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The Contribution of Skilled Immigration and International Graduate Students to U.S. Innovation

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THE CONTRIBUTION OF SKILLED IMMIGRATION AND INTERNATIONAL GRADUATE STUDENTS TO U.S. INNOVATION

ABSTRACT

The impact of international students and skilled immigration in the United States on innovative activity is estimated using a model of idea generation. In the main specification a system of three equations is estimated, where dependent variables are total patent applications, patents awarded to U.S. universities, and patents awarded to other U.S. entities, each scaled by the domestic labor force. Results indicate that both international graduate students and skilled immigrants have a significant and positive impact on future patent applications as well as future patents awarded to university and non-university institutions. Our central estimates suggest that a ten-percent increase in the number of foreign graduate students would raise patent applications by 3.3 percent, university patent grants by 6.0 percent and non-university patent grants by 4.0 percent. However, enrollments of US graduate students have no detectable effect. There is evidence that bureaucratic hurdles in obtaining student visas are impediments to innovation and may reduce innovation by more than it is increased by the Bayh-Dole Act.

Key Words: Innovation, US Immigration, Patenting, Section 214(b)

JEL Codes: I2, J6, O3

1. Introduction

Since the advent of far-tighter restrictions on the issuance of U.S. education visas in the wake of the attacks of September 11, 2001, 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, American university officials are increasingly concerned that these restrictions could cause "...a crisis in research and scholarship..."¹ The same point finds its way into editorials.² Lawrence Summers, president of Harvard, warned the U.S. State Department that the decline in foreign students threatens the quality of research coming from U.S. universities³, although this claim has been disputed by a prominent analyst⁴.

If limits and delays in the number of foreign graduate students in science and engineering and, more generally, of foreign skilled workers has the long-term impact of limiting innovation, productivity would suffer. Recent evidence indicates that productivity growth in the United States has been generated largely by advances in technology (Basu et al., 2001; Basu, et al, 2003). 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 US industries and universities (Hall, 2004; Kortum, 1997).

¹ Recently a letter to this effect was published by a broad coalition of US academics representing 25 organizations and 95 individuals. See "Academics Warn of Crisis over Visa Curbs", *Financial Times* May 16, 2004.

² "Visas and Science: Short-Sighted," *The Economist*, May 8, 2004.

³ *Financial Times*, April 28, 2004.

⁴ Borjas, (2004; 2002).

The United States remains at the cutting edge of technology despite frequent complaints about quality deficiencies in its secondary education system.⁵ Indeed, among the major developed countries and the newly industrialized countries, the United States ranks near the bottom in mathematics and science achievement among eighth graders.⁶ What may reconcile these factors is that the United States attracts large numbers of skilled immigrants that enter directly into such technical fields as medicine, engineering, and software design. Moreover, the education gap is filled by well-trained international graduate students and skilled immigrants from such countries as India, China, Korea, and Singapore (the last two of which rank at the top in mathematics and science achievement). Certainly the United States sustains a significant net export position in the graduate training of scientists, engineers, and other technical personnel.

It is likely that international graduate students and skilled immigrants are important inputs into the U.S. capacity for continued innovation, but this basic hypothesis surprisingly has not been formally tested. In this paper we estimate an innovation production function in which graduate students and skilled immigrants are an input into the development of new ideas, both at universities and in the private sector. The model permits productivity differentiation between domestic and foreign graduate students and domestic and foreign skilled workers in producing patents awarded to universities and private businesses.

Results of the econometric analysis indicate that increases in the presence of foreign graduate students have a positive and significant impact on future U.S. patent

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

applications and grants awarded to both firms and universities. This finding extends to the relative presence of skilled immigrants in the labor force, with an increase in the skilled immigrant share significantly raising later patent awards in both types of institutions. Put simply, we find that both enrollment of foreign graduate students and immigration of skilled workers have a strong and positive impact on the development of ideas in the United States.

The paper proceeds as follows. In the next section we review literature that motivates this study. In Section Three we develop a simple model and set out the econometric specification. In Section Four we provide results and discuss their economic and policy significance. In Section Five we conclude.

2. Background and Literature Review

The question of whether skilled and other forms of immigration bring net benefits is much discussed in media and policy circles in rich countries.⁷ It is even the subject of negative, and rather polemical, pieces by well known scholars (Borjas, 2002, 2004; Huntington, 2004). It is evident that a major component of such gains must be the contribution of skilled immigrants and students to an economy's capacity to innovate and raise productivity. As noted earlier, the question has not been the subject of systematic empirical analysis. However, there are related strands of literature that help motivate our analysis.

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

2a. Basic Economic Models

Labor economists have focused on the static implications of immigration into the United States for domestic wage inequality and prices (Briggs 1996). It is evident that inflows of unskilled workers, which have been a rising share of U.S. immigrants in recent decades, could reduce the wages of domestic unskilled labor and contribute to rising wage inequality (Clark, et al, 2002).⁸

Davis and Weinstein (2002) argued that a single-factor Ricardian model could be used to analyze the implications of factor inflows into the United States. Aggregating labor and capital into a single factor, they calculated simply that such inflows implied a loss of some \$72 billion per year for US natives relative to a free-trade baseline without immigration. The reason is that the incoming factors contribute to production capacities without expanding per-worker productivity, leading to significant losses on the terms of trade and lower real wages.

In our view this analysis is misleading because it fails to account for at least two important issues. First, in a broader static model immigrants can raise the productivity and real wages of native skilled workers. Second, and more relevant for our analysis, is the possibility that skilled migrants may generate dynamic gains through increasing innovation. Such innovation could contribute to future productivity gains of native workers, resulting in a net increase in real wages. Put differently, in a dynamic context immigration of skilled workers would be complementary to local skills, rather than substitutes for them. Thus, more realistic theory suggests that skilled migration would

⁷ See, for example, “The Politics of Immigration: Business v. Bush,” *The Economist*, October 18-24, 2003, pp. 29-30, and “German Immigration: Brains Not Welcome Here,” *The Economist*, May 1-7, 2004, p. 50.

support rising aggregate real incomes in the long run.⁹ Ultimately, the impacts of immigration on real incomes through innovation are an empirical issue.

Indeed, pessimistic claims about the impacts of foreign workers seem inconsistent with continued political support, arising from the high-technology sectors, in the United States for sustaining immigration of skilled workers and engineering and science students.¹⁰ Thus, an essential motivation for our paper is to investigate whether this support is rooted in the dynamic innovation impacts of such foreign workers studying and residing in the United States.

2b. Foreign Graduate Students and Skilled Immigration

The issue of international students and their contribution to host-country economies has been addressed only recently although students have been leaving their home countries for study abroad for nearly four thousand years (Cohen, 2001). Until World War II, a substantial proportion of international students studied in Europe, but this began to change after 1945. Most pronounced was the dramatic shift by Asian students since 1985 toward study in the United States.

Figures for the number of skilled immigrants and foreign student inflow into US higher education since 1960 are provided in Figure 1. Annual flows of skilled immigrants rose by a factor of 27 in this period, while those of international students rose by a factor of 6.4. An important impetus was the Hart-Cellar Immigration Act of 1965,

⁸ In fact, Borjas, et al (1997) found that immigration into the United States during 1980-95 accounted for about 25 to 50 percent of the decline in the relative wage of high-school dropouts. They suggested that unskilled immigration had relatively little positive impact on skilled-labor wages.

⁹ See also Chander and Thangavelu (2004), who show in a theoretical model that permitting high-skilled immigration plus offering education subsidies is sufficient to ensure new technology adoption.

¹⁰ See “The Politics of Immigration” above note 7.

which removed the National Origins quotas established by the Johnson-Reid Immigration Act of 1924, and resulted in greater flows of skilled immigration and foreign students. These trends were accelerated after passage of the Kennedy-Rodino Immigration Act of 1990. Studies by Cobb-Clark (1998), Clark, et al (2002) and Antecol et al. (2003) indicate that legislative reforms resulted in a sharp increase in the flow of highly talented international workers into the United States. Further, there is an important relationship between human capital investment and immigration (Duleep and Regets, 1999).

Figure 2 indicates that skilled immigrants as a proportion of the U.S. labor force have increased sharply since 1965, and especially after 1990. Foreign graduate students as a proportion of total labor force have also gone up rapidly. Figure 2 also shows that there was an increase in patenting activities as well, though most of this rise came after 1990. Thus, basic evidence suggests that skilled immigration is correlated with increases in innovative effort.

It is worth noting that foreign graduate students have a high propensity to remain in the United States, at least for the early proportion of their careers, and those who are educated in that country earn higher wages (Bratsberg and Ragan, forthcoming; Schoeni, 1997). 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. Another 15 percent planned to go to a third country. Despite attempts by the U.S. Congress to forbid employment of international students after graduation since the early 1980s,¹¹ and in some cases restrict the flow of

¹¹ In 1982 and again in 1984 legislation sponsored by Senator Simpson and Representative Mazzoli forbidding the employment in the United States of international graduates of US universities passed both chambers of Congress before dying in the Conference Committee. In 1995 Senator Simpson and Representative Lamar Smith unsuccessfully resurrected the proposal.

international students to domestic universities,¹² the United States still allows a significant proportion to stay and work after graduation and in a majority of cases even grants them permanent residence. Thus, graduate training of foreign students may have long-lasting impacts on innovation capacities.

On a negative note, Borjas (2002) speculates that foreign students in the United States benefit the economy to the tune of \$1 billion a year, but this gain is more than offset by the costs of taxpayer-financed grants and subsidies at public universities. In another paper Borjas (2004) finds a strong negative correlation between the enrollment of native men in US graduate programs and the enrollment of foreign students. Institutions which experienced the largest increase in foreign enrollment were also institutions that experienced the steepest fall in the enrollment of native males.

For our purposes the interesting aspect of this claim is that Borjas seems to suggest that domestic and foreign graduate students are highly substitutable and display similar characteristics. In fact, other information indicates that this assertion is questionable. Although data on the quality of domestic graduate student applicants compared to their international counterparts are not readily available, results from TIMMS and other international tests indicate that the native U.S. student pool for engineering and science programs is likely to be limited due to lower math and science achievement.¹³ This suggests that student populations are not readily substitutable and that university technical training programs may have increased their demand for foreign students.

¹² Senator Diane Feinstein tried to put a moratorium on all international students soon after the September 11, 2001 attack. The proposal was shelved after protests from US universities. Representative Dana Rohrbacher has proposed that US universities replace international students with domestic students even though the latter may be less qualified.

As a result it is not surprising that a recent study (Freeman et al., 2004) indicates that there has been a sharp drop in the proportion of PhDs in science and engineering awarded to U.S.-born males between the early 1970s and 2000. In 1966 these students accounted for 71 percent of science and engineering PhD graduates, while six percent were awarded to U.S.-born females and only 23 percent of doctoral recipients were foreign-born. The situation was reversed by 2000, when only 36 percent of doctoral recipients were U.S.-born males, 25 percent were U.S.-born females and 39 percent were foreign-born. Contradicting Borjas (2004), the authors found that foreign students were not substituted for domestic students. The number of PhDs granted to undergraduates from U.S. institutions, most of whom were U.S. citizens, did not change much during this period, while there was a huge growth in the number of foreign bachelor's graduates obtaining U.S. doctorates. Thus the change in proportion is mostly due to the expansion of PhD programs, with a majority of the new slots being taken by foreign students rather than through substitution.

These same trends explain the fact that the proportion of foreign born faculty with U.S. doctoral degrees at U.S. Universities has gone up 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.¹⁴

In the last few years, however, there has been a steep decline in foreign student applications for admission into U.S. universities and a corresponding increase in applicants to universities in Asia, Australia and New Zealand.¹⁵ This is due both to difficulties in obtaining U.S. visas since September 2001 and to the fact that some

¹³ <http://nces.ed.gov/pubs99/1999081.pdf>

¹⁴ <http://www.nsf.gov/sbe/srs/seind02/append/c5/at05-24.xls>

countries are catching up to the United States with regard to attracting foreign students and skilled labor from abroad (Hira, 2003). Recent evidence also suggests that collaboration between foreign and U.S. universities has shown marked increase during the past two decades and increasingly research activities are being “dispersed” abroad, particularly to Asian countries, partly to take advantage of complementary capabilities (Adams et al., 2004). While modern communication technologies and cuts in public funding presumably have contributed to this trend, it is likely that if qualified students become increasingly unavailable in the United States the tendency will accelerate.

2c. University Research and Patenting

In the United States, patenting of new inventions by universities began to accelerate during the 1960s, although such institutions as Stanford had been innovating and attempting to patent inventions from the early 1920s (Etzkowitz, 2003; Henderson and Jaffe, 1998). University innovation and patenting may have been significantly boosted by the Bayh-Dole Act of 1980, which allowed U.S. universities to commercialize research results (Sampat et al., 2003; Mowery et al., 2001). Currently the determinants of university patenting in the United States and its implications for the economy are a central subject for inquiry (Lee, 1996; Thursby and Kemp, 2002; Jensen and Thursby, 2001; Thursby and Thursby, 2000; Owen-Smith and Powell, 2003).

National governments typically play a significant role in financing research that supports patenting. Furthermore, there is also considerable university-industry collaboration, especially in the United States, with a significant proportion of research funding coming from industries (Cohen et al., 1994; Dasgupta and David, 2002; Agrawal

¹⁵ <http://smh.com.au/articles/2004/07/14/1089694426317.html?from=moreStories&oneclick=true>

and Cockburn, 2003; Link and Scott, 2003). Indeed, U.S. state and federal budget cuts have created a vacuum in research financing that is increasingly being filled by both domestic and international corporations (Beath et al., 2003). For example, recently BMW set up a fund to finance most of the research of the Automotive Engineering Department at Clemson University in South Carolina.¹⁶

As noted earlier, prior studies of university patenting have not analyzed the role of skilled immigrants or foreign graduate students as input into the innovation production function. That role could be important as most countries in the world are not in a position to produce domestically all the skilled labor necessary for rapid technological development and innovation. Hence, they must rely on skilled immigration and foreign talent to augment their skills. Recent experience indicates that countries such as the United States, Australia, Singapore, United Arab Emirates and more recently, People's Republic of China, which have been relatively open to foreign talent, have experienced faster rates of economic growth than such countries as Germany, Japan and Korea, where opposition to any form of foreign talent is significant. Thus, it seems plausible from this experience that a relatively open-door skilled immigration policy could play an important role in innovation and follow-on growth.

3. Modeling Framework

To estimate the contribution of skilled immigrants and foreign graduate students to U.S. innovation, we modify the "national ideas production function" that is widely used in innovation studies (Stern, et al, 2000; Porter and Stern, 2000). This may be written in general form as

¹⁶ <http://www.clemson.edu/centers/brooks/news/BMW.pdf>

$$\dot{A}_t = \delta H_{A,t}^\lambda A_t^\phi \quad (1)$$

Thus, the rate of new ideas produced depends on both the allocation of resources to the R&D sector ($H_{A,t}$), the productivity of those resources (λ), the stock of ideas already in existence (A_t) and the ability of that stock to support new invention (ϕ). Note that if $\phi > 0$, prior research increases current R&D productivity (the "standing on shoulders" effect), but if $\phi < 0$, prior research has discovered the easier ideas and new invention becomes more difficult.

Our measures of new ideas production are total patent applications, total patents awarded, and patents granted to U.S.-based universities and other institutions and firms. All of these data refer to activities within the United States. Patents are not an ideal measurement of innovative output, primarily because patents vary widely in their economic and technical significance (Griliches, 1984). However, patenting activity is the most commonly used proxy in innovation studies and does capture three important aspects of innovation (Kortum, 1997; Stern, et al, 2000). First, patents do reflect an important portion of innovative output and are likely correlated with others, such as trade secrets and copyrights. Second, to be awarded a patent, inventions must be novel and non-obvious, suggesting that patent grants do capture something new. Third, it is costly to apply for a patent, so the patenting entity believes there is something economically valuable about its technological innovation.

The primary novelty of our approach is in the definition of $H_{A,t}$. In prior studies these resources have been measured by R&D expenditures (perhaps broken into university and non-university sources) and scientists and engineers. We retain the use of R&D but incorporate international students and skilled immigrants as components of the

inputs into idea generation. We permit the productivity of each resource to differ, as follows.

$$H_{A,t}^{\lambda} = H_{F,t}^{\lambda_F} H_{G,t}^{\lambda_G} H_{I,t}^{\lambda_I} H_{S,t}^{\lambda_S} H_{R,t}^{\lambda_R} \quad (2)$$

Here, H_F is the flow (enrollments) of international graduate students, H_G is the flow (enrollments) of US graduate students, H_I is the number of skilled immigrants in the country, H_S is the number of total PhD engineers and scientists, and H_R is expenditure on R&D. It should be noted that there is some overlap between skilled immigrants and engineers and scientists, but it is not possible with available data to distinguish sharply between these factors.

To capture the stock of existing knowledge (A_t), we employ the accumulated number of patents awarded. This variable captures the technical ability of the economy at any time to translate its knowledge stock into a stream of new inventions. Finally, the parameter δ in equation (1) captures the aggregate ability of the economy (or the university sector) to convert inputs and knowledge stock into new ideas. For this purpose we take δ to be a function of time (capturing changes in US ideas productivity) and key policy changes. The primary policy we consider is passage of the Bayh-Dole Act in 1980, which should have changed the ability of universities (and perhaps enterprises also) to convert technical inputs into new ideas. A second policy is a rough measure of periods during which enforcement of visa restrictions may be expected to be rigorous, as discussed below.

To implement this structure econometrically, we must account for several other factors. First, there is a lag between the time research inputs are utilized and the granting of a patent. It takes around five years on average, to conduct research in an area and

apply for patents and another two years for patents to be awarded (Popp et al., 2003). The exact times for applications and awards vary according to the field. For pharmaceuticals it could take as long as fifteen years for patent applications, due to the lengthy period for clinical trials, and a further two years for the patent award (DiMasi et al., 2003). In contrast, in some areas of engineering it could take as little as three years for patent application and one year for patent awards. Thus, in the primary specification we entertain a five-year lag for patent application and a seven-year lag for patents awarded. We also test for the robustness of this assumption by using other lags.

Second, because we undertake time-series estimation, there may be problems with stationarity in the levels of patents, immigrants, and international students. Over our period the absolute numbers of foreign students have increased dramatically over time, as have patent applications. Thus, we scale relevant variables so they are measured in proportion to the aggregate labor force, as indicated below. We also employ a linear approximation of equation (1) in the estimation. Finally, we estimate equations capturing the determinants of total patents, university patents, and patents issued to other entities. Because the error terms associated with these equations are likely to be correlated our estimation technique is seemingly unrelated regression.

Putting these ideas together yields two specifications. Our basic econometric specification is as follows.

$$IPA_{t+5} = \alpha_1 + \lambda_{F1}FOR_t + \lambda_{G1}USGR_t + \lambda_{I1}IM_t + \lambda_{S1}SK_t + \lambda_{R1}RD_t + \phi_{1t}TOTPATSTOCK_t + \delta_{B1}BD + \eta_{1t}$$

$$IPG_{t+7} = \alpha_2 + \lambda_{F2}FOR_t + \lambda_{G2}USGR_t + \lambda_{I2}IM_t + \lambda_{S2}SK_t + \lambda_{R2}RD_t + \phi_{2t}TOTPATSTOCK_t + \delta_{B2}BD + \eta_{2t}$$

In the first equation the dependent variable is total patent applications as a percentage of the U.S. labor force, five years after inputs are employed. These inputs include foreign graduate students as a percentage of total labor force (FOR), U.S. graduate students as a proportion of labor force (USGR), skilled immigrants as a proportion of labor force (IM), PhD's employed in science and engineering as a percentage of labor force (SK), and real research and development expenditures as a percentage of labor force (RD). Regarding skilled immigrants we use two measures in different sub-specifications. The first is simply the annual flow of skilled immigrants. However, this flow is not completely comparable to such other measures as graduate students and engineers and scientists, which are defined as the total amount in activity (e.g., added over all enrollments for students rather than new enrollments). Therefore, we also define a variable IM2, which is the number of skilled immigrants cumulated over the preceding ten-year period.

The estimation also includes the knowledge stock, as proxied by cumulative total patent stock over the past five years (TOTPATSTOCK), again divided by the labor force. Finally, there is a dummy variable capturing the Bayh-Dole Act, which takes on the value zero before 1980 and unity from 1980 onwards. The second equation is for patent grants and has the same structure, except that the independent variables enter with a seven-year lag. In both equations we anticipate the coefficients on all explanatory variables to be positive.

Note that this first specification does not distinguish between university and non-university patenting activity because data from the U.S. Patent and Trademark Office did not make this distinction for patent applications in early years of the sample. However, patent grants are broken out in this way. Thus, a second series of equations distinguishes between patents awarded to universities and patents awarded to other organizations:

$$\text{IPA}_{t+5} = \alpha_1 + \lambda_{F1}\text{FOR}_t + \lambda_{G1}\text{GR}_t + \lambda_{I1}\text{IM}_t + \lambda_{S1}\text{SK}_t + \lambda_{R1}\text{RD}_t + \phi_1\text{TOTPATSTOCK}_t + \\ + \delta_{B1}\text{BD} + \eta_{1t}$$

$$\text{UIPG}_{t+7} = \alpha_2 + \lambda_{F2}\text{FOR}_t + \lambda_{G2}\text{GR}_t + \lambda_{I2}\text{IM}_t + \lambda_{S2}\text{SK}_t + \lambda_{R2}\text{URD}_t + \phi_{U2}\text{UPATSTOCK}_t + \\ \phi_{O2}\text{OPATSTOCK}_t + \delta_{B2}\text{BD} + \eta_{2t}$$

$$\text{OIPG}_{t+7} = \alpha_3 + \lambda_{F3}\text{FOR}_t + \lambda_{G3}\text{GR}_t + \lambda_{I3}\text{IM}_t + \lambda_{S3}\text{SK}_t + \lambda_{R3}\text{ORD}_t + \phi_{U3}\text{UPATSTOCK}_t + \\ \phi_{O3}\text{OPATSTOCK}_t + \delta_{B3}\text{BD} + \eta_{3t}$$

The first equation is the same as the initial equation in the pair listed above. The second equation captures patents granted to universities (UIPG) after a seven-year lag. It employs the same variables except it incorporates university real R&D expenditures, cumulative university and non-university patent stocks during the past seven years (UPATSTOCK and OPATSTOCK), all divided by labor force, and the dummy variable for the Bayh-Dole act. The third equation captures non-university patents awarded (OIPG) after a seven-year lag. It incorporates non-university real R&D (ORD) expenditures, cumulative university and non-university patent stocks (UPATSTOCK and OPATSTOCK), and the Bayh-Dole dummy.

Again, all independent variables in the second set of equations are expected to be positively related to the dependent variables. Patent applications and awards should increase with the stock of cumulated knowledge. Increases in technical inputs, including R&D expenditures, the proportion of international graduate students, and the proportion of skilled immigrants should expand patenting activity after a lag. University patents awarded as a proportion of labor force should be positively affected by the Bayh-Dole Act of 1980, which gave the universities considerable leeway in research and patenting. Both university and non-university patents should be positively affected by their lagged

own-patent stock. However, because there is likely to be learning by each group from the ideas protected by patents owned by the other, we anticipate a spillover impact measured by the coefficients on UPATSTOCK (in the non-university equation) and OPATSTOCK (in the university equation).

In a supplementary set of estimated equations we include another policy variable, which is a dummy for those years in which the U.S. government might be expected to enforce its student-visa restrictions rigorously. U.S. immigration laws allow students to convert visas to one of the employment categories. However, a regulation known as Section 214(b) of the Immigration and Nationality Act of 1952 allows consular officers to reject visas to students who might attempt to convert their visas once in the United States. In turn, this regulation makes it difficult to obtain student visas, affecting the inflow of graduate students. The law places the burden of proof on the applicant to demonstrate the existence of links in his home country (e.g., family) that would make return more likely.

For our purposes the interesting feature of the law is that it provides flexibility to consular officials in the rigor with which student visa applications are scrutinized. We argue that this regulation is more likely to be strictly enforced during periods when there is restrictive immigration legislation pending in Congress, such as the Simpson-Mazzoli legislation of the early 1980s, or during periods of high unemployment. It is evidently less strictly enforced when there is a liberal immigration bill pending in Congress, as during the late 1980s with the Kennedy-Rodino Immigration Bill, or during periods of low unemployment. These various periods, and their classification into "rigorous" and "lenient" enforcement epochs, are presented in Table 1.

Because stricter enforcement of Section 214(b) can be seen as increasing the costs of obtaining admission to the United States, it can affect both the number and quality of students. The impact of a lower level of student arrivals presumably already is included in the earlier specifications. However, increases in mobility costs could also affect the composition of students coming to the United States. The impact on composition is not obvious and would depend on the distribution of (skilled) incomes in the home country relative to that in the United States (Roy, 1951; Borjas, 1987). If students came from countries with significantly more unequal income distributions among skilled workers, the marginal migrating student would likely be of higher quality and more productive than the average migrating student. The increase in mobility costs would then lead to a decline in the average quality of the immigrant student population. The converse would be true if the home countries of immigrants had significantly more equal skilled income distributions. In the absence of more detailed information on source countries, the direction of the quality effect remains an empirical question which we address in subsequent estimation. If the coefficient in the estimation is negative it would suggest that tighter current enforcement of restrictions on student visas would diminish innovative activity in future periods.

These econometric models are implemented with annual data over the period 1965 to 2001.¹⁷ The data were collected from a variety of sources. Figures on U.S. graduate students were gathered from the U.S. Department of Education *Statistical Quarterly*. No separate data were available on the number of U.S. graduate student enrollment in science and engineering for the entire period of analysis. Data on international graduate students were gathered from *Open*

Doors, the publication of Institute for International Education. No data were available on international graduate students in science and engineering for the period prior to 1983 and hence total international graduate students had to be used as a proxy. This is not overly restrictive for approximately 80 percent of international graduate students enter science and engineering fields and most of the rest go into business fields and economics.¹⁸

Data on patents awarded to different institutions, such as universities and industry, were gathered from the National Science Foundation, *Science and Engineering Statistics*. Figures on research and development expenditures (divided by the GDP deflator), total number of scientists and engineers, total labor force, total number of international students and total skilled immigrants entering the country are available from the *Statistical Abstracts of the United States* published annually by the U.S. Census Bureau. Skilled immigrants are defined to include both those coming under H1-B1 visas (both capped and uncapped) and employment-based immigration. Simple correlations among the variables in this study are listed in Table 2.

4. Empirical Results

Regression results for total patent applications and grants as a proportion of labor force are presented in Table 3 for our basic specifications. The first two columns employ the flow measure of skilled immigrants while the last two columns employ the 10-year

¹⁷ Note in particular that we do not include the period after September 11, 2001. Our intent is to discover whether foreign students and skilled immigration could account for increases in technical productivity prior to that period, which may inform policy discussions in the ensuing era.

¹⁸ See various issues of *Open Doors*.

cumulative measure.¹⁹ We argue that the second pair of columns should contain the better specification, given the closer parallel between input measures than in the first pair.

It may be seen that lagged patent stock as a proportion of labor force had a significant and positive impact on patents applied in both pairs of equations, and on patent grants in the second pair. The elasticity of patent applications with respect to increases in cumulative knowledge is estimated at around 0.13 and is clearly positive. This result suggests that, *ceteris paribus*, there is a dynamic spillover from knowledge to the registration of new ideas, confirming the "standing on shoulders" idea. As anticipated, lagged real R&D expenditures had strongly positive effects on patenting activity in both equations. The elasticity of patent applications with respect to lagged R&D is between 0.61 and 0.63, while that of patent grants is between 0.93 and 0.98. These results suggest that the productivity of R&D spending is high in the United States. The total human scientific stock in the United States, our variable SK (scientists and engineers in the labor force), also had a powerful and positive impact on measured innovation, with an elasticity of between 0.49 and 0.82.²⁰

The presence of skilled immigration, whether measured as an annual flow or a cumulated total, is estimated to increase patent applications (after five years) with an elasticity between 0.07 and 0.11, with a similar impact on patent grants (after seven years). Further, the presence of foreign graduate students had a significantly positive impact on both applications and awards, with elasticities ranging between 0.31 and 0.38.

¹⁹ To clarify, the variable IM2 is the sum over ten years of the numbers of skilled immigrants, which is then lagged consistently with the other variables. Thus, for example, patent applications in the year 1965 were related to skilled immigration over the period 1949-1958.

²⁰ The results reported involve five-year lags for patent applications and seven-year lags for patent awards. We experimented also with different lag structures, which tended to reduce the significance of some coefficients but did not change the results materially. Results are available on request.

It is interesting that the sensitivity of patent activity with respect to foreign graduate students is more than three times larger than that with respect to skilled immigration. However, lagged enrollments of U.S.-native graduate students did not have a significant impact on total patenting activity. This result strongly supports the view that the presence of foreign students and skills in the United States is pro-innovation in relation to the enrollment of domestic students. Finally, implementation of the Bayh-Dole Act had positive and marginally significant impacts on later patent applications and grants in the second pair of equations.

In Table 4 the regressions are broken down into total patent applications, university patent grants, and other patent grants, using the SUR technique. The coefficients for the patent applications equations are quite similar to those in Table 3, as expected, and require no further discussion. Of interest here is whether there are detectable differences in behavior between patent grants to universities and patent grants to non-university actors. Beginning with the university equations, it is interesting that both lagged university patent stocks and lagged other patent stocks were significant and positive. The own-elasticity estimate is large, at 0.65 to 0.66, suggesting that university-owned information is productive in converting new ideas into grants in the future. There is also a positive and (marginally) significant elasticity of university awards with respect to the non-university patent stock, suggesting a spillover elasticity of around 0.19 to 0.26. In contrast, in the non-university awards equations there was a spillover learning elasticity from university patent stocks of about 0.28, while the own-elasticity was either not significant or was marginally significant and positive at 0.35. This finding points to

the importance of university-registered patents as sources of technical information for general innovation in the U.S. economy.

As anticipated, lagged R&D expenditures had strongly positive effects on patenting activity in all six equations. The implementation of the Bayh-Dole Act appears to have induced significantly more patent grants to university researchers but had an insignificant impact on total patent applications and other patents awarded.

Turning to human inputs, we find that the ratio of foreign graduate students to total labor force had a significant and positive effect in all six patenting equations. The elasticity of total patent applications to increases in foreign students is around 0.33 to 0.35, similar to that of the previous specification. As expected, foreign graduate-student enrollments had a larger positive impact (0.60 to 0.68) on future university patent awards than on other patenting (0.40 to 0.46), though both estimated elasticities are significant and large. Note that these impacts are also larger than those found for the overall patent-grants equations in Table 3. Further, the results indicate that the presence of US domestic graduate students had little impact on any patenting activity.

It is of interest to put these elasticities in perspective by computing the impacts on patent levels from a change in migration. Using the estimates in the last three columns of Table 4, a ten-percent rise in the number of foreign graduate students (from its mean level over the sample of 125,537 per year) would increase later patent applications by 5,014 (3.35 percent of sample mean), university grants by 68 (6.8 percent) and other-institution grants by 6,544 (4.6 percent). These are large figures in the context of U.S. patent

flows.²¹ Corresponding increases in the cumulative number of skilled immigrants (IM2) would have smaller, but significantly positive impacts, on later patenting activities.

The regressions indicate next that the ratio of skilled immigrants to labor force had a significantly positive effect on patenting activity in both university and non-university settings. These elasticities are considerably greater inside the university setting than outside academic institutions, with the former approximately two to three times larger. Finally, the overall ratio of PhD scientists and engineers in the labor force (SK) had a positive and significant impact on patent applications and patents awarded. As in the case of skilled immigration, the larger impact of the human scientific stock was on the university sector with an elasticity of around 1.5.

The Durbin-Watson statistic for the equations presented in Tables 3 and 4 do not indicate the presence of serial correlation, while the R-squared coefficients suggest that the regressions fit the data well.

As we argued earlier, an additional policy variable of potential importance in explaining the relationship between foreign students and innovation is the rigor with which United States consular officials enforce visa restrictions using Section 214(b). Because such enforcement alters the costs of achieving entry it could affect both the level and the quality composition of incoming foreign students. Accordingly, in Tables 5 and 6 we repeat the regression analysis, including our qualitative indicator variable for presumed periods of severity in enforcement. Note that if such enforcement were to reduce relative enrollments of higher-quality students it should have a negative impact on ultimate patenting activity.

²¹ These figures are means across the entire sample. If these elasticities were applied to the far-higher average patent numbers in the 1990s the corresponding predicted increases in innovative activity would be

Comparing Tables 5 and 3 we note first that the inclusion of the indicator variable for enforcement does not change the other results appreciably, though it generates a small reduction in the coefficients on SK, RD and TOTPATSTOCK. Table 5 clearly shows that episodes of stricter enforcement tend significantly to reduce later patent applications and patent grants in total. Indeed, most of these coefficients are larger in magnitude than those on the Bayh-Dole dummy, suggesting that even marginal restrictions on imports of technically proficient foreign graduate students may at least offset the innovation impacts of the law permitting universities to engage in greater patenting. Given the widespread view that Bayh-Dole has been responsible for significant amounts of additional university invention and licensing, this finding seems important in policy terms.

There are some differences in results between Tables 4 and 6. Specifically, inclusion of the enforcement dummy tends to reduce the elasticities of patent grants with respect to prior patent stocks. The university own-elasticity falls from around 0.65 to around 0.31, though remaining significant. The non-university own-elasticity falls from around 0.28 to around 0.13. There is also an increase in the cross-elasticity between other patent stocks and university grants, suggesting a larger spillover in that direction than was estimated in Table 4. Finally, the presence of engineers and scientists in the labor force remains a strong positive determinant of patent success, but, controlling for immigration enforcement, the impact becomes stronger in the non-university context.

Other results remain robust. In particular, foreign graduate students and skilled immigrants are strongly positive influences on later patent grants in the United States, with somewhat higher elasticities in the university equations. Indeed, the coefficients on skilled immigration increase markedly with the inclusion of the enforcement variable.

The estimates in the final three columns suggest that a ten-percent rise in foreign graduate students would increase later patent applications by 5,301, university patent grants by 73 and other patent grants by 6,829, again evaluated at sample means. The Bayh-Dole Act has significantly positive effects on patent applications and grants when the regressions employ the cumulative skilled immigration measure. Finally, the magnitudes of the Section 214(b) coefficients remain somewhat larger than those of Bayh-Dole dummy in several equations.

Summing up the results, it is evident that skilled immigrants, as well as PhDs in science and engineering, have a positive impact on total patent applications as well as patents awarded to universities, industries and other enterprises. This underscores the contributions made by skilled immigrants to innovation at all levels of the U.S. economy. Patent applications and awards increase significantly with lagged increases in R&D expenditures. Innovation and patenting by both universities and non-university institutions are increased a bit as a result of the Bayh-Dole legislation of 1980.

Next, larger enrollments of international graduate students as a proportion of total labor force result in a significant increase in patents awarded to both universities and non-university institutions as well as increases in total patent applications. This finding points out the importance of scientific contributions made by international graduate students in both settings. There are two likely reasons for this result beyond the direct impact of foreign graduate students on university innovation. First, research by foreign graduate students is likely to affect patenting by non-university institutions due to increasing collaboration between the academic and non-academic groups. Research is frequently sub-contracted by industries to universities with a share of royalties awarded to the

contributing academic department. Furthermore, industries also tend to purchase the intellectual property rights of any discovery from the innovating university and hence tend to benefit indirectly from international student contributions.²²

It is interesting that the results consistently show that foreign students, skilled immigrants, and doctorates in science and engineering play a major role in driving scientific innovation in the United States, while the proportion of U.S. graduate students plays no role. It should be noted that our variable includes all domestic graduate students and not just those in science and engineering. There are only a few observations available that distinguish between domestic and foreign graduate students in these technical fields. These data indicate that enrollments of domestic students as a proportion of total graduate students have remained fairly steady at around 65 percent recently. However, the former accounted for an average of only 45% of all graduating students during the 1990s, suggesting a significantly larger school-leaving rate. Furthermore, a significant proportion of U.S.-born students go into other fields, such as law and management, perhaps due in part to under-preparation in mathematics and science. U.S. census data indicates that only nine percent of U.S.-born graduates work in scientific fields whereas 17 percent of foreign-born graduates work in scientific fields.

While the Bayh-Dole Act increased patenting activity by universities and non-university institutions, strict implementation of Section 214(b) by consular officers contributed to declines in future patenting activity at all levels. As discussed earlier, this law authorizes consular officers to deny student visas to so-called “intending

²² Dasgupta and David (1992) and Cohen, Florida, and Goe (1994).

immigrants”. The results indicate that stringent enforcement of this regulation has been a significant impediment to patenting activity in the United States.

The results also indicate indirectly that the United States gains from trade in graduate education services. Relatively open access to international students has allowed U.S. universities to accept the brightest graduate students in science and engineering from all over the world. In turn, international graduate students contribute to innovation and patenting in science and engineering while domestic graduate students evidently do not in the aggregate. Presumably, this is because international graduate students are more concentrated in such fields as science and engineering than are domestic students. Indeed, in a number of highly ranked engineering schools, international students account for nearly 80 percent of doctoral students, while in fields such as law they rank as low as one percent.²³ Further, because of work restrictions for international students, domestic students have greater opportunities to be employed in non-research activities in both university and non-university institutions. Hence, it is not surprising that the presence of international students along with skilled immigrants, including international faculty, exchange visitors, research fellows and post-doctoral research associates, is a significant factor behind sharp increases in innovation and patenting at universities.

5. Concluding Remarks

This study provides the first systematic econometric results about the contributions of foreign graduate students and skilled immigrants to U.S. innovation and technological change. While it may have become conventional wisdom in some circles that these personnel flows contributed extensively to learning in the United States, the

idea had not been tested. Our results strongly favor the view that foreign graduate students and immigrants under technical visas are significant inputs into developing new technologies in the American economy. The impacts are particularly pronounced within the universities but spill over as well to non-university patenting.

The significant contributions of international graduate students and skilled immigrants to patenting and innovations 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 situation is broadened by the contributions of foreign students to innovation in the United States, whereby the indirect impact of technical education is additional patent rents.

However, as other countries improve their offerings of scientific graduate education, visa restrictions in the United States could have adverse implications for competitiveness. Specifically, global liberalization of higher education services would permit U.S. universities to get around visa problems by locating research campuses in other countries, such as Singapore,²⁴ that welcome international talent (Amsden and Tschang, 2003), following the examples of INSEAD and the University of New South Wales. Indeed, studies indicate that Japanese corporations have moved research activities abroad partly in response to strict Japanese immigration policies (Iwasa and Odatiri, 2004). It is also noteworthy that U.S. corporations have significantly increased patenting activity and innovation abroad (Maskus 2000) and recent evidence indicates

²³ *Open Doors*, Institute for International Education

²⁴ "Singapore's Man With a Plan," *The Economist*, August 14, 2004.

that U.S. universities are increasingly collaborating in research with universities abroad (Adams et al. 2004).

One of the striking findings in the current paper is that tight enforcement of restrictions on student visas bears the potential to reduce innovative activity by as much as it is stimulated by provisions of the Bayh-Dole Act. It is conceivable that prior to the 1980s, in the pre-globalization era, restrictive immigration policies through strict implementation of Section 214(b) worked to protect the jobs of American workers and ensure higher wages for domestic graduates. However, with the rapid economic development of countries in regions such as South East Asia and with global job mobility increasing, such restrictions are likely to be self-defeating, at least in economic terms.

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Table 1. Periods of Stringent and Lenient Implementation of Section 214(b)

Year	Status of the Economy or Legislation	Enforcement
1965-1973	Hart-Cellar Act passed in 1965	Lenient
1974-1978	High unemployment	Restrictive
1979-1986	Simpson-Mazzoli legislation pending in the conference committee	Restrictive
1987-1991	Kennedy-Rodino legislation passed in 1990	Lenient
1992-1993	High unemployment	Restrictive
1994-1995	Simpson-Smith legislation	Restrictive
1996-2001	Abraham-Brownback-Cannon-Drier-Lofgren legislation on H1-B passed in 2002	Lenient

Table 2. Correlations among Variables

	IPA	IPG	UIPG	OIPG	FOR	USGR	IM	IM2	SK	RD	URD	ORD	TPS	UPS	OPS	BD	SEC
IPA	1.0																
IPG	0.93	1.0															
UIPG	0.68	0.80	1.0														
OIPG	0.94	0.99	0.79	1.0													
FOR	0.54	0.65	0.94	0.65	1.0												
USGR	0.34	0.48	0.90	0.47	0.94	1.0											
IM	0.48	0.56	0.82	0.55	0.82	0.81	1.0										
IM2	0.39	0.48	0.84	0.48	0.89	0.90	0.95	1.0									
SK	0.43	0.29	0.00	0.29	-0.08	-0.16	-0.19	-0.27	1.0								
RD	0.90	0.93	0.76	0.93	0.61	0.48	0.44	0.44	0.28	1.0							
URD	0.35	0.52	0.90	0.51	0.92	0.95	0.71	0.81	-0.22	0.53	1.0						
ORD	0.76	0.65	0.19	0.66	0.01	-0.17	0.01	-0.06	0.44	0.73	-0.17	1.0					
TPS	0.39	0.20	-0.09	0.20	-0.10	-0.21	0.06	0.01	0.38	0.18	-0.36	0.55	1.0				
UPS	0.71	0.80	0.97	0.79	0.91	0.86	0.81	0.84	0.00	0.80	0.85	0.28	-0.02	1.0			
OPS	0.63	0.50	0.17	0.50	0.06	-0.08	0.25	0.18	0.33	0.50	-0.20	0.80	0.72	0.29	1.0		
BD	0.31	0.48	0.82	0.47	0.82	0.85	0.58	0.65	-0.14	0.48	0.92	-0.18	-0.51	0.77	-0.29	1.0	
SEC	-0.54	-0.53	-0.24	-0.54	-0.03	0.04	0.20	0.24	-0.48	-0.58	-0.08	-0.052	-0.07	-0.21	-0.10	-0.13	1.0

Table 3. International Students, Skilled Immigration, and Patenting Activity in the United States, 1965-2000

	IPA	IPG	IPA	IPG
CONSTANT	-4.899 (-5.93)*	-8.320 (-5.58)*	-4.995 (-5.34)*	-7.852 (-4.09)*
FOR	0.313 (4.24)*	0.333 (3.27)*	0.336 (4.04)*	0.384 (3.19)*
USGR	-0.377 (-0.63)	-0.422 (-0.51)	-0.481 (-0.57)	-0.526 (-0.34)
IM	0.074 (4.80)*	0.111 (4.56)*		
IM2			0.111 (3.30)*	0.135 (2.14)**
SK	0.661 (4.14)*	0.489 (2.32)**	0.815 (4.02)*	0.628 (2.05)**
RD	0.627 (11.19)*	0.979 (9.84)*	0.610 (9.74)*	0.928 (7.89)*
TOTPATSTOCK	0.129 (1.90)**	-0.233 (-1.41)	0.134 (1.87)**	0.145 (1.55)***
BD	0.049 (1.28)	0.041 (0.91)	0.079 (1.78)***	0.079 (1.58)***
R-Squared	0.95	0.94	0.94	0.92
DW	1.72	1.60	1.59	1.47

Notes: IPA is patent applications and IPG is patents granted, both as a percentage of labor force. FOR and USGR are foreign and U.S. graduate students as a proportion of labor force. IM is skilled immigrants as a proportion of labor force, while IM2 is the cumulative number of skilled immigrants as a proportion of the labor force. SK is total PhD scientists and engineers as a proportion of labor force. RD is total real R&D expenditures as a proportion of labor force. TOTPATSTOCK is cumulative patents awarded as a proportion of labor force. BD is the dummy variable for the Bayh-Dole Act. 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 one-percent (*), five-percent (**), and ten-percent (***) levels.

Table 4. International Students, Skilled Immigration, and Patenting Activity in the United States, 1965-2000

	IPA	UIPG	OIPG	IPA	UIPG	OIPG
CONSTANT	-4.800 (-5.82)*	4.240 (1.38)	-6.726 (-3.92)*	-4.848 (-5.19)*	4.687 (1.30)	-5.833 (-2.87)*
FOR	0.325 (4.40)*	0.596 (2.54)**	0.399 (3.85)*	0.352 (4.25)*	0.676 (2.69)**	0.463 (3.71)*
USGR	-0.385 (-0.65)	-0.487 (-1.23)	-0.526 (-0.51)	-0.500 (-0.59)	-0.544 (-1.33)	-0.548 (-1.36)
IM	0.074 (4.79)*	0.141 (2.56)**	0.063 (2.21)**			
IM2				0.113 (3.33)*	0.153 (1.55)***	0.047 (1.60)***
SK	0.674 (4.22)*	1.537 (3.02)*	0.661 (2.72)**	0.839 (4.10)*	1.580 (2.33)**	0.654 (1.98)**
RD	0.605 (10.84)*			0.575 (9.27)*		
URD		0.595 (3.14)*			0.542 (3.03)*	
ORD			0.399 (3.85)*			0.345 (3.42)*
TOTPATSTOCK	0.138 (2.00)**			0.148 (1.95)**		
UPATSTOCK		0.659 (4.22)*	0.280 (3.32)*		0.653 (4.10)*	0.285 (3.34)*
OPATSTOCK		0.192 (1.51)***	-0.500 (-1.48)		0.261 (1.55)***	0.352 (1.51)***
BD	0.053 (1.41)	0.129 (1.58)***	0.038 (0.63)	0.088 (1.95)**	0.172 (1.53)***	0.047 (0.71)
R-Squared	0.95	0.98	0.92	0.94	0.97	0.90
DW	1.95	1.68	1.59	1.63	1.63	1.49

Notes: IPA is patent applications, while UIPG and OIPG are university patents awarded and other patents awarded, all as a percentage of labor force. FOR and USGR are foreign and U.S. graduate students as a proportion of labor force. IM is skilled immigrants as a proportion of labor force and IM2 is the cumulative number of skilled immigrants as a percentage of the labor force. SK is total PhD scientists and engineers as a proportion of labor force. RD is total real R&D expenditures as a proportion of labor force. URD and ORD are, respectively, university and non-university real R&D expenditures as a proportion of labor force. TOTPATSTOCK is cumulative patents awarded as a proportion of labor force. UPATSTOCK is cumulative patents awarded to universities as a proportion of labor force. OPATSTOCK is cumulative patents awarded to non-university institutions as a proportion of labor force. BD is the dummy variable for the Bayh-Dole act. Independent variables in the IPA equations are lagged five years and those in the UIPG and OIPG equations are lagged seven years.

Figures in parentheses are t-ratios and marked as significantly different from zero at the one-percent (*), five-percent (**), and ten-percent (***) levels.

Table 5. International Students, Skilled Immigration, and Patent Applications and Awards in the United States with Section 214(b), 1965-2001

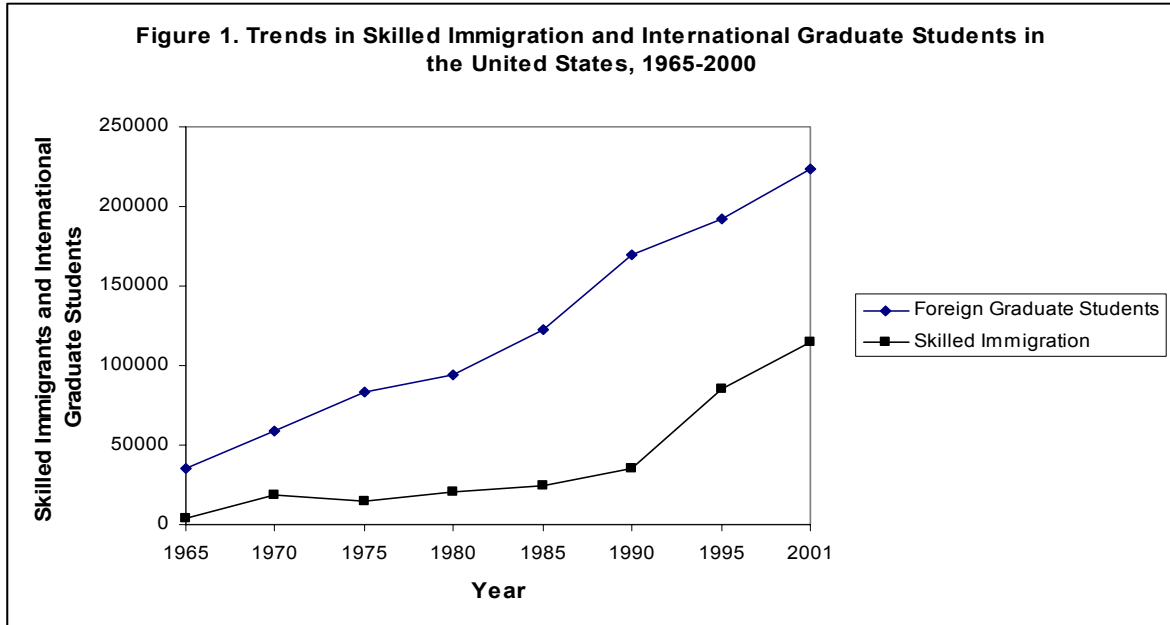
	IPA	IPG	IPA	IPG
CONSTANT	-5.088 (-6.75)*	-7.45 (-5.19)*	-5.53 (-6.77)*	-7.83 (-4.37)*
FOR	0.351 (5.11)*	0.393 (4.14)*	0.372 (5.16)*	0.435 (3.98)*
USGR	-0.540 (-1.11)	-0.424 (-1.27)	-0.585 (-1.35)	-0.629 (-0.95)
IM	0.086 (5.84)*	0.115 (5.14)*		
IM2			0.180 (5.18)*	0.201 (3.30)*
SK	0.387 (3.56)*	0.267 (1.62)**	0.793 (4.51)*	0.521 (1.85)**
RD	0.505 (7.52)*	0.712 (5.11)*	0.406 (5.26)*	0.622 (3.99)*
TOTPATSTOCK	0.136 (2.12)**	-0.032 (-0.18)	0.126 (1.92)**	0.038 (1.84)**
BD	0.036 (1.02)	0.049 (1.18)	0.089 (2.27)**	0.101 (2.01)**
SEC214(b)	-0.052 (-2.77)**	-0.084 (-2.70)**	-0.087 (-3.65)*	-0.112 (-3.00)*
R-Squared	0.96	0.95	0.95	0.94
DW	2.22	1.82	1.91	1.95

Notes: SEC214(b) is a dummy variable for the enforcement of the “intended immigrant clause” regarding student visa applicants. Otherwise see Table 3.

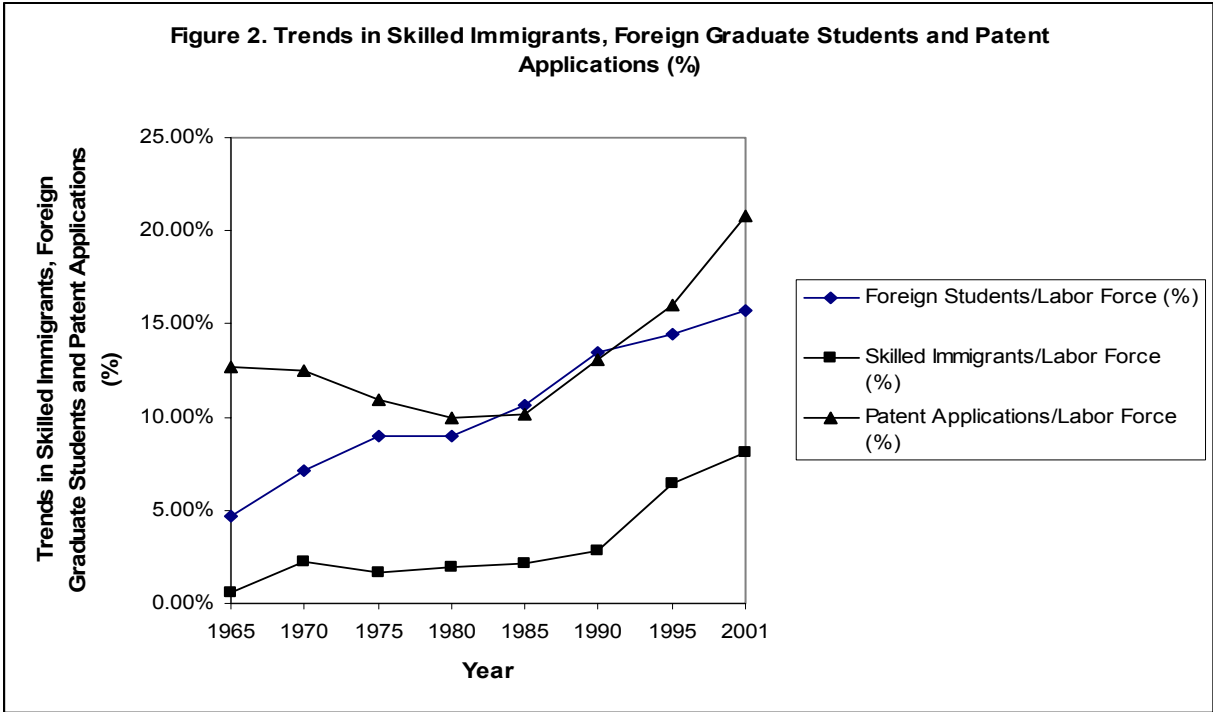
Table 6. International Students, Skilled Immigration, Patent Applications, and University and Non-University Patent Awards in the United States with Section 214(b), 1965-2001

	IPA	UIPG	OIPG	IPA	UIPG	OIPG
CONSTANT	-5.07 (-6.73)*	3.15 (1.28)	-6.47 (-4.34)*	-5.51 (-6.75)*	0.259 (0.09)	-7.26 (-4.06)*
FOR	0.353 (5.13)*	0.716 (3.80)*	0.469 (4.75)*	0.374 (5.20)*	0.733 (3.61)*	0.482 (4.48)*
USGR	-0.388 (-1.34)	-0.199 (-1.10)	0.217 (-0.94)	-0.589 (-1.46)	-0.663 (-1.38)	-0.633 (-1.48)
IM	0.086 (5.83)*	0.218 (4.77)*	0.093 (3.72)*			
IM2				0.180 (5.19)*	0.454 (3.89)*	0.173 (2.70)*
SK	0.535 (3.54)*	0.406 (1.86)**	0.981 (1.94)**	0.785 (4.46)*	0.476 (1.89)**	1.073 (1.65)**
RD	0.499 (7.47)*			0.396 (5.20)*		
URD		0.468 (2.86)**			0.413 (2.57)**	
ORD			0.317 (3.15)*			0.296 (2.96)*
TOTPATSTOCK	0.143 (2.25)**			0.138 (2.06)**		
UPATSTOCK		0.307 (2.10)**	0.125 (1.57)**		0.324 (2.14)**	0.133 (1.60)**
OPATSTOCK		0.680 (1.70)**	-0.017 (-0.50)		0.326 (1.73)**	0.309 (1.65)**
BD	0.038 (1.10)	0.195 (1.96)**	0.063 (1.22)	0.093 (2.38)**	0.299 (2.65)**	0.097 (1.62)**
SEC214(b)	-0.056 (-2.82)**	-0.269 (-5.04)*	-0.123 (-4.09)*	-0.088 (-3.75)*	-0.309 (-5.05)*	-0.136 (-4.00)*
R-Squared	0.96	0.99	0.94	0.95	0.98	0.93
DW	2.23	1.86	1.78	1.94	1.85	1.82

Notes: SEC214(b) is a dummy variable for the enforcement of the “intended immigrant clause” regarding student visa applicants. Otherwise see Table 4.



Source: U.S. Statistical Abstracts 1960-2003



Source: *Open Doors*, Institute for International Education, for foreign graduate students; Department of Homeland Security's *U.S. Immigration Statistics* and *Statistical Abstract of the United States* for skilled immigrants; U.S. Patent Office for patent applications and *Statistical Abstract of the United States* for total U.S. labor force.