NBER WORKING PAPER SERIES

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Working Paper 11217
http://www.nber.org/papers/w11217

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
March 2005

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NBER Working Paper No. 11217
March 2005
JEL No. J1, J4

ABSTRACT

The rapid growth in the number of foreign students enrolled in American universities has transformed the higher education system, particularly at the graduate level. Many of these newly minted doctorates remain in the United States after receiving their doctoral degrees, so that the foreign student influx can have a significant impact in the labor market for high-skill workers. Using data drawn from the Survey of Earned Doctorates and the Survey of Doctoral Recipients, the study shows that a foreign student influx into a particular doctoral field at a particular time had a significant and adverse effect on the earnings of doctorates in that field who graduated at roughly the same time. A 10 percent immigration-induced increase in the supply of doctorates lowers the wage of competing workers by about 3 percent.

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THE LABOR MARKET IMPACT OF HIGH-SKILL IMMIGRATION

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The fraction of doctoral degrees awarded to foreign students rose from 11.3 to 24.4 percent between 1976 and 2000, with nonresident aliens receiving a remarkably high share of the doctoral degrees awarded in the physical sciences (36.5 percent in 2000), engineering (50.7 percent), and the life sciences (25.7 percent).[1] Over half of the foreign-born doctorates remain in the United States (Michael Finn, 2003), suggesting they may have a sizable impact on the labor market for high-skill workers.

This paper addresses a core question in any evaluation of the costs and benefits of the foreign student program: Have foreign students harmed the economic opportunities of competing native workers?[2] The foreign student influx provides a near-ideal research framework for measuring the impact of immigration. Although an exogenous supply increase in a particular field at a particular time may affect the education decisions of future generations of students, there is relatively little that current doctorates can do about the situation except to absorb the supply shock—presumably through lower wages.

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* Kennedy School of Government, Harvard University and National Bureau of Economic Research. I am grateful to Alberto Abadie, Ronald Ehrenberg, Richard Freeman, and Paula Stephan for helpful suggestions and to the Sloan Foundation for research support.

[1] U.S. Department of Education (2002), Tables 207, 270, 272.

[2] Early studies, based on comparisons of labor market conditions across cities, found little evidence that immigrants affected local labor market opportunities (see the survey by Rachel Friedberg and Jennifer Hunt, 1995). In more recent research, George Borjas (2003) examines the evolution of earnings at the *national* level and finds that immigration indeed lowers the earnings of competing native workers. An immigrant-induced 10 percent increase in the size of a skill group lowers the wage of native workers in that group by 3 to 4 percent

I. Data

The study uses data drawn from the National Science Foundation's Survey of Earned Doctorates (SED) and Survey of Doctoral Recipients (SDR). The SED provides a *population* census of all doctorates granted by a U.S. institution, with a response rate of around 92 percent. I use the SED to calculate the magnitude of the immigrant supply shock by field and year of degree. The SDR is a biennial longitudinal file that provides a 7 percent sample of doctorates in science or engineering granted by U.S. institutions, and contains detailed information on a worker's earnings. The existing panel consists of five waves, beginning in 1993.

Because the SED did not collect data identifying a person's detailed immigration status prior to 1967, I restrict the study to persons granted doctoral degree between 1968 and 2000. An "immigrant" is a person who is either a naturalized citizen or a non-citizen *at the time the degree was awarded*; all other persons are classified as natives.[3] Because the SDR data contains information on labor market outcomes of doctorates in 22 science and engineering fields, I restrict the analysis of the SED data to persons who received doctoral degrees in those fields.

The SED asks newly minted doctorates if they intend "to live, work or study in the United States or a foreign country after receiving the doctorate." The data indicate that 70.9 percent of the foreign-born doctorates intend to remain in the United States. Consider the population of persons granted a doctorate in field f and calendar year c. This population includes native doctorates and immigrants who intend to remain in the United States. Figure 1 shows the trend in the number of doctorates granted each year to native and foreign students (aggregated across all fields), as well as the trend in the immigrant share (the fraction granted to foreign

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[3] Over 95 percent of the foreign-born doctoral recipients received their high school diplomas abroad, suggesting that most entered the country using a foreign student visa.

students). The annual number of doctorates granted to natives declined in the 1970s, but has risen since. There was an even steeper rise in the number granted to foreign students. As a result, the immigrant share rose rapidly, from 17.5 percent in 1968 to 34.8 percent by 2000.

Table 1 shows that the foreign student supply shock differs across fields, in terms of both size and timing. In electrical engineering, the immigrant share rose from 30.0 percent in the 1970s to about 48 percent in both the 1980s and 1990s. In biological sciences, the immigrant share hovered around 10 percent in the 1970s and 1980s, and rose to 27.5 percent in the 1990s.[4]

II. Regression Analysis

The empirical analysis pools all five waves of the SDR. Let $w_{ifc}(t)$ denote the annual earnings of worker i, who has a doctorate in field f, received his doctoral degree in year c, and is observed at time t. Consider the following specification for the labor demand function:

$$\log w_{ifc}(t) = \eta \log L_{fc} + x_{ifc}(t) + d_f + y_c + \pi_t + (d_f \times \pi_t) + \varepsilon_{ifc}(t), \quad (1)$$

where L_{fc} gives the total number of doctorates in field f and cohort c; $x_{ifc}(t)$ is a vector indicating the number of years that the worker has been in the labor market; d_f is a vector of fixed effects indicating the worker's field of doctoral study; y_c is a vector of fixed effects indicating the worker's year-of-graduation cohort; π_t gives a vector of period fixed effects indicating the calendar year in which the worker's earnings are observed. The worker's experience is defined as the number of years between the time the worker is observed in a particular SDR wave and the

[4] The analysis ignores the supply shifts associated with foreign-born workers who received their doctorates abroad or who intend to leave the United States after graduation. Borjas (2004) shows that the results summarized here are not sensitive to the inclusion of these flows.

time the worker received the doctoral degree. The vector $x_{ifc}(t)$ contains as many fixed effects as there are values for the experience variable. The parameter η gives the factor price elasticity.

The interactions between the field and period fixed effects account for the possibility that the economic returns to particular fields changed over time. The regression cannot contain additional vectors of interactions among the fixed effects because they would be either perfectly collinear with the variables already included in the regression or they would make it impossible to identify the factor price elasticity.

The application of OLS to equation (1) leads to incorrect standard errors and a biased estimate of the elasticity η for a number of reasons. First, the same worker can be observed up to five times during the duration of the SDR panel, so that the estimation must adjust for within-worker correlation in the error term. Second, the variable L_{fc} is constant within the subset of workers who graduated at the same time with a doctoral degree in the same field. Finally, OLS leads to biased estimates of η because the supply of workers to the various cohort-field groups will likely be endogenous over the 33-year period spanned by the data.

I use a two-stage approach to correct for these potential problems. In the first stage, I stack all workers across SDR waves and estimate the fixed effect for worker *i* in field *f* and cohort *c*. In particular, consider the regression model:

$$\log w_{ifc}(t) = v_{ifc} + x_{ifc}(t) + \pi_t + (d_f \times \pi_t) + \varepsilon_{ifc}(t), \tag{2}$$

where v_{ifc} is the individual fixed effect. Let $\hat{v}_{fc}$ be the mean value of the estimated individual fixed effects within each field-cohort cell. The second-stage regression model is then given by:

$$\hat{v}_{fc} = \eta \log L_{fc} + d_f + y_c + \xi_{fc}. \tag{3}$$

This second-stage regression has one observation per field-cohort cell. I use the total of the sampling weights assigned to each person in the SDR (i.e., added across all the waves in which a particular person appears in the survey) to calculate the average $\hat{v}_{fc}$. The standard errors of the second-stage regression are adjusted using a standard Huber-White correction to account for the heteroscedasticity introduced by the sampling error in the dependent variable.[5] I use instrumental variables in the second stage regression to correct for endogeneity. I instrument log L_{fc} by the log of the number of immigrants in the (f, c) cell. The influx of foreign students into some doctoral fields at particular times is the supply shifter required to identify the labor demand function.[6]

Finis Welch's (1979) study of the impact of cohort size on the earnings of baby boomers suggests that workers who received their doctoral degree in the same field at roughly the same time are more likely to influence each other's earnings than workers who are in the same field but graduated at very different times. To capture this insight, I aggregate the data into three-year intervals, indicating if the worker earned his doctorate between 1968 and 1970, 1971 and 1973, and so on. There are then a total of 11 three-year cohorts in the data for each field.

I use two measures of earnings as alternative dependent variables. The first gives the adjusted annual salary as constructed by the NSF from information on a worker's income per pay period. The second is the total annual (earned) income in the calendar year prior to the survey. Although total annual income is a preferable variable, it is not available for the 1993 survey.[7]

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[5] All second-stage regressions also include a variable indicating the fraction of the (f, c) cell that is male. This variable is not very important and does not alter the results in any way.

[6] The R-squared of the first-stage regression in the IV regression model is .976. The coefficient of log M in this regression is .452 (.079).

[7] The first stage regression has 105,921 observations when the dependent variable is the log of adjusted annual salary and 84,036 observations when it is the log of annual income.

The top row of Table 2 reports the factor price elasticities estimated in the sample of native doctoral recipients. The elasticity for the annual income equation is -.31 (.14). In other words, an immigration-induced 10 percent increase in the supply of a narrowly defined high-skill group lowers the wage of that group by 3 percent. This factor price elasticity is slightly higher than those reported by Richard Freeman (1976) in his study of the engineering labor market.

To determine if the adverse wage impact of the foreign student influx also lowers the earnings of foreign doctorates, I estimated the first-stage model using only the sample of foreign-born doctorates, obtained the mean $\hat{v}_{fc}$ for each (f, c) cell, and estimated the labor demand function in (3). Although the estimated factor price elasticities tend to be slightly more negative than those estimated in the sample of native-born doctorates, the difference between the two sets of estimates is not statistically significant ($t = -0.46$). This similarity is not surprising because the two groups have almost identical incomes within field-cohort cells. Foreign and native doctorates belonging to the same field-cohort cell are close to being perfect substitutes. The bottom row of Table 2 uses this insight and estimates the model using the entire sample of doctorates, regardless of whether they are native-born or foreign-born. The factor price elasticity for annual income is around -.3.

High-skill labor markets likely adjusted to the supply shocks and these adjustments cloud the interpretation of the results. Suppose that native students would have taken the place of the foreign students admitted to the various graduate programs if there had been a prohibition on the entry of foreign students. The total supply of doctorates in particular field-cohort cells would then have been the same regardless of whether foreign students had been admitted and the wage structure in the doctoral labor market today would be exactly what we now observe, despite the fact that not a single foreign student entered the country.

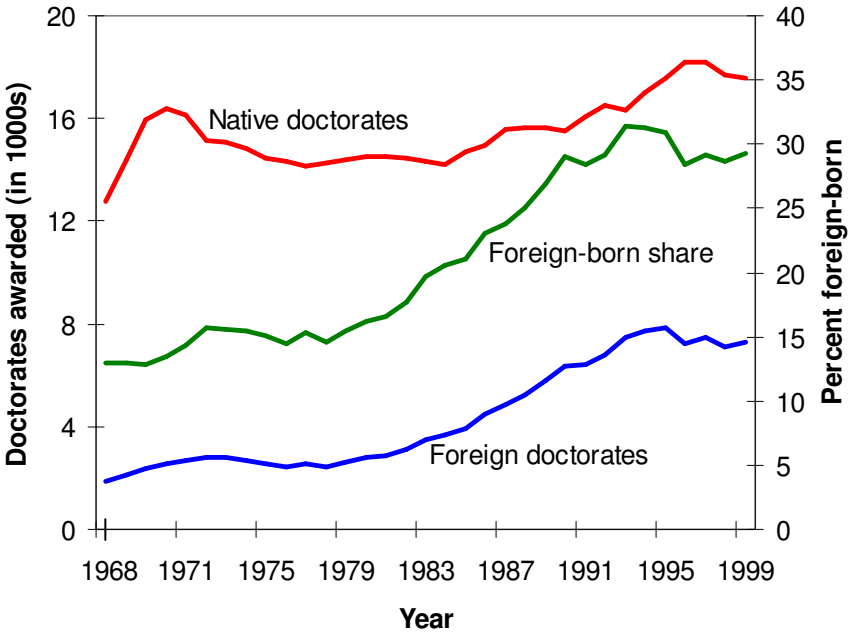
Alternatively, native students may have responded to the foreign student influx by moving to other fields, or by going to law or business school. These "internal migration flows" would lower wages throughout the entire high-skill sector, not just in the fields penetrated by immigrants. The measured labor market impact of immigration would then underestimate the actual impact, since the supply response of native students arbitrages wage differences.

III. Summary

This paper analyzed the impact of immigration on high-skill labor markets. The empirical study is based on the intuitive notion that shifts in the labor supply of a finely-detailed skill group should affect the earnings and employment opportunities of that group. Immigration-induced shifts in the supply of students entering particular doctoral fields at particular times can then be used to identify the impact of immigration on the earnings of doctorates.

The analysis shows that increases in the number of foreign-born doctorates, primarily through the foreign student program, have a significant adverse effect on the earnings of competing workers, regardless of whether the competing workers are native-born or foreign-born. An immigration-induced 10 percent increase in the supply of doctorates in a particular field at a particular time reduces the earnings of that cohort of doctorates by 3 percent.

Figure 1. Doctorates awarded, 1968-2000



Source: Survey of Earned Doctorates. The foreign-born population includes only those newly minted doctorates who intend to stay in the United States after graduation.

Table 1. Foreign-born share, by field

	Percent foreign-born		
Field:	1970-79	1980-89	1990-99
Computer and information sciences	19.6%	33.9%	41.6%
Mathematical sciences	16.1	33.7	42.6
Agricultural and food sciences	20.0	21.6	34.6
Biological sciences	10.1	11.3	27.5
Environmental life sciences	10.2	10.5	24.2
Health and related sciences	11.5	11.1	16.7
Chemistry, except biochemistry	15.8	21.1	34.0
Earth sciences, geology, oceanography	11.8	13.7	23.5
Physics and astronomy	18.0	28.1	37.5
Other physical sciences	18.2	24.2	39.1
Economics	17.2	28.7	36.7
Political science	9.4	15.9	14.4
Sociology and anthropology	6.8	9.6	13.0
Other social sciences	12.2	18.5	22.2
Psychology	3.2	3.4	4.9
Aerospace and related engineering	29.7	44.1	35.1
Chemical engineering	37.1	40.9	43.6
Civil and architectural engineering	42.3	51.8	54.2
Electrical, electronic engineering	30.0	47.0	49.2
Industrial engineering	34.9	45.0	46.0
Mechanical engineering	31.0	50.7	49.1
Other engineering	28.2	40.8	43.9
All fields	19.7	27.5	33.4

Source: Survey of Earned Doctorates. The foreign-born population is restricted to foreign-born doctorates who intend to stay in the United States at the time of graduation.

Table 2. Estimated factor price elasticities (IV estimates)

Sample:	Adjusted annual salary	Income earned last year
1. Native doctorates	-.260	-.306
	(.126)	(.141)
2. Foreign doctorates	-.423	-.432
	(.223)	(.235)
3. All doctorates	-.285	-.329
	(.140)	(.158)

Notes: Standard errors are reported in parentheses. The instrument is the log of the number of doctorates awarded to foreign students in a particular field-cohort cell. The regressions have 240 observations in the native and "all doctorates" sample; and 235 observations in the foreign doctorates sample. All regressions are weighted by the total sampling weight for the field-cohort cell. The standard errors are adjusted for heteroscedasticity by using the Huber-White correction.

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