8

SKILLED IMMIGRANTS, HIGHER EDUCATION, AND U.S. INNOVATION

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Introduction

Policies governing the entry of foreign citizens with education and skills have been under considerable debate in the United States in recent years. During the dot-com boom of the late 1990s, American information technology companies pushed strongly for increases in H1B visas, which permit temporary entry of skilled programmers and other professionals. The issuance of these visas has since been scaled back, which may be both a cause and consequence of the much-discussed offshoring of U.S. programming jobs to India and other nations. In the wake of the terrorist attacks of September 11, 2001, U.S. immigration authorities also have clamped down on the number of visas issued to foreign students wishing to gain a graduate education in the United States. While these restrictions have been relaxed somewhat more recently, they may have precipitated a worldwide decline in the number of foreign students who study science and engineering in the United States, as discussed in the next section. In general, there are increasing calls among some American policymakers to restrain the volume of immigration, including skilled workers.

While the motivations for such concerns are varied, opponents of further restrictions focus on one potential negative outcome of limiting skilled immigration. Specifically, the view is widely held that bringing in foreign-trained doctors, engineers, managers, and scientists helps relieve domestic shortages of such skills, thereby promoting continued U.S. leadership in innovation and technology.

Similarly, education officials express concerns that if American universities train a declining share of international graduate students, their ability to perform both basic and applied research will suffer, which is an issue of particular importance as those institutions rely more heavily on licensing incomes.

These are important concerns, which we will discuss in the following section. In this chapter, however, our concern essentially is to investigate in a straightforward way the veracity of such claims. We do this by summarizing the results of a recent study of ours that sheds light on the role of skilled foreigners and students in U.S. science and technology (Chellaraj, Maskus, and Mattoo 2005). In particular, this study investigated the contributions of foreign graduate students and skilled immigrants to patenting activity, finding powerful and positive effects. In this chapter, we also consider briefly the implications of the source distribution of skilled immigrants. Together, these findings suggest strongly that a general decline in the interest of foreign students and professionals in migrating, even temporarily, to the United States will have sharply negative implications for innovation capacity and competitiveness.

The chapter proceeds as follows. In the next section we review recent trends in immigration of skilled workers and discuss the policy environment. In the third section we summarize the central results of the innovation study, while in the fourth section we discuss the implications of relative changes in source countries as originators of immigrants. We offer brief concluding remarks in the final section.

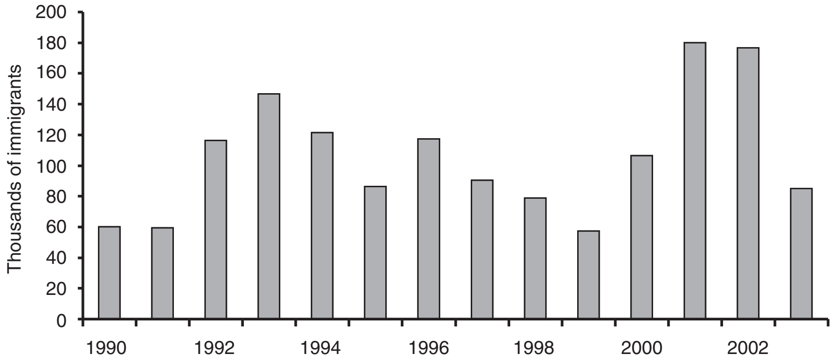
Skilled Immigration Trends and Policy

In this section we review basic data on trends in the arrival of skilled immigrants and foreign students in the United States. Then we consider relevant policy questions.

Trends in Skilled Immigration and Education

The data in figure 8.1 demonstrate the significant increase since 1990 in skilled immigration into the United States. For this purpose, skilled immigration is defined to include employment-based immigrant categories, covering priority workers, professionals with advanced degrees or aliens with exceptional ability, skilled workers, professional workers, and a few other categories. These are people (and their families) who intend to migrate permanently to the United States, rather than on the temporary H1B visas. As shown in figure 8.1, the number of skilled immigrants was just below 60,000 in 1990, rose sharply by 1993, and fell to its original level by 1999. There was a surge in such immigration in 2001 and 2002, however, before falling sharply in 2003 in the wake of tighter restrictions. It is evi-

FIGURE 8.1 Skilled Immigrants



Source: U.S. Citizenship and Immigration Service 1990–2004.

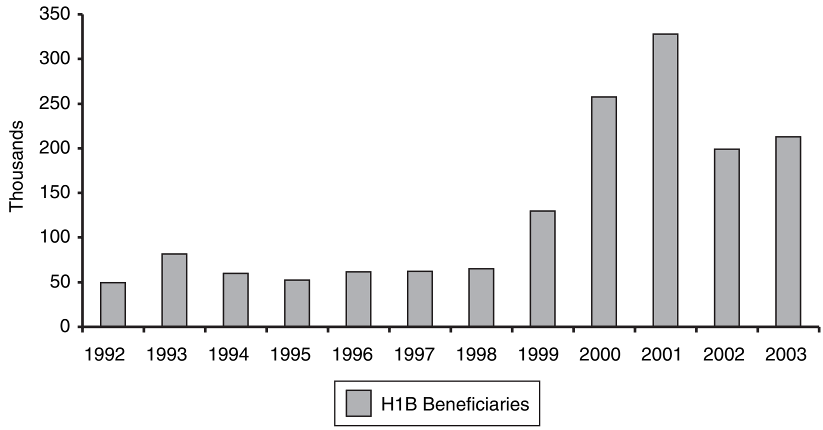
dent that there is considerable volatility in these figures, associated with both cyclical and policy factors.

Another measure of the availability of foreign skills resident in the United States is the number of H1B visas issued for people with "specialty occupations," those that are almost entirely based in advanced technologies. This number peaked in 2001, at 331,206 visas. The number of visas issued after that was much lower, at 197,537 visas in 2002 and 217,340 in 2003, generally reflecting a tightening of the number of such visas issued.

Finally, it is important for our discussion to note trends in foreign graduate students in the United States. One simple measure is provided in figure 8.3, which shows the number of foreign students enrolled in U.S. universities each year from 1990 to 2003. While this includes both graduate and undergraduate enrollments, it captures broadly what has happened in terms of the presence of skilled foreign students in the United States. Later in this chapter, we focus specifically on graduate enrollments. At this point, we simply note the dramatic increase in the number of foreign students enrolled in U.S. universities and colleges in the 14-year period, rising from 326,264 in 1990 to a peak of 698,595 in 2001.

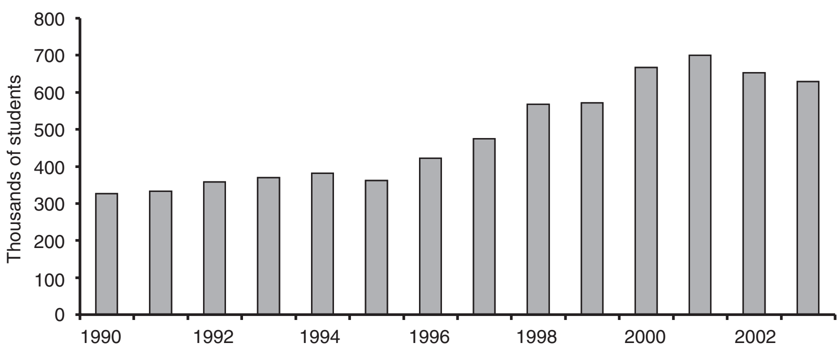
However, visas issued fell by 10.5 percent between 2001 and 2003, indicating a sharp decline in enrollments for the present cohort of foreign students. Visa applications for students fell by 74,000 between 2001 and 2003 (Florida 2005). Applications from Chinese, Indian, and Korean students dropped 45 percent, 28 percent, and 14 percent, respectively, over the same period.

FIGURE 8.2 H1B Beneficiaries, 1992–2003



Source: U.S. Citizenship and Immigration Service 1990–2004.

FIGURE 8.3 Foreign Students



Source: U.S. Citizenship and Immigration Service 1990–2004.

Additional perspective on this last decline is available from other sources. For example, an industry association reports that universities have seen large declines in foreign student applications since 2002 (Institute for International Education 2004). Moreover, foreign graduate enrollments slipped by perhaps 6 percent between 2003/04 and 2004/05. It is likely that some portion of these reductions is associated with tighter visa restrictions after the September 11 attacks, which have made it more difficult to obtain a visa on a timely basis.

However, in addition to this supply-side effect, there has been a reduction in demand for foreign-student visas, as universities in Australia, the United Kingdom, Singapore, and elsewhere have become more competitive at attracting and training advanced students (Chellaraj, Maskus, and Mattoo 2005). Indeed, many countries now actively subsidize foreign graduate students in technical and managerial fields, in the hope that the skills those students possess will translate into higher domestic productivity (Hira 2003). This benefit could emerge as students frequently choose to remain and work in the locations in which they are trained, and they are increasingly encouraged to do so by receiving countries (such as Singapore).[1]

Policy Concerns

Since the onset of far-tighter restrictions on the issuance of U.S. education visas in the wake of the 2001 terrorist attacks, immigration policy for foreign graduate students has become the subject of intense debate. Those who are concerned about the policy shift claim that it will harm the nation's innovation capacity. For example, U.S. university officials are increasingly concerned that these restrictions could cause a crisis in research and scholarship.[2] The same point has been made in a number of editorials.[3] Lawrence Summers, president of Harvard, warned that the decline in foreign students threatens the quality of research coming from U.S. universities.[4]

If limits and delays in the number of visas issued to foreign graduate students in science and engineering and, more generally, to foreign skilled workers have the long-term impact of limiting innovation, productivity would suffer. Technological improvements largely have been driven by the rate of innovation, which has been increasing in recent years as measured by the rapidly growing number of patents awarded to U.S. industries and universities (Kortum 1997; Hall 2004).

The United States remains at the cutting edge of technology despite frequent complaints about quality deficiencies in its secondary education system.[5] Among the major developed countries and the newly industrial countries, the United States ranks near the bottom in mathematics and science achievement among eighth graders.[6] What may reconcile these facts is that the United States attracts large numbers of skilled immigrants that enter directly into technical fields (Gordon 2004). Moreover, the education gap is filled by capable international graduate students and skilled immigrants from such countries as India, China, and the Republic of Korea. For its part, the United States sustains a significant net export position in the graduate training of scientists, engineers, and other technical personnel.

It is worth noting that foreign graduate students traditionally have demonstrated a high propensity to remain within the United States, at least for the early portion of their careers (Finn 2001; Bratsberg and Ragan 2002). Aslanbeigui and Montecinos (1998) found that 45 percent of international students from developing countries planned to enter the U.S. labor market for a time and 15 percent planned to stay permanently. Despite attempts since the early 1980s by the U.S. Congress to forbid the employment of international students after graduation,[7] and in some cases to restrict the flow of international students to domestic universities,[8] the United States still allows a significant proportion of these students to stay and work after graduation and often grants permanent residence. Thus, graduate training of foreign students may have long-lasting impacts on innovation capacities.

There are a variety of channels through which the presence of foreign graduate students could affect innovation and productivity. These students serve first as direct inputs into knowledge creation by working within university laboratories and coauthoring scientific papers. Second, because they may stay in the United States and become faculty or, more likely, technical personnel in private industry, their knowledge base supports additional inventiveness. Moreover, scientific papers and patent applications developed with their inputs directly support further innovative activities, both within universities and in the broader economy. For example, the Bayh-Dole Act of 1980 permits U.S. universities to claim intellectual property rights on inventions developed within their laboratories, even if the research was supported by public grants. Those patents may, in turn, be licensed to commercial enterprises, which is a growing phenomenon.

Moving beyond graduate students, the presence of technical workers, such as software engineers and technical designers, under temporary H1B visas, may have a significantly positive impact on innovation in a variety of industries. Furthermore, and perhaps most significantly, permanent immigration of workers in skilled occupations, including both faculty and private practitioners in engineering, medicine, and information technologies, should have a direct effect on innovation and patenting. For example, the proportion of foreign-born faculty with U.S. doctoral degrees at U.S. universities has increased sharply during the past three decades, from 11.7 percent in 1973 to 20.4 percent in 1999. For engineering, it rose from 18.6 percent to 34.7 percent in the same period.[9] These relative changes in the sources of scientific talent have coincided with large increases in innovation capacity, as measured by patent applications and scientific papers.

A Study of Innovation Impacts

While the claim that foreign graduate students and skilled personnel should enhance innovation seems self-evident, it had not been tested statistically before the study we now summarize (Chellaraj, Maskus, and Mattoo 2005). In that study, we estimated a number of versions of the so-called "ideas production function," which may be listed as follows:[10]

$$\dot{A}_t = \delta H^{\lambda}_{A,t} A^{\phi}_t \tag{8.1}$$

This specification indicates that the number of new ideas $\dot{A}$, typically measured by patent applications or patent grants in a particular year, depends on the stock of knowledge A (measured by cumulative patents issued in the past) and the use of human capital and other scientific inputs H. The parameter ϕ governs the returns to past knowledge in terms of generating new ideas. If the value of ϕ exceeds 0, there is a "standing on shoulders" effect and past knowledge is productive. If the value of ϕ is less than 0, there are diminishing returns to past knowledge and new invention becomes more difficult. The parameter λ is the elasticity of new ideas with respect to technical inputs. Finally, the coefficient δ reflects the overall productivity with which the economy (or specific institutions) converts inputs and past knowledge into new ideas.

We broke down the technical inputs into several key variables, some of which had not been examined in this context. These variables included foreign graduate students as a percentage of total graduate students, the cumulative number of skilled immigrants as a share of the labor force, the cumulative number of doctoral scientists and engineers as a percentage of the labor force, and scaled real expenditures on research and development (R&D). In addition, we included the accumulated stock of patent grants scaled by the labor force, a dummy variable capturing the influence of the Bayh-Dole Act of 1980, the unemployment rate to capture cyclical impacts on innovation, and a time trend to control for overall technology movements. The dependent variables were patent applications or patent grants, with the latter also broken down into grants issued to universities and other institutions.[11]

The data were aggregate time series of these variables for the United States during the time period from 1965 to 2001. Explanatory variables were lagged either five years (in the case of patent applications) or seven years (in the case of patent grants) to reflect the time period required to convert inputs into patentable ideas. Basic econometric tests suggested that the scaling procedures chosen, along with the time and unemployment controls, were sufficient to ensure the absence of serial correlation in the residuals.[12]

We summarize the results here (detailed results are presented in annex 8.A) by listing estimated elasticities for the variables capturing foreign graduate students and skilled immigration.[13] The coefficients in table 8.1 demonstrate clearly that the relative presence of foreign graduate students has a strongly positive impact on future patent applications and grants. That is, a 10 percent increase in the share of foreign graduate students in the total number of graduate students tends to increase total U.S. patent applications by 4.8 percent, patent grants earned by universities by 6.0 percent, and patent grants earned by nonuniversities (largely commercial firms) by 6.8 percent. The last of these findings is particularly interesting, because it suggests strongly that the presence of foreign graduate students spills over into wider gains in U.S. innovation through the channels described above.

The results in table 8.1 and detailed results presented in annex 8.A also demonstrate that an increase in the ratio of cumulative skilled immigrants,[14] as a proportion of the U.S. labor force, has a positive, although smaller, effect on the development of new ideas.[15] A 10 percent rise in this ratio over the same time period tended to increase future applications by 0.8 percent and university patent grants by 1.3 percent.

The impacts listed in table 8.1 are large in the context of contributions to the patenting of new ideas. These elasticities may be put in perspective by computing the implied impacts on patenting from a change in enrollments or skilled immigration. Computed at sample means, a 10 percent rise in the ratio of foreign graduate students to total graduate students would imply an increase in later applications of 6,636 (or around 4.7 percent of the mean total applications of 141,092). Thus, we compute a marginal impact of another foreign graduate student to be around 0.6 patent applications in the economy as a whole.[16] Regarding university and nonuniversity grants, the calculations imply that a 10 percent rise in the ratio of foreign graduate students would generate another 56 university grants and an additional 5,979 nonuniversity grants.[17] Accordingly, the enrollment of foreign graduate students ultimately generates more nonuniversity patent awards.

The results may be used for similar computations of the effects of skilled immigration. A ten percent rise in the cumulative number of skilled immigrants

TABLE 8.1 The Impacts of Foreign Graduate Students and Skilled Immigrants on Patent Applications and Grants, 1965–2001

	Applications	University grants	Other grants
Foreign graduates	0.48 (7.46)***	0.60 (3.64)***	0.68 (5.95)***
Skilled immigrants	0.08 (2.40)**	0.13 (2.78)***	0.09 (2.63)***

Source: Chellaraj, Maskus, and Mattoo 2005.

Note: ** denotes significance at the 5 percent level; *** denotes significance at the 1 percent level.

would increase later patent applications by 1,037, university grants by 12, and nonuniversity grants by 814. Again, skilled immigration has considerably smaller impacts on patenting activity than do enrollment of foreign graduate students. In summary, it seems that skilled immigrants have a positive impact on total patent applications and patents awarded to universities, industries, and other enterprises. This result highlights the contributions made by skilled immigrants to innovation in the U.S. economy. Overall, it seems that foreign students and skilled immigrants play a major role in driving scientific innovation in the United States.

Relatively open access to international students has allowed U.S. universities to accept the most capable graduate students in science and engineering. In turn, international graduate students contribute to innovation. This conclusion stems from the fact that international graduate students are relatively concentrated in such fields as science and engineering. In a number of highly ranked engineering schools, international students account for nearly 80 percent of doctoral students.[18] Overall, the presence of international students along with skilled immigrants is a significant factor behind sharp increases in innovation and patenting at U.S. universities and the ultimate beneficial spillovers to broader innovation.

The Sources of Skilled Immigration[19]

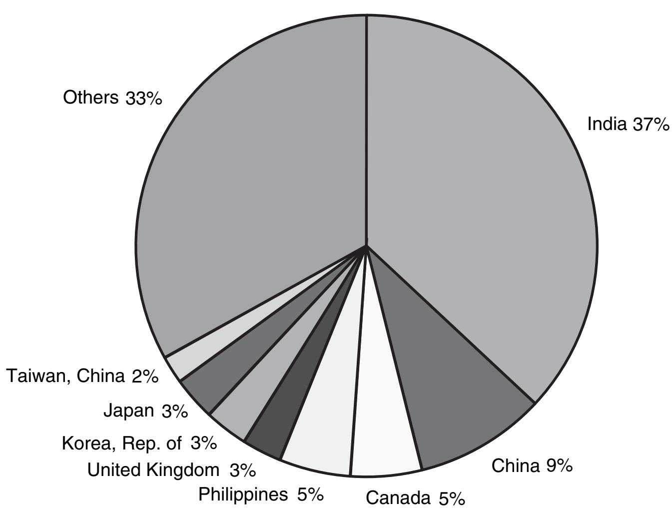
Recent research suggests that an innovation-friendly immigration policy needs to look beyond the aggregate number of educated immigrants entering the United States. Engagement of the educated in skilled (and potentially innovative) activities depends on where the immigrants come from and how they enter the United States. U.S. Census data reveal striking differences in the occupational performance of highly educated immigrants from different countries, even after controlling for individuals' age, experience, and level of education. With some exceptions, educated immigrants from Latin American and Eastern European countries are more likely to obtain unskilled jobs than immigrants from Asian and industrial countries. For example, a hypothetical 34-year-old Indian college graduate who arrived in 1994 has a 69 percent probability of obtaining a skilled job, while the probability is only 24 percent for a Mexican immigrant of identical age, experience, and education.

A large part of the variation can be explained by attributes of the country of origin that influence the quality of human capital, such as expenditure on tertiary education and the use of English as a medium of instruction. For example, coming from an English-speaking country increases the likelihood of obtaining a skilled job in the United States by 11 percent for a hypothetical college graduate. Similarly, a 10 percent increase in tertiary education increases the same probability by 7.5 percent.

In addition to the attributes of the home country, the selection effects of U.S. immigration policy also play an important role in explaining variations in occupational performance. There are three main ways to legally enter the United States: (a) family preferences, (b) lotteries for underrepresented nationalities and as refugees, and (c) skills-based programs such as the H1B visas where a prior offer of employment commensurate with skills is a requirement for entry. The first two routes do not discriminate among immigrants based on their education or skill levels, but the third route has strict skill requirements. If there are already many immigrants from a given country, then family preferences make it easier for potential immigrants from that country to enter the United States. Conversely, if the family preferences, lottery, and asylum policies are restricted, we see an improvement in the average human capital of immigrants because H1B visas become the primary route for entry. Immigrants from such countries as India and China have been the largest beneficiaries of H1B visas in recent years (figure 8.4) and also have performed best in terms of occupational placement (Mattoo, Neagu, and Özden 2005).

To be sure, immigration policy cannot be driven by innovation concerns alone. But it is useful to recognize that the impact on innovation depends not only on the overall number of educated immigrants, but also on where these immigrants come from and how they enter the United States. From a U.S. perspective, the negative impact of innovative activity would be greater if immigration restrictions

FIGURE 8.4 HIB Beneficiaries by Country, 2003



Source: U.S. Citizenship and Immigration Service 1990–2004.

altered the composition away from source countries that create higher quality (or more U.S.-compatible) human capital or away from allowing entry that is conditional on an offer of skilled employment.

Conclusion

We have argued that there is empirical evidence to support the view that foreign graduate students and skilled immigrants are significant inputs into developing new technologies in the U.S. economy. The impacts are particularly pronounced within universities but also affect nonuniversity patenting. There is evidence to suggest that educated immigrants from particular source countries, such as China and India, and those who enter the United States contingent on offers of employment are mostly likely to engage in skilled activities.

The significant contributions of international graduate students and skilled immigrants to patenting and innovation in the United States may have international and domestic policy implications. At the international level, it is evident that the United States has a significant direct comparative advantage in exporting the services of higher education, especially in training scientists, engineers, and related personnel. This advantage generates additional benefits, both directly as foreign students contribute to innovation in the United States and indirectly as exploitation of the fruits of this innovation generates domestic economic rents.

However, continued dominance of the United States in this regard cannot be taken for granted. As other countries such as Singapore (Furman and Hayes 2004; Koh and Wong 2005) improve their offerings of scientific graduate education and encourage these students to stay on after graduation, visa restrictions in the United States could have adverse implications for competitiveness. The United States is likely to face increasing global competition for talent from countries such as China.[20] Moreover, global liberalization of higher education services would permit U.S. universities to get around visa problems by locating research campuses in other countries,[21] such as Singapore, that welcome international talent (Amsden and Tschang 2003). It is also noteworthy that U.S. corporations have significantly increased patenting activity and innovation abroad (Maskus 2000). In response to this increase, legislation has been introduced in the U.S. Congress in 2005 to facilitate the movement of skilled immigrants into the United States.[22]

Hence, a central implication of this chapter is that reducing foreign students and skilled immigrants, particularly from certain source countries, through tighter enforcement of visa restraints could reduce innovative activity significantly. Indeed, with the rapid economic development of countries in such regions as Southeast Asia, and with global job mobility increasing, such restrictions are likely to be self-defeating, at least in economic terms.

Endnotes

1. http://www.hindu.com/thehindu/features/singedu/stories/2004080800140200.htm

2. Recently, a letter to this effect was published by a broad coalition of U.S. academics representing 25 organizations and 95 individuals. See Grimes and Alden 2004.

3. Brumfiel 2004; *The Economist* 2004.

4. Grimes 2004.

5. See, for example, National Governors Association, "The High School Crisis and America's Economic Competitiveness to be Discussed," September 29, 2003, at http://www.nga.org/nga/newsRoom/1,1169,C_PRESS_RELEASE%5ED_5948,00.html.

6. For comparison with other countries, see the results of the Trends in International Mathematics and Science Study (TIMMS) at http://timss.bc.edu/timss2003.html.

7. In 1982 and again in 1984, legislation sponsored by Senator Simpson and Representative Mazzoli, and supported by anti-immigrant groups such as the Federation of American Immigration Reform (FAIR), forbidding the employment in the United States of international graduates of U.S. universities, passed both chambers of Congress before dying in the Conference Committee. In 1995, Senator Simpson and Representative Lamar Smith unsuccessfully resurrected the proposal.

8. Senator Feinstein tried to put a moratorium on all international students soon after the September 11, 2001, attack. The proposal was shelved after protests from U.S. universities. Representative Rohrabacher has proposed that U.S. universities replace international students with domestic students although the latter may be less qualified.

9. http://www.nsf.gov/sbe/srs/seind02/append/c5/at05-24.xls.

10. Stern, Porter, and Furman 2000; Porter and Stern 2000.

11. One of the issues in the specification of the model is the direction of causality. While skilled immigration and the presence of international students are argued to positively impact patenting, patenting and scientific progress could also attract skilled immigration and foreign students, and the two could be simultaneously determined. The use of lagged values of immigrant and student presence addresses the problem to a certain extent.

12. For further details, refer to the manuscript available at http://spot.colorado.edu/~maskus/papers/patentpaper_March%2016_2005.pdf.

13. Other variables had the anticipated coefficients, with most highly significant.

14. Cumulative skilled immigrants are defined as the number of skilled immigrants accumulated over the preceding six-year period, divided by the labor force. Skilled immigrants include those entering the country on H1B visas. They do not include L visa holders, because these are essentially temporary postings, generally granted to foreign corporations such as Toyota and BMW with plants in the United States.

15. For this purpose, "skilled immigration" was measured as inflows of immigrants in employment-based categories.

16. These figures are calculated at means across the entire sample. If these elasticities were applied to the far-higher average patent numbers in the late 1990s, the corresponding predicted increases in innovative activity would be larger.

17. The mean number of nonuniversity awards is far larger than that of university grants, so these volume impacts are sensible.

18. Institute for International Education 1990–2004.

19. This section is based on Mattoo, Neagu, and Özden (2005).

20. Of immediate concern for the United States is global competition for the skilled workforce from China. According to the British government's Department of Trade and Industry (DTI), China engages in significant recruitment of U.S. and other scientists, luring them with promises of greater freedom and well-funded centers, particularly for stem cell research (Morrison 2005).

21. http://smh.com.au/articles/2004/04/21/1082530235581.html. http://dukemednews.duke.edu/news/article.php?id=6687.

22. The Jackson legislation, Kennedy-McCain Legislation, and the Cornyn-Kyl legislation would allow unused employment-based immigration visas in the previous years to be used in the current and future years. However, the Tancredo legislation, which is not given much chance of debate, let alone enacted into law, proposes to sharply curtail skilled immigrants and restrict them to two years of employment in the United States. However, the Jackson, Kennedy-McCain, and Cornyn-Kyl legislations are not going to be of much help if the U.S. State Department regulations such as Section 214(b) continue to be bottlenecks.

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ANNEX 8.A International Students, Skilled Immigration, and Patenting Activity in the United States, 1965–2001

	IPA (8)	UIPG (9)	OIPG (10)
CONSTANT	5.068 (3.09)***	2.705 (1.29)	3.589 (2.31)***
FORTGR	0.480 (7.46)***	0.604 (3.64)***	0.676 (5.95)***
SEDDOCCUM	0.200 (2.03)**	0.445 (2.82)***	0.564 (5.09)***
IMCUM	0.075 (2.40)**	0.128 (2.78)***	0.092 (2.63)***
SK	0.762 (3.00)***	0.732 (1.71)*	0.940 (3.25)***
RD	−0.177 (−1.19)	n.a.	n.a.
URD	n.a.	0.021 (0.10)	n.a.
ORD	n.a.	n.a.	0.383 (2.46)**
TOTPATSTOCK	0.526 (3.96)***	n.a.	n.a.
UPATSTOCK	n.a.	0.439 (1.83)*	0.183 (1.10)

ANNEX 8.A *(continued)*

	IPA (8)	UIPG (9)	OIPG (10)
OPATSTOCK	n.a.	0.211 (0.56)	−0.158 (−0.51)
BD	0.140 (2.55)***	0.288 (3.13)***	0.257 (4.22)***
TIME	−0.007 (−1.29)	0.014 (0.57)	0.014 (−3.67)***
UNEMPLOY	0.006 (0.13)	0.141 (1.60)	0.037 (0.72)
R-Squared	0.94	0.99	0.94
DW	1.60	1.82	2.52

Source: Chellaraj, Maskus, and Mattoo 2005.

Note: IPA is patent applications and IPG is patents granted, both as a percentage of labor force. UIPG is patents granted to universities as a proportion of labor force, OIPG is patents granted to nonuniversity institutions as a proportion of labor force. FORTGR is foreign graduate students as a proportion of total graduate students. SEDDOCCUM is the cumulative number of doctorates earned in engineering and science in U.S. universities over a period of five years as a percentage of labor force for IPA and over a period of seven years for UIPG and OIPG. IMCUM is the cumulative number of skilled immigrants over a period of six years after which it is lagged seven years as a proportion of the labor force. SK is total doctoral scientists and engineers as a proportion of labor force. RD is total real research and development (R&D) expenditures as a proportion of labor force. URD is real university R&D expenditures as a proportion of labor force, and ORD is real nonuniversity R&D expenditures as a proportion of labor force. TOTPATSTOCK is cumulative patents awarded over a period of five years as a proportion of labor force. UPATSTOCK is cumulative patents awarded to universities over a period of seven years as a proportion of labor force. OPATSTOCK is cumulative patents awarded to nonuniversity institutions over a period of seven years as a proportion of labor force. BD is the dummy variable for the Bayh-Dole Act with a value of "0" before 1980 and "1" after 1980. TIME variable is a time trend. UNEMPLOY is the unemployment rate. DW is the Durbin-Watson test for autocorrelation. Variables in the IPA equations are lagged five years, while those in the IPG equations are lagged seven years. Figures in parentheses are t-ratios and marked as significantly different from zero at the 1 percent (***), 5 percent (**), and 10 percent (*) levels. n.a. = not applicable.