Differential Employment Patterns for Citizens and Non-Citizens in Science and Engineering in the United States: Minting and Competitive Effects

Sharon G. Levin, Grant C. Black, Anne E. Winkler and Paula E. Stephan

(Revised) February 3, 2004

Sharon G. Levin (314-516-5560; slevin@umsl.edu) is Professor of Economics at the University of Missouri-St- Louis (UM-St. Louis) -- 8100 Natural Bridge Road, St. Louis, MO 63121. Grant C. Black is a Visiting Research Assistant Professor of Economics at the Andrew Young School of Policy Studies, Georgia State University (GSU), Atlanta, GA 30303, USA. Anne E. Winkler is Professor of Economics and Public Policy Administration at UM-St. Louis. Paula E. Stephan is Professor of Economics at the Andrew Young School of Policy Studies, GSU. The Alfred P. Sloan Foundation grant 93-5-3 (Levin 9/97), the Andrew Young School of Policy Studies at GSU, and the Graduate School at the University of Missouri-St. Louis (UMSL) supported this research. We thank Bill Amis, Dan Lysy at UMSL, and A.J. Sumell and Avani Raval at GSU for their assistance.

Differential Employment Patterns for Citizens and Non-Citizens in Science and Engineering in the United States: Minting and Competitive Effects

Abstract

We examine the consequences of the heavy inflow of foreign talent for U.S. scientists and engineers over the period 1973-1997 using data from the Survey of Doctorate Recipients. Of particular interest is whether non-citizens trained in the United States have displaced citizens from jobs in science and engineering (S&E). Using a novel adaptation of the shift-share technique, we find that citizen S&E doctorates have fewer jobs in S&E and fewer academic jobs than would be expected for two reasons: the citizen doctoral population has experienced slower growth than the non-citizen doctoral population and citizen S&E doctorates have been displaced. Whether the displacement observed was a voluntary response of citizens to better opportunities elsewhere or an involuntary response indicative of having been pushed out by foreign talent remains to be determined.

Keywords: science policy**,** employment, and displacement

INTRODUCTION

There has been a dramatic increase in the number of doctoral scientists and engineers who have come from abroad to study and work in the United States. Not surprisingly, America's "dependency on foreign scientists" (Stossel, 1999) has been a cause of national concern in recent years. The on-going debate on the number of temporary high-tech (H-1B) visas to be issued each year is clearly one manifestation of this concern.[1] Moreover, the events of September 11, 2001 further heightened the nation's concern and have resulted in a series of proposals to greatly regulate or restrict the number of foreign students from countries the State Department considers sponsors of terrorism (Stephan et al., 2002).

How large has the inflow of foreign talent been? As Table 1 indicates, over the period 1973-1997, the number of U.S.-trained doctoral scientists and engineers living in the United States who were citizens (either native-born or naturalized) at the time their degree was awarded increased almost three-fold; those who were non-citizens increased eight-fold. Thus while fewer than one in ten U.S. doctoral-trained scientists living in the U.S. in the early 1970s were non-citizens at the time their degree was awarded, by 1997 more than one in five were non-citizens.[2] The citizen-non-citizen growth differential has been most striking in the mathematical/computer sciences followed by engineering and earth/environmental sciences (Figure 1). In the first instance, the number of citizens grew almost three-fold while the number of non-citizens grew thirteen-fold; in the latter two, citizen growth was more than two-fold while non-citizen growth was more than nine-fold.

What are the consequences of this heavy inflow of foreign talent for U.S. science? Are immigrant[3] scientists and engineers a source of strength and vitality, contributing disproportionately to U.S. science? Are immigrants a threat in the workplace, lowering real wages, increasing unemployment and ultimately discouraging native talent from pursuing scientific careers? There are no simple answers to these questions. In fact, the immigration debate resembles a "welfare" problem, much like free trade, where the gains to society as a whole have to be weighed against the losses incurred by specific groups (Smith and Edmonston, 1997, p. 146).

What is known thus far?[4] In a study of more than 4,700 scientists and engineers making "exceptional" contributions to science and engineering (S&E) in the United States, Levin and Stephan (1999) address the vitality question, providing strong evidence that the answer is "yes." They find that, with but one exception, the proportion foreign born among exceptional contributors is always significantly higher than expected given the proportion of foreign-born scientists and engineers in the scientific labor force. Thus they conclude that the United States has benefited from the inflow of foreign talent.

Although there is a "widespread perception that 'immigrant hordes' have an adverse effect on the employment opportunities of U.S. citizens" (Borjas, 1994, p. 1667), the question of how immigrants affect employment outcomes in S&E remains to be determined. In terms of jobs, the evidence is sketchy, consisting of anecdotal reports and selected data implying that in some fields immigrants "take" coveted positions away from U.S. citizens in science, especially in academe. For example, the American Mathematical Society reported: "Immigrants won 40% of

the 720 mathematics jobs available last year (1995) . . . and helped boost the unemployment rate into double digits among newly minted math Ph.D.s" (Phillips, 1996, p. A2). The National Research Council recently noted a growing "imbalance between the number of life-science Ph.D.s being produced and the availability of positions that permit them to become independent investigators," a situation exacerbated by the "influx of foreign-citizen Ph.D. candidates together with the increase in foreign-trained Ph.D.s who have sought postdoctoral training in the U.S." (1998, p. 4).[5]

There is some evidence that real wages may have been adversely affected by the heavy inflow of foreign talent. Espenshade et al. (2001) estimate that average annual earnings for scientists and engineers, assuming the composition of the S&E labor force has remained constant, rose by 12.7 percent from 1970 to 1990 and declined by 3.8 percent between 1990 and 1997. They conclude that, "perhaps not coincidentally, this is also the period when the population of foreign-born scientists and engineers grew most rapidly (p. 102)."

Because the Espenshade et al. study included individuals with college degrees or higher, it is not clear what the effects would have been if only doctoral-level scientists and engineers, a much smaller segment of the S&E labor force, had been included. One could hypothesize that because of the greater investment in human capital required at the doctoral level than at the bachelor's level, the increased flow of foreign scientists would more strongly discourage American citizens from pursuing careers in science and engineering at the doctoral level than at the bachelor's level.[6] As a result, the negative salary effects observed by Espenshade et al. would likely have been attenuated by this "unobservable" decrease in the supply of citizens.

Since we cannot control for this supply shift, we focus on what can be measured: the employment outcomes for those who have received doctorates in S&E in the United States. The present study explores the differential employment patterns of U.S. doctoral recipients in S&E over the period 1973-1997. The goal is to gauge the extent to which non-citizen "immigrant" doctorates in S&E may be displacing their citizen-counterparts. To accomplish this, we analyze data from the biennial Survey of Doctorate Recipients (SDR) using a novel application of the shift-share technique.

METHODOLOGY

It is not obvious how to measure displacement short of specifying a multi-equation econometric model that attempts to capture the complexity of the labor market for scientists and engineers. Such an exercise, however, is fraught with difficulty.[7] Rather than abandon the question, we undertake an alternative approach based on a "gedanken" or thought-experiment designed to address, albeit imprecisely, what we believe to be the right question.

> Gedanken experiments are powerful (precisely) because they make explicit the alternatives being compared. The professional imperatives of many disciplines, including economics, lead to a preference for precise answers to the wrong questions over imprecise answers to the right questions (Pollak, 1998, p. 6).

We compare the actual changes in employment for U.S.-citizen (non-citizen) S&E doctorates in different sectors of the economy with a counterfactual -- the changes that would have occurred had their employment in each sector grown at the overall growth rate for all S&E

doctorates together, regardless of citizenship. This approach acknowledges the fact that the growth in U.S.-trained S&E doctorates has been fostered both directly and indirectly by a variety of policies, including changes in immigration laws and the widespread availability of funds supporting graduate and postdoctoral study in science. The counterfactual makes explicit the assumption that in the absence of these policies the United States could have implemented a different set of policies that would have elicited an equal amount of growth from citizens alone. Whether this is the "correct" counterfactual is, of course, subject to debate. But many believe that "the United States should be able, if it so chose as a matter of social policy, to meet its needs for scientists from within its own population, especially by harnessing the talents of under-represented minorities and women" (Bouvier and Martin, 1995, p.3).[8]

We adapt a technique originally developed in the regional science literature, known as shift-share, to implement the thought-experiment. (See, for example, Dunn, 1960; Esteban-Marquillas, 1972; Gordon, Hackett and Mulkey, 1980; Andrikopoulos, Brox, and Carvalho, 1990; Kiel, 1992; Grobar, 1996). Although, several shortcomings of the "classic" shift-share methodology have surfaced over the years, and alternative formulations have been suggested, with careful application it remains a valuable tool for examining changes over time (Loveridge and Selting, 1998). Indeed, in recent years, shift-share has been applied to a broad set of policy issues including disease death rates (Hoppes, 1997), migration (Ishikawa, 1992), occupational sex composition (Smith, 1991), insurance (Halperin and Mabry, 1980), productivity growth (Haynes & Dinc, 1997) and regional crime growth (Blair and Mabry, 1980).

The classic (regional science) application of shift-share decomposes employment growth for industry i in region j, G_{ij}, into three components: (1) a reference group or "overall" growth component (such as employment growth in the United States), $O_{ij;}$ (2) an industrial-mix component, $M_{ij;}$ and (3) a "competitive" component, C_{ij}.

The present study employs a "dynamic" variant of the classic shift-share technique. (The Appendix provides details on why this variant of shift-share was chosen.) Here the reference group is U.S.-S&E doctoral recipients; "regions" refer to the employment sectors of S&E doctorates (academe, industry, etc.); and "industries" refer to the citizenship status of S&E doctorates (citizen or non-citizen). For each citizenship group in each sector, the following identity must hold:

$$(1) \qquad G_{ij} - O_{ij} = M_{ij} + C_{ij}$$

where

$O_{ij} = b_{ij}\, r_{oo}$

$M_{ij} = b_{ij}\, (r_{io} - r_{oo})$ -- now termed the "minting" effect

$C_{ij} = b_{ij}\, (r_{ij} - r_{io})$

and b_{ij} = employment for citizenship group i in sector j during the base period, r_{oo}= the overall growth rate for all S&E doctorates, r_{io} = the growth rate for citizenship group i, and r_{ij} = the growth rate for citizenship group i in sector j.

Thus, we compare the *actual* employment growth of a specific "citizenship" group (citizen or non-citizen) in a specific "sector" (e.g. academe, industry) -- G_{ij} -- with a *predicted* measure of employment growth, as determined by the counterfactual -- O_{ij}. The resulting

differential is divided into two components: the minting effect, $M_{ij,}$, and the competitive effect, C_{ij}. The minting effect is the employment change citizens (non-citizens) experienced in a particular sector due to the differential in growth rates between its doctoral recipients and all doctoral recipients. By definition, it must sum to zero for the two citizenship groups. The competitive effect is the difference between the actual change in employment for each group in each sector and the employment growth that would have occurred had each group grown at its overall growth rate. By analogy, as in the case of international trade, competitive effects across sectors for a particular group (citizen or non-citizen) must sum to zero.

Since C_{ij} captures the differential rate at which jobs in various sectors of the economy have grown for each citizenship group, after accounting for the overall growth in the number of doctoral recipients and the differential minting effects observed, we define displacement as the difference between citizen and non-citizen competitive effects. Thus, for example, suppose we observe that employment growth for citizens in academe is smaller than predicted by the counterfactual. This may have occurred for two reasons: the citizen share of S&E doctorates may have declined (the minting effect); citizens may have experienced slower employment growth in academe than in other sectors such as industry (the competitive effect). To determine whether citizens did less well compared to their non-citizen counterparts in academe -- whether displacement has occurred-- we subtract the non-citizen competitive effect from the citizen competitive effect (both measured in percentage terms to adjust for relative size differences). While the term "displacement" has a negative connotation in the sense that non-citizens may have forced citizens out of desirable positions in academe, causality is not implied. Indeed,

citizens may be more likely than their non-citizen counterparts to opt for better employment opportunities elsewhere in the economy.[9]

Although the decomposition into a minting effect and a competitive effect is based on an accounting identity, from a public policy standpoint these are powerful distinctions to make since the prescriptions for remedy differ. For example, to the extent that the minting effect works against citizens, efforts are needed to help expand their numbers. To the extent that the competitive effect works against citizens relative to their non-citizen counterparts, then policy makers need to consider whether the displacement is of an involuntary or voluntary nature. Have U.S.-citizens been pushed out of positions in S&E by the inflow of foreign talent or have they been pulled out by the lure of better salaries and opportunities elsewhere in the economy?

DATA

Ideally, one would want data tracking the doctoral population of scientists and engineers in the United States by field of training and employment over a number of years. Such data should include all scientists and engineers regardless of birth origin and place of doctoral education. Because such data do not exist, we use the best alternative, the biennial Survey of Doctorate Recipients (SDR). From our perspective, the SDR has two primary weaknesses: (1) it excludes scientists and engineers working in the United States who received their doctoral training abroad and (2) it excludes scientists with medical degrees who do not possess doctoral degrees. The former represents a growing segment of the U.S. scientific labor force, particularly in the life and physical sciences (National Science Foundation, November 1995), while the latter

represents an active group of researchers in the life sciences community. As a result, we have only a partial view of the displacement issue.[10]

We study the degree to which displacement, as we have defined it, has occurred during the period 1973-1997. We define S&E doctorates to include individuals educated in engineering, the mathematical sciences, computer and information sciences, physics and astronomy, chemistry, earth, environmental and marine sciences, agricultural sciences (excluding agricultural economics), medical sciences, and the biological sciences. The sample is limited to those who have met the following criteria: respondent is located in the U.S. at the time of the survey, respondent earned a U.S. doctorate in S&E, and the respondent's age is 65 or less. Observations with missing information on employment status, citizenship or birth year are excluded. Sample observations are weighted to adjust for different initial probabilities of sample selection and subsequent non-response.[11] The database is initially divided into four, six-year year intervals (1973-1979, 1979-1985, 1985-1991, and 1991-1997). Then each component in the decomposition for each time period is summed over the four periods so that a single number captures the "dynamic" nature of employment growth for the entire 1973-1997 period.[12] The analysis is performed for all S&E fields combined as well as by major subfield.

For the period 1973-1991, we designate the sectors of employment as IN S&E, OUT S&E, and OTHER. The sector IN S&E includes individuals employed full-time or with postdoctoral positions in S&E fields; OUT S&E includes individuals employed full-time or with postdoctoral positions not in S&E fields; OTHER refers to "all else" and includes those employed part-time, retired, unemployed, or students pursuing additional degrees. The sector IN

S&E is further disaggregated into employment in ACADEME, INDUSTRY, or OTHER IN S&E in order to focus on what has been occurring within the academic sector (Figure 2). In this framework ACADEME includes those S&E doctorates that were either employed full–time or held a postdoctoral position in a university, college, or Federally Funded Research and Development Center (FFRDC) in a S&E field.[13]

Due to a substantial revision in the SDR in 1993,[14] it is not possible to distinguish in the post-1991 data between the employment sectors IN S&E and OUT of S&E. Instead, we designate the sectors more broadly as ACADEME, NONACADEME and OTHER, without making the "IN" and "OUT" distinction (Figure 2), and perform the decompositions for the period 1973-1991 (to compare with the prior analysis) as well as for the entire period 1973-1997.

DEMONSTRATION OF THE DECOMPOSITION

Table 2 decomposes the employment change for all S&E fields combined for citizens and non-citizens over the period 1973-1991. As Table 2 shows, total employment growth for citizen S&E doctorates in the sector IN S&E was 122,522, which was 28,773 fewer than would have been expected based on the overall growth in S&E doctorates, 151,295 (the overall effect). As discussed earlier, this difference can be decomposed into the minting effect [-16,307] and the competitive effect [-12,466].

The negative minting effect indicates that one reason growth in IN S&E jobs for citizen doctorate-holders was lower than expected was the lower growth rate at which Ph.D.s were being

awarded to citizens compared to non-citizens during the period. Indeed, almost 57% of the employment shortfall for citizen scientists and engineers in the IN S&E sector [-16,307/28,773] is accounted for by the changing composition of the doctoral population. The competitive effect [-12,466] indicates that slightly more than 40% of the shortfall in citizen employment growth in the sector IN S&E is explained by the slower growth of positions held by citizens in S&E relative to the remaining sectors.

For non-citizens the story is considerably different. Altogether, growth in the IN S&E sector was 16,021 [38,227-22,186] greater for them than would have been predicted based on the overall growth in doctorates. But, because of the exceptionally strong minting effect, we would have predicted non-citizen employment growth IN S&E to be even greater than this (an increase of 16,595). The difference is reflected in a competitive effect of –554. Thus, not only did citizens experience a negative competitive effect during this period but non-citizens did as well. A critical point, however, is that the competitive disadvantage for citizen S&E doctorates was not only absolutely larger, but also relatively larger than that faced by non-citizens. For citizen S&E doctorates, the competitive disadvantage was 8.5 percent [12,466/147,277], where the denominator is the total change in citizen S&E doctorates. For non-citizens, the competitive disadvantage was but 1.3 percent [-544/41,564], where the denominator is the total change in non-citizen S&E doctorates. In other words, after controlling for overall growth and minting effects, both non-citizen and citizen shares' of employment in the S&E sector fell, but the effect was considerably larger for citizens.[15] Thus, using the terminology introduced earlier, the

displacement of citizens from the sector IN S&E for all fields combined was 7.2 percent [8.5%-1.3%].

DISPLACEMENT FROM IN S&E AND ACADEME IN S&E, 1973-1991

Table 3 presents the estimates of displacement derived from the decompositions performed for all fields combined and major subfields over the period 1973-1991.[16] Looking first at displacement from the IN S&E sector, we see that both non-citizen and citizen S&E doctorates have generally experienced negative competitive effects. With but three exceptions, all for non-citizens and all quite small, both groups have lost employment share relative to other sectors. For each field, however, the competitive effects in absolute value percentage terms are greater for citizens than non-citizens, leading to substantial displacement. The largest effects have been felt by citizen doctorate-holders in engineering [-9.8%] followed by those in the biological sciences [-7.8%].

Looking next at displacement from the ACADEME IN S&E subsector, we see that both citizens and their non-citizen counterparts have been at a competitive disadvantage. Thus, not only have both groups, more often than not, experienced a scarcity of jobs in the IN S&E sector relative to jobs in the OUT S&E and OTHER sectors, but also both groups have experienced competitive losses in academic appointments within the S&E sector. The competitive effect for citizens, however, is generally more negative. As a result, displacement of citizen doctorates from ACADEME IN S&E for all fields combined is -4.2 percent, but the results vary widely by field. In the mathematical/computer sciences, the displacement is -18.6 percent. By contrast,

citizen doctorates in earth/environmental sciences and chemistry did relatively better than their non-citizen counterparts in the academic sector.[17]

DISPLACEMENT FROM ACADEME, 1973-1997

Table 4 extends the analysis to 1997, the most recent year for which data were available at the time of this study. As noted earlier, due to a substantial revision in the SDR, the analysis is conducted for the broad sectors ACADEME, NONACADEME and OTHER, without making the distinction between being employed in or out of S&E. Because most S&E doctorates with academic appointments are employed in fields of S&E, we expect the findings for the new sector ACADEME over the period 1973-1991 to be similar to those observed in Table 3, where academe was restricted to appointments within the S&E sector. Table 4 (columns 1-3) documents that this is the case.

A key finding of Table 4 is evidence of increased displacement from academe since 1991 for citizen doctorate-holders in all fields except the mathematical/computer sciences where the rate of displacement, although still extremely high, has declined. Even in the earth/environmental sciences and chemistry, where citizens had smaller employment losses in academe compared to the other sectors than did their non-citizen counterparts from 1973-1991, the picture changed during the 1990s. The competitive position of non-citizens dramatically improved in both fields, while that of citizens improved slightly in the earth/environmental sciences and deteriorated further in chemistry, leading to the conclusion that citizens have now been displaced from academe in these two fields in recent years as well.

STATISTICAL SIGNIFICANCE

In this last section we estimate a model of the difference in growth rates (r_{ij} - r_{io}) that determine the competitive effects used to measure displacement from academe. Of particular interest is whether there is a *statistically significant* difference in this measure by citizenship group, and whether the sign and significance of this relationship has changed over time. Such a finding would lend further support to our analysis of displacement presented above. For this estimation, we define DIF to be the difference between $r_{ij,}$ the growth rate for citizenship group i in sector j (academe) and r_{io}, the overall growth rate for citizenship group i. DIF is calculated for both citizen groups, for each of the six major fields (the biosciences, chemistry, earth/environmental sciences, engineering, math/computer sciences, and physics and astronomy) and for the four time periods (T73-79, T79-85, T85-91, and T91-97), yielding a total of 48 observations. Using ordinary least squares, we then regress DIF on the categorical variables for time period, field, citizenship (CIT) and the interaction of time period and citizenship. The results are shown in Equation 2. In this regression, the omitted categories are non-citizens, engineering, and time period T73-79; the t-statistics appear in parentheses below the estimated coefficients.

(2) DIF = -0.476 + 0.382*T79-85 + 0.382*T85-91 + 0.341*T91-97 + 0.125*BIOSCI
(-5.49) (3.97) (3.97) (3.55) (1.50)

+ 0.021*CHEM + 0.083*EARTH/ENV – 0.005*MATH/CS +0.010*PHYS/ASTR
(0.25) (1.00) (-0.06) (0.12)

+ 0.258*CIT - 0.267*CITxT79-85 - 0.234* CITxT85-91 – 0.307*CITxT91-97.
(2.69) (-1.97) (-1.71) (-2.26)

Adjusted R-Square = 0.2848. F-value = 2.56 (significant at 0.02)

Equation 2 shows that the difference in growth rates (DIF) by citizenship status is statistically significant. The positive and statistically significant coefficient on CIT indicates that in the earliest time period, citizens in academe did relatively better than their non-citizen counterparts in terms of employment growth, but the interactions with time show that in the most recent time period, they had lower employment growth in academe relative to the other sectors than did non-citizens. Nonetheless, DIF was negative for all fields, time periods and citizenship groups, on average. In other words, the employment growth rate in the academic sector was smaller than the employment growth rate in other sectors. This finding is consistent with the negative competitive effects in academe shown in Tables 3 and 4.

CONCLUSION

The decompositions performed highlight the fact that citizen S&E doctorates have fewer jobs in S&E and fewer academic jobs because non-citizens displace them and because the citizen doctoral population has experienced slower growth than the non-citizen doctoral population. Indeed, almost 60% of the shortfall in positions held by citizen doctorates within S&E over the period 1973-1991 can be attributed to this differential minting effect. This suggests that if the U.S. were to foster policies designed to increase the number of citizens choosing careers in S&E a sizeable portion of the differential would be remedied. Examples of such policies are increased emphasis on S&E in K-12 school curricula and scholarships targeted to students choosing S&E majors in college. Special efforts could also be directed to increasing the numbers of minorities and, in some fields where they are underrepresented, women, in S&E studies.

The minting effect is not the entire story. The analysis indicates that a significant number of citizen doctorate-holders in S&E have been displaced by non-citizens who have received their doctoral training in the United States. This is not because non-citizens were immune to competitive effects that led to shortfalls in employment in the sectors IN S&E and ACADEME during this period. In fact, as we have seen, citizens and in most cases non-citizens have experienced employment shortfalls in these sectors. But citizens generally had larger employment shortfalls than their non-citizen counterparts and, by our definition, have been displaced. Earth/environmental sciences and chemistry were the only exceptions where the employment shortfalls of citizens were somewhat smaller than that of non-citizens in the (relatively) declining academic sector during the period 1973-1991. For the longer period, the findings are unequivocal: the employment shortfalls experienced by citizen doctorates in academe were larger than those of their non-citizen counterparts.

The analysis cannot determine, however, whether displaced citizens were, on balance, pushed out by the heavy inflow of foreign talent or pulled out by the lure of better opportunities elsewhere in the economy. That is, we do not know whether the displacement that we observe is involuntary or voluntary. One finding, in particular, does suggest that an element of pull may be involved, at least in certain fields. The finding that displacement from academe is greatest for S&E doctorates trained in the mathematical/computer sciences is suggestive of pull, given the high salaries that industry pays in these fields as well as the high salaries some of these individuals can command outside of S&E (National Science Board, 2000, p. 3-19). Notably, the

information technology sector expanded considerably during the period investigated in this study.

Earlier work by Levin and Stephan (1999) and Stephan and Levin (2001) suggested that in the global competition for intellectual capital, the United States has been a winner. There are costs, however, associated with winning. The present study suggests that some of these costs are borne by those U.S. citizens trained in S&E who may have been involuntarily displaced from positions in science by the heavy inflow of foreign talent. Other costs are borne by U.S. citizens who are discouraged from choosing careers in S&E because of the flow of talent from abroad. Furthermore, despite international flows of scientific knowledge, nations that are a source of the brain drain clearly pay a price when their talented scientists and engineers locate permanently in the U.S.

NOTES

[1]See, for example, Finn, 1995; Glanz, 1996; Matloff, 1988; Teitelbaum, 1996; and Phillips, 1996. The H-1B quota was ultimately tripled from 65,000 to 195,000 over the period 2001-2003 and then reset at 65,000 as of October 1, 2003. The H-1B "nonimmigrant" visa may be issued to individuals who seek temporary entry in a specialty occupation as a professional for a maximum of six years. Employers must certify that no qualified U.S. workers are available to fill the positions for which the H-1B visas are sought.

[2] Data are from the Survey of Doctorate Recipients (SDR), a biennial, longitudinal survey of recipients of U.S-earned doctoral degrees in S&E initiated by the National Science Foundation (NSF), Science Resource Statistics, in 1973. Citizenship status is defined at the time the doctorate was received. Non-citizens include permanent and temporary residents as well as individuals that had applied for citizenship at the time the doctorate was received.

[3] Here the term immigrant, as commonly used, refers solely to those not native born.

[4] Few studies (exceptions are Sworny, 1991; North, 1995; Levin and Stephan, 1999; Alarcón, 2000; Espenshade et al., 2001; Stephan and Levin, 2001) have focused on scientists and engineers. Borjas (1994, 1999) and Smith and Edmonston (1997), for example, studied the economic consequences of immigration in general.

[5] U.S.-citizen information technology (IT) workers also claim that the increased flow of H-1B visa holders has adversely affected their careers in IT (Matloff, 1988).

[6] The extent to which immigrant scientists and engineers discourage U.S. citizens from pursuing careers in S&E is not investigated here. Although this so-called "pipeline" question is of immense importance, it is beyond the scope of the present study.

[7] Because of the large number of exogenous factors that affect scientific labor markets and the associated time lags (such as war, recession, changes in the federal budget, alternations in immigration policy, etc.) it is extremely difficult to specify a robust model of supply and demand. A case in point is the difficulty that researchers have in successfully forecasting scientific labor markets (Leslie and Oaxaca 1993; National Research Council, 2000). Moreover, key data are often unavailable. For example, the SDR the best source of information about doctoral scientists and engineers does not provide researchers with detailed information on the firms that employ S&E doctorates.

[8] North (1995) observes that "while the large-scale presence of foreign-born S/Es, particularly at the Ph.D. level, was neither deliberately created by America's universities and corporations nor thrust upon them against their will (p. 145) . . . their presence and growing numbers are soothing the American educational and business establishments, permitting the status quo to continue without the awkward adjustments that would be needed were they not here" (p. 161). At least two adjustments would need to take place if the flow of foreign talent were curtailed: (1) upward adjustments in wages for scientists and engineers so talented U.S. citizens would be lured into productive careers in S&E as opposed to more lucrative careers in other professions such as business, law, and medicine; and (2) industry, academe, and government would have to devote more resources into recruiting U.S. citizens into S&E careers.

[9] Non-citizens may be less disturbed by the relatively low salaries paid in academe than are citizens because the opportunities that non-citizens have in the United States are often so much better than those available to them in their native countries.

[10] Another potential weakness of the SDR is that it only tracks those non-citizen degree recipients who intend to stay in the United States. Since stay rates are fairly high (Finn, 2001), especially in the first two years after graduation, this in and of itself should not pose a serious problem for the analysis.

[11] Because several changes were made to the SDR beginning in 1991 in an attempt to increase its response rate, including computer-assisted telephone interviewing of non-respondents, we use the mail-only weight for better comparability with the pre-1991 data for the interval 1985-1991.

For the interval 1991-1997, we use the population weight that takes into account the changes in survey methodology.

[12] This is discussed in more detail in the Appendix.

[13] INDUSTRY includes those S&E doctorates employed full-time or as post-doctorates in private industry or self-employment in S&E fields, while OTHER IN S&E includes those employed full-time or as post-doctorates in sectors/institutions that are excluded from the previous categories, i.e., primary and secondary educational institutions and all levels of government except FFRDCs.

[14] Specifically, prior to 1993, the employment and educational fields shared the same classification codes. With the 1993 survey, the educational field classifications were reorganized and condensed, and an occupational code replaced the former field codes. Attempts to consistently link the former field codes with the new occupation codes proved unsuccessful and discussions with NSF confirmed the incompatibility. For a discussion of this and related issues concerning the design changes in the SDR, see Mitchell, Moonesinghe, and Cox (1998).

[15] A look at the other sectors in Table 2 reveals another striking outcome for citizen S&E doctorates. Employment in OTHER, which is a catch-all category for those employed part-time or not presently employed, has grown more than expected given the overall growth and minting effects, and this competitive "advantage" has not been shared by non-citizens. Indeed 7,470 more citizens are found in this sector than expected, while there are 107 fewer non-citizens. This suggests that citizens are more likely to either opt for or be forced into part-time work, early retirement, unemployment, or additional schooling relative to their non-citizen counterparts.

[16] Detailed tables of the decompositions by time period, fields of training and alternative sectors are available upon request.

[17] Because the competitive effects across sectors sum to zero for each citizenship group, as noted earlier, there must also be sub-sector additivity. Thus, while both groups fared relatively worse in academe compared with the other sub-sectors (INDUSTRY IN S&E and OTHER IN S&E) within the sector IN S&E, the competitive losses in academe for non-citizens were considerably larger than for citizens, accounting for the lessening in displacement observed. In chemistry and the earth/environmental sciences, the large decline for non-citizens in academic appointments relative to the remaining sub-sectors within the IN S&E sector largely accounts for the lessening displacement of citizens from academe.

Figure 1. Growth in U.S. citizen and non-citizen recipients of doctorates in S&E in the United States, by fie
training, 1973 - 1997. *Source*: Calculated from the SDR.

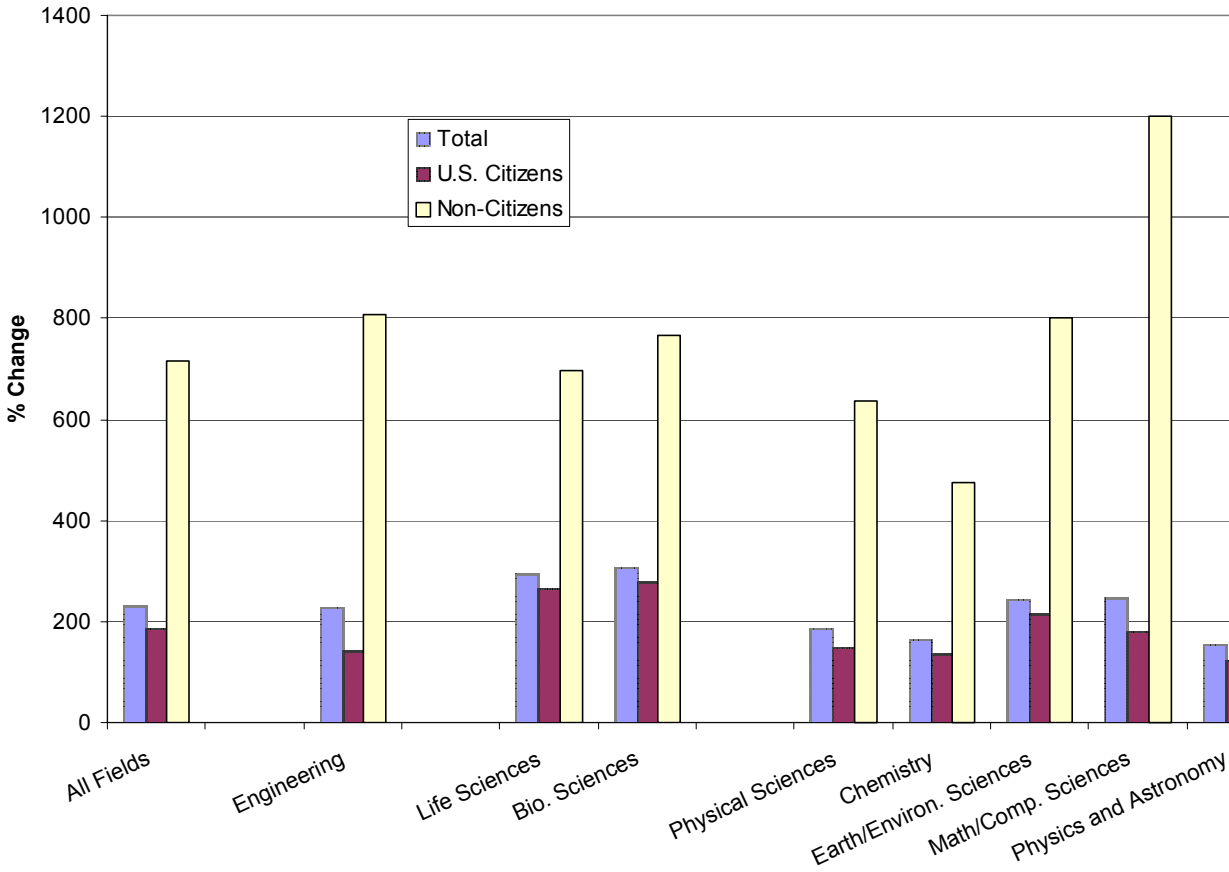
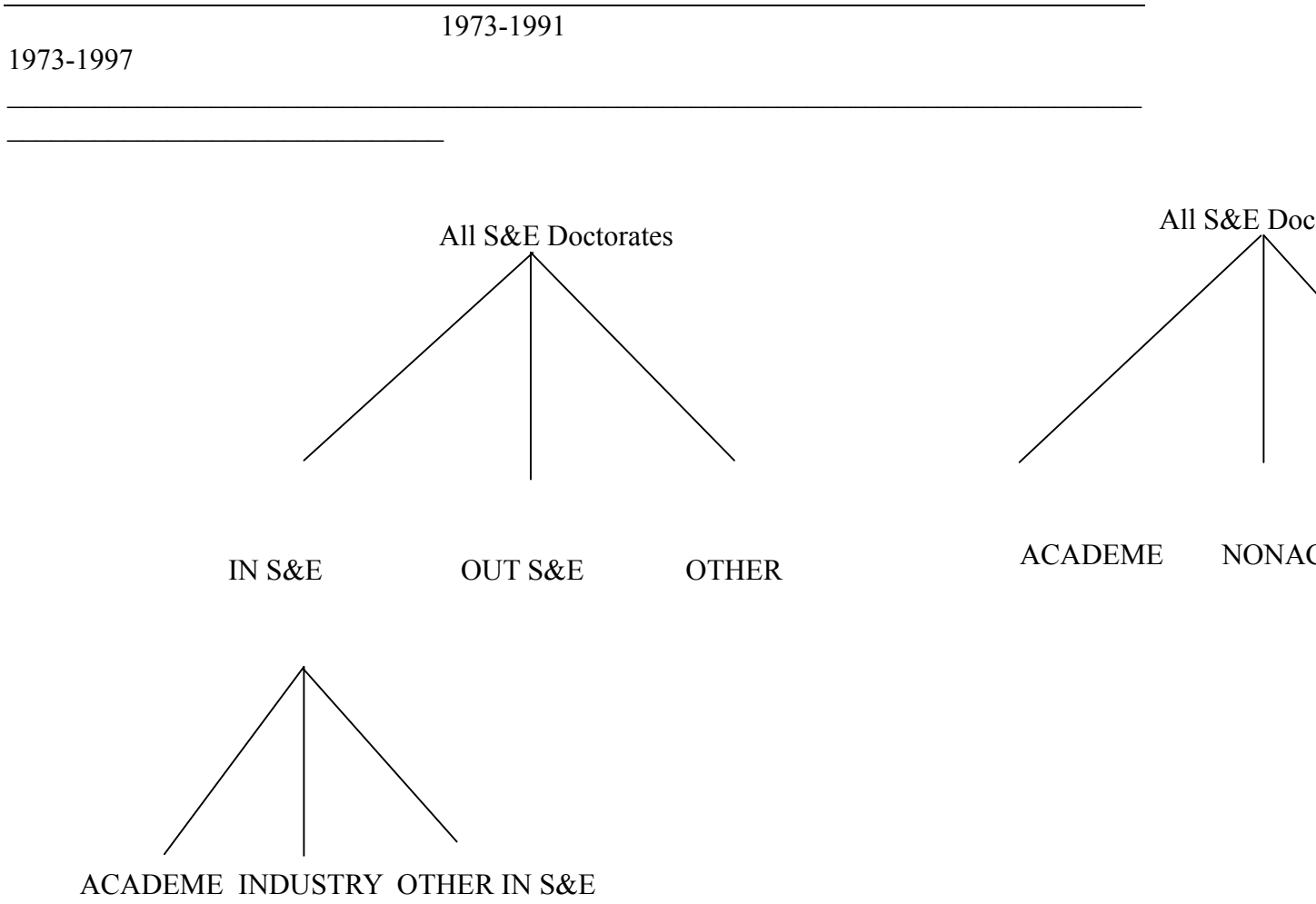


Figure 2. Sectors used in the decompositions, 1973-1991 and 1973-1997.



rowth in science and engineering (S&E) doctorates by field of training and citizenship status at the time the degree was earned
ed States.

	ALL S&E Doctorates			Citizen Doctorates			Non-Citizen Doct	
	1973	1997	Growth	1973	1997	Growth	1973	1997
Combined	110,914	367,617	231.4%	101,506	290,980	186.7%	9,408	76,637
g	26,649	87,585	228.7%	23,220	56,426	143.0%	3,429	31,159
ces	36,050	142,330	294.8%	33,668	123,386	266.5%	2,382	18,944
cal Sciences	25,951	105,842	307.9%	24,342	91,882	277.5%	1,609	13,960
ciences	48,215	137,702	185.6%	44,618	111,168	149.2%	3,597	26,534
nvironmental	4,621	15,916	244.4%	4,397	13,896	216.0%	224	2,020
try	20,567	54,327	164.1%	18,936	44,968	137.5%	1,631	9,359
omputer Sciences	9,300	32,376	248.1%	8,680	24,305	180.0%	620	8,071
and Astronomy	13,727	35,083	155.6%	12,605	27,998	122.1%	1,122	7,085

E includes engineering, the life sciences, the earth/environmental sciences, chemistry, the mathematical and computer
nd physics and astronomy. Data are from the SDR.

Table 2. Decomposition of the growth in science and engineering doctorates, all fields combined, 1973-1991.

	Citizens by sector			
	IN S&E	OUT S&E	OTHER	ALL
Total change	122,522	11,182	13,573	147,277
Overall effect[a]	151,295	6,914	6,842	165,051
Minting effect[b]	-16,307	-727	-740	-17,774
Competitive effect[c]	-12,466	4,995	7,470	0

	Non-Citizens by sector			
	IN S&E	OUT S&E	OTHER	ALL
Total change	38,227	1,755	1,582	41,564
Overall effect[a]	22,186	675	930	23,790
Minting effect[b]	16,595	419	759	17,774
Competitive effect[c]	-554	661	107	0

Notes: [a]The growth in employment that citizens (non-citizens) in each sector would have experienced had their numbers grown at the same rate as the overall number of S&E doctorates. [b]The employment change due to the differential rate at which citizens and non-citizens earned doctorates. [c]The employment change due to the differential rate at which employment in each sector grew relative to the other sectors.

Table 3. Measuring displacement from full-time employment in science and engineering fields (IN S&E) and fr in science and engineering fields (ACADEME IN S&E), 1973-1991.

	IN S&E			ACADE
	Competitive Effects		Displacement[a]	Competitive Effe
	Citizens	Non-Citizens		Citizens Non-C
All Fields Combined	-8.5%	-1.3%	-7.1%	-12.1%
Engineering	-10.9%	-1.1%	-9.8%	-10.6%

Life Sciences	-8.0%	-2.4%	-5.6%	-13.2%
Biological Sciences	-6.5%	1.3%	-7.8%	-14.4%
Physical Sciences	-7.7%	-1.1%	-6.6%	-15.9%
Earth/Environmental Sciences	-12.9%	-12.4%	-0.5%	-10.0%
Chemistry	-7.4%	0.2%	-7.5%	-13.2%
Math/Computer Sciences	-7.1%	-0.4%	-6.7%	-26.4%
Physics and Astronomy	-5.8%	0.6%	-6.5%	-15.5%

Notes: [a]Calculated as the competitive effect for citizens (%) less the competitive effect for non-citizens (%). The
rounding error. A negative competitive effect indicates that jobs in this sector for this group fell at the expense o
remaining sectors, after accounting for the overall growth and minting effects. For example, -8.5% (for citizens,
is calculated as -12,466/122,522 from Table 2. For details, see text.

Measuring displacement from ACADEME, 1973-1991 and 1973-1997.

	1973-1991			1973-1997		
	Competitive Effects		Displacement[a]	Competitive Effects		Displacem
	Citizens	Non-Citizens		Citizens	Non-Citizens	
Combined	-11.5%	-7.5%	-4.0%	-15.0%	-8.7%	-6.3
ng	-10.8%	-4.7%	-6.0%	-17.2%	-10.4%	-6.8
nces	-12.6%	-9.3%	-3.2%	-12.1%	-1.6%	-10.4
ical Sciences	-14.2%	-7.8%	-6.5%	-12.3%	0.5%	-12.8
Sciences	-14.9%	-6.2%	-8.7%	-21.3%	-10.6%	-10.7
Environmental Sciences	-8.5%	-18.3%	9.8%	-6.5%	-2.3%	-4.2
stry	-13.7%	-19.5%	5.8%	-17.1%	-9.4%	-7.7
Computer Sciences	-23.0%	-7.1%	-15.9%	-30.8%	-16.6%	-14.3
s and Astronomy	-14.2%	-5.3%	-8.9%	-31.5%	-22.2%	-9.4

alculated as the competitive effect for citizens (%) less the competitive effect for non-citizens (%). The figure reported is subject
error. A negative competitive effect indicates that jobs in this sector for this group fell at the expense of offsetting increases in th
g sectors, after accounting for the overall growth and minting effects. For details see text.

APPENDIX

Shift-Share Methodology

As discussed in the text, this study employs a "classic" version of the shift-share technique enhanced by a modification first suggested by Barff and Knight (1988) called "dynamic" shift-share. In this Appendix we discuss this version of shift-share in the context of the broader shift-share literature (for an excellent review, see Loveridge and Selting (1988)).

Over the years, researchers have offered several critiques and modifications of the classic shift-share technique. For example, Esteban-Marquillas (1972), among others, has pointed to the lack of independence between the industry-mix and competitive effects. This has led to the development of various homothetic models of shift-share. There is not consensus, however, that using homothetic employment rather than actual employment in computing the competitive effect is actually beneficial. Keil (1992), for example, points to the "great danger" (p. 482) of using this approach when the regional industrial structure gravely differs from the national industrial structure. And, Loveridge and Selting find that the homethetic models "clearly do not solve the very problem they purport to eliminate (p. 54.)" In our preliminary work, we found that the classical competitive effect and the homothetic competitive effect were very similar and thus opted for the simpler classical technique.

In another vein, Richardson (1978), observed that classic shift-share focuses on employment change between two points in time, but ignores events between these time points. This is particularly problematic if a long time horizon is considered and/or there is a substantial change in employment, particularly in the industrial mix of employment. As a solution, Barff

and Knight (1988) advocated "dynamic" shift-share analysis, in which the decomposition is done on an annual basis and then the annual figures for each of the three shift-share components are summed. In the present study, we use a simpler dynamic variant in which the decomposition is done for each six-year interval and these interval changes are then summed.

Several other concerns about classic shift-share have also been voiced. Among these is the concern that the shift-share results may be sensitive to the degree of industrial disaggregation. In our work, since there are just two well-defined industries – citizen and non-citizen S&E doctorates – the appropriate level of disaggregation is not an issue. Furthermore, there has also been some discussion that the results may differ according to the degree of regional disaggregation. While this is generally true, as noted by Dunn (1980), such differences may usefully inform the analysis, rather than detract from it. This we believe is the case here, where we gain a greater understanding of what has happened in S&E by sub-dividing this "region" into Academe, Industry, and Other.

Finally, a general concern with all shift-share work is that it is lacking theoretical substance. While Loverdige and Selting (1998) point out that there has been only limited success in building a theoretical basis for shift-share using neoclassical microeconomics and location theory, nevertheless they conclude that

> The continuing use of shift-share seems to suggest its theoretical limitations may be outweighed by the information it supplies about regional economies. Given the growth in use of purely empirical models in other areas of economics, this aspect of shift-share is perhaps less of an issue than it appeared to be twenty years ago (p. 40).

REFERENCES

Alarcón, Rafael. (2000). Skilled immigrants and cerebreros: Foreign-born engineers and scientists in the high-technology industry of Silicon Valley. Chapter 12 in Immigration Research for a New Century: Multidisciplinary Perspectives, edited by Nancy Foner, Rubén G. Rumbaut and Steven J. Gold. New York: Russell Sage, 301-321.

Andrikopoulos, A., Brox, J., & Carvalho E. (1990). Shift-share analysis and the potential for predicting regional growth patterns: Some evidence for the region of Quebec, Canada. Growth and Change, 21(1), 1-10.

Barff, R.A. & Knight, P.L. III. (1988). Dynamic shift-share analysis. Growth and Change, 19(2), 1-10.

Blair, D. & Mabry, R. (1980). Regional crime growth. Growth and Change, 11(1), 48-51.

Borjas, G. (1994). The economics of immigration. Journal of Economic Literature, 32(4), 1667-1717.

Borjas, G. (1999). Heaven's door. Princeton: Princeton University Press.

Bouvier, L. & Martin, J. (1995). Foreign-born scientists, engineers and mathematicians in the United States. Washington, DC: Center for Immigration Studies.

Dunn, E. S. Jr. (1960). A statistical and analytical technique for regional analysis. Papers and Proceedings of the Regional Science Association, 6, 98-112.

_____. (1980). The development of the U.S. urban system, volume I/ concepts, structures, regional shifts. Baltimore, MD: Johns Hopkins University Press for Resources for the Future.

Espenshade, Thomas J., Usdansky, Margaret L. & Chung, Chang Y. (2001). Employment and earnings of foreign-born scientists and engineers. Population Research and Policy Review, 20, 81-105.

Esteban-Marquillas, J. M. (1972). A reinterpretation of shift-share analysis. Regional and Urban Economics, 2, 249-255.

Finn, M. (2001). Stay rates of foreign doctorate recipients from U.S. Universities, 1999. Document prepared for the Division of Science Resources Studies of the National Science Foundation. (http://www.orau.gov/orise/pubs/).

Finn, R. (1995). Scientists' heated debate on immigration mirrors issues argued through out the U.S. The Scientist, 9(23), 1, 8-9.

Glanz, J. (1996). Proposals that would limit visas strike fear at universities. Science, 272, 190-191.

Gordon, J., Hackett, W. & Mulkey D. (1980). Using the shift-share technique in economies with widely varying sectoral growth rates: Observations and a suggested model modification. The Review of Regional Studies, 10(1), 57-67.

Grobar, L. (1996). Comparing the New England and Southern regional recessions. Contemporary Economic Policy, 14, 71-84.

Halperin, S. & Mabry, R. (1984). Property and casualty insurance lines comparison: A shift share analysis. The Journal of Risk and Insurance, 51(3), 524-535.

Haynes, K. & Dinc, M. (1997). Productivity change in manufacturing re ions: A multifactor/shift-share approach. Growth and Change, 28(2), 201-211.

Hoppes, R. (1997). Shift-share analysis for regional health care policy. Journal of Regional Analysis and Policy, 27(1), 35-45.

Ishikawa, Y. (1992). The 1970s migration turnaround in Japan revisited: A shift-share approach. Papers in Regional Science, 71(2), 153-173.

Keil, S. (1992). On the value of hometheticity in the shift-share framework. Growth and Change, 23(4), 469-493.

Leslie, L. R. & Oaxaca, R. L. (1993). Scientist and engineer supply and demand. In Higher education: handbook of theory and research. Vol. IX, edited by John C. Smart. NY: Agathon Press, 154-211.

Levin, S. & Stephan, P. (1999). Are the Foreign Born a Source of Strength for U.S. Science? Science 285, 1213-1214.

Loveridge, Scott & Selting, Anne C. (1998). A review and comparison of shift-share identities. International Regional Science Review, 21(1): 37-58.

Matloff, N. (1988). Debunking the myth of a desperate software labor shortage. Testimony to the U.S. House Judiciary Subcommittee on Immigration, Updated April 8th.

Mitchell, S., Moonesinghe, R. & Cox, B. (1998). Using the Survey of Doctorate Recipients in time-series analysis: 1989-1995. Task 2 Report to the National Science Foundation, Washington, DC: Mathematica Policy Research, Inc., June 30th.

National Research Council. (1998). Trends in the early careers of life scientists. Washington, DC: National Academy Press.

_____. (2000). Forecasting Demand And Supply of Doctoral Scientists and Engineers: Report of a Workshop on Methodology. Washington DC: National Academy Press.

National Science Board. (2000). Science and engineering indicators -2000. Arlington, VA: National Science Foundation.

National Science Foundation. (1995). Data brief. November 14th.

North, D. (1995). Soothing the establishment: The impact of foreign-born scientists and engineers on America . Lanham, MD: University Press of America.

Phillips, M. (1996). Math Ph.D.s add to anti-foreigner wave. Wall Street Journal, September 4th, A2.

Pollak, R. (1998). Notes on how economists think. Paper presented at the Joint Center for Poverty Research Conference on Welfare Family Process and Child Development, May 7-8th.

Smith, J. & Edmonston, B. (Eds.) (1997). The New Americans: Economic, demographic, and economic impacts of immigration. Washington, DC: National Academy Press.

Smith, S. (1991). Shift share analysis of change in occupational sex composition. Social Science Research, 20, 437-451.

Stephan, P. (1996). The economics of science. Journal of Economic Literature, 34, 1199-1235

Stephan, P. & Levin, S. (2001). Exceptional contributions to US science by the foreign-born and foreign-educated. Population Research and Policy Review, 20, 59-79.

Stephan, P., Black, G., Adams, J. & Levin, S. (2002). Survey of foreign recipients of U.S. Ph.D.s. Science, 295, 2211-2212.

Stossel, S. (1999). Uncontrolled experiment; America's dependency on foreign scientists. The New Republic, March 29th, 17-22.

Survey of Doctorate Recipients. (1973-1997). Washington, DC: National Research Council.

Svorny, S. (1991). Consumer gains from physician immigration to the U.S.: 1966-1971. Applied Economics, 23(2), 331-337.

Teitelbaum, M. (1996). Too many engineers, too few jobs. New York Times, March 19th, A23.