year dummies multiplied by the treatment dummy (i.e. EEA) should not be significant if year effects and group dummies pick up trend effects (Granger, 1969; Angrist & Pischke, 2009). This modifies our estimated equation to:

$$y_{ijt} = \beta_t Y_{it} + \gamma_j D_j + \lambda X_i + \rho H_{jt} + \sum_{\tau=0}^{m} \delta_{-\tau} D_{i,t-\tau} + \sum_{\tau=2}^{q} \delta_{+\tau} D_{i,t+\tau} + \varepsilon_{ij}, \tag{7}$$

Where the first summation term captures lagged effects, and the second captures lead effects. Note that lagged effects now replace the original treatment effect ($D_{EU-15} \cdot D_{t\geq 1994}$) and that we omit the first lead effect (i.e. 1993), which is then the baseline year against which we compare the effects.

If lead terms (i.e. prior to 1994) are statistically significant, the common trend assumption is in doubt. In Figure 3 we depict the lead and lag effects estimated for models 1.2, 2.2, and 3.2 in Table 4.

In sum, most of the lead effects are statistically insignificant. The point estimate most close to zero is the low educated. For the middle educated, there seems to be slight tendency of an increase before 1993, whereas 1990 is statistically significantly different from zero (p<0.05), with a point estimate of −4.9 percent. For the highly educated, there is a slight negative trend in the point estimates prior to 1993, with a statistically significant (p<0.05) effect of +4.7 percent in 1990. The most robust result is therefore for the low educated. The lagged effects are very interesting as well. For the low educated, we see that the strongest positive probability effect is found for 1994 and 1995 (periods 0 and 1, respectively), that is, closest to the reform change. These are estimated at +4.3 percent and are statistically significant at the 1 percent level, while the effects in 1996 and 1997 are smaller (around +3 percent), and only statistically significant at the 10 percent level. For the middle educated, we see no significant effects among the lagged effects and the point estimates do not seem to display a systemic pattern when holding other variables constant. For the highly educated, we see a 5.2 percent decline in 1994, which is statistically significant at the 5 percent level, whereas the lagged effects for 1995 and 1996 are not statistically significant and are close to zero, although the effect for 1997 turns more negative but is not statistically significant at the 10 percent level. In sum, these results suggest that the common trend assumption is not seriously challenged and that the effects on the low- and highly educated immigrants are the strongest during the first years after the liberalization of migration. The fact that the effect is strong in the early years of the reform supports the conclusion that the liberalization indeed had an effect on the skill composition of new EU-15 immigrants to Sweden.

Table 5 extends the post-1994 period to 2007. Here we only use developed countries as our baseline. We do this because among ‘All other regions’, immigration occurs more often for humanitarian reasons, and data could be more erratic. The extension affects the interaction dummy and has the implication that whether the EEA had long-run effects. If the estimated coefficient α is close to zero, it suggests that the effects that we find in Table 3 are, instead, more transitory. The results in Table 5 indicate that it seems safe to claim that the effects are indeed somewhat transitory; although, there is still significantly positive impact ($p<0.1$) on the probability that immigrants from the EU-15 were low-educated and significantly negative impact ($p<0.01$) on the probability that immigrants from the EU-15 were highly educated relative to those from ‘Other developed regions’ when other variables are held constant, however, the coefficients are much lower for each of them (+1.2 percent, model 1.2; −2.5 percent, model 3.2) and the small significant differences are mainly attributed to the first years of liberalization (see Table 4). For the middle educated, the main difference concerns the fact that, without controls, the effect now is not significantly different from zero any more (model 2.1). In sum, it seems there is no long-run impact on the educational profile of new immigrants from the EU-15.

Table 4 Linear probability models with *lead* and *lag effects* for migrants aged 18−64 being low, middle, or highly educated at the time of migration, 1990−1997.

	Control: Other developed regions					
	1.1	1.2	2.1	2.2	3.1	3.2
	Dev_low1	Dev_low2	Dev_mid1	Dev_mid2	Dev_hig1	Dev_hig2
EU-15*1990	0.007	0.002	−0.031	−0.049**	0.024	0.047**
	(0.016)	(0.017)	(0.021)	(0.024)	(0.022)	(0.023)
EU-15*1991	0.006	0.006	−0.018	−0.032	0.013	0.025
	(0.018)	(0.018)	(0.025)	(0.025)	(0.026)	(0.026)
EU-15*1992	−0.000	0.009	0.005	−0.007	−0.005	−0.003
	(0.018)	(0.018)	(0.025)	(0.025)	(0.026)	(0.026)
EU-15*1994	0.033**	0.043***	0.000	0.009	−0.034	−0.052**
	(0.015)	(0.015)	(0.023)	(0.022)	(0.024)	(0.023)
EU-15*1995	0.035**	0.043***	−0.055**	−0.037	0.020	−0.006
	(0.016)	(0.016)	(0.023)	(0.024)	(0.024)	(0.024)
EU-15*1996	0.017	0.028*	−0.067***	−0.032	0.050**	0.004
	(0.015)	(0.016)	(0.023)	(0.025)	(0.024)	(0.025)
EU-15*1997	0.015	0.030*	−0.030	0.008	0.015	−0.038
	(0.015)	(0.018)	(0.023)	(0.027)	(0.024)	(0.027)
Age at migration		−0.040***		−0.043***		0.083***
		(0.002)		(0.002)		(0.002)
Age^2 at migration		0.001***		0.000***		−0.001***
		(0.000)		(0.000)		(0.000)
Female		−0.037***		0.030***		0.007
		(0.004)		(0.005)		(0.005)
Marriage		−0.024***		0.004		0.020***
		(0.005)		(0.006)		(0.006)
Children		0.110***		−0.037***		−0.073***
		(0.006)		(0.007)		(0.006)
Human capital		−0.889		−2.105*		2.993***
		(0.767)		(1.149)		(1.145)
Year of immigration FE	Yes	Yes	Yes	Yes	Yes	Yes
Region of origin FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	35,266	35,266	35,266	35,266	35,266	35,266
Adjusted R^2	0.205	0.233	0.407	0.434	0.501	0.535

Robust standard errors in parentheses. ***p<0.01; **p<0.05; *p<0.1.

Notes: (1) EU-15*1993 is the reference group.

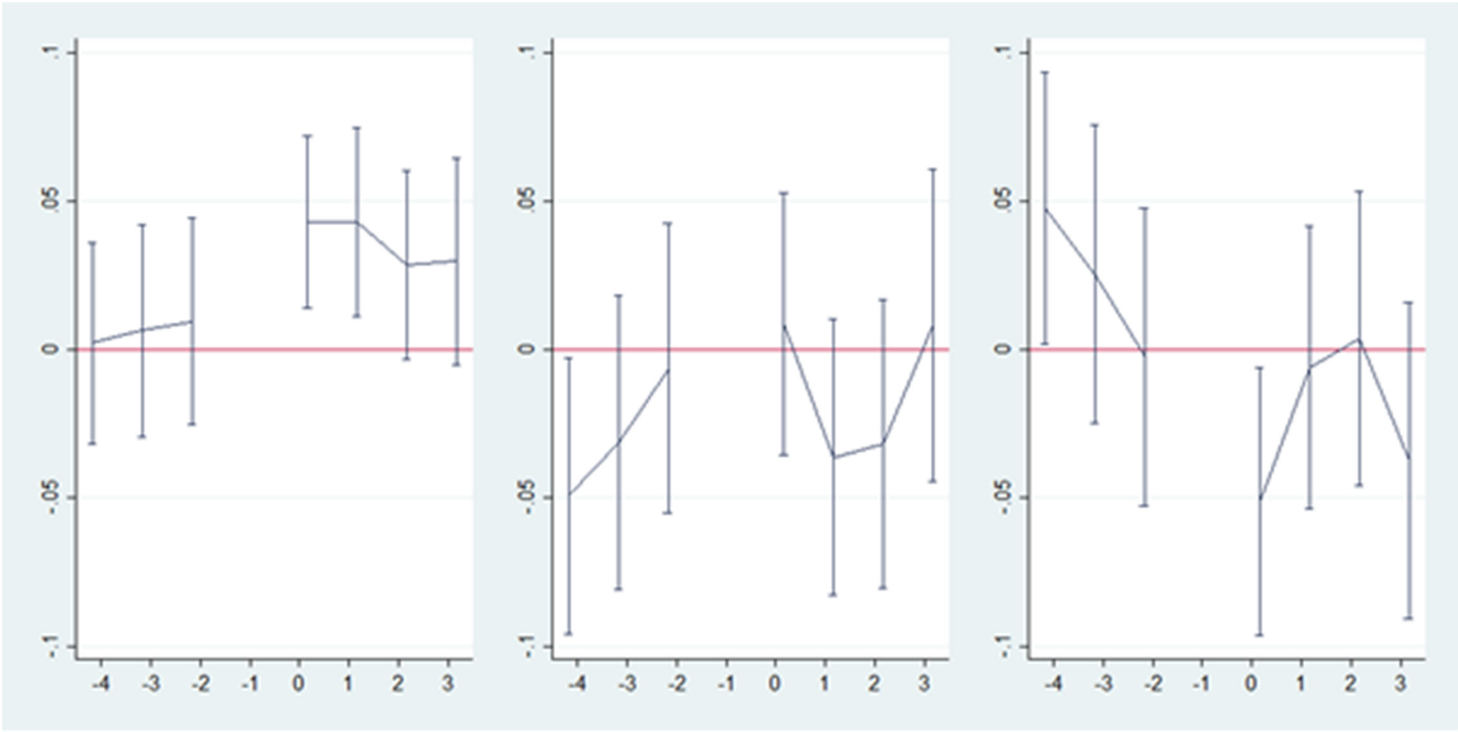

Figure 3 Lead and lag effects on the probability of observing the low educated (left), the middle educated (center), and the highly educated (right) among immigrants from the EU-15 countries before and after 1994 (period 0) from regression models 1.2, 2.2, and 3.2 in Table 4.

Table 5 Linear probability models for migrants aged 18−64 being low, middle, or highly educated at the time of migration, 1990−2007.

	Control: Other developed regions					
	1.1	1.2	2.1	2.2	3.1	3.2
	Dev_low1	Dev_low2	Dev_mid1	Dev_mid2	Dev_hig1	Dev_hig2
EU-15*1994−2007	0.008	0.012*	−0.002	0.012	−0.006	−0.025***
	(0.007)	(0.007)	(0.009)	(0.009)	(0.009)	(0.009)
Age at migration		−0.028***		−0.054***		0.082***
		(0.001)		(0.001)		(0.001)
Age^2 at migration		0.000***		0.001***		−0.001***
		(0.000)		(0.000)		(0.000)
Female		−0.028***		0.008***		0.020***
		(0.002)		(0.003)		(0.003)
Marriage		−0.018***		−0.001		0.018***
		(0.003)		(0.003)		(0.004)
Children		0.065***		−0.005		−0.060***
		(0.003)		(0.004)		(0.004)
Human capital		−0.319***		−0.346***		0.665***
		(0.056)		(0.096)		(0.100)
Year of immigration FE	Yes	Yes	Yes	Yes	Yes	Yes
Region of origin FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	103,516	103,516	103,516	103,516	103,516	103,516
Adjusted R^2	0.148	0.172	0.335	0.364	0.618	0.641

Robust standard errors in parentheses. ***p<0.01; **p<0.05; *p<0.1

7.2 Results for inventors

Table 6 examines the probability that an immigrant will become an inventor from the time of migration until 2007, based on patent documents. On the left-hand side of the table, we use the period 1990−1997 and on the right-hand side 1990−2007.

We find that, in the short run, there is a 0.4 percent higher on the probability of becoming inventors among immigrants from the EU-15 compared with those from ‘Other developed regions’ or ‘All other regions’ in three of the four models (models 1.1, 2.1, and 2.2). Immigrant from EU-15 became more likely to be inventors compared with those from ‘All other regions’, maybe because the latter immigrant group who migrated in 1994−1997 was lower qualified, who had lower employment rate compared with those who migrated in 1990−1993 and the employment rate decreased more than those of the EU-15 (see Table 1). They may have lower chances to participate in inventive activity than those from the EU-15. However, there is no significant effect when we examine the long period (1990−2007) compared with ‘Other developed regions’ (models 3.1−3.2).

In addition, we see a negative but not significant effect in our main interested model 1.2, where we use ‘Other developed regions’ as our baseline and holding other variables constant. It turns negative and insignificant after the inclusion of human capital (the coefficient of α is still positively significant when we include only variables X_i, results are available upon requests). This suggests that the growing number of inventors from EU-15 immigrants is because of its increasing human capital, but not because of free migration.

Table 6 Ordinary least square (OLS) regressions of the probability of a migrant becoming an inventor from the time of migration until 2007, 1990−2007.

	1990−1997				1990−2007	
	Control: Other developed regions		Control: All other regions		Control: Other developed regions	
	1.1	1.2	2.1	2.2	3.1	3.2
	Dev_pat1	Dev_pat2	All_pat1	All_pat2	Dev_pat1	Dev_pat2
EU-15*1994−1997	0.004**	−0.001	0.004**	0.004**		
	(0.002)	(0.002)	(0.002)	(0.002)		
EU-15*1994−2007					−0.000	−0.001
					(0.001)	(0.001)
Age at migration		0.001***		0.000***		0.001***
		(0.000)		(0.000)		(0.000)
Age^2 at migration		−0.000***		−0.000***		−0.000***
		(0.000)		(0.000)		(0.000)
Female		−0.005***		−0.003***		−0.004***
		(0.001)		(0.000)		(0.000)
Marriage		0.001		0.001**		−0.000
		(0.001)		(0.000)		(0.000)
Children		−0.001		−0.001**		−0.001
		(0.001)		(0.000)		(0.000)
Human capital		0.363***		−0.016		0.020*
		(0.128)		(0.012)		(0.012)
Year of immigration FE	Yes	Yes	Yes	Yes	Yes	Yes
Region of origin FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	35,266	35,266	117,311	117,311	103,516	103,516
Adjusted R^2	0.006	0.009	0.005	0.005	0.005	0.006

Robust standard errors in parentheses. ***p<0.01; **p<0.05; *p<0.1

7.3 Control variables

When looking at the educational level, we observe a curvilinear relationship with age at migration and educational level. The higher the age at migration, the higher the probability that an immigrant is highly educated. It is the opposite result in terms of middle and low education. Female immigrants are more likely to be highly educated among immigrants from 'Other developed regions' but are less likely to be highly educated when we include immigrants from developing regions. Married immigrants are more likely to be highly educated. However, immigrants with children were less likely to be highly educated. In line with expectations, when we look at immigration using 'Other developed regions' as a baseline, an immigrant is much more likely to be highly educated if the human capital for the region of origin is higher. However, there is opposite effect when we use 'All other regions' as the comparison group. This result, which goes strongly against theory, suggests that forces other than economic ones (e.g., refugee status) are at work when using this control group.

When we look at the probability of becoming an inventor, age effects have coefficients very close to zero although they are always statistically significant. In line with many other studies, we find that female immigrants are less likely to become inventors (Ding et al., 2006; Azoulay et al., 2007). In general, marital status has no significant effect on the probability of becoming an inventor except when we use 'All other regions' as a baseline in short run. Holding all other variables constant, we find a very small negative effect on the probability that an immigrant would become an inventor if they have children. Finally, the human capital level of the country of origin has a positive effect when we use 'Other developed regions' as a control group, but the effect is negative and not significant when we use 'All other regions' as the baseline.

8 Conclusion

This paper presents evidence on the change of skill structure of immigrants to Sweden from the EU-15 as the result of the implementation of the EEA in 1994, which allows free mobility among member countries. We use both education and inventor data to infer changes in skill levels.

Using DiD regressions, we find that the educational level of immigrants from the EU-15 decreased following 1994 compared with immigrants from 'Other developed regions' in the first years after the implementation of liberalization of migration within the EEA. However, the long-run effect is much weaker both by extending the post-1994 period to 2007 and investigating by lead and lag effects in our regression results. The results suggest that the effects of the EEA is largely transitory. In terms of the probability of an immigrant becoming an inventor, we initially see an increased probability, but the effect turns insignificant when we control for variance in human capital in immigrants' region of origin. This suggests that the growing number of inventors from the EU-15 is the result of its increasing human capital, but not the result of liberalization of migration. The education results are reconcilable with the assumption that moving costs decreased more for low-skilled people as a result from free migration in EEA.

When we include developing regions in the control group (i.e. 'All other regions'), the effect of decreasing educational level for immigrants from the EU-15 tend to be smaller and become insignificant in terms of the low and high education after the liberalization of migration in EEA; moreover, the probability of an immigrant becoming an inventor increased in the short run. This, however, does not repudiate the assumption that we expect a decreasing skill level of immigrants from the EU-15 after 1994. This is because it is debatable whether 'All other regions' is an appropriate control group, as it constitutes mixes of developing and developed countries with large heterogeneity. Arguably, countries within 'Other developed regions' are more homogeneous and this group is a much more appropriate comparison for the EU-15 countries. Moreover, during the study period, there were large number of refugee migrants from developing regions, who mainly migrated for political reason but not for economical motivations.

It is difficult to generalize the impact of liberalization of migration on skill structure of immigrants in Sweden to other countries or other periods. This is because Sweden has some special features in terms of its migration policy (e.g. dominated by refugees and family-reunification movers since 1968) and economic situation (e.g. relative high wages for low-skilled workers) compared with other countries. Nonetheless, the results indicate that for countries with a negative selection of migrants, liberalization of migration may have negative effect on the skill structure of their new immigrants in the short-run, which they may need to prepare for. However, in the long-term, they may not need to worry too much about it.

Appendix

The member countries of EEA; GDP, population and GDP per capital in EU-15 countries in 1994

EEA countries for which the agreement had an impact on mobility to Sweden are the EU-15 countries: Austria, Belgium, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, and the UK. Normally, Sweden, Finland, and Denmark would be included, but as they are also Nordic countries, they have already had free mobility since 1954 and hence are excluded.

Table A1 Member countries of EEA at its inception and corresponding GDP, population and GDP per capita in 1994

Country	GDP in 1994 (A)	Population in 1994 (B)	GDP/capita (C)
Non-Nordic EEA countries			
Austria	141,845	8,028	17,670
Belgium	181,217	10,123	17,902
France	1,071,856	59,459	18,027
Germany	1,374,614	81,414	16,884
Greece	105,717	10,430	10,136
Ireland	47,429	3,596	13,191
Italy	959,866	57,228	16,773
Luxembourg	10,554	404	26,145
Netherlands	280,344	15,384	18,223
Portugal	112,096	10,028	11,179
Spain	497,471	39,708	12,528
United Kingdom	1,000,281	58,089	17,220
Sum	5,783,290	353,891	–
Weighted average	–	–	16,342
Nordic EEA countries			
Denmark	103,317	5,206	19,847
Finland	78,928	5,086	15,518
Iceland	4,651	266	17,481
Norway	90,364	4,337	20,837
Sum	277,260	14,895	–
Weighted average	–	–	18,614
Sweden	**151,582**	**8,789**	**17,248**

Notes: Total GDP, in millions of 1990 US$ (converted at Geary Khamis PPPs).
Source: Conference Board (2016).

Table A2 Ordinary least square (OLS) regressions of the probability of a migrant being low, middle, or highly educated at the time of migration and becoming an inventor from the time of migration until 2007, 1990–2007 vs. 1985–2007

	Control: Other developed regions							
	1990–2007				1985–2007			
	1.1	1.2	1.3	1.4	2.2	2.2	2.3	2.4
	90_low2	90_mid2	90_hig2	90_pat2	85_low2	85_mid2	85_hig2	85_pat2
EU-15*1994–2007	0.014**	0.012	−0.026***	−0.001	0.013**	0.004	−0.017***	−0.000
	(0.007)	(0.009)	(0.009)	(0.001)	(0.005)	(0.007)	(0.006)	(0.001)
Age at migration	−0.024***	−0.055***	0.079***	0.001***	−0.025***	−0.048***	0.073***	0.001***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)
Age^2 at migration	0.000***	0.001***	−0.001***	−0.000***	0.000***	0.001***	−0.001***	−0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Female	−0.025***	0.008***	0.017***	−0.004***	−0.026***	0.010***	0.016***	−0.004***
	(0.002)	(0.003)	(0.003)	(0.000)	(0.002)	(0.003)	(0.003)	(0.000)
Human capital	−0.318***	−0.347***	0.665***	0.020	−0.390***	−0.298***	0.689***	0.015*
	(0.056)	(0.096)	(0.100)	(0.012)	(0.056)	(0.083)	(0.084)	(0.009)
Year of immigration FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region of origin FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	103,516	103,516	103,516	103,516	128,474	128,474	128,474	128,474
Adjusted R^2	0.167	0.364	0.640	0.006	0.237	0.396	0.611	0.006

Robust standard errors in parentheses. ***p<0.01; **p<0.05; *p<0.1

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How Immigrants Invent
Evidence from Sweden

This thesis investigates the inventive performance of immigrants in Sweden. The results show that it is influenced by immigrants' age at migration, region of origin, educational level, match between education and occupation and migration policy.

In general, first-generation immigrants are less likely to patent than native Swedes. The exception is the group working in the high-tech knowledge-intensive service (KIS) sector, where first-generation immigrants are more likely to patent than natives mainly because they are more highly educated; furthermore, their high and similar representation in high-skill occupations as natives enable them to have as high patenting rate as natives when other variables are held constant. In most sectors, however, the main barriers to first-generation immigrants' probability of patenting are their over-representation in low-skill occupations and their lower education-occupation match compared with natives. When the analysis is limited to inventors, first-generation immigrant inventors perform as well as their native counterparts.

Second-generation immigrants with a non-Nordic European background perform better than native Swedes, which appears to be because they are positively affected from having more highly educated parents than their native counterparts and the close geographic proximity of their non-native parents' region of origin to Sweden.

The liberalization of migration after the inception of the European Economic Area (EEA) in 1994 had a negative effect on educational profile of new EU-15 immigrants to Sweden in the short run when compared with new immigrants from 'Other developed regions', but there is no such effect in the long run and no systemic effect on the EU-15 immigrants' probability of becoming an inventor.

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