Highly-skilled migration Volume OUP

What type of migration is best able to foster innovation?

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We would like to thank, for their comments and suggestions, Philippe Fargues, Fabio Montobbio, Herbert Brücker, Hillel Rapoport, the participants in the Highly-Skilled Seminar in Oxford, and the European Commission which funded this research project within the Migration Policy Centre.

1. Motivation

Europe is an ageing society where the share of the elderly (>65 years old) as a percentage of the working age population (20-64) now stands at around 30%, with Italy and Germany above average and France below (Fargues 2011). This implies a reduction in the total stock of population, in particular of the younger generation, and more of the elderly. This last group holds most capital and conditions the production of goods and services toward their consumption demands. The change in the composition of the European population may have a dramatic effect on investment, growth and innovation all of which are favoured, instead, by the young, who have a longer time horizon and who are more risk prone.

Population ageing creates the demand for both temporary and permanent migrants as care givers in the public and private sectors or in the family services, according to the welfare system adopted by the country. But there is also a demand for permanent migrants because the total population is shrinking.

Even if Europe is in need of foreign labour, there is much resentment among the native population, who are afraid that migrants reduce the number of jobs available to natives; that they are a burden for the welfare state; and, thus, that they increase taxes; and that foreign nationals increase criminality. Research has found only a limited competitive role played by migrants, and a limited use of the welfare state on their part. But this resentment encourages restrictive immigration policies or very selective immigration policies which are put forward by conservative parties tapping resentment of immigrants, while progressive parties are in search of reasons to combat this restrictive drive.

The last chance to implement more open migration policies seems be, to point to the role that migrants can play in favouring growth and innovation. In the 1960s and 1970s foreign labour led to North European economic growth, by providing the additional labour needed in manufacturing. Migratory labour was essential then for its quantity not for its quality. Today, instead, the focus of migration policies is on highly-skilled migrants, both because they seem to contribute to the welfare state instead of relying on it, and because they spur innovation.

This matters, because in the growth and innovation arena Europe is facing a global challenge, with new countries, particularly India and China, overtaking the developed world. In the first phase of globalization emerging countries competed in the production of goods and their comparative advantages were mainly price-based. Today, however, the upgrade of national innovative systems allows them to compete in terms of innovation and technology as well, coming closer to the "technological frontier", as shown by the large increase in their world share of patent applications. For example, if we consider the trend of patents registered at the Patent International offices, which are a proxy for potential innovation, previously, the USA dominated, with Japan alone rivalling it in the early 1990s. Now, though, China is about to pass Japan and will soon run the USA close. The registration of European patents at the EU patenting office is increasing, but by such a small number that the distance between Europe and the top patenting powers has widened.

Migrants are one option for reducing the lag in European innovation. Migrants are, after all, younger and thus have a longer horizon, especially if they are highly skilled, so their specific human capital might enhance innovation.

The objective of this research paper is to discuss the results of the research on the link between immigration and innovation and their implication for migration policy.

2. What is meant by innovation and how it is measured

Innovation is a very evocative word. It has a positive connotation but is difficult to define. According to the OECD's Oslo Manual (2005) "An innovation is the implementation of a new or significantly improved product (good or service) or process, a new marketing method or a new organizational method in business practices, workplace organization or external relations.[1]"

In economic terms the process of innovation should also produce an economc advantage for the company, sector or country which is able to innovate. This might result in lower production costs or larger sales, and, naturally, in more gains for the company, sector or country which produces the innovative good or service. In terms of global competition, being able to invent a new product or to produce an older one at lower cost with a new production system creates a notable advantage beneficial for the economy and the society.

The technological capability of a firm is partly embedded in its labour force, and skilled employees are a key asset for an innovative firm because they can master new technologies. Their role has been particularly stressed as regards the type of human capital demanded by innovative firms.

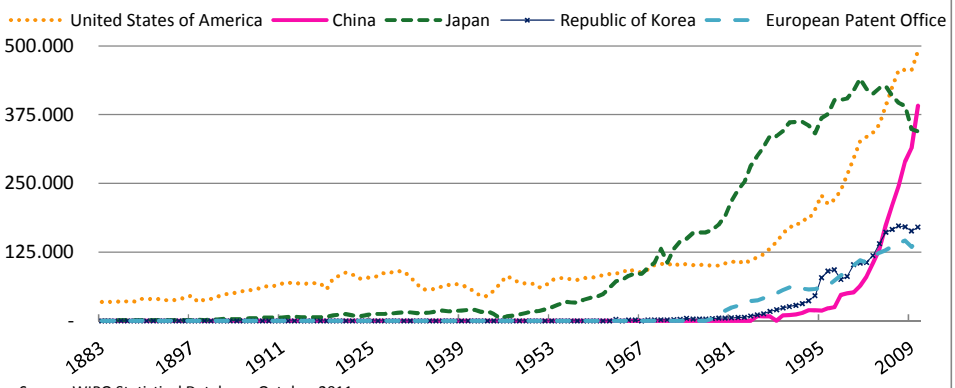
If it is not easy to define what innovation is, it is even more difficult to measure it. If we look at innovation in a comparative way there are three types of measures.

The most popular indicators of innovation are the **number of patent applications** at the industry or country level (e.g. Furman *et al*. 2002). These provide valuable information on the technological activities of inventors and companies over long time series (Pavitt 1985; Grupp 1990; Griliches 1990). The economic literature has validated the use of patents. It has shown, indeed, that there is a high level of correlation with R&D activities at the firm level (Griliches 1990) and that patents are a good proxy for the technological effort of companies and non-firm organizations aiming to create new products and processes. Given the high cost of registration only companies and non-firm organizations which really

[1] This is the synthetic definition reported in all the OCDE publication as for instance Ministerial report on the OECD Innovation Strategy Innovation to strengthen growth and address global and social challenges Key Findings , page 1, which was defined in the version 1992 and since than always referred to as OSLO Manual definition. In page 16 of the 2005 Oslo Manual you find the same definition split in 4 points.

aim to create new products and processes undergo this procedure.[2] To avoid the defensive or irrelevant registration of patents a more appropriate measure of innovation is to weight the number of patents for their "citations", which better capture the importance of a given invention. Also to better capture the innovative effect of the patent, each of them is assigned to the sector in which the invention will likely be implemented, which may be different from the sector in which the patent is produced, typically manufacturing.[3]

Figure 1: Trend in patent applications at the top five offices, 1983-2010.



Source: WIPO Statistical Database, October 2011.

In recent years, with the global harmonization of intellectual property systems, many countries have increased patenting activities, in particular the ones with relatively higher *per capita* growth rates. Patenting levels are not directly comparable across national patent offices because of different registration systems and different national legislations. However, Figure 1 gives an interesting snapshot of the relative dynamics of patenting activity in different regions of the world, which we cited in the introduction. In the 1970s the United States was forced into second place by Japan, while the rapid growth of patent applications at Chinese and Korean patent offices in the last 20 years is particularly

[2] The use of patents at the aggregate level has important limitations: (1) the technological and economic value of patents varies considerably (e.g. Shankerman and Pakes 1986) as many patents have low economic and technological value, while a few are extremely valuable; (2) many inventions are not patented, even if patents are increasingly used by companies, the evidence provided by many surveys of R&D managers indicate that, in many sectors, patents are not considered the major source of profit from new products and processes (e.g. Cohen *et al*. 2000); (3) companies show significantly different propensities to patent across sectors. Finally, like R&D measures, patents tend to be a better proxy for technological activities of large firms. Small firms tend to have a lower propensity to patent because – all things being equal – the use of intellectual property rights requires high fixed costs of implementation and scale (Bound *et al*. 1984; Patel and Pavitt 1994). Therefore, the size distribution of firms may have an important effect on the aggregate number of patents at the national level.

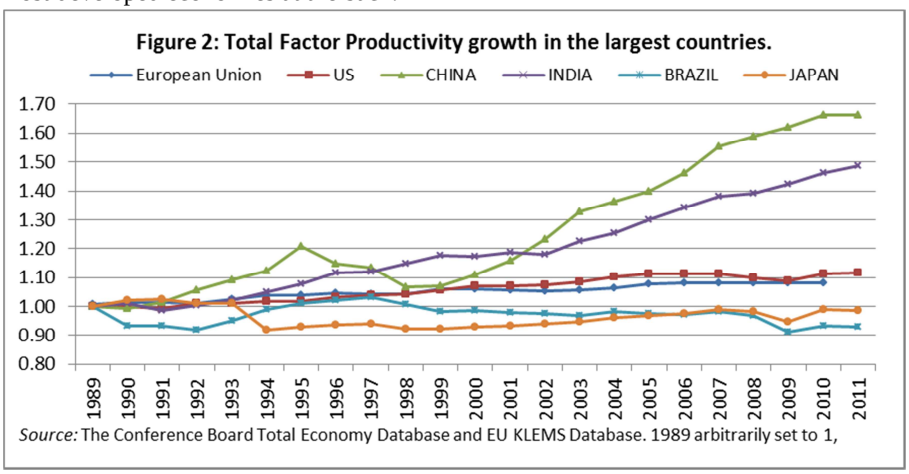
[3] In the literature, expenditure on research and development (R&D) is also often used as a proxy for the innovation potential. However, R&D has even more limitations than the use of patents and is also used as an input in the production of innovation, instead, as a final indicator (Hatzichronoglou 1997).

impressive. These figures show very clearly why, in Europe, the search for competiveness and innovation is a top priority.

The number of patent applications is more similar to a measure of potential innovation, because they do not account for the actual market success of an invention, while the second more typically used measure is the growth of **Total Factor Productivity** (TFP) which is closer to a measure of its results.

Solow (1957) defined the growth of TFP ($\Delta A/A$[4]) as "technical progress in its broadest sense"; Abramovitz (1956) famously named it the "measure of our ignorance" (Prskawetz et al. 2006: 4), because it is obtained as a residual after subtracting from the value added growth rate the growth rates of capital and labour, weighted by their respective shares in the value added aggregate. Both Solow and Abramovitz also stressed the lack of a specific theory accounting for its dynamics.[5] Indeed, TFP is sensitive to many different improvements in production that can be guided by changes in the quality of labour by age, education, skill and occupation and nationality (Jorgenson and Griliches 1967). Denison (1985) in his calculation attributes 16% of it to increases in education. Endogenous growth models stress the role of human capital by changing the focus from the quantity of labour to the quality of labour, highlighting the role of skills within the workforce (Romer 1990).

Figure 2 shows that using TFP indicators the race for innovation is still led by India and China, with the most developed economies at the back.



[4] $Y_t = A L_t^{\alpha} K_t^{1-\alpha}$ In a traditional production function where Y_t represents the production in time t, L_t and K_t labour and capital in time t, A represents the innovation but also all that is not explained by L and K.
The growth rate of A (is the growth of innovation.

[5] Other shortcomings of the use of the growth of Total Factor Productivity depend on underlying assumptions about the presence of constant returns to scale in the economy and from the adoption of the Euler Theorem according to which the overall compensation of labour equals its marginal productivity. Notwithstanding all these simplifying assumptions TFP growth still remains a good proxy for the share of growth of a firm, country or region which does not depend on the increase of standard productive inputs, and hence which is typically associated with innovation.

This value can be calculated by using a production function for whichever sector or area or country. Moreover, it is also possible to calculate the value for the services sector, which is under-represented by the patent measure. The EU-KLEMS dataset provides, for all European countries, an accurate measure of multifactor productivity (O'Mahony and Timmer, 2009). KLEMS TFP growth series are estimated from micro data and aggregated at the sector level, hence they are more accurate than their calculation from aggregate data.

To get information **at the firm level**, surveys are the only way to capture the innovative dynamics in detail. In the European Union the **Community Innovation Survey**, which is a harmonized survey led by the EU Commission, provides information on the type of innovation implemented by individual firms. The innovation can be directed towards the creation of a new product or a new process or it can be linked to organizational or marketing innovation. The survey, which is repeated every two years, provides more detailed information on the problems encountered by the company, the networks from which they get information and to which they provide information. For some countries it is even possible to understand which sectors are more positively affected by the utilization of foreign labour, distinguishing by their quality levels (highly-skilled or low-skilled) (see Ozgen 2015). The survey is very rich, thus much additional information is collected and different correlations detected according to the size of the company, its openness to international trade and the like.

3. Why do migrants spur innovation?

Research on the contribution of migrants to the innovation process has recently grown rapidly. Why, according to this research, then, should migrants spur innovation?

There is a **quantity interpretation**. Their contribution to the innovation process both in its creation and implementation can be related to the need of additional workers as in the 1960s and the 1970s in Northern Europe. In that case an excess demand for labour dominated the labour market, natives were not available and migrants complemented natives in production. The quantity dimension dominates in this interpretation: migrants have the same productivity as similar natives (narrow vision) or, in addition to their similar productivity, they are more flexible and as George Borjas (2001) said they grease the wheels of the EU economy (broader vision).

There is another interpretation, which is fashionable today, namely the idea that migrants have **different qualities both as individuals and as a group.** It considers migrants and natives as imperfect substitutes. Migration is a self-selecting phenomenon, thus migrants can be more productive than similar natives. Even if they have the same level of education, their motivation and engagement are different from natives and this fact can produce a production differential.[6] In addition, migrants bring with them not only technical knowledge but also soft skills, which can contribute to production and which can create a synergic increase in productivity. Migrants with a different background provide a different vision and ideas, and can widen the approach to a problem, or help in finding a solution (see

[6] See Epstein and Venturini (2011) for the effort differential exerted by migrant workers.

Hong and Page 2004). This interpretation can be traced back to the work of Jacobs (1961, 1969) who stressed the important role played in New York after World War Two, by migrants from different countries of origin. The mix produced an impressive laboratory for innovation, which magnified all the technical and soft skills brought by the migrants. The **diversity of migrants** is in general interpreted as diversity in terms of country of origin or diversity in ethnic origin – referring to one of the fractionalism measures developed by Alesina *et al*. (2003) – and the higher it is, the higher, according to this theory, the effect on innovation and growth.

It is well known that diversity can create negative externality in production. Different spoken languages increase communication costs, for example: special conditions are needed for positive effects. Probably there is an optimal mix that spurs a promising atmosphere and favours workers' interactions. This also implies that small groups with members from different backgrounds suffer from a dominant one[7].

The positive role of diversity, as described by Jacobs, can then be reinterpreted following Vernon Henderson (1988) in terms of sector complementarity. Namely the synergic results of the migrant mix are induced by migrants working in different sectors which complement each other (see also Florida 2003; Glaeser et al. 1992). We might even suggest that migrants have different talents which make them productive in different sectors. It is, then, the complementarity between different sectors that increases innovation outcomes and not diversity *per se*. The synergic role of the diversity of backgrounds among migrants is not powerful *per se*. On the contrary it is filtered by sector complementarity, which spurs innovation. This interpretation explains why the same diversity of origin affects innovation in one area and not in another. From this interpretation are derived the so-called Jackobian externalities, according to which the complementarity between different sectors fosters knowledge spillovers between firms and sectors and eventually favours innovation.

4. Variables used in empirical research

The variables used in different explicit or implicit forms of production function are related to the quantity of foreign workers and their quality in terms of education, age and country of origin.

Quantity of foreign workers:

The variables used to capture the role in the production of innovation played by foreign labour vary from the share of migrants to the number of migrants, both in micro and macro studies. The role of the number of migrant workers is always linear and constant for whichever size the community of migrants reaches. Only Fassio et al. (2015) by using a log share model introduce the hypothesis of decreasing returns in the contribution of the share of migrants to innovation.

Quality of foreign workers:

Education:

[7] See Ozgen *et al.* 2012 for the use of a square term of diversity to find out the optimal diversity dimension which spurs innovation.

Highly-skilled migrants are usually defined as tertiary educated or, in specific cases (Kerr and Lincoln 2010; Hunt and Gauthier-Loiselle 2010 in the USA), they refer to PhD students in Science, Technology and Mathematics (STEM). By 'low skilled workers' is meant workers with elementary education but, frequently, also, medium educated workers because they are measured as the differential between total employment and the highly-skilled.

The effect of higher education on innovation is rooted in endogenous growth theory and it is very well documented. According to endogenous growth models human capital stimulates aggregate productivity independently of specific fields of education because the diffusion of innovation requires higher education among workers (Carnoy and Marenbach, 1975; Hanushek and Woessmann, 2008; Di Liberto et al. 2011). The sectors which produce innovation employ in general highly educated workers in Science and Technologies, but sectors which only adopt innovation produced elsewhere also need highly-educated workers to favour implementation (see Lutz *et al*. 2008).[8] Also, low and medium educated workers are frequently needed as complements to the highly-educated and they could be crucial, as well, in implementing the innovative process.

An appropriate education variable should take into account not only the human capital level but also the quality of education (and not just the number of years in education). The number of years in education might be a misleading indicator and could produce distorted results, as Razin and Wahba (2011) show. There is an implicit assumption that each year of education increases the skills and competences of a worker in a homogenous way, regardless of the quality of a country's educational institutions. The use of an appropriate weight that controls for education quality as provided by the PISA dataset[9] in Europe is a possible solution. Research, however, limits the analyses to the level of education and does not consider on-the-job experience, which is part of the creation of human capital. Controlling for age is a possible solution in capturing the decline in productivity of human capital or its accumulation which can increase total human capital as the worker ages. It must be stressed that the issue of over-education (brain waste) is receiving more and more attention in migration literature but not in the literature on innovation.

Age:

Variable used: Average age or share of young workers.

The effect of age on innovation and productivity is less straightforward than the effect of education. The Human Capital theory (Becker, 1975) shows that at the end of the education period workers reach

[8] A less straightforward relation exists when the field of education is taken into account. Specific fields of education are more conducive to innovation because they are more related to the production of innovative processes. At the same time the "Endogenous growth" literature stresses that human capital stimulates aggregate productivity independently of specific fields because the diffusion of innovation requires higher education among the workers. On the one hand, only S&T education seems conducive to innovation, on the other, without a large diffusion of more general higher education it is impossible to diffuse the innovation, and thus higher education in general plays a positive role in the growth of total production.

[9] Program for International Student Assessment, National Center for Education Statistics.

their maximum productivity, which depreciates as working time goes on. This result can be imputed to the decline in cognitive abilities for older individuals found in laboratories (Oberg 1969: 246; Jones 201010). The workers can, however, combat obsolescence in knowledge and productivity by investing in additional forms of education or on the job training. The accumulation of additional human capital contrasts with the depreciation of initial capital. This practice is very common, for instance in the EU27 in 2005, 30% of workers in the 40-54 age bracket were involved[10] in continuing vocational training (Jones and Hayden 2009). Investment in the additional accumulation of human capital is larger in the initial phase of a working career because the worker can live off the return on any training for many years. Investment in education later in life is less rewarding because the costs incurred during the investment phase are more likely to be higher than any benefit. The wage-productivity profile of a worker during his working life increases slowly over time. It peaks around 40-45 and declines thereafter.

It is very difficult to measure worker productivity and workers' investment in training on the job across many countries and industries. As a consequence researchers use age to proxy the evolution of worker productivity. If productivity favours innovation we might expect, according to human capital theory, that the age variable has a negative effect on innovation. In other words, the younger the workers the higher human capital and productivity.

Accordingly, there are concerns over the future innovation capacity of Europe as an ageing area with long term, below replacement, fertility and rising life expectancy. Enhancing European global competitiveness looks particularly challenging because competitors are countries with larger numbers of younger citizens and countries enjoying a very rapid increase in higher education. According to human capital theory, the fear over competition with these other countries is, then, for Europe, well founded and only policies limiting human capital decline can reduce the loss of competitiveness (see Jones and Hayden 2009).

However, research on Innovation Communication Technologies and Nobel prize laureates and their contribution to innovation (Jones, 2010; Levin and Stephan 1991, Frosch, 2011) gives some hope to "old" Europe. It suggests that the relationship between generations, diffusion and the adoption of innovative products, and age is much more complex than has been suggested above. In knowledge intensive sectors inventors are younger, while in more experience-based fields inventors are older. Feyrer (2008: 90, 92) points out an "age dividend" suggesting that the reduction in innovation can be imputed to a reduction in the labour force and not to its ageing, because older workers are more innovative producers (see also Frosch 2011).

Thus, the age innovation distribution of individuals seems bimodal: the first mode is in early adulthood after the end of education when the innovative risk propensity dominates the results; and the second mode comes later when higher ability, which includes also team and organizational abilities, accumulated during a working life, brings results. This suggests that the introduction of the age variable to proxy the innovation ability will produce an increasing profile at a lower age and at higher

[10] Calculation of the DG Employment based on the fourth European Working Condition Survey.

age. According to this perspective older workers might enhance competitiveness and therefore Europe's future innovative capacity might be less endangered than presently seems to be the case.

Occupation:

Variable used share of migrants in high occupation (ISCO 1, 2, 3).

The distinction between higher education and highly-skilled occupations belongs to the tradition of labour economic literature where an investment in education has to find an appropriate remuneration. Employment in inappropriate jobs suggests incorrect educational investment. In the case of women and foreign nationals discriminatory behaviour is also frequently reported and the stronger term "brain waste" is used. As mentioned before, the issue is quite complex because the same number of years of education do not necessarily imply the same level of human capital. The field of education, first, but also the quality of education are fundamental in determining the productivity of a given worker. Over-education, in fact, is receiving more and more attention as evidence becomes available of an increased mismatch between education and the jobs available on the labour market (OECD, 2014: 209).

With this proviso about limitations to any analysis, the effect of the workers in highly-skilled occupations on innovation has advantages and disadvantages: by limiting analyses to the highly-educated in highly-skilled occupations we eliminate the over-educated and present a more precise relationship between innovation and human capital. But, by doing so, the aggregate effect of an increase in the highly-educated, even if over educated, is not controlled while it could be the dominant component.

Fundamentally it is not known if better recognition of the education levels of foreign workers, that is recognition of their education degree, will favour the innovation and growth process; or, whether, alternatively, it is the use of highly-educated workers for elementary jobs that enhances a firm's productivity. We do not know, in other terms, if "brain waste" among foreign workers – e.g. tertiary educated migrants in manual jobs – is functional to the innovation process or, on the contrary, if it slows it down. In this light, it would be interesting to understand the human resource management of innovative firms versus more traditional ones. It would be important to learn not only the share of highly-skilled occupations but also the match between education and occupation.

Diversity

Another variable used in analyses is the **diversity index**, which measures the different national compositions of migrant populations. Most empirical studies employ the diversity of country of origin (country of birth or citizenship) as an appropriate proxy for the different soft skills which foreign nationals bring with them. The impact of ethnic fractionalism has also been studied by using Alesina et al.'s (2003) measure which scores ethnic, linguistic and religious heterogeneity.

The most frequently used measure of diversity index is D_i = 1-Herfindal index (F_j = , in which s_{ij} is the share of the group *i* (*i*=1, ..., *N*) in population (region, firm, sector etc.) *j*, where the groups differs by origin) or Theil index (T_j =))). The first index is more frequently adopted and it gives more importance to large groups having a squared term, while the second having a logarithmic form gives more importance to the marginal values.

The diversity index can include nationals or otherwise. In the first case they are strongly correlated with the share of migrants variable because migrants in general are a minority, hence it is typically limited to foreign groups.

As previously mentioned diversity has advantages but it can have also costs. The use of a linear form implies that more diversity should increase or decrease innovation. More likely there is an optimal amount of diversity: thus for instance the squared form used by Ozgen *et al*. (2012) could give a better understanding if there is an optimal amount of variety of countries of origin which favours innovation and could help better define the specific migration policy.

5. Research results

Research results are subdivided according to the type of innovation measure adopted: patents, which are closer to potential innovation; TFP which, instead, measures the outcome of innovation efforts; and surveys at firm level, which are more detailed but more heterogeneous.

5.1 Patents

Research on the effect of foreign workers on patents distinguishes between migrants registered as authors or co-authors of patents, named migrant inventors, and the effect of foreign workers on the production of innovative patents without foreign nationals necessarily being recorded as authors.

Table 1 Summary of results in studies on patents and migrants

Tabella formattata

	Est. effect	***Study***	***Unit of analysis***	***Inst.***
Area approach: Multi-ethnic society				
Share of Migrants	**positive**	OP (2013)	188 countries	Gravity
	no effect	ONP (2012)	EU NUTS2 regions	MacDonalds
	negative	BC (2012)	Italy NUTS3	Antonji and Card (1991)

Share of Highly Skilled Migrants	**no effect**	BC (2012)	Italy NUTS3	Antonji and Card (1991)
	positive	G (2012)	UK, TTWA 7digit post code	Card (2005, 2007)
Share of Highly Skilled Migrants (H-1B visa)	**positive**	KL (2010)	USA city level	N/A
Share of Migrants in Top Occupation	**positive**	BCV (2012)	EU 20 countries	Card (2001)
Share of Highly Skilled in High Tech	**positive**	BCV (2012)	EU 20 countries	Card (2001)
Share of Low Skilled Migrants	**negative**	BC (2012)	Italy NUTS3	Antonji and Card (1991)
Diversity Index (without natives)	**positive**	ONP (2012)	EU NUTS2 regions	MacDonalds
Diversity Index (with natives)	**positive declining**	DG (2014)	EU regions, 27 country	N/A
	negative	BC (2012)	Italy NUTS3	Antonji and Card (1991)
	positive	Na (2014)	UK, individual inventors	N/A
	positive	N (2010)	Germany NUTS3	5Ylag, space lag /latitude
Sector approach: Multi-ethnic production				
Highly Skilled Migrants	**positive**	FMV (2015)	19 Sectors for 13 years in in UK, DE, FR	GMM
Diversity Index (without natives)	**no effect**	FMV (2015)	19 Sectors for 13 years in in UK, DE, FR	GMM
Firm approach: Multi ethnic team.				
Immigrants' participation in ownership	**no effect**	M (2011)	Germany, firm level	N/A

Note: The following abbreviations are used

OP Ortega and Peri (2014); BC Bratti Conti (2012); G Gagliardi (2011); KL Kerr, Lincoln (2010); BCV Bosetti, Cattaneo, Verdoloni (2012); ONP Ozgen, Nijkan, Poot (2012); N Neibuhr (2010); M Mueller (2011); DG Dohse and Gold (2014), Na Nathan (2014); FMV Fassio, Montobbio Venturini (2015).

a. The first group of research focuses on **foreign nationals as inventors**, namely as authors or co-authors of patents registered at the local office. The first and most influential research has been based on the USA because there was more potential for data exploitation: the data on patents from the United States Patent and Trademark Office (USPTO) and the change in the H1B visa legislation, which made it easier for foreigners with degrees in STEM (Science Technology and Mathematics) to come and work in the USA (Kerr and Lincoln 2010; Hunt and Gauthier-Loiselle 2010). Research suggests that as legislation allowed more foreign STEM visas, foreign inventors became more numerous.

Policy implication:

The results indicate that the impact of highly-skilled migrants is positive and the policy conclusion is that letting in more highly-educated foreigners (STEM) enhances the overall production of patents. These results are, however, difficult to export outside the USA because they are conditioned by education and labour market functioning. There is no guarantee that the introduction of similar legislation, implemented in the same way, would have the same result elsewhere. The USA is a multi-ethnic society and has, as its language, the international language of communication, English. Both these points make it more attractive for foreign nationals to settle there as well easier to work there. In addition, in the USA, investments in both public and private scientific laboratories have created the conditions for profitable returns from migration. Also, the link between property and management can be very long, and the selection of workers based only on efficiency principles. Bureaucracy is limited and the labour market is flexible. Entering and leaving the labour market is easy, unemployment duration is short even in periods of recession, and the wage dispersion, namely the difference between the top and bottom wage quintile, is at least double that of the EU. This scenario represents a strong incentive for highly-skilled migrants to apply for a position in the USA with or without specific legislation because there is a demand for their skills and the cost of settlement and integration is lower.

b. The second group of research analyses the role of foreign workers in the production of patents and here there are many interesting European studies.

i. These studies adopt a regional approach and use country or region (EU countries or regions, Italian regions, German regions) or sub regions/provinces (UK) as the unit of analyses. This choice allows the tackling of issues arising from the potential endogeneity of migrant flows by using as an instrument of

the share of migrants the well known Card (2001) procedure.[11] The endogeneity of the share of migrant variable is easily explained. If a multinational decides to invest in a given region and hires a large number of foreign workers, the relation goes from the multinational firm, which produces a lot of patents, to the migrants not *vice versa*. To avoid this mistake the variable should be instrumented and Card (2001) stresses that the localization of migrants is determined by the localization of previous migrants, thus that the migratory chain determines migrant settlement and previous flows could be used to instrument the variable.

The spatial approach follows the first interpretation of Jacobs according to which innovation takes place at the territorial level. Thus, in addition, to the share of highly-skilled migrants, authors often test the impact of the diversity index of migrants' origin, obtaining positive and statistically significant results. Table 1 summarized the results of studies measuring the impact of migration on patent production.

Policy implication: The policy prescription derived from this analysis is that migration policies should be more open to highly-skilled migrants from abroad. Moreover, as the diversity measure has a positive value, migrants should be selected through a quota system favouring the heterogeneity of countries of origin.

ii. The sectoral perspective adopted by Fassio, Montobbio and Venturini (2015) questions the prevailing approach, described above, by adopting the Vernon Henderson (1988) interpretation of Jacobs in terms of sector complementarity. Migrants have different talents which make them productive in *different sectors*. Thus it is the complementarity of different sectors which increases innovation. The authors develop the analyses of the role of migrants in patent creation *at sector level*. They also add an age variable to complement education and diversity. The patent variable is available only for the manufacturing sector where additional information on R&D investments and openness to trade allows the introduction of fixed effects, but also many time variant controls. The endogeneity of the share of migrants is controlled as in Card by using previous variables, namely, in this case, a GMM system method.

The results show that sector differentiation matters in understanding the role of highly-skilled and low-skilled migrants. In high tech sectors highly-skilled migrants matter as well as the diversity measure, neither of which are significant in low tech sectors[12].

[11] The methodology implemented by Card takes advantage of the fact that migrants of a certain nationality tend to move to locations where other people of the same nationality have already settled. Therefore, by using the original distribution of nationalities across different geographical areas at the beginning of the observed period and the exogenous migration flow from a specific country of origin toward the country of destination under analysis, it is possible to create a fictional flow of migrants for each geographical area, built up as if the new entrants would settle only where other foreign workers of their same nationality had already settled.

[12] For brief presentation see also Venturini 2013.

Policy implication:

This implies that migration policy should be driven by the demand for labour, avoiding an indiscriminate openness to highly-skilled migration, but, rather, following strictly demand as with foreign inventors.

5.2 Total Factor Productivity

The research on Total Factor Productivity follows for the most part the regional (spatial) approach, where the unit of analysis is the country. Two studies stand out: Ortega and Peri (OP, 2014) and Alesina, Harmoss and Rapoport (AHR, 2013). The first compares the openness to trade with the openness to migration in OECD countries, while the second compares diversity by country of origin and by ethnicity in 195 countries. These two studies have a cross-country approach, which allowed the use of the gravity model to instrument the potentially endogenous flows of migrants.

Both studies confirm that the share of migrants and the share of highly skilled migrants play a positive role in production. Moreover, diversity in countries of origin contributes positively too. Alesina, Harmoss and Rapoport (2013) compare the effect of ethnicity diversity with the diversity of origin of migrants, suggesting a negative impact for the first and a positive impact for the second, showing that the two indexes do not overlap.

Table 2 Summaries of results in studies of Total Factor Productivity and Migrants

		Est. effect	*Study*	*Unit of analysis*	*Inst.*
Area approach: Multi-ethnic society					
	Share of Migrants	**positive**	AHR(2012)	195 countries	Gravity
		positive	OP (2013)	188 countries	Gravity
		no effect	OP(2009)	OECD countries	Gravity
	Share of Highly-Skilled Migrants	**positive**	OP(2012)	OECD countries	Gravity
		no effect	AHR (2014)	195 countries	Gravity
	Share of Low-Skilled Migrants	**positive**	AHR (2014)	195 countries	Gravity
	Diversity Index (without natives)	**no effect**	AHR (2014)	195 countries	Gravity
	Diversity Index Highly-Skilled (without natives)	**positive**	AHR (2014)	195 countries	Gravity
	Diversity Index Low Skilled (without natives)	**no effect**	AHR (2014)	195 countries	Gravity
Sector approach: Multi-ethnic production					

Share of Migrants	**positive**	FKV(2015)	89 Sectors, 13 years FR, DE, UK	Card (2005, 2007)
Share of Highly-Skilled Migrants	**positive**	FKV(2015)	89 Sectors, 13 years FR, DE, UK	Card (2005, 2007)
Diversity Index (without natives)	**positive/no effect**	FKV(2015)	89 Sectors, 13 years FR, DE, UK	Card (2005, 2007)

Note: The following abbreviations are used
AHR Alesina, Harnoss and Rapoport (2013); OP Ortega and Peri (2009); OP Ortega and Peri (2012); OP Ortega and Peri (2014); FKV Fassio, Kalantaryan and Venturini (2015).

Finding a positive impact for migrant diversity at country level does not provide any final answer, as the results obtained are likely to mix up the sector composition of the destination country and the different countries of origin of migrants. This issue is also related to the unlikely high coefficient of the share of migrants found by Ortega and Peri (2014), which presents an elasticity of 0.6: according to their study an increase of 1% of the share of migrants should lead to an increase of 6% in the Total Factor Productivity. This sounds very optimistic.

The sector analyses undertaken by Fassio, Kalantaryan and Venturini (2015) address the impact of migrants on the Total Factor Productivity in France, Germany and the United Kingdom from 1995-2008. The results confirm the heterogeneous impact of the foreign labour force once different sector groups are considered. While the share of migrants has a significant effect on the Total Factor Productivity in all sectors, stressing the general positive impact of the foreign workers on innovation, the share of highly-skilled migrants is significant only in the high-tech sectors. These include both high tech manufacturing and high tech services, where the age variable is always negative, stressing the importance of being young for innovation. The study also demonstrates that medium and low skilled migrants are positively associated with the growth of Total Factor Productivity in manufacturing and low-tech sectors. Moreover, variegated migrant backgrounds (different countries of origin) seems to have no significant impact in most sectors. It has a statistically significant positive association only when the service sector is considered. There probably the human capital composition is more important.

Thus migrants seem important in spurring innovation, but using a sector approach considerably reduces their elasticity with respect to TFP growth. Indeed, considering that, on average, the share of migrants out of total employment is not higher than 10% in France, Germany and the UK, an increase from 10% to 11% would lead to a TFP increase of 3% in high tech sectors (where the effect is stronger). However, the increase would be of only 0.8% in the services sectors. Moreover, given the logarithmic form adopted, if the size of the migration community is large this effect declines. Diversity does not seem, in fact, to be crucial, while the role of low skilled migrants does emerge in some sectors.

Policy prescription:

The migration policies that favour the growth of TFP should be point-system based. This would allow policies to be designed with special attention to sector and, hence, labour demand dynamics.

A migration policy centred on a quota system, which can capture the diversity of countries of origin, seems relevant at national level but loses its importance when tested at the sector level. It seems to point, in fact, both to complementarity between sectors and to specialization in migrants at sector level.

5.3 Survey at firm level

Research at firm level should give the final word on the relations between migration and innovation. However, the results here are ambiguous. We sum up the research at firm level in Table 3, and, at first glance, the results are very heterogeneous with no clear pattern. The analyses refer to samples of firms from different countries. Hence, the inconsistency of results from different studies (not significant, negative or positive) could be related to different national innovation dynamics. Moreover, it is likely that the national firm mix is affected by the national institutional organizations or the natural economies of scale. These create differences that reduce possible generalizations.

The only consistent result, estimated for Ireland and Germany, suggests that diversity in the composition of migrants at the regional level favours plant innovation. Again this result could be interpreted, as suggested before, as the result of complementarity among different firm sectors. Migrants of different origins specialized in different sectors give complementary services and products to firms.

The different contribution of migrants in the innovation of products or processes makes it even more difficult to disentangle the role of foreign labour. For Lee and Nathan (2013 ethnic fractionalism in firm employment plays no role in the innovation of products, while instead it seems more effective in the introduction of new working practices. The opposite is documented by McGuirk and Jordan (2012).

Policy implication
Migration policy needs to be very country specific because it should follow the demands of firms which work in different sectors and regions. They should not necessarily favour highly-skilled immigration because the empirical evidence does not support a clear production function with a specific role for human capital.

Table 3 Summary of results in firm studies

	Est. effect	***Study***	***Unit of analysis***	***Instrument.***
Firm approach: Multi ethnic team.				
Share of Migrants	**no effect**	TBS (2012)	Germany, plant level	SYSGMM, Card (2005)

	negative	ONP (2013)	Netherlands, firm level	N. of foreign restaurants., past foreign pop
Share of Highly-Skilled among Migrants	**no effect**	OPNNP(2014)	Germany, Netherlands, plant level	G Similar plant GLOBE measure, N Lagged 4 years
Share of Highly-Skilled Migrants	**no effect**	ONP (2013)	Netherlands, firm level	N of foreign restaurants, past foreign pop.
Diversity index (without natives)	**negative**	PPP(2014)	Denmark, firm level	Ackergberg et al. (2006), serial dep.
	positive	ONP (2013)	Netherlands, firm level	N. of foreign restaurants, past foreign pop.
Diversity index at Regional Level (without natives)	**positive**	MJ (2012)	Ireland, business level	N/A
	positive	TBS (2012)	Germany, plant level	SYSGMM, Exclusion
Diversity index at Firm Level (without natives)	**no**	OTK (2011)	Denmark, plant level	N/A
	no effect	TBS (2012)	Germany, plant level	SYSGMM, Exclusion
Ethnic Fractionalisation Index	**positive/ no effect**	OPNNP(2014)	Germany, Netherlands, plant level	4 year lags of n. of Countries of Birth in municipality, diversity in similar plants.
	no effect	LN (2013)	London Business Survey	N/A
Cultural Diversity	**positive/ no effect**	LN (2013)	London Business Survey	N/A
Cultural Diversity among Highly-Skilled	**positive**	BS (2013)	Germany, plant level	N/A

Note: The following abbreviations are used
TBS Trax, Brunow and Suedekum (2012); ONP Ozgen, Nijkan and Poot (2013); LN Lee and Nathan (2013); PPP Parrotta, Pozzoli and Pytlikova (2014); MJ McGuirk and Jordan (2012); OTK

Østergaarda, Timmermansa and Kristinsson (2011); BS Brunow and Stockinger (2013); OPNNP Ozgen, Peters, Neibuhr, Nijkamp and Poot (2014)

Conclusion

Highly-skilled workers are in high demand. They seem the best solution for satisfying Europe's population and labour needs: they exploit national welfare services less; they socialize with natives more[13] and integrate better; and, last but not least, they can favour innovation.

With the Lisbon strategy, the European Council launched the competitiveness objective. The European Commission, meanwhile, with the Blue Card Directive, inside the Global Migration Approach, provided the instrument to foster competitiveness through highly-skilled migration, defined as the migration of the tertiary educated.

The presence of highly-skilled foreign workers is not evenly distributed among the European Member States: it varies from 10.4% to 34% (OECD 2009). However, the demand forecast for highly-skilled workers will increase, in 2020, by 8% in the occupation structure.[14]

This research paper has tried to elucidate why and if highly-skilled foreign workers favour innovation measured at national or regional and sector level in terms of patent registrations or by the Total Factor Productivity, or at firm level through surveys.

Research at firm level is idiosyncratic, the results changing according to the country considered and to sector composition: it is, thus, difficult to give general policy prescriptions.

Nevertheless, the cross-national studies do not have a time dimension and do not control for the specific country effect. Therefore, the results are also not easy to extend to specific cases. The sector approach suggests, meanwhile, that the positive effect of highly-skilled workers varies according to the sector and that it is positive in the High Tech sectors but not in others and in some sectors low skilled workers, too, favour innovation.

These results would lead to the following policy conclusions:

i. An open-to-highly-skilled policy cannot spur a generalized increase in innovation, as is frequently suggested. If it is advocated, it should have different aims, for instance a reduced use of the welfare state and easier integration. Even if more highly-educated migrants do not damage the growth rate and direction of the economy of the destination country, they can create

[13] De Palo, Faini and Venturini 2007 show that highly educated migrants interact more in their social live with natives.
[14] Or 16% of the qualification structure, 10 million highly-skilled jobs, see CEDEFOP 2010.

over education. This can reduce integration and satisfaction among the migrant community and lead to public funded integration policies;

ii. migrant diversity (in terms of country of origin), at regional or country level seems to favour innovation. Yet it appears to be, above all, the result of complementarity among different sectors of production in which migrants are specialized. Thus, a migration policy which includes a quota for migrants of different origin is perhaps unlikely to spur innovation. If "Indian engineers" are in high demand in Europe, it is not because European countries have few highly-skilled Indians in their labour force. Rather, it is because Indian engineers are the best engineers on the world market at the present time;

iii. to favour innovation migration policy should, instead, follow sector and firm demand for highly-skilled workers in STEM or in general fields . A points system which stresses the necessary skills in short supply seems to be the most appropriate policy.

American research on the increase in foreign patent inventors after the introduction of the H1B Visa, which facilitated migrant entrance to the USA, provides evidence in this direction . The sector analysis demonstrates that the effect of foreign skilled labour differs according to the relevant sector .

In the European Union the Blue Card directive should be revised, but it goes in the right direction by favouring the hiring of the highly-skilled by firms in short supply.

But the crucial issue becomes how to match migration with highly-skilled labour market shortages. In general forecasts are based on arbitrary assumptions and frequently do not meet the needs. Information collection through job placing offices or employer surveys seems better able to chart local demand. But they are difficult to manage at the national level where migration policy is organized. Perhaps firms should simply apply to the national migration office, thus linking supply and demand. However, this system works only in countries where bureaucracy is efficient.

The focus, thus, shifts from the migration policy to its implementation, which depends on various idiosyncratic factors: the institutional efficiency of the country of destination; its geographical position; the language spoken etc. This implies different results achieved by the same policy in different contexts. It should be remembered, finally, that in all destination countries inflows of migrants for labour reasons are a minority of total inflows. About 50% of inflows are family reunifications, about 20% refugees and about 30% labourers. A "labour migration policy" has to be very efficient in pursuing labour market priorities, then, because about 70% of foreign inflows respond to different priorities.

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