Highly-Educated Immigrants and Native Occupational Choice*

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Abstract

Economic debate about the consequences of immigration in the US has largely focused on how influxes of foreign-born labor with little educational attainment have affected similarly-educated native-born workers. Fewer studies analyze the effect of immigration within the market for highly-educated labor. We use *O*NET* data on job characteristics to assess whether native-born workers with graduate degrees respond to an increased presence of highly-educated foreign-born workers by choosing new occupations with different skill content. We find that highly-educated native and foreign-born workers are imperfect substitutes. Immigrants with graduate degrees specialize in occupations demanding quantitative and analytical skills, whereas their native-born counterparts specialize in occupations requiring interactive and communication skills. When the foreign-born proportion of highly-educated employment within an occupation rises, native employees with graduate degrees choose new occupations with less analytical and more communicative content.

Key Words: Immigration, Occupational Choice, Highly-Educated Workers, Communication Skills, Mathematical Skills.

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1 Introduction

Between 1950 and 2007, the foreign-born share of employees in the US with a masters, professional, or doctorate degree rose from 5.9% to 18.1%. Figure 1 shows that this trend is quite similar to that of the share of immigrants among workers with low education. It is somewhat surprising, therefore, that economic analysis has paid comparatively little attention to the relationship between foreign and native labor within the market for these highly-educated workers.

This paper adds to the literature by exploring the substitutability of highly-educated native and immigrant workers. Borjas (2003, 2006) and Borjas and Katz (2005) argue that workers with identical educational attainment (and experience) are perfectly substitutable. In contrast, papers focusing on less-educated workers by Manacorda et. al. (2006), Ottaviano and Peri (2008), and Peri and Sparber (2009) have argued that native and immigrant workers possess somewhat differentiated skills. This imperfect substitutability is important because it allows natives to specialize in occupations requiring tasks in which they have a comparative advantage, thereby mitigating possible wage losses from immigration. Although we do not estimate wage consequences of immigration in this paper, it is reasonable to assume that such effects for highly-educated labor will also depend upon the substitutability of foreign and native-born workers. Thus, we document the characteristics of occupations adopted by highly-educated native and foreign-born labor, and then analyze how native-born employees with graduate degrees change their occupations (and their associated skill content) in response to increases in the proportion of similarly-educated foreign labor.

We begin by assuming that highly-educated native and foreign workers provide two general skills in their occupations. First, they are responsible for performing interactive (or communication) tasks such as talking with supervisors, subordinates, or customers. Second, they also supply quantitative (or analytical) tasks such as performing advanced mathematical analysis, designing new products using the principles of physics, and diagnosing ailments or diseases. Given that highly-educated immigrants, relative to native-born workers, will have imperfect language skills, knowledge of local networks, and familiarity with social norms, natives should have a comparative advantage in supplying communication skills, while highly-educated immigrants will have a comparative advantage in performing quantitative and analytical tasks.

To assess the potential for specialization among highly-educated native and foreign-born workers, we merge data on occupational skills and abilities from the National Center for *O*NET* Development with individual-level Current Population Survey (CPS) data from 2003-2008. Together, this allows us to measure the skills that native-born workers with graduate degrees used in both their current occupation and the occupation they held in the previous year.

We then use the 1990 Census and 2002-2007 American Community Surveys (ACS) to construct the foreign-born share of highly-educated employment for each year and occupation. After merging this information with the individual-level CPS and skill data, we analyze whether the change in occupational skills used by a highly-educated native employee over the course of a year is related to the change, since 1990, in the share of highly-educated immigrants in the occupation he/she held in the previous year.[1]

We find that native and foreign-born workers with graduate degrees are imperfect substitutes. Immigrants specialize in occupations demanding quantitative and analytical skills, while natives specialize in occupations requiring interactive and communication skills. We then perform a series of regressions to assess the native response to migration. Our basic specification finds that individual native workers move to occupations with higher communication content in response to an increase in the share of immigrants within their original occupation. We interpret the effects as causal – omitted variables and reverse causality concerns are abated since our regressions control for an array of individual and occupation characteristics, and our explanatory variable of interest measures the lagged increase of immigrants. Moreover, we show that the response in skill specialization is larger for native workers than for immigrants and hence unlikely to originate from common occupation-specific demand shifts. Nevertheless, as the variation of immigrants across occupations is not genuinely random (or exogenous), the causal interpretation of the results should be taken with some caution.

For completeness, we close the empirical exercise by also testing whether immigration is related to changes in native employment status. We find little to no evidence that highly-educated native employees in occupations with large increases in the proportion of similarly-educated immigrants are more likely to become unemployed or leave the labor force.

[1] CPS, Census, and ACS data come from IPUMS (Ruggles et al. (2005)).

2 Motivation

Many developed countries actively work to attract highly-educated immigrants.[2] It is easy to imagine that such workers generate aggregate gains. Endogenous growth literature and its emphasis on human capital spillovers and scale effects in promoting technological development suggest high-education immigration could bolster total factor productivity, GDP per capita, and wages.[3] A diversity of immigrant perspectives, experiences, and networks could spur idea generation and trade.[4] Borjas (1999) argues that educated immigrants can improve fiscal conditions by increasing tax revenues without burdening social services. Such immigrants might also reduce short-run wage gaps across education levels by increasing the relative supply of highly productive workers.

Despite possible aggregate benefits, recent US policy changes have attempted to reduce the number of college-educated foreign-born workers entering the country. In 2004, the annual cap on the number of new H-1B visas (which permit college-educated foreign-nationals to work in the US for three years, renewable to six) was lowered from 195,000 to 65,000. Similarly, the American Recovery and Reinvestment Act of 2009 included a provision making it more difficult for firms receiving TARP (Troubled Asset Recovery Program) funds from hiring H-1B workers as part of the bill's overall economic stimulus package. Though most foreign-born workers with advanced degrees are exempt from these regulations, it is conceivable that future legislation will attempt to limit their entry in the US labor market as well.[5]

Presumably, policy-makers are concerned that highly-educated immigrants compete with similarly-educated natives. Comparatively few economic studies have analyzed the effect of immigration within the market for workers with graduate degrees, however. One area of exception is in documenting differences in skills between native and foreign-born workers. Foreigners exhibit a greater proclivity for quantitative skills, with differences emerging at an early age. Chellaraj, Maskus, and Mattoo (2005) cite Trends in International Mathematics and Science Study (TIMMS)[6] evidence that "among the major developed countries and the newly

[2]See Kapur and McHale (2005) and Chiswick and Taengnoi (2007).

[3]See Romer (1986), Lucas (1988), Romer (1990), Ciccone and Hall (1996), and Hunt and Gauthier-Loiselle (2009).

[4]See Gould (1994), Rauch and Trindade (2002), Ottaviano and Peri (2005, 2006a), and Sparber (2008, 2009).

[5]The US Department of Labor provides detailed H-1B information at http://www.dol.gov/compliance/guide/h1b.htm. Also see Thibodeau and Vijayan (2009).

[6]See http://timss.bc.edu/timss2003.html.

industrialized countries, the United States ranks near the bottom in mathematics and science achievement among eighth graders." At the graduate school level, Black and Stephan (2007) note that foreign students accounted for 60% of the growth in science and engineering (S&E) Ph.D. production in the United States and a third of S&E degrees are awarded to students on temporary visas between 1981 and 1999.[7]

Skill differences continue to be apparent after students enter the workforce. Chiswick and Taengnoi (2007) find, not surprisingly, that immigrants with limited English proficiency or whose mother tongue is linguistically distant from English work in occupations in which English communication skills are not important. Hunt and Gauthier-Loiselle (2009) argue that highly-educated immigrants specialize in science and engineering occupations and then contribute proportionally more than natives to patented innovations.

Like most of the related literature, our paper focuses on native/immigrant imperfect substitutability within broad education groups (in our case, among those with a graduate degree). Some, however, have gone farther by noting differences within narrowly-defined fields. Stephan and Levin (2007) show that science and engineering graduates making exceptional contributions to US S&E in the recent past were disproportionately foreign-born. Levin et. al. (2004) compare actual employment changes for native and immigrant S&E doctorates in occupational sectors with changes that would have occurred if employment in each sector had grown at the same rate of all S&E doctorates. They find that the share of native S&E doctorates employed in non-S&E positions (7.6%) was greater than the corresponding share among immigrants (4.2%). Moreover, the share of native Ph.D.s in non-S&E jobs after accounting for sectorial composition predicted by trends in native and immigrant S&E Ph.D. attainment (3.4%) is also higher than the figure associated with immigrants (1.6%).

One could easily argue that policy and other selection issues might influence the type and skill-set of the highly-educated immigrants who arrive in the US.[8] However, it is the existence of differences themselves that can imply imperfect substitutability between native and foreign-born workers. Past evidence suggests that a comparative advantage in the US labor market

[7] Also see Stephan et al. (2002).

[8] Papers studying immigrant selection issues include Bhagwati and Rao (1999), which claims that "the preponderance of foreign students get into technical and scientific programs because they (chiefly Asians) happen to be 'good at' mathematics and far less so at 'verbal' skills." Similarly, Chiswick (1999) explains the attraction of foreign students to US science by arguing that "science involves internationally transferable skills in contrast to the tendency for the humanities to be much more country specific."

exists such that highly-educated natives choose communication-intensive jobs, while foreign-born workers are attracted to math, science, and engineering occupations. We add further evidence by documenting similar behavior in Section 3.

After addressing imperfect substitutability and comparative advantage, the relevant question for our analysis is then how natives with graduate degrees respond to new arrivals of similarly-educated immigrants. Literature in this area is less complete. Levin et. al. (2004), for example, explicitly state that the occupational effects they term "displacement effects" are not causal, while Stephan and Levin (2007) note that "the question of how immigrants affect employment outcomes in S&E has yet to be investigated."

George Borjas has done the most work trying to identify the consequences of highly-educated immigration. Borjas (2007) notes that universities only offer a fixed number of seats in the short-run. Thus, a rise in foreign enrollment can potentially push natives out of universities or into lesser-quality schools. Though he does not find a crowd-out effect for natives in general, he does find evidence supporting the crowding-out of native white men. Interestingly, Groen and Rizzo (2007) provide evidence to suggest that such natives may be moving toward educational programs in accordance with comparative advantage. They find that although the share of Ph.D.s granted to US citizens in the sciences declined between 1963 and 2000, the propensity for native students to pursue an MBA increased markedly.

In terms of employment effects, Borjas (1999) argues that immigration policies favouring highly-educated immigrants are likely to be detrimental to highly-educated native workers (though probably beneficial to the US economy as a whole). Borjas (2003) finds that the immigration influx in the 1980s and 1990s caused wages to fall by 4.9% for college graduates. Similarly, Borjas (2006) argues that a 10% immigration-induced increase in the supply of S&E doctorates causes the wages paid to native S&E doctorates to decline by 3-4%.[9] Half of this wage effect can be explained by the displacement of natives into low-paying post-doc positions in the sciences. He also argues that native and foreign-born doctorates are perfectly substitutable within "cohort by scientific field of study" groups. This is both because a science doctorate is a "highly specialized endeavor, requiring the investment of a great deal of time and effort, and the training is very specific," but also because he finds that native and foreign-born wages exhibit no statistically distinctive response to immigration. This result is echoed by Bound and

[9] Borjas (2005) provides a similar result in a more condensed version of Borjas (2006).

Turner (2006), who argue that their "initial evidence on the relative wages of foreign and U.S. born Ph.D.s indicates near perfect substitutability."

We believe that the reality may be more nuanced, especially if highly-educated native and foreign workers work in differing occupations and employ differing skills. In the empirical analysis of Section 4, we more formally assess how employed native-born workers with graduate degrees respond to immigration through their choice of occupation and the skills those occupations require.

3 Data and Methodology

To ascertain how the occupational skills used by native-born workers change in response to immigration, we must develop a dataset that has individual-level demographic information, measures of occupational skill content, and foreign-born employment data across time. We achieve this by merging *O*NET* occupational characteristic information, individual-level CPS data from 2003-2008, and aggregated occupational employment data from the 1990 Census and 2002-2007 ACS surveys.

In 1998, the National Center for O*NET Development's *O*NET* database replaced the US Department of Labor's *Dictionary of Occupational Titles* (*DOT*) as the primary source of information about US job characteristics. Since then, *O*NET* has gathered information on hundreds of variables for more than 800 SOC-defined occupations. Prior to 2003, *O*NET* acquired its data from surveys administered to job analysts and experts. Beginning in 2003, however, information has come from job incumbent surveys. The database is updated twice a year, and its active "production database" is available for download.[10]

*O*NET* categorizes its variables into six distinct surveys, though we choose to select variables only from two – the Abilities and Activities surveys. These surveys ask respondents to evaluate the importance of 52 particular abilities (skills) and 41 activities (tasks) required by his/her current job on a scale of 1 to 5. In principle, this would allow us to assess workers' comparative advantage for 8,556 skill pairs. Instead, we are motivated by past literature and common practice to focus on the seven interactive (or communication) and five quantitative (or analytical) skills shown in Table 1. Interactive skills include the ability to comprehend and

[10] We use the *O*NET* 11.0 database, available at http://www.onetcenter.org/database.html.

express both oral and written material. They also include the importance of communicating with coworkers and people outside a person's workplace. Strictly speaking, quantitative and analytical skills are not synonymous. Lawyers, for example, require very little mathematical acumen but a high degree of inductive reasoning ability. Nonetheless, we treat quantitative and analytical skills as synonyms so that the terms represent the importance of performing mathematical functions, analysis of data and information, and deductive and inductive reasoning tasks.[11]

The National Center for *O*NET* Development uses its surveys to assign an average level of importance for these skills to each SOC occupation. It also provides an SOC-to-Census 2000 Occupation Code crosswalk. This allows us to merge *O*NET* job characteristic information with individuals in the 2000 Census who hold those occupations. The somewhat arbitrary scale of measurement of the original *O*NET* data motivates us to re-scale the variables and assign percentile values for each job characteristic based upon wage earning employees between 18 and 65 years of age in the 1% sample of the 2000 Census.[12] Unfortunately, Census occupation codes are not constant throughout the time period of our analysis. To compensate, we then calculate occupation-specific skill values for the time-consistent IPUMS variable *occ1990* by taking the weighted average of skill values among the year-2000 occupations that comprise each *occ1990* code.

In their analysis of the effects of immigration on workers with little educational attainment, Peri and Sparber (2009) simply aggregate re-scaled *O*NET* values to the state level. They then use variation across states over a long time horizon (1960-2000) to identify the effects of immigration on the skills used by less-educated natives. The methodology is appropriate since evidence suggests that markets for less-educated labor are local, and native-born workers without college experience do not respond to immigration by moving across state borders.[13] Regressions employing cross-state variation in immigration rates and skill use may be inappro-

[11] It is important to note that highly-educated workers use these skills extensively. Many of the omitted skill measures focus on manual tasks (which highly-educated workers do not often use) or on skills in which the comparative advantage is not immediately obvious (such as creativity or organizational ability). Exceptions to this rule exist, as Table 3 will make apparent, but it would be simple to incorporate additional skills into the analysis.

[12] Thus, for example, a Mathematical Reasoning ability value of 0.91 for Economists imply that Economists used more of these skills than 91% of the workforce in 2000.

[13] See Card (2007), Card and Lewis (2007), Cortes (2008), Ottaviano and Peri (2007), or Peri and Sparber (2010).

priate, however, if labor markets are national in scope.[14]

It would be controversial to impose the assumption that highly-educated natives are unresponsive to immigration, so we choose a methodological alternative to Peri and Sparber (2009) that is robust to labor mobility conditions by instead analyzing the effect of immigration on employed individuals at the national level in a shorter and more recent time period. Specifically, we assess how the change in the foreign-born share of workers with a graduate degree in an occupation since 1990 subsequently affects the yearly change in occupational skills used by highly-educated native employees.[15] Though this identification strategy avoids potential problems with cross-region variation, it will fail to account for occupational changes that take longer to develop. Such delays in response could be caused by the need for further educational training to enter new highly-specialized fields (as discussed in Borjas (2006)), as well as rigorous training to meet occupational licensing requirements.[16] We therefore believe that our results will represent a lower-bound estimate of the native response to immigration.

The individuals in our analysis come from the CPS, which records both a respondent's occupation in the year of and prior to the survey. We focus on the post-9/11 period and merge *O*NET* occupational skill data to CPS individuals from 2003-2008.[17] In principle, immigration figures could also be constructed from CPS data. However, these aggregated values have a large potential for measurement error, since CPS surveys are relatively small in scale. Instead, we use the much larger 1990 Census and 2002-2007 ACS datasets. The foreign-born share of highly-educated employment in a 2003-2008 CPS individual's prior-year occupation is simply the share calculated from current-year 2002-2007 ACS occupation data. Changes an occupation's foreign-

[14] See Borjas (2006) for evidence.

[15] We use longer differences (between 1990 and year t) in measuring the inflow of foreign-born to allow for slow responses and reduce noise and measurement error in the explanatory variable. At the same time this implies that the cross-sectional variation identifies most of the effect.

[16] Ball, Dube, and Sorensen (2010) note that licensed occupations have a high degree of interactive content. Moreover, undocumented immigrants find it particularly costly to acquire a license, as evidenced by the fact that Mexican-born workers are less likely to work in licensed professions than natives are, and this difference is only marginally significant for those with post-graduate degrees. Bratsberg and Raaum (2010) use licensing requirements as a source of exogenous variation in immigration rates of less-educated workers across industries and argue that such requirements inhibit migrant mobility more than native mobility. If also true among highly-educated workers, licensing requirements could be a confounding factor in our analysis.

[17] Ruggles et al. (2005) provides CPS data through IPUMS. We base the current-year occupation merge on the variable *occ1990*. The variable *occly* measures an individual's occupation in the prior-year. Using the IPUMS-provided occupation-to-*occ1990* crosswalk, we are able to construct an analogous *occ90ly* variable that provides time-consistent codes for an indivual's occupation in the prior year. We base the prior-year occupation merge on this variable.

born share simply measure the difference in this proportion between the 1990 Census and the relevant ACS year.[18]

Before turning to the empirical analysis, a few descriptive statistics, tables, and charts will be helpful. Over the survey period, 6.2% of the 44,018 highly-educated native individuals in the sample changed their occupation in the course of a year. Table 2 lists each occupation with more than 100 CPS observations, the percentage-point change in the foreign-born share between 1990 and the 2002-2007 ACS samples, the proportion of highly-educated natives that chose new occupations over the course of a year, and the percentage of the native highly-educated workforce that was new to a given occupation during a year. Turnover rates vary sizably. Around 10% of highly-educated natives in several management occupations leave their occupation in a year, but only about 1% of lawyers and architects do. Given that an individual's occupation in both the preceding and current year are recorded in the same survey, we believe that most of the observed changes reflect actual changes and not simple coding errors. The change in the foreign-born share also varies considerably – it declined for both Police Officers and Kindergarten Teachers, but rose by more than 20 percentage points for Electrical Engineers and Computer Software developers.

Table 3 lists the average occupational skill intensity among highly-educated employees between 2003-2008 for all skill measures, including those not used in the analysis. The value of 0.78 for Inductive Reasoning, for example, indicates that the average occupation chosen by workers with graduate degrees required more inductive reasoning skills than that used by 78% of the entire labor force. Note that all skill measures we use (italicized in Table 3) have average values above 0.5, suggesting that these are skills often adopted by highly-educated workers.

Table 4 provides select skill values for occupations commonly employing highly-educated labor (more than 25% of the workers in each occupation hold a graduate degree). Column (1) lists the foreign-born share of highly-educated workers for each occupation in the table. Columns (2) and (4) provide the level of quantitative and interactive skills computed by averaging our five

[18] Individual-level regressions in Section 4 include non-group quarter, wage-earning, civilian employees, 25 to 65 years old, with a masters, professional, or doctorate degree, who worked in defined states, industries, and occupations both in the year of and prior to the CPS survey (note that CPS data does not allow us to identify whether individuals aged 25 and older are enrolled in school). Immigrant share estimates do not require that the individual is currently employed. Skill percentiles are based upon non-group quarter, wage-earning, civilian employees, 18-65 years old, working in defined industries and occupations in the 1% 2000 Census, regardless of educational attainment and country of birth.

quantitative and seven interactive skills, respectively. The fourth column records the relative quantitative versus interactive value, and the final column converts this ratio into a percentile so that the occupation with the median value of quantitative versus interactive skill level (among all workers between age 18 and 65 in 2000) has a value of 0.5. Though far from a perfect one-to-one correspondence, the table demonstrates that foreign-born laborers disproportionately work in occupations demanding high quantitative versus interactive skills. Also, the occupational ordering of relative skill values appears to be reasonable. Musicians use fewer quantitative versus interactive skills than managers do, and managers use fewer of these relative skills than scientists do.

Table 5 provides summaries for the average skill levels of highly-educated natives, immigrants, and various foreign-born groups from 2003-08 (averages exhibit no trends over this short time horizon). Immigrants with graduate degrees choose occupations with quantitative versus interactive skills 4 percentiles above the median occupation. Highly-educated natives choose jobs 7.6 percentiles below the median. We interpret the clear tendency for highly-educated natives to select occupations requiring communication skills at higher rates than immigrants choose those occupations, and the inclination for immigrants to choose jobs requiring quantitative skills more often than natives do, as evidence for imperfect substitution and comparative advantage. An analysis of skill specialization and skill response remains appropriate.

4 Empirical Analysis

4.1 Skill Response

Equation (1) presents our main empirical specification.

$$\begin{aligned} \Delta\left(\frac{Q}{I}\right)_{i,t}^{Native} &= \alpha + \beta \cdot \Delta FB_{i,t,occly} + \gamma \cdot X_{i,t} + FE_t + \varepsilon_{i,t} \qquad (1) \\ \text{where } \Delta\left(\frac{Q}{I}\right)_{i,t}^{Native} &= \left(\frac{Q}{I}\right)_{i,t,occ}^{Native} - \left(\frac{Q}{I}\right)_{i,t,occly}^{Native} \\ \text{and } \Delta FB_{i,t,occly} &= FB_{i,t,occly} - FB_{i,1990,occly} \end{aligned}$$

The dependent variable is the change in the relative quantitative versus interactive skills used by a native employee with a graduate degree between his/her current occupation (occ) and his/her occupation last year ($occly$), as recorded in the year t CPS survey. Since it measures flows between occupations, the dependent variable accounts for both occupational inflows and outflows among highly-educated workers. The variable equals zero for all natives who did not change occupations in a given year.

The variable $FB_{i,t,occly}$ is the foreign-born share among employees with a graduate degree in individual i's occupation in the year prior to year t, as estimated from occupation data in year $t-1$ ACS surveys. Similarly, $FB_{i,1990,occly}$ is the same share in 1990 as estimated by the Census. The main regressor of interest, $\Delta FB_{i,t,occly}$, is simply the difference in these values. If increases in the proportion of highly-educated immigrants cause native employees with graduate degrees to move to occupations with lower quantitative/interactive content, β should be negative. As there are delays and persistence in the occupational response of natives we include the change of foreign-born share in the occupation during the whole period between year 1990 and year $t-1$.

The vector $X_{i,t}$ includes a number of demographic characteristics, including the individual's age and indicator variables for gender (male or female), educational attainment (masters, professional, or doctoral degree), race (Asian, black, Hispanic, white, or multiple/other race), current state of residence, and current industry of employment. The regression also includes fixed effects for the year of the CPS survey.

If the lagged share of immigrants in an occupation is systematically related to some occupation-specific technological change that also affects the relative demand of quantitative versus interactive skills in the occupation, the estimates of coefficient β can be inconsistent. To help control for this, we include two occupational growth variables which may proxy for generic occupation-specific productivity changes. The first accounts for demand trends that an individual would have been able to observe before considering a new occupation. It measures the growth, since 1990, of a native worker's currently-chosen occupation (occ) to year $t-1$. The second attempts to control for factors that might encourage a native to leave his/her occupation. It measures the growth, also since 1990, of a native's prior occupation ($occly$) to year $t-1$.

Results for the baseline specification are in Table 6. All regressions are weighted by individual survey weights[19] and standard errors are clustered by the occupation of employment of

[19] All skill change regressions use analytical weights. Weights (and averages) are hourly-adjusted so that they

the preceding year. Cells contain the estimate (and standard error) of the coefficient β for each possible combination of quantitative and interactive skill variables. Each of these 35 separate regressions has 44,018 observations, with R^2 values ranging from 0.03 to 0.18.

The regressions provide evidence for imperfect substitutability between highly-educated native and foreign born workers, and suggest that natives respond to immigration by adopting occupations with less quantitative versus interactive content. Moreover, we believe that since the model has several individual and occupation-level controls, includes of an array of fixed effects, and measures the association between an individual's behavior with occupation-level changes, we may be justified in interpreting the coefficient estimates as causal. Limitations of this interpretation are noted in the following discussion and the Appendix.

Each estimate of the coefficient on the immigrant share is negative, and 30 of the 35 values are significant. The magnitudes, however, are fairly small. The standard deviation of the skill change and change in foreign-born share variables are quite similar, so magnitudes can be interpreted as approximations for effects presented in standard deviation terms. A one standard deviation shock to the change in foreign-born share reduces the quantitative versus interactive skill use of natives by 0.03 to 0.11 standard deviations. Alternatively, we could assess the effects of a ten percentage-point increase in the immigrant share of highly-educated workers. This shock would induce natives with graduate degrees to choose occupations with 0.73 percentiles less quantitative versus interactive content according to the estimate using Deductive Reasoning and Written Expression skills, for example. Depending upon the specification, the same shock is estimated to lead to a decline between 0.3 and 1.1 percentiles. Though not in Table 6, we also perform a regression in which Q and I are first constructed from an average of the relevant *O*NET* values and then converted into percentiles. This delivers a highly significant β estimate of -0.104 (standard error of 0.023) that is large in magnitude when compared to the estimates in Table 6.

The results are robust to the alternative measures of quantitative and interactive occupational skill content. It is worth noting, however, that the magnitudes are always smallest when the importance of Analyzing Data or Inductive Reasoning abilities are the proxies for analytical skills. The responses are greatest in regressions using Mathematical abilities or the importance

equal the IPUMS variable *perwt* multiplied by the individual's usual number of hours worked and by the number of weeks in the year the individual typically works.

of Estimating the Quantifiable Characteristics of Products. Thus, responses are stronger in regressions using variables more closely linked to quantitative (as opposed to analytical) skills. Among the interactive skills, the importance of Written Comprehension tends to deliver the lowest magnitudes, while the importance of Resolving Conflicts and Negotiating generates the largest.

One possible objection is that omitted variables might still be correlated with both the immigrant share of an occupation and trends in occupational employment. Although the short panel and the rich set of fixed effects and covariates should mitigate this problem, further information can be gleaned by including foreign-born workers in the model. The regressions in Table 7 introduce foreign-born workers with graduate degrees, an indicator variable for native workers, and a term interacting the native worker dummy with the change in the foreign-born share of workers. In each cell of the table, the first value represents the coefficient on the foreign-born share for all highly-educated workers. The second value (in bold) represents the differential effect experienced by natives. (i.e., immigrants experience the first effect, while natives experience the sum of the two effects).

The general effect is negative in all 35 specifications and significant in all but four. Thus, all highly-educated workers with graduate degrees respond to a high presence of foreign labor by seeking occupations with less quantitative versus interactive content. More interesting, however, is that there is strong evidence that this effect is larger among native-born workers. The coefficient on the interaction term is negative in 26 of the specifications, significant in 14, and never positive and significant. Similar to the results in Table 6, this differential effect is least likely to be significantly negative when analytical skills are measured by the importance of Analysis of Data and Information, Deductive Reasoning, or Inductive Reasoning. Altogether, the results of Table 7 are consistent with the interpretation that native workers are more likely to shift occupations according to their comparative advantages (and away from quantitative skills) in response to a large inflow of educated foreign-born workers in the occupation. However, we acknowledge the possibility that lingering correlation with omitted variable could bias the results, so this causal interpretation necessitates some caution.

The analysis has so far treated immigrants as a homogenous group. The summary statistics in Table 5, however, demonstrate that different types of immigrant groups might exhibit different comparative advantages. Groups more similar to natives tend to work in occupations with lower quantitative versus interactive content (but with values above the US native average). Foreign-born US citizens – who have a strong attachment to the United States – work in occupations with Q/I values three percentiles lower than those of non-citizens. Established immigrants who have been in the US for a number of years have lower Q/I values than new arrivals. Given the differences in demonstrated comparative advantage, it is worth asking if natives have a varied response to changes in the shares of these immigrant groups.

Table 8 dichotomizes the change in immigrant share into two groups. Group 1 maintains quantitative versus interactive skill values dissimilar to natives; Group 2 is more similar to natives. The dependent variable in each regression is our usual change in the relative quantitative versus interactive skills used by a native employee, but with values using the average quantitative and interactive skill measures. In column 1 we assess the native response to increases in the share of non-citizen and citizen immigrants. Although the estimated response to non-citizen immigrants is 50% larger than the effect from citizens, the difference is not significant (the final row of the table reports the p-value on a test of equality of the coefficients).

Column 2 explores the potential difference in effects from new and established immigrants, delineated by whether an immigrant has been in the US five or fewer years. Unfortunately, the 1990 Census only records an immigrant's arrival date in five year intervals so that we cannot pinpoint exact arrival dates for that dataset. This implies that our variables could exhibit sizeable measurement error. Regression estimates produce a coefficient on new immigrants that is larger than that of established immigrants, but the difference is small and insignificant. In column 3 we separate the effects of new immigrants and very established immigrants (those in the US more than 15 years). Here the relative magnitudes of effects is the opposite of what we might expect given comparative advantage, but the difference is insignificant. Altogether, therefore, the results of Table 8 fail to uncover any differential effects from the arrivals of heterogenous immigrants despite observed differences in comparative advantages among immigrant groups.

Several additional robustness checks, which we choose not to include here for space considerations, add further evidence that a skill response does occur. These include specifications that remove all state and industry fixed effects, a test of differential effects for immigrants from English speaking developed countries, regressions among Ph.D. recipients only, and a discussion of the potential role for mean reversion. Many of these results can be found in the working paper version of this analysis.[20] The Appendix provides results discussing the implications of changing the time difference in the measurement of the independent variable, $\Delta FB_{i,t,occly}$. Most of our alternative specifications provide supporting evidence that native-born employees with a graduate degree respond to immigration by choosing new occupations with more quantitative and less interactive content.

Conclusions regarding wage implications of the skill reallocation would require a more formal theory that not only accounts for skill complementarity and imperfect substitution, but also for possible scale effects as argued by endogenous growth theory. We choose not to provide this analysis, but instead offer a brief comment. Peri and Sparber (2009) argued that less-educated natives mitigate wage losses from immigration through two channels. First, immigration encourages further skill specialization, which reduces direct competition with immigrants. We have now demonstrated that this same channel may be at work among highly-educated workers as well. Second, low education natives specialize in skills that offer a higher rate of return than that paid to skills used by low education immigrants. Thus, low education natives earn a secondary benefit from immigration-induced specialization. This channel does not exist within the market for highly-educated workers, however, as there is no systematic relationship between the average highly-educated worker's wage and his or her quantitative versus interactive relative skill use across occupations. If highly-educated natives protect their wages, they do so through increasing skill specialization.

4.2 Employment

The skill response regressions in Section 4.1 only include native workers who were employed both in the year prior to and the year of the CPS survey. While those regressions imply that workers who remain employed in each year respond to immigration by changing the skill content of their occupations, they say nothing about those who have lost their jobs or have left the labor force. If highly-educated foreign-born workers increase the probability of natives leaving employment, one needs to account for this effect too when evaluating labor market impacts of highly-educated immigration. The regressions in Table 9 provide probit (Columns 1 and 4) and linear probability model (Columns 2-3 and 5-6) regression results that explore how the

[20] See _____ .

labor force status of natives changes in response to immigration. Each regression is weighted by individual survey weights and standard errors are clustered by the occupation of employment of the preceding year.

In Columns 1-3, the binary dependent variable equals one if the US-born individual who had been employed in the year prior to the CPS survey was currently unemployed. Of the 44,838 observations who had remained in the labor force, 586 (1.3%) were unemployed. The dependent variable in the final three regressions instead measures whether a highly-educated native had either become unemployed or left the labor force (4.3% of the sample of 44,252). Each specification measures $\Delta FB_{i,t,occly}$ as the change in the foreign-born share of highly educated workers in a native worker's occupation in the year prior to the survey (as described in Section 4.1). The vector $X_{i,t}$ retains the previously defined control variables, though it drops the growth rate of highly-educated employment in the individual's current occupation.[21] Each column includes fixed effects for the CPS year and the individual's current state of residence. Columns 3 and 6 add dummies for the industry of most recent employment.

The estimates in the first row of Table 9 provide weak evidence that highly highly-educated immigrants could push similarly-educated natives out of employment. According to column 2, a ten percentage-point rise in the immigrant share is related to a 0.27 percentage-point increase in the probability that a native worker is currently unemployed. This effect disappears, however, when further controls are added. Moreover, the foreign-born share never significantly determines whether a highly-educated worker becomes not-employed (unemployed or left the labor force). We believe that rather than causing highly-educated native employees to lose their jobs, it is more likely that immigration instead encourages those employees to respond by choosing new jobs that usually contain less quantitative and more interactive skill content.

5 Conclusion

Native and foreign-born workers with graduate degrees work in occupations requiring distinctively different tasks, suggesting the two groups are imperfectly substitutable. Natives specialize in occupations demanding interactive or communication skills, while highly-educated

[21] The CPS records an individual's most recent occupation if he or she is currently unemployed. Individuals currently out of the labor force receive a separate (NA) occupation code.

immigrants disproportionately work in occupations requiring quantitative and analytical skills. Increases in the foreign-born share of highly-educated employment are associated with a decrease in the quantitative versus interactive content of occupations chosen by similarly-educated natives. That is, natives respond to immigration by changing occupations to those with less quantitative and more interactive content than their previous occupations required.

The wage consequences of immigration were not examined in this paper, but they are likely to depend upon the degree of task reallocation experienced by native workers. If the evidence from the labor market for less-educated workers is an indication, the occupational skill response among highly-educated natives is likely to mitigate their potential wage loss from highly-educated immigration.

References

Autor, David H., Frank Levy, and Richard Murnane (2003) "The Skill Content of Recent Technological Change: an Empirical Exploration." *Quarterly Journal of Economics*, 118 (4), pp. 1279-1333.

Ball, Geoffrey, Arindrajit Dube, and Todd Sorensen (2010). "Immigration and the Native Occupational Shifts: A note on the Role of Tasks and Licensing." Mimeo.

Black, Grant C. and Paula E. Stephan (2007) "The Importance of Foreign Ph.D. Students to U.S. Science" in Paula E. Stephan and Ronald G. Ehrenberg eds., *Science and the University*, University of Wisconsin Press.

Bhagwati, Jagdish and Milind Rao (1999) "Foreign Students in Science and Engineering Ph.D. Programs: An Alien Invasion or Brain Gain?" in B. Lindsay Lowell ed., *Foreign Temporary Workers in America: Policies that Benefit the U.S. Economy*, Quorum Books, Westport, CT.

Borjas, George J. (1999) *Heaven's Door*. Princeton University Press, Princeton and Oxford.

Borjas, George J. (2003) "The Labor Demand Curve is Downward Sloping: Reexamining the Impact of Immigration on the Labor Market." *Quarterly Journal of Economics*, 118 (4), 1335-1374.

Borjas, George (2005) "Foreign-Born Domestic Supply of Science and Engineering Workforce" *AEA Papers and Proceedings*, 95 (2), 56-60.

Borjas, George (2006) "Immigration in High-Skill Labor Markets: The Impact of Foreign Students on the Earnings of Doctorates" NBER Working Paper #12085.

Borjas, George (2007) "Do Foreign Students Crowd Out Native Students from Graduate Programs?" in Paula E. Stephan and Ronald G. Ehrenberg eds., *Science and the University*, University of Wisconsin Press.

Borjas, George J. and Larry Katz (2005) "The Evolution of the Mexican-Born Workforce in the United States." NBER Working paper #11281, April 2005.

Bound, John and Sarah Turner (2006) "International Flows of Skilled Workers: Estimates of the Effects of Skilled Workers." Preliminary Draft.

Bratsberg, Bernt and Oddbjorn Raaum (2010) "Immigration and Wages: Evidence from Construction." CReAM Discussion Paper 06/10, London UK.

Card, David (2007) "How Immigration Affects U.S. Cities." CReAM Discussion Paper 11/07, London UK.

Card, David and Ethan Lewis (2007) "The Diffusion of Mexican Immigrants During the 1990s: Explanations and Impacts" in *Mexican Immigration to the United States*, George J. Borjas editor, The University of Chicago Press, Chicago, London, 2007.

Chellaraj, Gnanaraj, Keith E. Maskus, and Aaditya Mattoo (2005) "The Contribution of Skilled Immigration and International Graduate Students to U.S. Innovation." World Bank Policy Research Working Paper 3588.

Chiswick, Barry R. (1999) "Policy Analysis of Foreign Student Visas" in B. Lindsay Lowell ed., *Foreign Temporary Workers in America: Policies that Benefit the U.S. Economy*, Quorum Books, Westport, CT.

Chiswick, Barry R. and Sarinda Taengnoi (2007) "Occupational Choice of High Skilled Immigrants in the United States" IZA Discussion Paper No. 2969.

Ciccone, Antonio and Robert E. Hall (1996) "Productivity and the Density of Economic Activity" *American Economic Review*, 86 (1), 54-70.

Cortes, Patricia (2008) "The Effect of Low-Skilled Immigration on U.S. Prices: Evidence from CPI Data." *Journal of Political Economy*, 2008, Vol. 116, no. 3.

Freeman, Richard B., Emily Jin, and Chia-Yu Shen (2007) "Where Do New U.S.-Trained Science and Engineering Ph.D.s Come From?" in Paula E. Stephan and Ronald G. Ehrenberg eds., *Science and the University*, University of Wisconsin Press.

Gould, David M. (1994) "Immigrant Links to the Home Country: Empirical Implications for U.S. Bilateral Trade Flows" *The Review of Economics and Statistics*, 302-316.

Groen, Jeffrey A. and Michael J. Rizzo (2007) "The Changing Composition of U.S.-Citizen Ph.D.s" in Paula E. Stephan and Ronald G. Ehrenberg eds., *Science and the University*, University of Wisconsin Press.

Jennifer Hunt and Marjolaine Gauthier-Loiselle, (2009). "How Much Does Immigration Boost Innovation?," CEPR Working Paper 7116.

Kapur, Devesh and John McHale (2005) *Give Us Your Best and Brightest.* Brookings Institution Press, Baltimore, MD.

Levin, Sharon G., Grant C. Black, Anne E. Winkler, and Paula E. Stephan (2004) "Differential Employment Patterns for Citizens and Non-Citizens in Science and Engineering in the United States: Minting and Competitive Effects" *Growth and Change*, 35 (4), 456-475.

Lucas, Robert (1988) "On the Mechanics of Economic Development." *Journal of Monetary Economics*, 22 (1), 3-42.

Manacorda, Marco, Alan Manning, and Jonathan Wadsworth (2006) "The Impact of Immigration on the Structure of Male Wages: Theory and Evidence from Britain." Manuscript, London School of Economics, August 2006.

Ottaviano, Gianmarco I.P., and Giovanni Peri (2005) "Cities and Cultures," *Journal of Urban Economics*, Vol. 58(2): 304-337.

Ottaviano, Gianmarco I.P., and Giovanni Peri (2006a). "The Economic Value of Cultural Diversity: Evidence from U.S. Cities," *Journal of Economic Geography*, Vol. 6(1): 9-44.

Ottaviano, Gianmarco I.P. and Giovanni Peri (2006b) "Rethinking the Effects of Immigration on Wages" NBER Working Paper #12497.

Ottaviano, Gianmarco I.P. and Giovanni Peri (2007) "The Effect of Immigration on U.S. Wages and Rents: A General Equilibrium Approach" CReAM Discussion Paper, 13/07, September 2007.

Ottaviano, Gianmarco I.P., and Giovanni Peri (2008) "Immigration and National Wages: Clarifying the Theory and the empirics," NBER Working Paper # 14188, July 2008.

Peri, Giovanni and Chad Sparber (2009) "Task Specialization, Immigration, and Wages," *American Economic Journal: Applied Economics*, Vol. 1 (3): 135-169.

Peri, Giovanni and Chad Sparber (2010) "Assessing Inherent Model Bias: An Application to Native Displacement in Response to Immigration," *Journal of Urban Economics*, Forthcoming

Romer, Paul (1986) "Increasing Returns and Long-Run Growth" *Journal of Political Economy*, 94, 1002-1037.

Romer, Paul (1990) "Endogenous Technological Change" *Journal of Political Economy*, 98 (5), 71-102.

Rauch, James E. and Vitor Trindade (2002) "Ethnic Chinese Networks in International Trade" *The Review of Economics and Statistics*, 84 (1): 116-130.

Ruggles, Steven , Matthew Sobek, Trent Alexander, Catherine A. Fitch, Ronald Goeken, Patricia Kelly Hall, Miriam King, and Chad Ronnander (2005). *Integrated Public Use Microdata Series*: Version 3.0 [Machine-readable database]. Minneapolis, MN: Minnesota Population Center [producer and distributor], 2004. http://www.ipums.org.

Sparber, Chad (2008) "A Theory of Racial Diversity, Segregation, and Productivity," *Journal of Development Economics*, 87 (2): 210-226.

Sparber, Chad (2009) "Racial Diversity and Aggregate Productivity in U.S. Industries: 1980-2000" *Southern Economic Journal*, 75 (3): 829-856.

Stephan, Paula E. and Ronald G. Ehrenberg (2007) *Science and the University*. University of Wisconsin Press.

Stephan, Paula E., G. Black, J. Adams, and S. Levin (2002) "Survey of Foreign Recipients of U.S. Ph.D.s" *Science* 295, 2211-2212.

Stephan, Paula E. and Sharon G. Levin (2007) "Foreign Scholars in U.S. Science: Contributions and Costs" in Paula E. Stephan and Ronald G. Ehrenberg eds., *Science and the University*, University of Wisconsin Press.

Thibodeau, Patrick and Jaikumar Vijayan (2009) "Stimulus Package Sets H-1B Limits; E-Verify Usage Mandate Left Out," *Computerworld*, 43 (8): 14.

A Appendix

One concern with our general methodological framework is whether the measurement of our independent variable (the change in foreign-born share, $\Delta FB_{i,t,occly}$) from year t to 1990 allows for too long of a time lag. Occupational shocks that occurred early in the period have the potential for generating a spurious correlation between the change in immigration and a native worker's occupational response in later periods. The regression in Table A1 explores this issue by instead measuring $\Delta FB_{i,t,occly}$ as the change in foreign-born share between year t and 2000. This alternative produces the correct signs but weaker magnitudes: 33 of the 35 coefficients are negative, but only six are significant. When using average quantitative and interactive measures (results not in the table), we get a coefficient estimate of -0.43 that is significant at the 10% level. Results based upon differences using the longer time horizon should be interpreted with some caution as spurious effects could emerge, but we believe that the weaker coefficient estimates arise because the shortened period reduces identifying variation. That is, the time lag is not large enough for effects to have occurred.

Table 1
***O*NET* Skills, Variables, and Variable Descriptions**

Skill Type	O*NET Survey	Skill Variable Label	Skill Description
Interactive	Activities	Negotiate	Resolving Conflicts and Negotiating with Others
Communication	Activities	Comm In Org	Communicating with Supervisors, Peers, or Subordinates
		Comm Out Org	Communicating with Persons Outside Organization
	Abilities	Oral Comp	Oral Comprehension
		Writ Comp	Written Comprehension
		Oral Exp	Oral Expression
		Writ Exp	Written Expression
Analytical	Activities	Analyze	Analyze Data or Information
	Abilities	Deduce	Deductive Reasoning
		Induce	Inductive Reasoning
Quantitative	Activities	Est Quant	Estimating the Quantifiable Characteristics of Products, Events, or Information
	Abilities	Math	Mathematical Reasoning

Note: The source of definitions is the O*NET Database provided by the National center for O*NET development.

Table 2
Percentage of Native Employees with Graduate Degrees Changing Occupations in a Year, by Prior Year Occupation

Note: Data sources: % Natives Who Change Occupations: Annual CPS Survey, 2003-2008. %-Point Change in Foreign Share: 1990 Census and Annual 2002-2007 ACS Survey. Table lists only occupations with 100 or more observed native workers with a graduate degree.

% Natives Who Leave Occupation	% Natives New to Occupation	%-Point Change in Foreign Share	Occupation	% Natives Who Leave Occupation	% Natives New to Occupation	%-Point Change in Foreign Share	Occupation
5.6	2.5	24.4	Computer software developers	5.9	6.0	5.6	Financial managers
6.8	4.5	20.1	Electrical engineer	2.9	4.5	5.3	Geologists
6.9	5.7	18.9	Medical scientists	9.9	16.8	4.4	Purchasing managers, agents & buyers, nec
4.0	4.0	15.0	Chief executives & public administrators	4.2	1.4	4.2	Registered nurses
6.0	7.5	14.5	Chemists	9.1	13.5	4.0	Therapists, nec
3.1	12.6	12.9	Dentists	5.7	5.1	3.8	Vocational & educational counselors
4.6	6.3	11.6	Computer systems analysts & computer scientists	7.8	5.3	3.3	Social workers
8.9	6.9	10.5	Not-elsewhere-classified engineers	7.0	8.3	3.0	Managers of service organizations, nec
11.6	7.6	9.8	Economists, and market & survey researchers	31.0	6.5	2.8	Salespersons, nec
6.5	14.2	9.0	Real estate sales occupations	0.9	6.0	2.8	Lawyers
10.2	10.8	8.6	Management analysts	12.3	13.3	2.7	Secretaries
11.2	11.2	8.4	Designers	3.4	2.5	2.5	Clergy & religious workers
9.9	10.5	8.1	Managers of properties & real estate	2.4	11.7	2.2	Other health & therapy
6.7	4.6	8.1	Managers & administrators, nec	3.3	2.7	2.2	Secondary school teachers
3.3	2.6	8.0	Subject instructors (HS/college)	1.2	0.6	1.9	Veterinarians
8.2	5.0	7.9	Pharmacists	4.8	3.7	1.8	Managers in education & related fields
9.3	7.6	7.8	Human resources & labor relations managers	2.9	1.8	1.7	Primary school teachers
9.8	8.5	7.7	Administrative support jobs, nec	5.9	11.7	1.7	Farm workers
7.8	5.7	7.3	Personnel, HR, training, & labor relations specialists	7.4	5.7	1.6	Office supervisors
3.9	5.7	7.1	Biological scientists	4.1	7.4	1.6	Psychologists
5.0	4.0	6.5	Other financial specialists	10.2	5.4	1.5	Physical therapists
1.1	1.9	6.4	Architects	3.7	4.0	1.4	Speech therapists
2.9	6.0	6.3	Financial services sales occupations	2.8	3.6	1.3	Librarians
2.8	4.5	6.3	Physicians	5.1	7.8	1.2	Managers of medicine & health occupations
13.0	13.3	6.2	Cust. srvc, investigators & adjusters, exc. insurance	5.9	2.7	1.2	Mechanical engineers
10.7	6.4	6.2	Mgrs & specialists in marketing, advertising, & PR	7.5	13.6	1.1	Teachers, nec
3.7	2.7	6.0	Accountants & auditors	2.6	3.2	0.4	Special education teachers
13.9	8.2	6.0	Welfare service aides	5.0	6.4	0.1	Civil engineers
4.9	2.8	6.0	Supervisors & proprietors of sales jobs	4.1	5.3	0.0	Kindergarten & earlier school teachers
13.1	7.6	5.8	Editors & reporters	4.2	4.5	-0.1	Police, detectives, & private investigators

Table 3
Average Occupational Skill Intensity for Workers with Graduate Degrees, 2003-2008

Skill Average	Ability	Skill Average	Activity
0.32	Arm-Hand Steadiness	0.77	*Analyzing Data or Information*
0.54	Auditory Attention	0.59	Assisting and Caring for Others
0.71	Category Flexibility	0.67	Coaching and Developing Others
0.31	Control Precision	0.67	*Communicating with Persons Outside Organization*
0.76	*Deductive Reasoning*	0.67	*Communicating with Supervisors, Peers, or Subordinates*
0.43	Depth Perception	0.35	Controlling Machines and Processes
0.55	Dynamic Flexibility	0.67	Coordinating the Work and Activities of Others
0.43	Dynamic Strength	0.68	Developing and Building Teams
0.61	Explosive Strength	0.76	Developing Objectives and Strategies
0.33	Extent Flexibility	0.67	Documenting/Recording Information
0.54	Far Vision	0.45	Drafting… Technical Devices, Parts, and Equip.
0.40	Finger Dexterity	0.57	*Est. Quantifiable Characteristics of Products, Events, or Info.*
0.63	Flexibility of Closure	0.71	Establishing and Maintaining Interpersonal Relationships
0.73	Fluency of Ideas	0.70	Evaluating Info to Determine Compliance with Standards
0.53	Glare Sensitivity	0.71	Getting Information
0.38	Gross Body Coordination	0.69	Guiding, Directing, and Motivating Subordinates
0.45	Gross Body Equilibrium	0.31	Handling and Moving Objects
0.53	Hearing Sensitivity	0.69	Identifying Objects, Actions, and Events
0.78	*Inductive Reasoning*	0.38	Inspecting Equipment, Structures, or Material
0.63	Information Ordering	0.63	Interacting With Computers
0.28	Manual Dexterity	0.78	Interpreting the Meaning of Information for Others
0.61	*Mathematical Reasoning*	0.73	Judging the Qualities of Things, Services, or People
0.71	Memorization	0.75	Making Decisions and Solving Problems
0.32	Multilimb Coordination	0.59	Monitor Processes, Materials, or Surroundings
0.57	Near Vision	0.63	Monitoring and Controlling Resources
0.52	Night Vision	0.37	Operating Vehicles, Mechanized Devices, or Equipment
0.55	Number Facility	0.70	Organizing, Planning, and Prioritizing Work
0.72	*Oral Comprehension*	0.63	Performing Administrative Activities
0.74	*Oral Expression*	0.59	Performing for or Working Directly with the Public
0.75	Originality	0.33	Performing General Physical Activities
0.52	Perceptual Speed	0.68	Processing Information
0.52	Peripheral Vision	0.77	Provide Consultation and Advice to Others
0.68	Problem Sensitivity	0.41	Repairing and Maintaining Electronic Equipment
0.48	Rate Control	0.36	Repairing and Maintaining Mechanical Equipment
0.41	Reaction Time	0.69	*Resolving Conflicts and Negotiating with Others*
0.43	Response Orientation	0.69	Scheduling Work and Activities
0.61	Selective Attention	0.60	Selling or Influencing Others
0.47	Sound Localization	0.65	Staffing Organizational Units
0.44	Spatial Orientation	0.73	Thinking Creatively
0.75	Speech Clarity	0.66	Training and Teaching Others
0.68	Speech Recognition	0.76	Updating and Using Relevant Knowledge
0.66	Speed of Closure		
0.38	Speed of Limb Movement		
0.37	Stamina		
0.34	Static Strength		
0.54	Time Sharing		
0.34	Trunk Strength		
0.49	Visual Color		
0.49	Visualization		
0.32	Wrist-Finger Speed		
0.77	*Written Comprehension*		
0.77	*Written Expression*		

Note: *Skills used in data analysis italicized.*

<u>Table 4</u>
Quantitative and Interactive Skill Content of Selected Occupations

	(1)	(2)	(3)	(4)	(5)
Occupation	**Immigrant Share of Employees with Graduate Degrees, 2003-2008**	**Quantitative**	**Interactive**	**Quantitative / Interactive**	**Quantitative / Interactive Percentile**
Musician or composer	0.08	0.08	0.26	0.31	0.00
Vocational and educational counselors	0.06	0.50	0.81	0.61	0.11
Lawyers	0.05	0.63	0.81	0.78	0.20
Secondary school teachers	0.06	0.64	0.75	0.85	0.28
Managers of service organizations, n.e.c.	0.07	0.83	0.90	0.92	0.41
Management analysts	0.17	0.92	0.94	0.98	0.50
Managers of medicine and health occupations	0.09	0.95	0.86	1.10	0.60
Economists, market researchers, and survey researchers	0.26	0.88	0.69	1.27	0.69
Physicists and astronomers	0.25	0.98	0.65	1.51	0.81
Actuaries	0.13	0.97	0.49	1.99	0.91
Mathematicians and mathematical scientists	0.25	0.86	0.33	2.64	0.96

Note: Skill calculations are based upon *O*NET* task definitions, the 2000 Census and the IPUMS occ1990 occupation codes. Columns (2) and (4) represent skill intensity computed by averaging the five quantitative (and analytical) skill and seven interactive (and communication) skill measures described in Table 1. The occupations included are those near each decile of the 2000 distribution of workers' quantitative versus communication task intensity as shown in Column (5). The median worker had a Q/I percentile of 0.50 in 2000. More than 25% of employees in each listed occupation have a graduate degree.

Table 5

Quantitative versus Interactive Skill Measures by Highly-Educated Group, 2003-2008

Group	Q/I
Natives	0.424
Foreign-born	0.540
Foreign-born, US citizen	0.523
Foreign-born, non-US citizen	0.564
Foreign-born, in US more than 15 years	0.508
Foreign-born, in US more than 5 years	0.535
Foreign-born, in US 5 years or less	0.563

Note: Skill calculations are based upon *O*NET* task definitions, the 2000 Census and the IPUMS occ1990 occupation codes. Values represent skill intensity computed by averaging the five quantitative (and analytical) skill and seven interactive (and communication) skill measures described in Table 1.

Table 6
Native-Born Occupational Skill Response to Immigration

Dependent Variable: Change in Quantitative versus Interactive Occupational Skill Content (ΔQ/I) Used by Native-Born Workers with a Graduate Degree

	Interactive Skill Measure						
Quantitative Skill Measure	Negotiate	Comm In Org	Comm Out Org	Oral Comp	Writ Comp	Oral Exp	Writ Exp
Deduce	-0.064	-0.035	-0.034	-0.047	-0.041	-0.047	-0.073
	(0.022)***	(0.024)	(0.020)*	(0.020)**	(0.026)	(0.019)**	(0.024)***
Induce	-0.062	-0.036	-0.038	-0.040	-0.031	-0.040	-0.054
	(0.021)***	(0.027)	(0.020)*	(0.019)**	(0.026)	(0.020)**	(0.027)**
Analyze	-0.058	-0.035	-0.036	-0.050	-0.035	-0.049	-0.062
	(0.021)***	(0.021)*	(0.022)*	(0.018)***	(0.025)	(0.017)***	(0.018)***
Est Quant	-0.107	-0.096	-0.093	-0.086	-0.077	-0.092	-0.092
	(0.024)***	(0.025)***	(0.023)***	(0.019)***	(0.023)***	(0.019)***	(0.022)***
Math	-0.096	-0.075	-0.075	-0.076	-0.075	-0.084	-0.085
	(0.024)***	(0.025)***	(0.030)**	(0.027)***	(0.029)***	(0.024)***	(0.029)***

Note: Each cell contains estimates from a separate regression, and is defined by the different possible combinations of quantitative and interactive skill measures used in the dependent variable as indicated in the column and row headers. The explanatory variable is the change in the foreign-born share of workers with a graduate degree in the occupation since 1990.
Observations: 44,018 native-born workers with a graduate degree.
Individual Data Source: CPS, 2003-2008. Change in skill content determined by an individual's occupation in the year of and year prior to the CPS survey.
Other Controls: Age, growth rate of highly educated in current and prior-year occupations, indicators for educational attainment, gender, and race.
Fixed Effects: Year of survey, current state of residence, current industry of employment.
Regression Method: Least squares, with regressions weighted by CPS weights, adjusted for yearly hours worked. Standard errors (in parenthesis) are heteroskedasticity-robust and clustered by occupation of employment in the year prior to the survey.
*** indicates significance at the 1% level ** indicates significance at the 5% level * indicates significance at the 10% level

Table 7
Native and Foreign-Born Occupational Skill Response to Immigration

Dependent Variable: Change in Quantitative versus Interactive Occupational Skill Content (ΔQ/I) Used by Workers with a Graduate Degree

Interactive Skill Measure

Quantitative Skill Measure		Negotiate	Comm In Org	Comm Out Org	Oral Comp	Writ Comp	Oral Exp	Writ Exp
Deduce	General Effect	-0.032 (0.013)**	-0.017 (0.023)	-0.033 (0.019)*	-0.031 (0.014)**	-0.020 (0.019)	-0.039 (0.017)**	-0.036 (0.019)*
	Differential Effect on Natives	**-0.030 (0.019)**	**-0.016 (0.023)**	**-0.001 (0.020)**	**-0.016 (0.017)**	**-0.020 (0.021)**	**-0.006 (0.020)**	**-0.035 (0.022)**
Induce	General Effect	-0.046 (0.015)***	-0.027 (0.025)	-0.045 (0.020)**	-0.046 (0.017)***	-0.037 (0.022)*	-0.056 (0.019)***	-0.044 (0.021)**
	Differential Effect on Natives	**-0.014 (0.018)**	**-0.006 (0.025)**	**0.008 (0.021)**	**0.006 (0.020)**	**0.008 (0.023)**	**0.017 (0.023)**	**-0.007 (0.024)**
Analyze	General Effect	-0.043 (0.014)***	-0.043 (0.017)**	-0.051 (0.016)***	-0.053 (0.014)***	-0.062 (0.018)***	-0.054 (0.014)***	-0.057 (0.015)***
	Differential Effect on Natives	**-0.015 (0.019)**	**0.008 (0.022)**	**0.013 (0.022)**	**0.001 (0.020)**	**0.025 (0.026)**	**0.004 (0.019)**	**-0.005 (0.021)**
Est Quant	General Effect	-0.046 (0.012)***	-0.037 (0.019)**	-0.046 (0.016)***	-0.041 (0.015)***	-0.035 (0.017)**	-0.041 (0.014)***	-0.037 (0.014)**
	Differential Effect on Natives	**-0.059 (0.020)*** **	**-0.056 (0.023)** **	**-0.047 (0.020)** **	**-0.045 (0.019)** **	**-0.040 (0.021)* **	**-0.049 (0.019)*** **	**-0.052 (0.020)*** **
Math	General Effect	-0.039 (0.017)**	-0.028 (0.019)	-0.036 (0.019)*	-0.042 (0.017)**	-0.027 (0.017)*	-0.042 (0.016)***	-0.035 (0.019)*
	Differential Effect on Natives	**-0.055 (0.021)*** **	**-0.047 (0.020)** **	**-0.040 (0.021)* **	**-0.035 (0.019)* **	**-0.047 (0.020)** **	**-0.042 (0.018)** **	**-0.050 (0.021)** **

Note: Each cell contains estimates from a separate regression, and is defined by the different possible combinations of quantitative and interactive skill measures used in the dependent variable as indicated in the column and row headers. The explanatory variables include the change in the foreign-born share of workers with a graduate (masters, professional, or doctoral) degree since 1990 ("General Effect" estimate) and the change in foreign-born share interacted with an indicator variable for native-born workers ("Differential Effect" estimate in bold).
Observations: 51,992 workers with a graduate degree.
Individual Data Source: CPS, 2003-2008. Change in skill content determined by an individual's occupation in the year of and prior to the CPS survey.
Other Controls: Age, growth rate of highly educated in current and prior-year occupations, indicators for educational attainment, gender, race, and nativity.
Fixed Effects: Year of survey, current state of residence, current industry of employment.
Regression Method: Least squares, with regressions weighted by CPS weights, adjusted for yearly hours worked. Standard errors (in parenthesis) are heteroskedasticity-robust and clustered by occupation of employment in the year prior to the survey.
*** indicates significance at the 1% level ** indicates significance at the 5% level * indicates significance at the 10% level

<u>Table 8</u>
Native Response to Varied Immigrant Groups

Dependent Variable: Change in Quantitative versus Interactive Occupational Skill Content (ΔQ/I) Used by Native-Born Workers with a Graduate Degree

	(1)	(2)	(3)
Group 1	**Non-Citizen**	**New Immigrants**	**New Immigrants**
	-0.120	-0.111	-0.128
	(0.024)***	(0.036)***	(0.038)***
Group 2	**Citizen Foreign-Born**	**Established Immigrants**	**Very Established Immigrants**
	-0.081	-0.101	-0.137
	(0.036)**	(0.026)***	(0.042)***
Observations	44018	44018	44018
R-squared	0.04	0.03	0.04
p-value	0.31	0.81	0.85

Note: The explanatory variables are the change in Group 1 and Group 2 foreign-born shares of workers with a graduate degree in the occupation since 1990. In each column, Group 1 represents an immigrant group with a relative skill content (average Q/I) dissimilar from natives. Group 2 is more similar to natives. The final row reports the p-value from a test of equality of the two coefficients.
Dependent Variable: Computed by averaging the five quantitative (and analytical) skill and seven interactive (and communication) skill measures described in Table 1.
Individual Data Source: CPS, 2003-2008. Change in skill content determined by an individual's occupation in the year of and year prior to the CPS survey.
Other Controls: Age, growth rate of highly educated in current and prior-year occupations, indicators for educational attainment, gender, and race.
Fixed Effects: Year of survey, current state of residence, current industry of employment.
Regression Method: Least squares, with regressions weighted by CPS weights, adjusted for yearly hours worked. Standard errors (in parenthesis) are heteroskedasticity-robust and clustered by occupation of employment in the year prior to the survey.
*** indicates significance at the 1% level ** indicates significance at the 5% level * indicates significance at the 10% level

Table 9
Native Employment Response

Binary Dependent Variable:	=1 if Highly-Educated Native Becomes Unemployed			=1 if Highly-Educated Native Becomes Unemployed or Leaves Labor Force		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Δ Foreign-Born Share:	0.836	0.027	0.006	0.413	0.023	0.001
	(0.423)**	(0.014)*	(0.013)	(0.408)	(0.026)	(0.014)
Previous Year Q/I Skill Use	0.199	0.006	0.007	-0.008	0.000	0.003
	(0.161)	(0.005)	(0.004)	(0.117)	(0.007)	(0.004)
Model:	Probit	LPM	LPM	Probit	LPM	LPM
Additional Fixed Effects:	NA	NA	Current Industry	NA	NA	Current Industry
Observations	44838	44838	44838	46163	46163	46163
R-squared		0.01	0.02		0.01	0.50

Individual Data Source: CPS, 2003-2008.
Sample: Regressions include highly-educated natives who were employed in the year prior to the CPS survey.
Previous Year Q/I Skill Use: Determined by the average of the five quantitative and seven analytical skills, as defined in the text, of a native worker's occupation in the year prior to the CPS survey.
Δ Foreign-Born Share: Measures change in the Foreign-Born Share of highly-educated employment in a highly-educated native worker's prior-year occupation since 1990.
Other Controls: Age, growth rate of highly educated in current and prior-year occupations, indicators for educational attainment, gender, and race.
Fixed Effects: Year of survey and current state of residence. Note that current industry will be represented by an individual's most recent industry of employment if he or she is not currently employed.
Regression Method: Regressions use frequency weights equal to CPS weights, adjusted for yearly hours worked. Standard errors (in parenthesis) are heteroskedasticity-robust and clustered by occupation of employment in the year prior to the survey.
*** indicates significance at the 1% level ** indicates significance at the 5% level * indicates significance at the 10% level

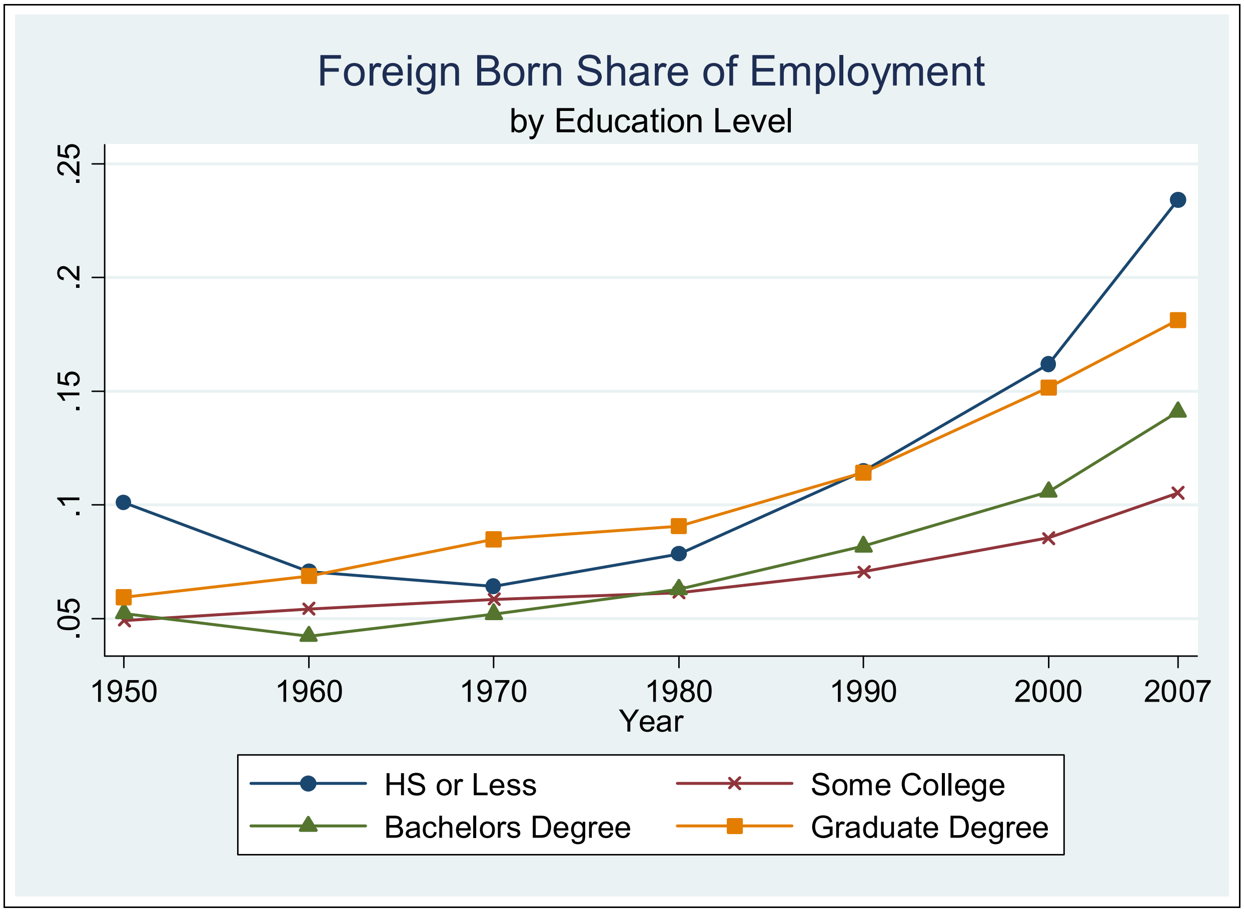
Table A1
Native-Born Occupational Skill Response to Immigration, Change in Immigration Measured to 2000

Dependent Variable: Change in Quantitative versus Interactive Occupational Skill Content (ΔQ/I) Used by Native-Born Workers with a Graduate Degree

Quantitative Skill Measure	Interactive Skill Measure: Negotiate	Comm In Org	Comm Out Org	Oral Comp	Writ Comp	Oral Exp	Writ Exp
Deduce	-0.041	-0.066	-0.010	-0.020	-0.022	-0.024	-0.025
	(0.029)	(0.025)***	(0.024)	(0.030)	(0.032)	(0.031)	(0.029)
Induce	-0.047	-0.049	-0.014	-0.004	-0.024	0.000	0.005
	(0.027)*	(0.028)*	(0.024)	(0.024)	(0.027)	(0.027)	(0.027)
Analyze	-0.041	-0.060	-0.009	-0.032	-0.019	-0.018	-0.023
	(0.027)	(0.029)**	(0.027)	(0.025)	(0.024)	(0.023)	(0.022)
Est Quant	-0.056	-0.068	-0.033	-0.038	-0.031	-0.033	-0.032
	(0.031)*	(0.028)**	(0.028)	(0.025)	(0.025)	(0.023)	(0.025)
Math	-0.042	-0.041	-0.011	-0.022	-0.038	-0.026	-0.012
	(0.030)	(0.025)	(0.030)	(0.029)	(0.031)	(0.028)	(0.026)

Note: Each cell contains estimates from a separate regression, and is defined by the different possible combinations of quantitative and interactive skill measures used in the dependent variable as indicated in the column and row headers. The explanatory variable is the change in the foreign-born share of workers with a graduate degree in the occupation since 2000.
Observations: 44,013 native-born workers with a graduate degree.
Individual Data Source: CPS, 2003-2008. Change in skill content determined by an individual's occupation in the year of and year prior to the CPS survey.
Other Controls: Age, growth rate of highly educated in current and prior-year occupations, indicators for educational attainment, gender, and race.
Fixed Effects: Year of survey, current state of residence, current industry of employment.
Regression Method: Least squares, with regressions weighted by CPS weights, adjusted for yearly hours worked. Standard errors (in parenthesis) are heteroskedasticity-robust and clustered by occupation of employment in the year prior to the survey.
*** indicates significance at the 1% level ** indicates significance at the 5% level * indicates significance at the 10% level

<u>Figure 1</u>
Foreign-Born Employment Share by Education Level



Data Source: US Census (1950-2000) and American Community Survey (2007). Sample includes non-group quarter, wage-earning, civilian employees, age 25-65, working in defined states, industries, and occupations, and with a defined birthplace. Prior to 1990, Graduate Degree holders are assumed to be those workers with five or more years of college experience.