1

Introduction

The International Mobility of Talent and Innovation – New Evidence and Policy Implications

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At the time of the French Revolution, the United States was the world's biggest exporter of cotton but did not possess appropriate technology – such as water spinning frames – to process it. Such technology existed in Great Britain. Aware of this technological advantage, the British authorities banned textile craftsmen from traveling to the United States. Nonetheless, in 1789, a twenty-one-year old Derbyshire-born apprentice of the early English textile industry, Samuel Slater, could not resist offers from American entrepreneurs and emigrated, bringing textile technology to the United States. Known as "Slater the Traitor" in Britain, he became the "Father of the American Industrial Revolution." In the United States, he partnered with industrialist Moses Brown, who had acquired a spindle frame but was unable to operate it. Slater used his knowledge to adapt the technology to local needs – one of the many factors that spurred American industrial development, for the United States to eventually overtake Britain as the world's leading industrial nation.

Interestingly, Slater's wife, Hannah, invented a type of cotton sewing thread and became the first American woman to be granted a patent in 1793. Moreover, Slater's brother John, a wheelwright, spent time studying Britain's latest technologies and emigrated to the United States in 1799 to join his brother in the emerging American textile industry.

This rich anecdote illustrates the important contributions migrating knowledge workers have made to the diffusion of knowledge and subsequent technological development in their adopted home countries. These contributions are no less important today. Take the case of Professor Venkatraman Ramakrishnan, who received the 2009 Nobel Prize in Chemistry for studies of the structure and function of the

ribosome. Professor Ramakrishnan was born in India and studied at Ohio University. When he received his Nobel Prize, he worked at the Laboratory of Molecular Biology of Cambridge in the United Kingdom. Like many of his fellow Nobel Laureates, Professor Ramakrishnan has been a prolific inventor, applying for numerous patents. He has also reinforced his ties with his homeland and regularly visits Bangalore, where he "works on papers and reviews, gives lectures and talks to colleagues and especially young scientists there."[1]

That science, technology, and innovation are central drivers of economic growth is well understood by policymakers worldwide. It is also not a new paradigm – indeed, since the onset of the first industrial revolution, technological breakthroughs have been responsible for generating levels of prosperity unimaginable to prior generations. What is new, however, is the knowledge intensity of economic output. Never before has the world economy devoted so many resources to pushing the knowledge frontier. Between 1993 and 2009 alone, global spending on research and development (R&D) doubled in real terms. To gain a competitive edge, firms are increasingly investing in intangible assets – not only R&D but also worker training, software, organizational and managerial know-how, design, and branding – rather than traditional "bricks and mortar" assets.[2] Developing a workforce fit for the modern knowledge economy thus has become a strategic goal for governments worldwide.

Harnessing the benefits of knowledge worker mobility plays an increasingly prominent role in achieving this goal. For example, virtually all governments in high-income countries have made efforts to attract skilled migrants from abroad – inciting what might colloquially be called a "global competition for talent." Examples of such efforts are the Indian and Chinese information technology (IT) workers migrating to the United States under the H-1B visa framework and the Blue Card initiative launched by the European Union. These often-sensitive immigration initiatives have incited lively public debate, contentious parliamentary discussions, and frequent policy adjustments. At the same time, governments have also recognized that there are benefits from knowledge workers moving abroad, especially in the form of such workers gaining experience and becoming part of global knowledge networks.

Better understanding of the circumstances and implications of knowledge worker migration thus has become an important task for economic research. Traditionally, economic analysis has focused on the damaging "brain drain" aspects of knowledge worker emigration, especially emigration from developing economies. While this is still an important

concern today, a burgeoning literature over the last fifteen years has sought to go beyond the brain-drain dimension and explore other consequences of skilled worker mobility. In particular, this literature has empirically analyzed the contribution of migrating knowledge workers to innovation in receiving countries and the role that overseas diasporas and return migrants play in fostering innovation in sending countries.

Against this background, this book has two objectives. First, it provides a synthesis of the recent literature on this topic, with an emphasis on research exploring how skilled migration contributes to innovation and knowledge diffusion. Second, it makes an empirical contribution to that literature by employing patent data as a new source of information on knowledge worker mobility.

As regards the first objective, the book's analytical chapters approach knowledge worker migration from a variety of angles, outlining key conceptual relationships and summarizing the state of empirical insight into those relationships. In so doing, the chapters seek to distill high-level policy implications. As for the second objective, patent data hold substantial potential for insight into one specific class of knowledge workers at the center of innovative activity – namely, inventors. However, using this microdata source poses unique challenges and requires new methodological approaches that several of this book's empirical chapters discuss.

In this opening chapter we offer an overview of the main contributions, summarize the key policy implications, and identify important research gaps for future investigations to fill. We start by reviewing the main cross-country patterns and trends shaping international knowledge worker migration (Section 1.1). In so doing, we discuss the pros and cons of alternative data sources and, in particular, methodological challenges and solutions for making effective use of patent data for migration research. As a second step, we review the main analytical questions addressed in this book and synthesize the findings of the analytical chapters (Section 1.2). Against the background of this discussion, we suggest what insights from the economic research imply for policymaking and identify useful possible directions for future research (Section 1.3).

1.1 How Important Is Knowledge Worker Migration?

In 2013, the population of migrants worldwide stood at an estimated 231.5 million – a 50.1 percent increase compared to 1990 (UN-DESA and

OECD 2013). With overall population figures growing at a similar pace, the world migration rate rose only modestly, from 2.9 to 3.2 percent. As Docquier and Rapoport (2012) note, these figures seem small compared to other measures of global integration. For example, the trade-to-gross-domestic-product (GDP) ratio tripled from 10 to 30 percent between 1960 and 2000.[3] However, as these authors argue, global migration figures mask important variation across countries and types of migrants. Once one focuses on migration to high-income countries and the skills composition of these migrants, important nuances emerge. For example, Docquier and Rapoport (2012) point out that the share of immigrants in the population of high-income economies has followed a similar dynamic as the world's trade-to-GDP ratio. Indeed, two-thirds of migrants live in high-income countries today. In the countries of the Organization for Economic Cooperation and Development (OECD), around 11 percent of the population is foreign born – compared to the 3.2 percent share for the world mentioned earlier (Arslan et al. 2014). In addition, the number of highly educated immigrants – those with at least tertiary education – living in OECD countries increased by 64 percent during the 1990s, compared to only a 23 percent increase for low-educated immigrants for the same period (Docquier and Rapoport 2009). The growth differential widened during the 2000s, with highly educated immigrants in OECD countries seeing 70 percent growth against 10 percent growth for low-educated immigrants (Arslan et al. 2014).

Notwithstanding its importance, the international mobility of labor remains understudied, especially when compared to other pillars of the globalization process such as trade and capital flows. One key reason for the limited research interest has been the paucity of migration data. Fortunately, the last fifteen years have seen new databases becoming available that have begun to improve our understanding of international labor mobility. The pioneering study by Carrington and Detragiache (1998) represents the first systematic attempt to construct a comprehensive data set on emigration rates by educational attainment – defined as the ratio of emigrants to total population. Their work reports emigration rates in 1990 for sixty-one sending countries to OECD destinations. They estimate skill levels by extrapolating the schooling levels of US immigrants by origin country to other receiving countries. Subsequent data-building efforts – described by Çaglar Özden and Christopher Parsons in Chapter 2 – have sought to overcome this limitation by employing census data of a large number of receiving countries to calculate the immigrant stocks by country of origin and skill level and eventually to obtain

bilateral stocks of migrants for a large number of countries and for several points in time.

Using data from the 2000 census round, Özden and Parsons (Chapter 2) establish several important migration patterns and trends. To begin with, high-skilled immigrant stocks are highly concentrated, meaning that relatively few destination countries account for the overwhelming majority of global high-skilled migration. The United States is by far the most attractive destination, followed by other English-speaking countries and then other OECD destinations. Other regions, such as the oil-rich countries of the Middle East, South Africa, and Singapore, have emerged as important destinations for skilled migrants. However, from 1990 to 2000, non-OECD countries have seen slower overall growth in high-skilled immigration than their OECD counterparts, exacerbating the concentration of skilled migrants in high-income economies.

One significant drawback of data on high-skilled migration is the definition of *skills*. Available data only offer information on the educational achievements of migrants, leading researchers to focus on individuals with tertiary education. Policymakers seeking to attract skilled immigrants tend to focus on the skill level of occupations, for which few migration data points exist. Recently, other approaches to categorizing high-skilled migrants have emerged, such as the use of income or wage ranges – though these need their own caveats when migrants work in occupations that do not reflect their true skill level.

Özden and Parsons find a strong correlation between the three skills definitions among US workers, including immigrants. However, they also report on large differences in educational achievements and wages within individual occupation groups, pointing to pronounced heterogeneity among high-skilled immigrants. Indeed, tertiary education may include nonuniversity tertiary degrees, undergraduate university degrees, postgraduate degrees, and doctoral degrees. To complicate matters further, the definition of educational attainment may differ from country to country; some migrants may be able to transfer the educational achievements acquired in their home country to their destinations, whereas others cannot, and some countries identify migratory background through an individual's country of birth, whereas others rely on citizenship information.

A final important limitation of census data is their infrequent availability: typically, they are only produced every ten years – or five years at best – and then published with a significant lag; for example, as of 2016, data from the 2010 census have been only recently released.

In sum, despite notable improvements, the availability and comparability of data on high-skilled migrants remain significant constraints for research into the causes and consequences of this phenomenon. In line with recent economic research in the field of innovation, this book embraces an alternative approach to studying the international mobility of high-skilled workers: the use of bibliographic information on inventors disclosed in patent applications.

The attraction of patent-inventor data for migration research lies in such data being available for a wide range of countries and years and for detailed technology classes. Moreover, inventors constitute a large and influential group of high-skilled workers and a special category of them. Inventors listed in patent documents constitute one specific class of workers that is bound to be more homogeneous than the group of tertiary-educated workers as a whole. In addition, inventors arguably have special economic importance because they create knowledge that is at the genesis of technological and industrial transformation. Thus the use of patent-inventor data for migration analysis enables the direct measurement of migrants' contributions to innovation in their destination countries, in particular, in relation to science-based and advanced technologies. Moreover, when these data are exploited together with patent citations and information on co-inventors, it is possible to track, respectively, knowledge flows and social networks either within the same destination country or reaching back to inventors' countries of origin. In principle, it is also possible to track returnee inventors and thus explore the implications of return migration for the economies of sending countries.

Inventor information retrieved from patent data thus may help us to find answers to several important questions. What is the contribution of foreign knowledge workers – of whom inventors are an important subgroup – to technological innovation in their host countries? Do high-skilled workers substitute for the local labor force, or do they complement each other? How desirable and effective are immigration reforms aimed at attracting and retaining highly talented foreign workers? And what challenges and opportunities may arise from high-skilled emigration for low- and middle-income countries, especially in the form of future inward knowledge flows and possibilities for technological catchup?

Of course, using inventor data for migration research presents its own challenges and requires new methodological approaches. One approach is to track inventors' international mobility by following their patenting

histories across different countries.[4] This approach can capture inflows and outflows of one single country, although it is not the most appropriate methodology to depict the full picture of inventor migration across several countries. For example, one may observe many inventors migrating from the United States to China and India, but most of them will likely be returnee inventors that applied for their first patent while studying or working in the United States and for subsequent ones after having returned to their home country.

More recently, other approaches have emerged. In this book, we present two alternatives. Our chapter (Chapter 4) describes the first, relying on information on both the nationality and residence of inventors. Such information is available for many patents filed under the Patent Cooperation Treaty (PCT). The World Intellectual Property Organization (WIPO) has released a data set that identifies inventors with migratory backgrounds as those whose nationality differs from their residence.[5] This data set has several attractions, notably the fact that it includes a large number of sending and receiving countries and covers a long time period. Equally important, it does not require performing complex – and necessarily imperfect – algorithms in order to ascertain the likely origin of inventors (see further below). Unfortunately, it also comes with some limitations. The data do not include immigrant inventors who became citizens of the host countries, likely leading to an underestimate of inventor migration. Moreover, the data set only covers inventors listed in PCT patents, which is a subset of all patenting inventors and, indeed, of all inventors regardless of whether they patent or not.

In Chapter 3, Stefano Breschi, Francesco Lissoni, and Gianluca Tarasconi describe the second alternative approach, which combines information on inventors published in patent documents with extensive information on the ethnic origin of names and surnames drawn from official registers. Kerr (2008, 2007) pioneered this approach, combining inventor name data from the US Patent and Trademark Office (USPTO) with the Melissa Ethnic-Name Database, a commercial repository of names and surnames of US residents classified by likely country of origin. Breschi, Lissoni, and Tarasconi make use of the IBM-GNR system, a commercial product that associates a list of names and surnames with a likely country of origin.[6] In particular, they apply it to inventors listed in applications filed at the European Patent Office (EPO). This approach has natural limitations. For example, it is inherently difficult to set apart inventors from Spain and those from Latin American countries. Similar problems exist for inventors from English-speaking countries.

In addition, to the extent that inventors are second-generation migrants, the ethnic origin of their names is bound to be misleading. However, use of the IBM-GNR database holds substantial promise because it can be applied to inventor data from around the world and not just the United States. It is also encouraging that the results from the "ethnic matching" algorithm put forward by Breschi, Lissoni, and Tarasconi seem consistent with the more reliable – if narrower – PCT inventor migration data set.

What can patent-inventor data tell us about global migration patterns and trends? First, these data suggest that inventors are not only more mobile than the average migrant but that they are also more mobile than other high-skilled migrants. The migrant share among tertiary-educated workers worldwide stood at an estimated 5.4 percent in 2000, whereas we estimate a migrant share of around 8 to 9 percent for the population of PCT inventors. Inventor migration data confirm that OECD countries receive the most migrants. They also show that countries such as Switzerland, the United States, Ireland, and Belgium stand out in attracting foreign inventors, whereas Japan, the Republic of Korea, and Italy rank at the bottom of the list.

Breschi, Lissoni, and Tarasconi go on and, by means of regression analysis, also confirm the significant contributions of foreign inventors to host-country productivity, as captured by the citations that patents of immigrant inventors receive. This question has been at the center of a large part of the migration economics literature, and results using inventor data seem to be consistent with previous research conducted for the United States (Kerr 2010; Peri 2007; Stephan and Levin 2001). Inventor data have the potential to deepen our understanding of the contributions of the foreign born, for example, by exploring whether those contributions differ by technology field and by generating evidence beyond the United States.

Making effective use of inventor data invariably requires efforts by researchers to go beyond the limited information on inventors provided in patent documents, which may only indirectly provide information on migratory background and certainly does not include information on educational attainment, gender, income, and other socioeconomic variables. Researchers have tried to enrich patent-inventor data by linking them to census information and social security registers.[7] This approach seems promising, and more such studies would be welcome. Finally, most investigations relying on patent-inventor data require some degree of name disambiguation, which is usually a time- and resource-intensive procedure.

Disambiguation means identifying whether two or more inventors who are listed in several patent documents and share the same or similar names relate to the same person. Disambiguation algorithms typically make use of the other bibliographic data provided in patents, such as the postal address, the names of co-inventors, citations, technological class, patent ownership, and other variables. While performing this operation, type I errors (false positives) occur whenever two inventors are presumed to be the same person when in fact they are not; type II errors (false negatives) occur whenever two inventors who are indeed the same person are not identified as such. Over the past decade, the scientific community has developed sophisticated algorithms that do an increasingly good job of minimizing both types of errors. However, this journey is far from complete, and further investments in name disambiguation, with relevant institutional support, has the potential to improve the quality of data available to researchers.

In sum, the first part of this book highlights the fact that data limitations have been an important obstacle to better understanding the international mobility of high-skilled workers. Fortunately, the situation is not as bleak as it was some fifteen years ago. In addition, patent-inventor data have emerged as a promising source for new micro- and macro-level investigations that have the potential to shed new light on a variety of research questions – including the ones discussed in the next section.

1.2 Causes and Consequences of Knowledge worker Migration

Economists and other social scientists have devoted great efforts to understanding the causes and consequences of human migration. Much of the early research interest starting in the 1950s, especially in developing countries, focused on internal rural-urban migration patterns. Soon interest shifted toward international migration too, with the rise of several theoretical contributions trying to formalize the cost-benefit analysis of the migration process in a context of welfare maximization and the development consequences of emigration for low- and middle-income economies.[8]

Interest diminished slightly during the 1980s, but a rich empirical literature emerged from the 1990s onward, encouraged by the creation of the new data sets described earlier. This literature also addressed new questions, especially in relation to the consequences of knowledge worker migration. The analytical chapters in this book offer a window into the current state of the art. This section summarizes the key insights

that emerge. It is divided into three parts, first asking why people and knowledge workers migrate, then looking at the impact in receiving countries, and finally exploring the consequences in sending countries.

1.2.1 Why Do People, and Particularly Knowledge Workers, Migrate?

An important stepping stone in better understanding why people migrate has been the use of so-called gravity models. Gravity models have gained widespread popularity in the international trade literature, though they were used long before to study the migratory patterns of labor.[9] Due to their empirical success, they have also become common in empirical migration research.[10] The gravity approach allows testing of a large range of hypotheses. For example, many studies have looked at the impact of income differentials on migration, finding that an increase in absolute differences in earnings per capita causes bilateral migration to rise. These studies employed different measures of relative income per capita – including, among others, wages, GDP, and posttax earnings. Other studies highlighted additional factors explaining observed migration patterns. These include the role of immigration policies in destination countries; cultural, linguistic, and geographic proximity between country pairs; and the diasporic networks between sending and receiving countries.

As described in Section 1.1, the international mobility of knowledge workers such as scientists and engineers has emerged as a critical component of total migration flows over the last twenty-five years. However, empirical evidence fostering understand of the factors behind the international mobility of these knowledge workers is still relatively sparse. At most, some studies have relied on census data split into educational levels to study differences in migration patterns of skilled workers versus unskilled workers. The rationale behind this approach is based on the idea that migrants tend to self-select; that is to say, the more educated ones are the more likely to migrate (Borjas 1987). Hence variables such as immigration policy, geography, and networks may explain not only the absolute flow of international migrants across country pairs but also, more important, their skills composition.

Yet, despite these commendable efforts, our understanding of the determinants of knowledge worker migration is still insufficient. Our chapter with Julio Raffo (Chapter 5) is an attempt to fill this knowledge gap. Using the newly released data set on inventors with nationality