INSIGHTS

POLICY FORUM

MIGRATION

Crossing borders along an endless frontier

Ideas do not carry passports. But lines on maps, as well as policies and pressures that influence who does or does not cross them, can be powerful determinants of whether and how ideas and skills align to advance scientific discovery and technological and economic progress. As headline-grabbing rhetoric and acts stir passions over immigration around the globe, *Science* invited social scientists to bring evidence to the discussion concerning the role foreign-born talent plays in scientific and technological discovery.

A mobility boost for research

By **Giuseppe Scellato,[1,2] Chiara Franzoni,[3] Paula Stephan[4,5]**

Although scientists are highly internationally mobile, it is not always clear if mobility is beneficial, and if so, in what circumstances. Our GlobSci project, which surveyed 17,852 scientists working in 16 countries (*1*), allowed us to examine outcomes related to mobility across a wide array of countries, rather than focus on mobility to the United States, as many studies do. We find that the impact factor of research by foreign-born scientists (measured by country of residence at age 18) is on average higher than that of natives who have no international mobility experience. The effect persists when we account for the fact that migrant scientists may be selected from among the best in the origin country, using individual-level data on migration during childhood, which is correlated to the likelihood of subsequent international mobility but arguably not correlated to the scientific quality of the migrant. Our findings suggest that cross-border mobility comes with a boost in research quality that would have been absent without mobility (*2*). The boost is consistent with the theory that migration enhances performance by facilitating knowledge recombination and specialty matching. In other work, we examined the role that mobile scientists play in the performance of single-laboratory–based research teams. Studying 4336 teams from among the 16 countries, we find a performance premium (in terms of impact factor and 3- and 6-year citation counts) for teams with a foreign-born corresponding author. This premium persists when comparing labs within a country and within the same institution. The premium is larger when migrants occupy a position of decision power in the team, such as the principal investigator, when the paper is reported by the respondent to be highly creative, and when the team works in an area of science where knowledge is produced predominantly in a few geographic locations (*3*).

REFERENCES

1. C. Franzoni, G. Scellato, P. Stephan, *Nat. Biotechnol.* **30**, 1250 (2012).
2. C. Franzoni, G. Scellato, P. Stephan. *Econ. Lett.* **122**, 39 (2014).
3. C. Franzoni, G. Scellato, P. Stephan. *J. Manage. Stud.* 10111/joms.12279 (2018).

10.1126/science.aan4052

Private strategy, public policy

William Kerr[6,5]

Firms, by design, are the central actors in the U.S. high-skilled immigration system. Whereas "points-based systems," in which governments select migrants on the basis of their curricula vitae, can struggle with underemployment of migrants (*1*), the U.S. system delegates selection to firms, roughly saying: "Tell us whom you want to employ, and we will admit them up to a limit and subject to basic conditions." Motivations of firms thus become motivations of the immigration system. But despite potential advantages, policy implementation is crude: The H-1B visa is basically first-come, first-served and uses a lottery in years with very high demand, like 2017. Thus, each visa is a random selection of potential firm motivations, only partly aligned with national intentions and that creates unanticipated winners and losers in how the impact of migration is felt among U.S. citizens. Firms can hire migrants to be more innovative, unlock growth of jobs and profits, and benefit citizens (*2*, *3*), but many employers use visas to keep their workforces younger, lowering wage costs and perhaps garnering employees more willing to work longer hours. Our study of 319 of America's largest employers and technology firms found that expansion of young, skilled immigrant employment led to more jobs for natives, but these mainly went to younger workers (*4*). Similarly, the H-1B system is very flexible and helps ensure that migrants are chosen to fit the current needs of employers. For example, the share of visas going to computer-related occupations has fluctuated 25 to 75% over 5-year time spans, depending on economic conditions (*3*). However, this flexibility also allows visas to be used in ways that the program did not intend, such as roughly a quarter of visas being claimed by Indian outsourcing companies to aid moving work away from the United States. Ultimately, high-skilled migration is not a zero-sum game, as the productivity of skilled workers in many industries is enhanced by proximity and collaboration with other skilled workers. One promising refinement is to award H-1B visas in order of the salaries to be paid, which could help ensure that higher-value–added applicants are selected and weaken any potential undercutting of American workers. This would need to ensure equal footing for small firms and an appropriate balance over occupations and industries. Innovative approaches need to be considered for determining the number of visas, such as an index to economic conditions, such that we are not locked into fixed quota levels that can span a decade without connection to current needs.

REFERENCES

1. S. P. Kerr, W. Kerr, Ç. Özden, C. Parsons, *J. Econ. Perspect.* **30**, 83 (2016).
2. W. Kerr, W. Lincoln, *J. Labor Econ.* **28**, 473 (2010).
3. S. P. Kerr, W. Kerr, W. Lincoln, in *Innovation Policy and the Economy*, W. Kerr, J. Lerner, S. Stern, Eds. (Univ. of Chicago Press, 2015), vol. 15, pp. 115–152.
4. S. P. Kerr, W. Kerr, W. Lincoln, *J. Labor Econ.* **33** (suppl. 1), S147 (2015).

10.1126/scieince.aan1521

Countering European brain drain

Reinhilde Veugelers[7]

Researchers who are internationally mobile during early stages of their academic career display, on average, higher scientific productivity (e.g., increased number and quality of subsequent publications) [e.g., (*1*)]. Using large-scale survey data on European researchers who have been mobile after their Ph.D., we found similar self-reported effects on productivity but also positive effects on their research career, such as access to a network of experts. Mobile European researchers who went to the United States were significantly more likely to report strong positive career effects than their mobile peers who moved within the European Union (EU) (up to twice as high) (*2*). Taking into account personal, field, and home-country characteristics, researchers who moved to the United States are particularly more likely to be strongly career-motivated compared with their intra-EU–mobile peers. Once this selection is accounted for, there are no longer significant differences in productivity effects between U.S.-mobile and intra-EU–mobile researchers. These results suggest that the United States manages to attract career-motivated EU researchers who are more likely to experience positive effects from mobility.

In search of a possible "elite" brain drain from Europe, we examined return rates for a sample of Europeans pursuing Ph.D. degrees in economics in the United States (*3*). Those better students who received Ph.D. degrees from top U.S. institutes are more likely to stay in the United States, conditional on finding a first job at a top institute. The probability of these individuals returning to Europe later on becomes very small. The results suggest a catch-22 regarding U.S. openness: To continue to attract elite researchers, the United States needs to continue to be at the scientific frontier with leading experts, often foreign-born. Making the United States a less-welcoming and convenient destination for the frontier-pushers may set in motion a downward spiral, by reducing the attractiveness of the United States as a destination for career-motivated top researchers. For Europe to

[1]*Politecnico di Torino, 10129 Turin, Italy.* [2]*Collegio Carlo Alberto, 10024 Moncalieri, Italy.* [3]*Politecnico di Milano, 20133 Milan, Italy.* [4]*Georgia State University, Atlanta, GA 30302, USA.* [5]*National Bureau of Economic Research, Cambridge, MA 02138, USA.* [6]*Harvard Business School, Boston, MA 02163, USA.* [7]*Katholieke Universiteit Leuven, 3000 Leuven and Bruegel, 1210 Brussels, Belgium.* [8]*University of Notre Dame, South Bend, IN 46556, USA.* [9]*Harvard University, Cambridge, MA 02138, USA.* [10]*Rutgers University, New Brunswick, NJ 08901, USA.* [11]*University of Michigan, Ann Arbor, MI 48109, USA.* [12]*University of California, San Diego, La Jolla, CA 92093, USA.* [13]*Center for Global Development, Washington, DC 20036, USA*

promote effective intra-EU mobility, it needs to address the selection issue and to support research environments, like European Research Council hubs, that will induce the best researchers to choose the EU for their mobility destination. Mobility support policies should target early-stage Ph.D. students, as researchers with mobility experience within Europe as Ph.D. students are more likely to remain internationally mobile within Europe post-Ph.D.

REFERENCES

1. S. Kahn, M. MacGarvie, *Rev. Econ. Stat.* **98**, 397 (2016).
2. R. Veugelers, L. Van Bouwel, *Res. Higher Educ.* **56**, 360 (2015).
3. L. Van Bouwel, R. Veugelers, in *The Mobility of Students and the Highly Skilled*, M. Gérard, S. Uebelmesser, Eds. (MIT Press, Cambridge, MA, 2014), pp. 57–81.

10.1126/science.aan3920

Mismatched supply and demand

Kirk B. Doran[8]

Immigration provides opportunities to increase knowledge production. But this depends on an increased demand for knowledge and on immigrants expanding the supply of skills not otherwise available. Unfortunately, this is not always the case. The first problem is university-sector demand: If universities do not take advantage of a supply increase by expanding faculty lines, new scientists can crowd out current ones, with little change in knowledge. This happened around 1991 when >1000 Soviet-trained mathematicians emigrated, many interacting with Western scientists for the first time. We learned the effect of this shock by comparing subfields of U.S. mathematics that the Soviets specialized in with those they knew nothing about (*1*). U.S. institutions eagerly hired Soviets with the best curricula vitae, especially midcareer mathematicians who had already excelled. But without an expansion in faculty slots, the only slots available were not those already taken by inferior tenured mathematicians, but rather, slots that would have been taken by newly minted Ph.D.'s. Because young scientists have more years of productivity ahead of them than do older ones, this proved disappointing: The new knowledge produced by Soviet émigrés was at best on par with the knowledge that would have been produced by the young mathematicians who lost or never got positions or who went to inferior research jobs. Average output of the most-affected American mathematicians declined by about one-third. The second problem is supply in the for-profit sector: If the U.S. H-1B visa program brings individuals with skills already common in the United States, then the potential for the firms that hire them to produce more knowledge than they otherwise would have is limited. We compared firms that randomly received access to H-1B visa immigrants to those that randomly did not (*2*). The supply of workers with similar skills was sufficiently prevalent that firms that missed out on hiring H-1B immigrants were able to quickly hire someone else. At the firms that hired them, the median H-1B visa employee crowded out approximately 1.5 other employees, with no increase in the firms' patenting or patent citations in subsequent years.

REFERENCES

1. G. J. Borjas, K. B. Doran, *Q. J. Econ.* **127**, 1143 (2012).
2. K. Doran, A. Gelber, A. Isen, "The effects of high-skilled immigration policy on firms: Evidence from H-1B visa lotteries" (NBER working paper no. w20668, National Bureau of Economic Research, Cambridge, MA, 2014).

10.1126/science.aan1229

Migration of ideas: China and U.S.

Richard Freeman[9,5]

Migration of ideas comes not only from permanent migrants but also from temporary migrants, such as international students, conference attendees, and visitors at foreign laboratories and centers. Given that collaborations generally arise from personal connections (*1*), it is hard to imagine internationally coauthored research expanding absent researcher mobility. Ties between U.S. and Chinese researchers exemplify how migration advances knowledge and benefits source and destination country. The United States is the top destination of Chinese international students and postdocs, and China is the top source of foreign students in the United States, and they contribute to U.S. scientific productivity (*2*). Those who return to China tend to outperform other Chinese researchers in terms of citations in international scientific journals (*3*). Homophily in citations suggests that

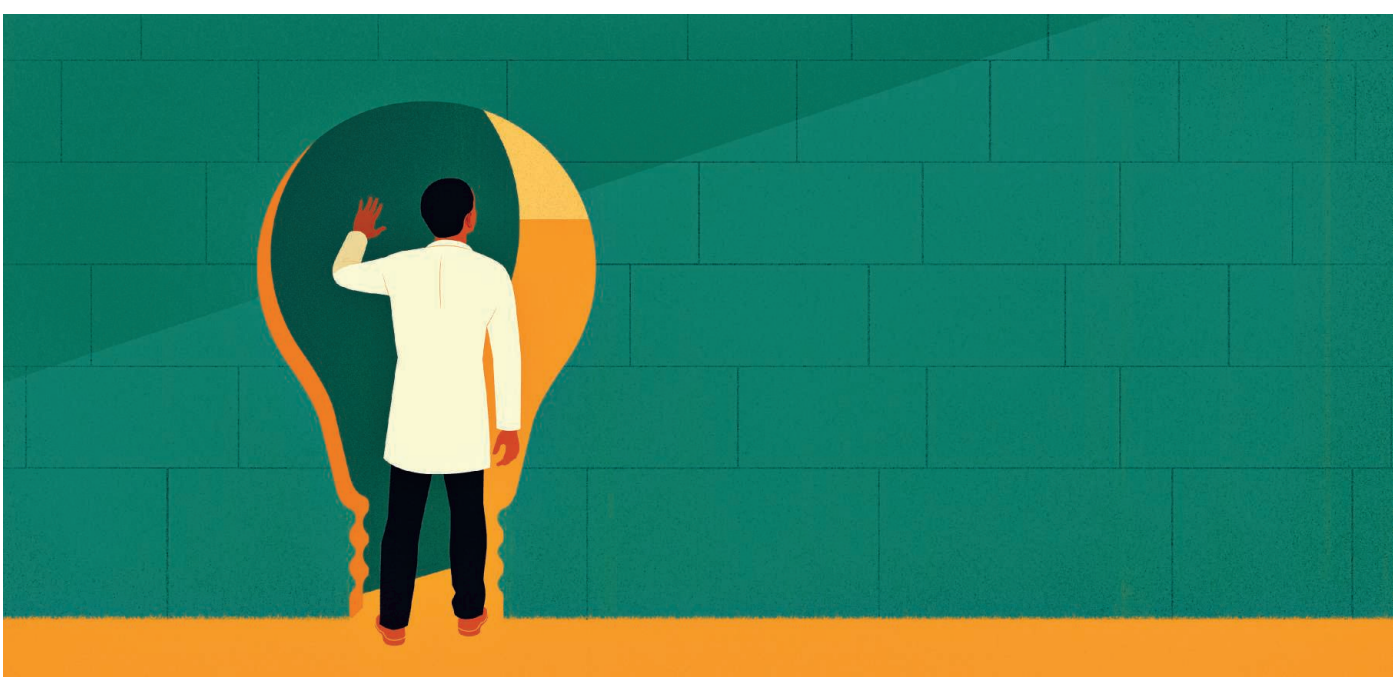

ILLUSTRATION: JOEY GUIDONE/@SALZMANART

a paper with authors from two countries is likely to spread new ideas or findings more rapidly across borders than if the paper's authors were from the same country. Having a foreign collaborator with a network of researchers in another country usually attracts overseas attention to research. In scientific work, China and the United States are each others' biggest partners: 16% of U.S. international collaborations are with China, and 48% of China's international collaborations are with the United States (*4*). U.S. corporations conduct research and patent inventions in China, and Chinese firms buy U.S. start-ups and patent in the United States. About 15% of author names on papers written at U.S.-based institutions are Chinese, whose first names (e.g., Xu rather than David) identify them as born overseas (*5*). Connections between migrants and natives on papers, patents, and citations does not directly measure the migration of ideas, which requires latent semantic analysis of the content of the underlying documents. But network links between collaborators from different countries establish a prima facie case for policies that treat foreign-born students and migrant researchers as valuable contributors to the United States and home-country scientific and economic progress and as possible future U.S. citizens as well.

REFERENCES

1. R. B. Freeman, I. Ganguli, R. Murciano-Goroff, in *The Changing Frontier: Rethinking Science and Innovation Policy*, A. Jaffe and B. Jones, Eds. (University of Chicago Press, 2015), pp. 17–48.
2. G. Borjas, K. Doran, Y. Shen, "Ethnic complementarities after the opening of China: How Chinese graduate students affected the productivity of their advisors" (NBER Working paper 21096, NBER, Cambridge, MA, 2015).
3. R. B. Freeman, W. Huang, in *Global Mobility of Research Scientists: The Economics of Who Goes Where and Why*, A. Guena, Ed. (Academic Press–Elsevier, 2015), pp. 155–175.
4. National Science Board, *Science and Engineering Indicators 2014* (National Science Foundation, Arlington, VA, 2014), appendix table 5-56.
5. R. B. Freeman, W. Huang, *J. Labor Econ.* **33** (suppl. 1, part 2), S289 (2015).

10.1126/science.aan5197

Immigrant patents boost growth

Jennifer Hunt[10,5]

There are lively debates in countries around the world as to how to stimulate economic growth and how much immigrants contribute to the economy. My research on the U.S. economy shows that skilled immigration increases patenting, which is likely to boost per capita economic growth. My analysis of self-reported patent activity in the National Survey of College Graduates, the only data source tying patentees to their birthplaces, shows that the foreign-born are twice as likely to patent as the native-born (*1*). Although 0.9% of college-educated natives have been awarded one or more patents in the past 5 years and 0.6% have been awarded a patent that has been licensed or commercialized, the figures for immigrants are 2.0% and 1.3%, respectively. Among patentees, natives and immigrants have similar numbers of patents. This immigrant patenting advantage has its origin in the educational background of immigrants, who are much more likely than natives to have studied physical sciences and engineering, fields strongly associated with patenting activity. Immigrants who first entered the United States on a student or trainee visa or on a temporary work visa are particularly likely to patent. However, immigrants' patenting advantage might not be fully reflected in overall national patenting activity if natives are deterred by immigration from entering the relevant fields of study and occupations. Alternatively, the immigrants' advantage could be magnified by collaborations and knowledge transfers, causing natives themselves to become more inventive. To study this, my coauthor and I used changing geographic variation in immigration (measured in the U.S. Census) and patenting activity (measured by the U.S. Patent and Trademark Office) over several decades (*2*). The results show that immigration of college-educated individuals increases patenting per capita and is likely to have increased Gross Domestic Product per capita by 1.4 to 2.4 percentage points over a decade. A comparison of these results and the implied effect of the immigrant-native patenting gap at the individual level suggests that immigrants have increased the inventiveness of natives. The United States, and in particular its universities and employers, is successful in choosing skilled immigrants who boost economic growth per capita and should consider expanding the number of such immigrants admitted.

REFERENCES

1. J. Hunt, *J. Labor Econ.* **29**, 417 (2011).
2. J. Hunt, M. Gauthier-Loiselle, *Am. Econ. J. Macroecon.* **2**, 31 (2010).

10.1126/science.aan2468

Reservoir of foreign talent

John Bound,[11,5] **Gaurav Khanna,**[12,13] **Nicolas Morales**[11]

Understanding the impact that increased high-skilled immigration has had on a country's economy involves evaluating counterfactuals—what would the economy have been like under a more restrictive immigration policy? We modeled decisions made by U.S. firms and workers, then used the introduction of the Internet and the subsequent innovation boom to calibrate these models and evaluate counterfactuals (*1*, *2*). Our work suggests that the influx of foreign-born computer scientists since the early 1990s—spurred by U.S. immigration policy that favors high-skilled workers and by increases in the availability of foreign talent, particularly from India—has had several economic impacts. It increased the size of the U.S. information technology (IT) sector but put downward pressure on wages of computer scientists and, as a result, discouraged some U.S.-born college graduates from becoming computer scientists. It increased firms' profits and benefited consumers via lower prices and more efficient products. Under our calibrated model, immigration, enabled by the H-1B visa program, raised overall worker incomes by 0.2 to 0.3% but decreased wages of U.S. computer scientists by 2.6 to 5.1% in 2001. Moreover, U.S. workers switched to other occupations, which lowered the number of domestic computer scientists by 6 to 11% in 2001 (*2*). The claim that U.S. employers cannot find enough adequately skilled computer scientists within the United States appears to be an overstatement. When demand for computer scientists expanded in the past, it was met by an increase in college students majoring in computer science and an increase in employers hiring workers trained in other science, technology, engineering, and mathematics fields (*1*, *2*). However, the ability to draw from a pool of skilled foreigners facilitated growth in the U.S. science and technology sector. The reservoir of foreign talent may have acted as a buffer in the IT sector, smoothing demand adjustments in the U.S. labor market and muting wage increases during the IT boom in the 1990s. In contrast, wages rose rapidly during the booms in the 1970s and early 1980s, when this large stock of foreign talent was less readily available (*3*). Any assessment of the overall impact of skilled immigration would also have to consider the effect it will have on the position of the United States in the world economy.

REFERENCES

1. J. Bound, B. Braga, J. M. Golden, G. Khanna, *J. Labor Econ.* **33** (suppl. 1, part 2), S187 (2015).
2. J. Bound, G. Khanna, N. Morales, "Understanding the economic impact of the H-1B program on the U.S." (NBER working paper 23153, NBER, Cambridge, MA, 2017).
3. J. Bound, B. Braga, J. Golden, S. Turner, *Am. Econ. Rev.* **103**, 203 (2013).

10.1126/science.aan2956