The Effects of Foreign Skilled Workers on Natives: Evidence from the H-1B Visa Lottery*

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Abstract

An ideal way to identify the consequences of foreign-born skilled labor flows would be to conduct an experiment in which foreign workers are randomly assigned to some "treated" local labor markets but not to other "untreated" markets. Causal wage and employment effects for natives could then be measured by comparing the outcomes of natives working in these treated and untreated markets. A similar experiment occurred in 2007 and 2008 when 65,000 H-1B skilled worker visas were randomly allocated to foreign applicants with job offers. Firms were unable to fill about 88,000 requested computer-related positions for H-1B workers in each of those two years. Our analysis tracks the consequences of this random H-1B supply shock on the employment and wages of natives across cities for computer-related occupations in 2009, 2010, and 2011. We find that negative H-1B shocks produced lower employment and wage growth for native-born workers in the same labor market. This implies that H-1B workers do not displace, but rather complement, natives in computer-related occupations.

Key Words: Skilled Workers, H-1B Visa, Computer-Related Occupations, Natural Experiment.

JEL Codes: J61, F22 , O33, R10

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1 Introduction

Access to foreign talent has long been considered a key ingredient for US scientific and technological success. Studies by Kerr and Lincoln (2010), Hunt and Gauthier-Loiselle (2010), and Peri (2007) have noted that US global leadership in science and technology heavily depends upon foreign-born workers who are responsible for a large share of US Nobel laureates, patents, journal articles, and other measures of innovative activity. But do such immigrants crowd out native talent from desirable jobs and push them into lower paid ones? Mixed results have been presented on this topic. While some recent papers emphasize that foreign skilled workers have improved macroeconomic productivity and the labor market opportunities for natives (Peri, Shih, and Sparber, 2013; Moser, Voena, and Waldinger, 2014) others have argued that foreign scientists have displaced natives and reduced their opportunities (Borjas and Doran, 2012). Most of the acrimony in the public debate and popular press regarding skilled immigration has focused on the H-1B visa program and whether the specialty workers it allows to enter the country affects the job prospects of natives, especially for computer-related occupations (e.g. Matloff, 2008; Hira, 2007).

The majority of scholarly articles examining the impact of the H-1B program has found no evidence for crowding out employment or innovation, but it is hard to guarantee that they have unequivocally identified the causal effects of foreign skilled workers on native outcomes. Those papers rely on pre-existing variation in demand for foreign skilled workers across labor markets (metropolitan areas) interacted with aggregate flows of skilled immigrants or with changes in policy (the cap of new H-1B issuances allowed). Strong persistence in unobserved demand shocks for highly skilled workers could generate a positive spurious correlation between foreign and native-born outcomes, which would bias models against finding crowding-out.

The main innovation of this paper is that it uses genuinely random variation in the allocation of H-1B workers across labor markets in the US resulting from the H-1B visa lotteries of 2007 and 2008. In those years, the number of new H-1B visa applications filed in the first month of acceptance far exceeded the 65,000 annual limit of available visas. The US government responded by holding lotteries to allocate visas, randomly processing 65,000 visa applications submitted by April 3rd in 2007 and April 7th in 2008. This produced a random negative shock in the supply of H-1B workers to different employers and to the cities in which they would have been located.

We merge two datasets to measure this supply shock across local labor markets. First, in order to hire an H-1B worker a firm must file a Labor Condition Application (LCA) stating the nature of the work. Publicly-available LCA data records vacancies opened by employers for foreign workers, our measure of foreign labor demand. Second, foreign workers with LCA-approved job offers then apply for an H-1B visa using an I-129 form. United States Citizen and Immigration Services (USCIS) retains the I-129 records only for those individuals randomly selected for processing. Individual-level I-129 data, which we acquired through a Freedom of Information Act (FOIA) request, serves as a measure of capped labor supply. We aggregate the supply and demand figures from these two datasets by metropolitan area and merge them accordingly. We select only the "computer-related occupations" because they represent two-thirds of applications, they are especially subject to the quota and they are those in which H1B workers represent a larger share of total employment. For each city we calculate the randomly distributed negative H-1B supply shock, namely the number of non-satisfied applications among those that were subject to the quota.

After developing our H-1B supply shock data, we merge it with city-level labor market data derived from the American Community Survey (ACS) in years 2006 (pre-lottery) through 2011 (3 years after the second lottery). The resulting dataset allows us to examine the causal relationship between skilled foreign labor flows and labor market outcomes. More specifically, our explanatory variable is the negative H-1B supply shock to computer-related occupations in a city relative to the pre-2007 computer-related employment in that city. This provides a measure of how the random lottery outcomes affected the availability of foreign-born workers in that local market. Our main outcome variables are the average computer-related native wages and employment in a city. As stated, we limit our attention to computer-related occupations because those jobs exhibit the largest incidence of H-1B workers in their total employment.

We first check whether the net growth of foreign-born employment between 2005/06 (before the lottery) and 2008/09, 2009/10, or 2010/11 (one, two, or three year after) was negatively affected by the random negative H-1B supply shock. The presence of a significant correlation confirms that employers who were randomly denied the ability to hire as many foreign workers as they intended in 2007 and 2008 hired fewer net foreign workers. The randomness of the lottery facilitates causal interpretation of our regression estimates. Our results show that a larger negative random H-1B supply shock to computer-related occupations in a city

significantly slowed employment growth of foreign college educated workers in that city. For a negative H-1B supply shock equal to one percentage point of initial computer-related employment in the city, the growth rate of college educated foreign-born computer workers was between 6 and 8% slower in that metropolitan area during 2008/09 (using the unweighted estimates). This confirms that a negative H-1B supply shock reduces the net hiring of highly-skilled foreign high tech workers.

The core of this paper, however, assesses the impact of the H-1B supply shocks on the growth of employment and wages for native workers in the same city, separately estimating the effects for natives with and without a bachelor's degree. While most of the foreign-born computer-related workers are college educated, about 40% of natives working in those occupations did not have a college degree (and had at most only some college education) in 2006. This motivates our decision to distinguish effects by educational attainment. We find that college educated natives working in computer occupations in cities with larger negative H-1B shocks exhibit slower employment and wage growth, sometimes with a significant coefficient. The effects are estimated with some noise, but the point estimate is always negative on both employment and wages suggesting a detrimental effect on demand for natives. Importantly, we do not find positive coefficients that would have implied a substitution toward natives from denied foreign-born H-1B workers. Moreover, non-college educated natives in computer-occupations and in cities with larger negative H-1B shocks seem to experience even stronger averse demand effects in the following one to three years. Quantitatively, a random negative H-1B shock of 1 percentage point of initial employment results in slower employment growth rates between 0 and 1 percentage point for native college educated workers in the same city. It is also associated with a slower wage growth between 0 and 0.9 percentage points for college-educated natives. The employment growth effects for non-college educated employment were a stronger loss between 1 and 6 percentage points in the following three years, but the effect on non-college graduate wage growth was smaller (between 0 and 0.5).

These results dispel the idea that by reducing skilled immigration, employers would increase their demand for native skilled workers. To the contrary, they suggest that immigrants are complementary to native workers and/or stimulate the productivity of natives in similar computer-related occupations. Increasing foreign employment allows firm expansion, growth in productivity, and improved labor market options for

natives by raising their employment and wage opportunities. Using our estimated coefficients on native employment and applying them in the aggregate, we calculate that by denying a total of about 178,000 computer-related H-1B applications, the 2007 and 2008 lotteries not only prevented those 178,000 jobs from being filled by foreign computer workers, but also destroyed between 60,000 (low estimate) and 231,000 (high estimate) native computer-related jobs by 2009/10 due to foregone complementarity and productivity effects. At the city level, New York might have foregone between 8,000 and 28,000 additional computer-related jobs for natives, whereas losses for San Francisco and San Jose were between 1,200 and 4,000 jobs.

The rest of the paper is organized as follows. Section 2 describes the H-1B visa program and the 2007 and 2008 lotteries. Section 3 provides a simple framework to understand the effect of negative random supply shocks of foreign workers on the demand for substitute or complementary native workers. Section 5 describes the data, the identification, and the power of the lottery in affecting supply. Section 6 presents our empirical framework and shows the empirical results on the one-year and three-year effects of reducing the H-1B supply on native computer-worker wages and employment. Section 7 concludes the paper.

2 The H-1B Program and the 2007 and 2008 Lotteries

Since the advent of the H-1B temporary visa program in 1990, it has been the main method of US workforce entry for foreign-born college-educated professionals, especially among scientists and engineers working in computer-related occupations. This program has been subject to an annual quota on new visa issuances that has evolved over time. The initial 65,000 limit was not met until 1997 an in 1998, this led to many visa denials. Congress increased the cap to 115,000 for 1999 and 2000, then to 195,000 for 2001 through 2003. Moreover, 2001 marked the beginning of cap exemptions for employees of higher-education, non-profit, and government-research organizations. In 2004 the cap reverted to 65,000, but 20,000 additional visas were granted for workers who earned a master's degree or Ph.D. from a US institution. The H-1B quota has been reached before the end of each fiscal year since 2004.

Several steps are required for an individual to acquire an H-1B. A firm wishing to hire a foreign-born specialty worker must first file an LCA with the department of labor. This document outlines the nature of the job and attests that the firm will comply with H-1B regulations. The form includes information on the

prevailing wage of the occupation, the wage to be paid to the prospective worker, and where the work will occur. Since the visa is temporary in nature and lasts for three years (and is renewable once), the LCA must also provide the beginning and end dates of the position. After the prospective employee has obtained an offer, he/she must submit an I-129 form to apply for an H-1B visa, and this application must be accompanied by an approved LCA. Thus, while the visa belongs to an employee (not the firm), a person can only obtain an H-1B if he/she has a job offer from an employer that has obtained LCA approval. There is no limit on LCAs since a firm is free to hire an existing H-1B worker from another firm. The cap applies only to new H-1B issuances to people working at for-profit firms.

I-129 H-1B applications are accepted beginning on April 1, six months prior to the October 1 start of the federal fiscal year, and throughout the fiscal year. As an LCA cannot be filed more than six months prior to intended employment an employer hoping to hire a new foreign-born skilled worker as soon as he/she would be eligible to work (October 1) will have to file an LCA on April 1, receive approval soon after, and give the paperwork to their prospective employee as part of his/her (I-129) visa application. In this strict setting, it is inconceivable for a person to file a visa application on April 1. In normal years, however, when firms expect H1B permits to be available year round, employers will file LCA in April, May, June and obtain H1B before the start of the foreign-worker employment.

Acute scarcity of visas induced a peculiar behavior in calendar years 2007 and 2008, however. Firms began to "predate" their LCAs. For example, they would file an LCA in March of 2007 claiming an intended start date of September 2007, but knowing that a new H-1B recipient would not be able to begin until October 2007. The benefit of this behavior is that H-1B processing had historically worked on a first-come, first-served basis. Individuals with approved job offers could submit visa applications on April 1 and, if experience from previous years held true, they could expect to receive a visa. The cost is that the firm would sacrifice one month of job approval at the end of the work period (since an individual LCA is only applicable for up to three years).

Figure 1 illustrates the marked difference in for-profit firm behavior that emerged in calendar years 2007 and 2008. While in 2005 and 2006 employers would file LCAs year round, they became highly concentrated in 2007 and 2008. More than a quarter of all LCAs filed in those latter years were filed in March with

"intended" September start dates. By comparison, only 10.7% of LCAs were filed in May for an October start date in 2006, the most common file month / submit month pair that year, and only 2.5% of LCAs in 2006 were filed in March with a September start date. The result of this collective firm behavior is that USCIS received 119,193 cap-subject H-1B applications by April 3, 2007, and approximately 163,000 petitions in the first week of April 2008.[1] USCIS randomly selected visas for processing until the 65,000 available visas were allocated. The unselected visa applications were not processed and returned (see Clemens, 2010).

As the number of applications was roughly double the number of granted visas, this process induced a rationing of (or a forced decrease in) the supply of foreign skilled workers that was both significant in size and randomly distributed among applicants. Firms submitting LCAs clearly had vacancies in specific occupations that they were planning to fill with foreign skilled workers, but the lottery generated a randomly distributed negative shock to their supply. By following what happened to the native employees in cities that received large negative shocks (bad luck in the H-1B lottery for foreign workers with job offers), and those in cities that felt a small shock (good luck in the lottery), we can track the causal effect of the negative shock induced by the visa rationing. Did employers who were denied the ability to hire their desired employees promptly substitute foreign workers with native workers? And did this tightening of the labor market force firms to pay native workers a higher wage to attract them? Or did they simply hire fewer workers because natives were poor substitutes and/or complemented foreign ones? Did the productivity of firms suffer from the reduced number of highly skilled foreigners in a way that all workers' wages and employment were negatively affected? These are questions we can ask using the data from the H-1B lottery in 2007 and 2008 plus the 2009, 2010, and 2011 employment and wage outcomes in labor markets that received larger or smaller negative foreign supply shocks. We describe the data in detail in Section 4 below, but first we show a very simple demand-supply framework to interpret the findings.

[1] See "USCIS Updates Count of FY 2008 H-1B Cap Filings," US Citizenship and Immigration Services, April 10, 2007; and "USCIS Runs Random Selection Process for H-1B Petitions," US Citizenship and Immigration Services, March 31, 2008 (date on press release is clearly wrong).

3 The Effects of a Random Negative Foreign Labor Supply Shock: A Framework

Our empirical analysis organizes the data into metropolitan areas and focuses on computer-related occupations – by far the largest group (65%) of H-1B applications. Computer and Information Technology is the sector in which foreign skilled workers are most crucial. Hence we can think of one observation as a local labor market characterized by a certain demand for foreign born skilled workers (given by their productivity) and a given supply of foreign workers (limited by the availability of H-1B visas that can be obtained by the local firms). While we can generally think of foreign-born labor supply as constrained in the short-term by the limits and quotas imposed by immigration laws, we can consider the lotteries of 2007 and 2008 as producing additional negative shocks to the supply of foreigners, randomly allocated across labor markets.

Let us illustrate the potential effects of such shocks on the wage and employment of native workers in the same labor market (computer occupations in a metro area) under two different assumptions about native workers. In the first case we consider foreign and native computer scientists as perfect substitutes, and we also assume that foreign computer scientists have no effect on firm productivity. In the second case we assume that foreign computer scientists are complementary to native ones and/or that their hiring may have a positive productivity effect on firms and hence increase the productivity of natives as well.

Figure 2 illustrates the first case. It represents the demand and supply for native (left panel) and foreign-born (right panel) computer scientists in one market (metropolitan area). The two types of workers are perfectly substitutable, and hence the demand for natives shifts one-for-one with foreign-born supply. In particular, the vertical axis measures wages per unit of productivity for each type of worker. The demand and supply for foreign computer scientists are represented in the right panel and they cross at the point F_0. Foreign born supply is given by the maximum number of H-1Bs obtainable in that market. The demand for native computer scientists is obtained as the residual for a perfectly substitutable type of worker. Hence at the wage per unit of productivity corresponding to the point F_0, demand for natives will be zero (reported on the left panel) and will increase as the wage decreases.

The equilibrium employment and wage for native workers will be at N_0, the crossing point with the native

supply of computer scientists, with native wages per unit of productivity equal to w_N^0 and employment of natives at E_N^0. Now consider an identical market in which, because of the lottery, D H-1B workers (visas) have been denied. That market will have a foreign-born supply equal to $F - D$ and the equilibrium would be in F_1. This equilibrium implies a corresponding shift up by the amount D of the residual demand for native computer scientists. Demand for natives is now represented by the line DN_1 and hence it would imply higher native employment and wages if the labor supply is upward sloping, or only higher native wages if the labor supply is vertical due to very tight labor markets (as was possibly the case in 2007). Figure 2 implies that the larger is the number of denied visas D relative to the unconstrained supply, the larger native employment would be relative to a market that did not receive rationing ($E_N^1 - E_N^0$), and the larger native wages would be ($W_N^1 - W_N^0$). This stems from the fact that the demand for natives is a residual from the demand for immigrants in the case of perfect substitution.

A very different scenario is depicted in Figure 3. In this case foreign and native computer scientists are not perfect substitutes. Instead, they are differentiated types of workers with the native labor market being characterized by the left panel, and the foreign-born labor market in the right. In this case the demand for native computer scientists, $DN_1(E_F)$, is a function of the employment of foreign computer scientists, E_F, but not in a residual way. In particular, it could be an increasing function of foreign-workers, as depicted in Figure 3, either because the two workers are complementary or because more foreign scientists increase overall firms' productivity. Alternatively, if natives and foreign computer scientists are neither complement nor substitutes, but they are different types of workers in segmented markets, a change in employment of foreign labor may have no effect on employment of native computer scientists (no shift in demand of natives). In Figure 3 we illustrate the case of complementarity – a negative foreign worker supply shock equal to D produces a decline in the demand for natives and possibly in their wages, because the demand for native shifts to the left. The equilibrium for labor markets with larger negative demand shocks (D) implies lower employment and wages for natives.

Observing the employment and wage response of native computer workers in metropolitan areas that had different random negative supply shocks, due to luck in the H-1B lottery, allows us to identify whether foreign skilled workers substitute for natives and are therefore promptly replaced by them in case of rationing, or if

instead they complement/enhance the productivity of natives so that reducing their supply does not help, and potentially hurts, native employment and wages.

4 Data and Empirical Measure of the H-1B Negative Supply Shock

Our data are from three separate sources. Lottery information comes from 2007 and 2008 LCA and I-129 data. Wage and employment information comes from the Census and American Community Surveys from 2000 through 2011.

First we obtained LCA data from the US Department of Labor. The forms include employer name, location (city and zip code), occupation, number of H-1B employees requested, the filing date, work start date, and work end date by year. This dataset helps to identify firm demand for foreign labor. It provides limited information on whether a hired employee would count toward the H-1B quota. Instead, we infer this from firm behavior in 2007 and 2008. Specifically, we assume that in those years, for-profit firms filing LCAs in March or April for September or October start dates are really hoping to hire a cap-dependent H-1B worker to start employment in October of the given year. This method will over-count cap-dependent demand since some firms meeting this criteria could include non-profit firms, firms hiring workers with advanced degrees from US universities, and/or firms that ultimately hire workers who renew their visas or come directly from another US employer.

Our second database includes individual data on processed H-1B visa applications. This data comes from I-129 forms and was obtained from the USCIS through a FOIA. The forms include employer name, location (city and zip code), occupation, and several individual characteristics of the applicant. This dataset helps to identify the capped supply of foreign labor. It provides more information about whether a person would count toward the H-1B quota. First, we assume that prospective cap-dependent employees file I-129 petitions in April preceding the start of the fiscal year. We also assume that employees of colleges, universities, and other non-profit firms are cap-exempt. Since these employees will be dropped from the LCA count, we drop them from the I-129 count as well. Other cap-exempt H-1B workers, since they cannot be identified in the LCA data, remain in the merged dataset. This includes people applying for visa extensions, job changes, and citizens of countries effectively exempt from H-1B limits due to special bilateral trade agreements

(Australians, Canadians, Chileans, Mexicans, and Singaporeans). These two datasets together provide us with a measure of unsatisfied demand for foreign labor. Specifically, we take the number of LCAs filed by for-profit institutions and subtract both the cap-dependent H-1Bs granted and the remaining cap-exempt H-1Bs granted to measure the number of denied visas by the lotteries of 2007 and 2008 (combined).

The first two columns of Table 1 show the distribution of occupations for metropolitan areas in the two years immediately preceding the H-1B lottery.[2] Note that computer-related occupations account for just 3.2% of urban employment, or 7.5% of people employed in occupations included in the H-1B program. Compare these figures to the second two columns, which display the occupational distribution of new H-1B visas issued among those that would have counted toward the quota in April 2007 and 2008. Computer-related occupations account for 65% of those visas, a figure comparable to the 63% of LCAs filed by for-profit firms for computer-related positions. Moreover, foreign-born workers represent a significant share of workers in computer-related occupations. In the 2005 census, nearly 25% of computer-related workers in US metropolitan areas were foreign-born. Altogether, these facts motivate us to focus our analysis on the effects of the H-1B lottery on computer-related occupations across the 236 metropolitan areas considered.[3]

We aggregate all computer-related LCAs filed by cap-bound for-profit employers for the 2007 and 2008 lotteries at the metropolitan area level. We also generate the number of cap-bound H-1B applications awarded in each city. The difference provides a measure of the absolute value of the negative supply shock to computer related occupations in metropolitan area c in 2007 and 2008 (combined). The resulting variable D_c (using the same notation as in Figures 2 and 3) takes values that differ across cities due to different shocks. In order to better capture the impact and magnitude of this random shock on the local market, we scale the absolute number D_c by the initial (pre-lottery) total employment in computer-related occupations in 2005/06 (we average the 2005/06 data in the ACS to have a larger and more reliable sample). Hence, our key explanatory variable is the negative supply shock as percentage of initial employment: $d_c = D_c / Empl_{c,2005/06}$.

Figure 4 provides a histogram of our explanatory variable for cells weighted by firms' aggregate demand for H-1B workers, and omitting an outlying observation (Trenton, NY) whose very large value casts doubts on its accuracy. Normalized negative supply shocks have a weighted mean value of 0.074 and standard deviation

[2] Rural areas are excluded from the analysis and summary statistics.

[3] Unfortunately, extending the analysis to other fields results in small occupation-by-metropolitan area cells with large measurement error and very large amount of noise so we elected not to pursue that avenue.

of 0.039. The unweighted values are 0.015 and 0.028, respectively. Table 2 provides summary statistics using the full sample of 236 cities. Overall, the data demonstrates a great deal of variation. Many cities experience small normalized supply shocks, in part, because they applied for few foreign-born highly-educated workers relative to the overall size of their workforce.

Finally, the third database that we use is the 2000 5% Census and 2005-2011 1% American Community Surveys to construct pre-lottery and post-lottery measures of the relevant employment and wage outcomes of native and foreign-born workers by city.[4] In particular we select civilian employees age 18-65 who do not live in group quarters, are not enrolled in school, and reside in metropolitan areas. Only those who worked in the previous year, earned positive wages, and are currently employed full time (more than 39 weeks per year and 34 hours worked per week) are included. Annual wage outcomes are converted to real 2010 dollars. By creating average wage and employment data at the metropolitan area level and merging it with our LCA and I-129 data, we can assess whether the random negative employment shocks to local labor markets affected outcomes for natives and immigrants working in those markets.

The dependent variables in our regressions use ACS data to construct the growth in employment and wages for different groups that has occurred for computer-related occupations in metropolitan area c since the period immediately preceding the H-1B lotteries. We choose 2005/06 as our base period. Our decision to merge two years helps us create a more representative and larger sample of cities. We then consider the growth rates of employment and wages one year (2008-2009), two years (2009-2010), and three years (2010-2011) after the lottery shocks obtained cumulating the 2007 and 2008 lotteries. We always average two years to have a more precise measure – in order to track outcomes in the short and medium run. While most of the foreign-born workers in computer related occupations have a bachelor's degree, more than 40% of natives did not (in 2006). Thus, it makes sense to consider the outcomes of college-educated and non college-educated natives in these occupations separately. As computer-related non-college educated natives may be doing different types of jobs, their complementarity with foreign-born labor may be relevant.

[4] These are the only recent years that data is available for metropolitan areas.

5 Identification and Power

We rely on the randomness of the lottery results and on the fact that the amount of denied visas was completeley unkonwn to employers ex-ante, in order to identify the causal effect of a negative foreign labor supply shift on the wage and employment outcomes of native computer scientists. We perform two checks before proceeding. While we have no reason to believe that the lottery was nonrandom at the employer level, we aggregate across employer cells of different sizes and confirm that enough variation is left in the explanatory variable and that this variation is random. First, we establish the exogeneity of the negative supply shock by testing whether it is correlated with the pre-lottery growth of foreign-born college-educated workers in computer-related occupations. This should help verify that the lottery outcome is genuinely random and not correlated with pre-lottery trends. Second, we test whether the variation in the lottery results actually does correspond to a change in the post-lottery employment growth of college-educated foreign-born computer-related workers within a city. It is possible that, once denied a new H-1B visa, firms can rapidly lure foreign-born computer scientists away from other firms. They could also seek alternative visas or explore ways to bypass the quota by sub-contracting to a local non-profit lab. Hence, we must check whether the H-1B negative supply shocks are significantly and negatively correlated with the post lottery growth of foreign-born college educated workers in computer-related occupations across cities.

In order to explore these two important facts we estimate the following specification

$$\%\Delta Empl_{c,s-t}^{foreign\text{-}college} = b_0 + \beta \cdot d_c + \varepsilon_c \tag{1}$$

The explanatory variable is the standardized negative H-1B shock in a metropolitan area (c) for computer-related occupations (d_c) as defined above and derived from the LCA and I-129 data. The dependent variable is the growth of college-educated foreign born employment in computer-related occupations in a metropolitan area between year s and t derived from ACS.

Table 3 displays the estimates of the coefficient β from specification (1). When we check that the lottery outcome is uncorrelated with the pre-existing trends in the computer-related occupations across metropolitan areas (Row 1) we set $s = 2000$ and $t = 2005/06$ so that the dependent variable captures the growth of foreign-

born college-educated computer-related employment before the lottery. When we check the power of the random shock to predict foreign employment growth after the lottery we consider $s = 2005/06$ as the base period and t represents one of three post-lottery periods. Rows 2 through 4 alternatively explore periods 2008/09, 2009/10, and 2010/11.[5]

Columns are distinguished by slight variations in estimation strategy. Column (1) provides an unweighted regression. Column (2) weights observations by the number of cap-bound LCAs filed by for-profit firms, and Column (3) weights by the logarithm of this demand variable normalized by year 2000 college-educated native employment. Column (4) again performs an unweighted regression, but drops Trenton, NJ – an extreme outlier in the explanatory variable. All regressions are estimated with heteroskedasticity-robust standard errors.

The results are clear and encouraging. While a significant amount of error is certainly present in measuring the exact employment by cell, we see that all specifications (1)-(4) in the first row show no significant correlation of the random lottery supply shock with the growth of foreign-born employment in the city before the lotteries. The point estimates vary quite a bit across specifications, and the standard errors are large, indicating noise in the data. Nonetheless, there seems to be no systematic correlation of pre-lottery foreign employment growth and lottery outcomes.

Conversely, the H-1B supply shock on growth of foreign-born workers significantly affects the growth in foreign employment from before the lottery to one year after the lottery (2008/09). A negative H-1B shock in a city equal to one percentage point of the existing employment caused a reduction in employment growth of foreign-workers in that cell between 1 and 8.9 percentage points. Using the average estimate (around 5) and converting the effect from number of visas lost into number of foreign jobs, as foreign labor accounted for about 1/4 of total computer-related employment, a loss of one H-1B visa implies about one to one and a quarter fewer foreign worker in those occupations. This suggests that firms did not substitute from foreign workers to other sources when they lost an H-1B visa. The effect seems larger if we do not weight cells and if we omit the outlier. Using estimates of column 4, one lost H1B visa caused up to two lost foreign workers to a firm. Every specification, however, demonstrates a significant slowdown in foreign employment

[5] In the specification with post-lottery changes, we also included the pre-lottery growth of foreign employment as a control. While there was no significant correlation with the lottery outcome, the pre-event variability should be controlled for.

growth when employers experience a larger negative shock in the H-1B lottery. Also, the negative effect on foreign employment growth seems to exhibit some reasonable non-permanent persistence. Two years after the lottery, some cities still show a lower than normal cumulative growth of foreign-born employment, but this is significant only in one case. Three years after the lottery, the point estimate is insignificant, though still negative.

Overall our estimates suggest that employers receiving large negative H-1B shocks were a random group that were hiring foreign-workers at rates similar to those that received smaller negative shocks before the lottery. However, in 2008/09, and possibly still in 2009/10, the negatively affected employers had increased their employment of foreign computer scientists significantly less than those not negatively affected. In term of jobs, they hired between 0.25 and 2 fewer foreign workers for each H-1B visa lost. This is a significant slowdown in foreign employment growth.We now move to consider whether slower growth of foreign-born computer workers meant faster growth of native workers and/or higher wages paid to natives.

6 Empirical Specification and Results

The basic regression that we estimate in order to analyze whether labor market outcomes for native-born computer workers were affected by the lottery supply shocks is as follows:

$$\%\Delta y^{native,j}_{c,2005/06-t} = b_0 + b_1 \cdot \%\Delta y^{native,j}_{c,2000-2005/06} + \beta \cdot d_c + \varepsilon_c \tag{2}$$

In (2) the dependent variable $\Delta y^{native,j}_{c,2005/06-t}$ is measured using the ACS data on the growth of outcome y (alternatively employment, wages, or the total wage bill) for native group j (college-educated and non-college educated) in computer-related occupations in metropolitan area c between the base period of 2005/06 and period t (alternatively 2008/09, 2009/10, and 2010/11). The term d_c captures the negative $H-1B$ supply shock as a percentage of pre-lottery total computer-related employment, described above, and it is our main explanatory variable. As previously argued, the variation of the term d_c is only driven by the randomness of the lottery. Hence it is reasonable to assume that it is orthogonal to other unobserved determinants of $\%\Delta y^{j}_{c,2005/06-t}$ that are captured by the random measurement error term ε_c. However, our regression also

controls for the pre-2006 trend of the dependent variable, $\%\Delta y^{native,j}_{c,2000-2005/06}$. This term is intended to control for past conditions of local labor markets which may have persistent influence. Under these assumption, the Ordinary Least Squares (OLS) estimates of the coefficient β consistently identify the causal effect of the negative supply shocks on the native outcomes. To account for the fact that the variance of the outcomes and the exogenous regressor can be different in small and large cells, we use robust standard errors and, in some specifications, we weight observations by the size of firms' H-1B demand.

6.1 Estimated Effects on Native Employment and Wages

Tables 4, 5, and 6 show the estimated coefficient, β,capturing the effect of a negative H-1B supply shock when the outcome is, respectively, the growth of native employment (Table 4), the growth of native wages (Table 5), and the growth of the overall native wage-bill (total wage income to natives, Table 6) in a city since the pre-lottery year 2005/06. While most immigrants working in computer-related occupations have a bachelor's degree, 40% of the native workers employed in those occupations do not (although they often have some college education). Hence we distinguish between natives with and without a bachelor's degree, as they may be doing different jobs within computer-related occupations (and hence exhibit a different degree of complementarity with foreign-born computer workers). We report outcomes for college-educated natives in the upper part of each table and the outcomes for non-college graduates in the lower part. Different rows display the lottery impact on the cumulative growth of the dependent variable since 2005/06 up to years 2008/09 (i.e., one year after the lotteries), 2009/10 (two years), and 2010/11 (three years).

The estimation results are commensurate with each other. Table 4 describes the results for native computer-related employment. No specification finds a positive and statistically significant native college-educated employment response to the negative random H-1B shock. This is true at one, two, and three years after the lottery. In fact, all but one instance delivers a negative point estimate, several of which are significant (especially those for natives without a bachelor's degree). A random negative shock to H-1B supply equal to 1 percentage point of initial employment is associated with a reduction between 0.4 and 1.3 percentage point of native college graduate employment growth in computer occupations within one to two years of the shock. While the estimates for college graduates are only significant in the case of the weighted

regression, the similar values and repeated negative point estimates suggest the presence of a mildly negative (and certainly not positive) demand shock for native college graduates.

Looking at the effect on non-college graduate natives, evidence favoring a complementarity effect seems even stronger as the majority of the estimates are negative and significant. A productivity explanation is also possible, however, as the negative impact on the demand for native non college graduate computer-workers seem to accrue progressively over time. This could indicate that foregone H-1B visas have had a lasting effect in reducing demand for natives by slowing productivity growth. The median estimate implies that an H-1B decrease equal to 1 percentage point of employment decreases native non-college graduate employment in the computer-related occupations in the city by 4.5 percent.

Figures 5 and 6 help illustrate the connection between the H-1B lottery and native employment. Both figures display scatterplots with normalized negative supply shocks (d_c) on the horizontal axis. The vertical axis represents native employment growth after partialling out the pre-lottery growth occurred between 2000 and 2005/06. For Figure 5, the dependent variable is college-educated native employment growth through 2008/09. For Figure 5, it is non-college-educated native employment growth through 2010/11. Both regressions omit the Trenton, NJ outlier and weight observations by firms' LCA demand.[6] The images help give a visual representation of what the regression results have found: Cities that (by luck) received larger negative shocks (cumulating the 2007 and 2008 H-1B lotteries) experienced lower employment growth among native-born workers in subsequent years. The figures show a small but clear negative correlation. While the figures show that there is a considerable amount of noise, especially for small metropolitan areas, they also show that there is no particular outlier driving the results.

None of the estimates for native college educated employment were positive and significant. One interpretation is that firms did not substitute foregone H-1B workers with natives because in the short run it is hard to replace them. Advocates for visa restrictions to help natives might counter that the increased demand for natives would translate into higher employment only after an extended period of time. While the estimates of employment effects after three years (third row of Table 4) do not show any sign of an increase in native demand, Tables 5 and 6 provide further evidence that the loss of foreign workers fails to lead to

[6] Both graphs also truncate the display to ignore small outliers on the vertical axis that are nonetheless included in the underlying regressions.

a net increase in demand for natives. Table 5 illustrates that even the wage growth of native computer workers (both those with and without a bachelor's degree) was lower in cities with larger negative random H-1B shocks. For college-educated natives the estimates are often significant, especially within 2-3 years from the shock. Again this suggests that losing the H-1B lottery results in a loss of productivity growth that translates into lower wage growth for natives. If a substitution effect exists, it is not strong enough to counter this positive complementarity/productivity effect. No positive impact on native wages is observed. Quantitatively, using the range of estimates from the second row of Table 5, a negative H-1B shock equal to 1% of 2005/06 employment reduced the real wage growth for college educated computer-related native workers between 0.26 and 0.79% in the period 2006-2009. This amounts to a loss in the range of $209-660 per year for that group of native workers (considering an average wage for that group equal to $83,521 in 2006 as measured from ACS data, in 2010 constant $). Using the estimate from row 2 Table 5, there was no effect on wages of non-college native computer workers.

In order to fully capture the effect of the negative lottery shock on the demand for native workers in the presence of vertical, horizontal, or positively sloped native labor supply, one should look at the variation of the total wage bill for that group (namely, the change in combined employment and wages). Table 6 provides these results and confirms that a negative H-1B shock to a city's computer-related workforce has a negative effect on labor demand for native college and non-college graduates in those same occupations. The effect is larger and usually more significant for non-college graduates, but it is never positive even for natives with bachelor's degrees. These results together suggest that a mildly positive productivity effect from the H-1B program may be at work, together with differentiation of jobs between native non-college and college graduates, and complementarity effects with native non-college graduates. Equipped with these estimates we now show calculations of the inferred effects on the number of foregone jobs for native computer workers – both in aggregate and in some important metropolitan areas – due to the 2007 and 2008 H-1B visa lotteries.

6.2 Calculated Native Job-Losses Due to Denied H-1B Visas

The range of coefficients estimated in the previous section allows us to estimate how rationing H-1B visas affected the number of jobs available to natives in computer-related occupations, both in specific metropolitan

areas and among all US metropolitan areas in total (where the vast majority of computer-related jobs are located). To do so, we multiply the number of computer-related H-1B applications that were denied in the lotteries relative to all computer-related jobs in a city (that is, our standardized negative H-1B supply shock) by the estimated effects on native job growth up to 2009/10 in computer-related occupations (as a percentage of 2005/06 native employment) from Table 4. We use the estimates from the second (college educated) and the fifth row (non college educated) of Table 4 and we choose the lowest and the highest estimated coefficients to produce the range of possible employment effects. Then we convert those growth rates into the annual number of native jobs foregone (not created) as a consequence of employing fewer foreign computer-specialists as of 2009/10.

Table 7 summarizes the results from this exercise. The first column shows the pre-lottery average number of computer workers in 2005 and 2006. More than 168,000 computer-related jobs were in New York and more than 54,000 in San Jose. Column (2) displays the average number of computer-related H-1B visas denied in the 2007 and 2008 lotteries. This number, relative to computer-related employment in column (1), provides our measure of the negative H-1B supply shock experienced by each city, as shown in Column (3). The intensity of city's foregone jobs depends upon the scale of the negative shock (which in turn depends on bad or good luck in the lottery) and on the city's reliance upon foreign worker applications relative to total computer employment. New York – a city receiving a rather large supply shock and having a high level of computer-related employment – lost between 8,000 and 28,000 computer-related native jobs (3,800-6,600 for college graduates and 4,000-21,400 for those without bachelor's degrees). Washington DC lost similar numbers, while Chicago lost between 4,500 and 16,600 jobs (2,400-13,000 of which were for non-bachelor's holders). Atlanta had between 3,000 and 11,000 fewer native jobs, while San Francisco and San Jose saw between 1,200 and 4,000 fewer jobs each as consequence of H-1B rationing.

In the last line of Table 7 provides the total numbers for all 236 metropolitan areas in the dataset. The 2007 and 2008 lotteries resulted in 88,000 computer-related visa denials per year. We estimate that by 2009/10, this eliminated an annual 25,000-42,000 additional computer-related jobs for native college graduates, and 35,000-188,000 jobs for natives without bachelors degrees. In total, H-1B restrictions in 2007 and 2008 eliminated 178,000 jobs for foreign computer-related specialists, and between 59,000 and 231,000

computer-related jobs for native-born Americans in US metropolitan areas.

We can also use the estimates of Table 5 to evaluate the wage impact of H-1B rationing on native computer-related workers. We do this only in the aggregate. Using the range of estimates in row 2 of Table 5, we calculate that non-college educated workers did not experience any wage effect (statistically insignificant coefficients), while college educated native computer workers had between 1.02 and 3.2% slower wage growth due to the aggregate H-1B denial rate, which the last row of Table 7 shows was equal to 4.1% of employment. As the yearly wage of college educated native computer workers was about $83,521 in 2006 (measured in 2010 constant dollars), this amounts to a yearly loss between $851 and $2,672 per worker, or between 0.94 and 2.96 billion dollars in aggregate yearly wage income to native woekers. While these calculations are based off several assumptions and therefore should not be taken too literally, they do provide an order of magnitude for the effects and dispel the notion that H-1B foreign workers harm native workers.

We emphasize two points before concluding. First, the native wage and employment effects analyzed here are only part of the consequences generated by foreign skilled workers. Previous research suggests that firm productivity (Peri, Shih, and Sparber, 2013), innovation, and possibly profits (Kerr and Lincoln, 2010) are all positively affected by foreign skilled workers. Moreover, the positive productivity and growth effects for computer-related employment may spill over to other areas of the economy. Here we simply show that among the outcomes that are often considered to be potentially hurt by H-1B workers, no detrimental effects are detected using a credible identification strategy and comprehensive data. Second, the positive surplus identified for natives can be added to the very large surplus (calculated in Clemens 2010) that the H-1B visa produces for wages and the marginal productivity of immigrants, thereby helping to provide a sense of the overall benefit that increased H-1B visas would generate for total productivity.

7 Conclusions

This paper used a simple framework to analyze an important question: If we reduce the number of H-1B visas, will native workers employed in computer-related jobs experience employment and wage benefits, losses, or no effect? We estimate the consequences of a random H-1B visa rationing that took place in April 2007 and 2008 due to excess demand relative to the quota. In those years, some foreign-born individuals

with job offers who requested a new visa were randomly awarded a visa while others were not. By corollary, some firms were randomly unable to employ the individuals they had intended to hire.

We grouped employers of computer-related occupations by metropolitan area. We then estimated the size of the negative lottery rationing in each city and examined the consequences of these shocks on native computer-workers in the same metropolitan area. *A priori*, it is conceivable that native and foreign-born skilled workers are close substitutes. By denying a foreign (H-1B) worker to a firm, the lottery could prompt that firm to search for a similar native worker. If firms hiring foreign workers do so hoping to depress wages, then the unexpected negative shock should push firms to pay native workers more in order to lure them away from competitors. This would imply that the negative H-1B shock should be positively and significantly related to native employment and wages. In other words, a positive value of the estimated effects on native employment and wages would be a sign that immigrants are close substitutes for natives and more immigration would hurt the employment and wage opportunities of natives.

On the other hand, it is also conceivable that native and foreign-born computer workers are complementary, or that foreign-born workers improve the productivity of firms, thereby leading firms to expand their hiring. In this case denying firms the ability to hire foreign workers reduces the need for complementary natives as well. It might also reduce productivity growth and hence employment growth. Demand and wages could stagnate or decline for all workers. Additional H-1B workers would cause firms to expand while native computer specialists would not be crowded out and could even experience improved labor market opportunities. In other words, a negative or zero value of the estimated effects on native employment and wages would be a sign that immigrants complement natives and/or improve productivity, and more immigration would not hurt the employment and wage opportunities of natives.

Our estimates support this second conclusion: Employers of computer-related workers did not hire more natives when the foreign workers they intended to hire were denied H-1B visas. Instead the employment and wages of natives in similar occupations was at best unchanged and at worst harmed. This is consistent with the notion that H-1B workers complement native computer workers and/or increase the productivity of the firm, and that skilled foreign-born workers have improved (or at worst left unchanged) the employment and wage opportunities of natives. Let us emphasize that the evidence found in this study is consistent with

two previous findings. First, Peri, Shih, and Sparber (2013) estimated the effect of foreign STEM workers (driven by H-1B visa variation) on native STEM workers in US cities and they found that for each new foreign STEM worker between 0.5 and 0.6 native STEM jobs are created. The elasticity estimated in this paper would imply on average 0.85 new computer-related jobs for each new H-1B worker, which is somewhat larger but still commensurate with that value. Second, an influential paper by Moretti (2010) shows that each job in the tradable high tech sector generates from 0.5 to 2 additional jobs in the local economy. In this paper we have simply considered the additional within-occupation jobs created by H-1B workers and obtain significant effects. It is possible that a similar effect on jobs spreads from computer-related employment across the rest of the economy so that the overall surplus is even larger than what calculated here.

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Figure 1: Fraction of LCA Applications by Month of Submission, 2005-2008

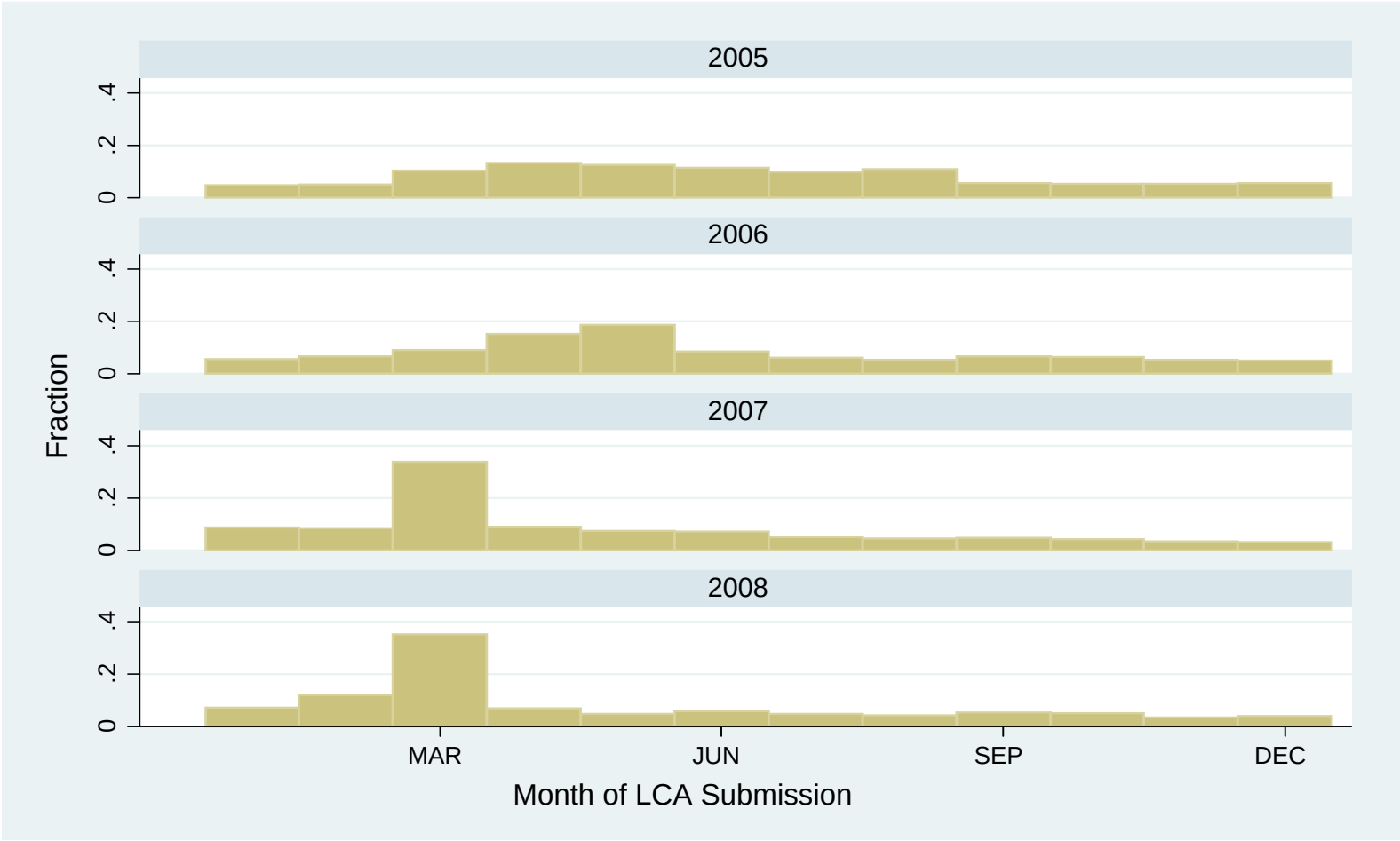


Figure 2
Effect of Negative H-1B Supply Shock when Native and Foreign-Born Computer Scientists are Perfect Substitutes

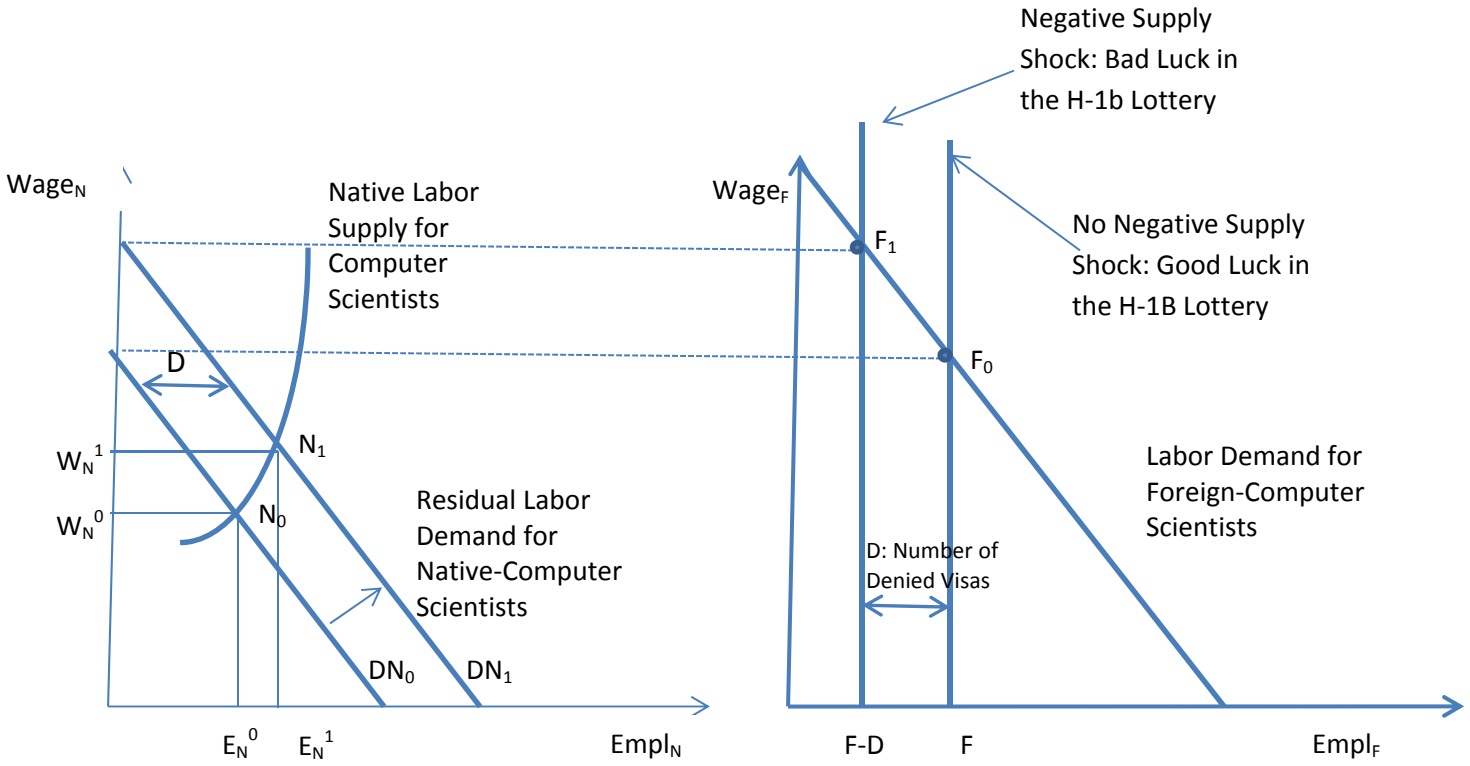


Figure 3
Effect of Negative H-1B Supply Shock when Native and Foreign-Born Computer Scientists are Complements or Have Positive Productivity Effects

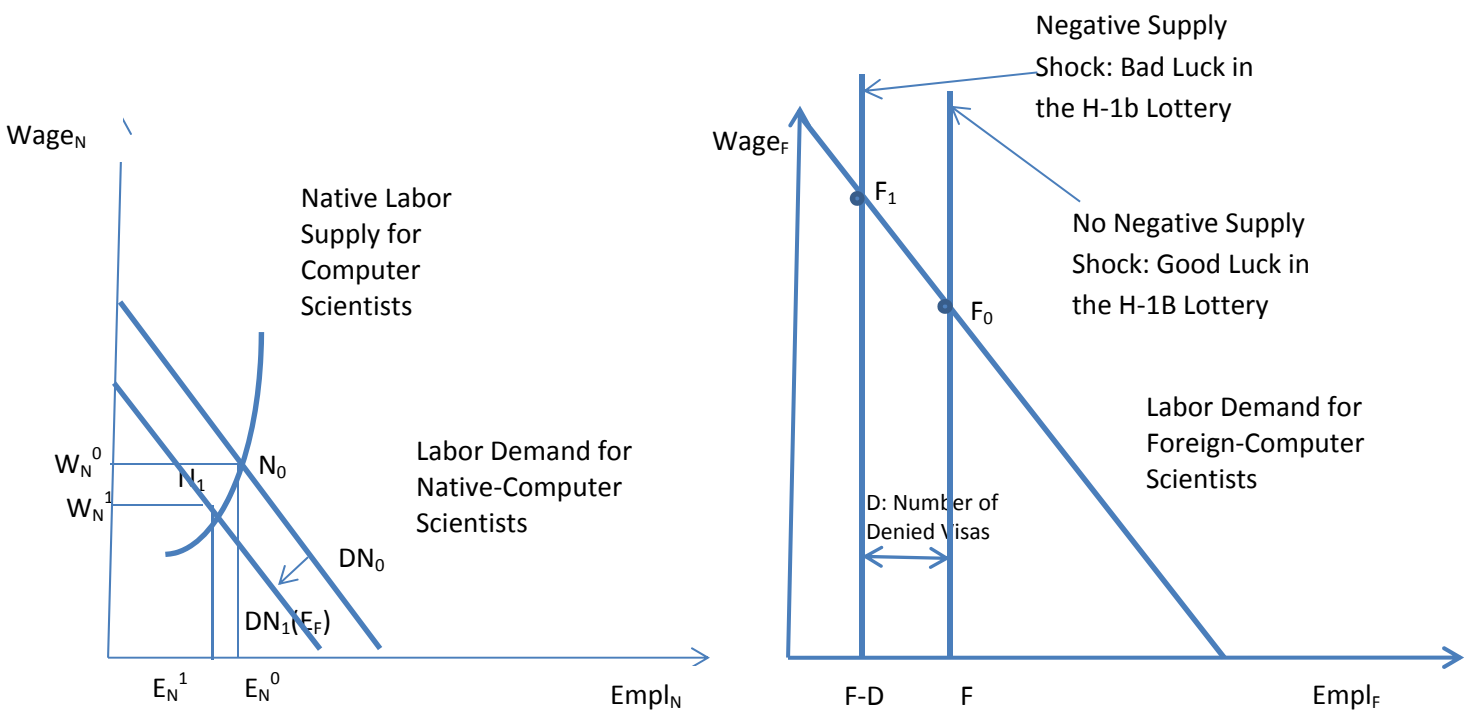


Figure 4

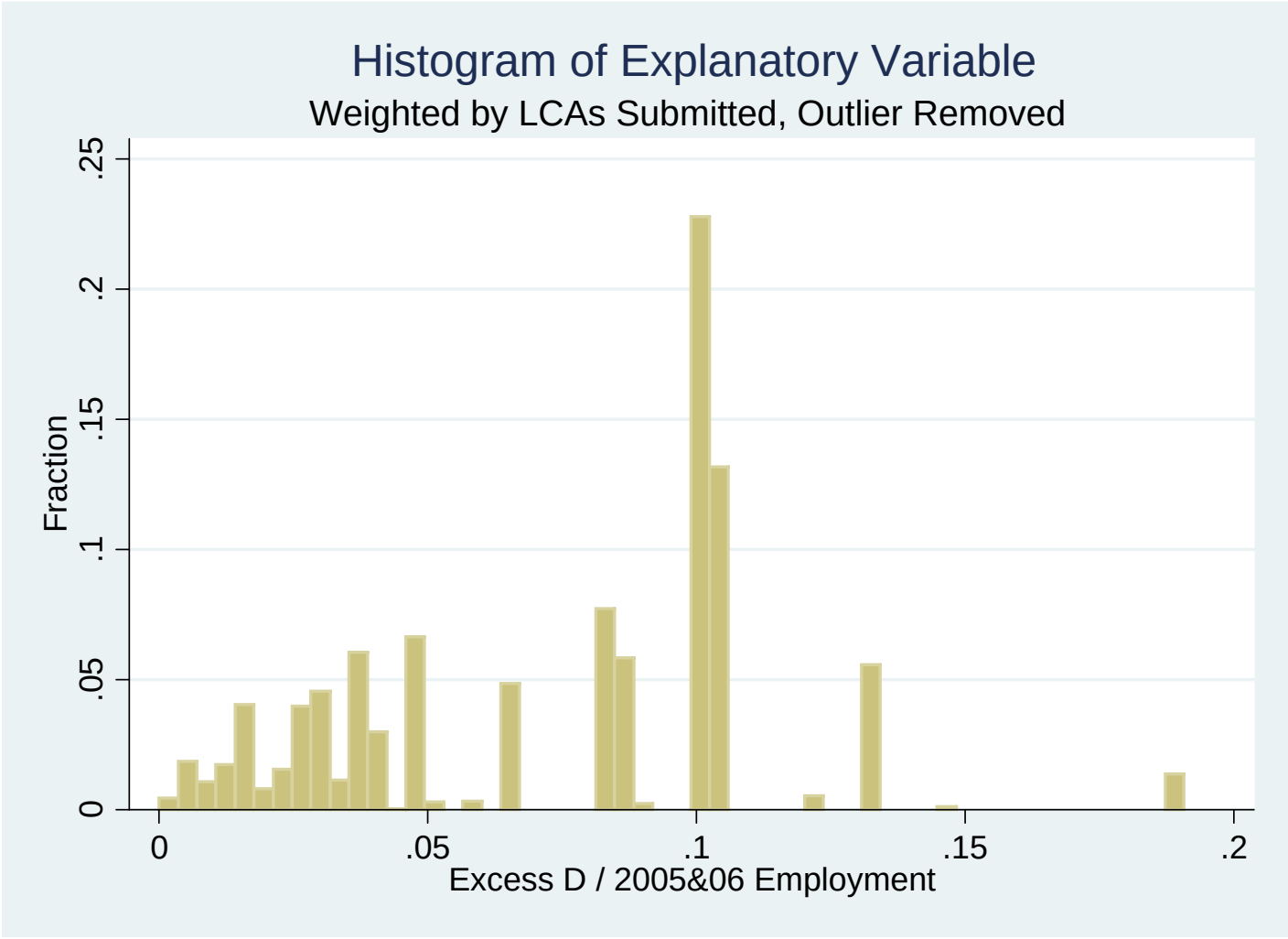
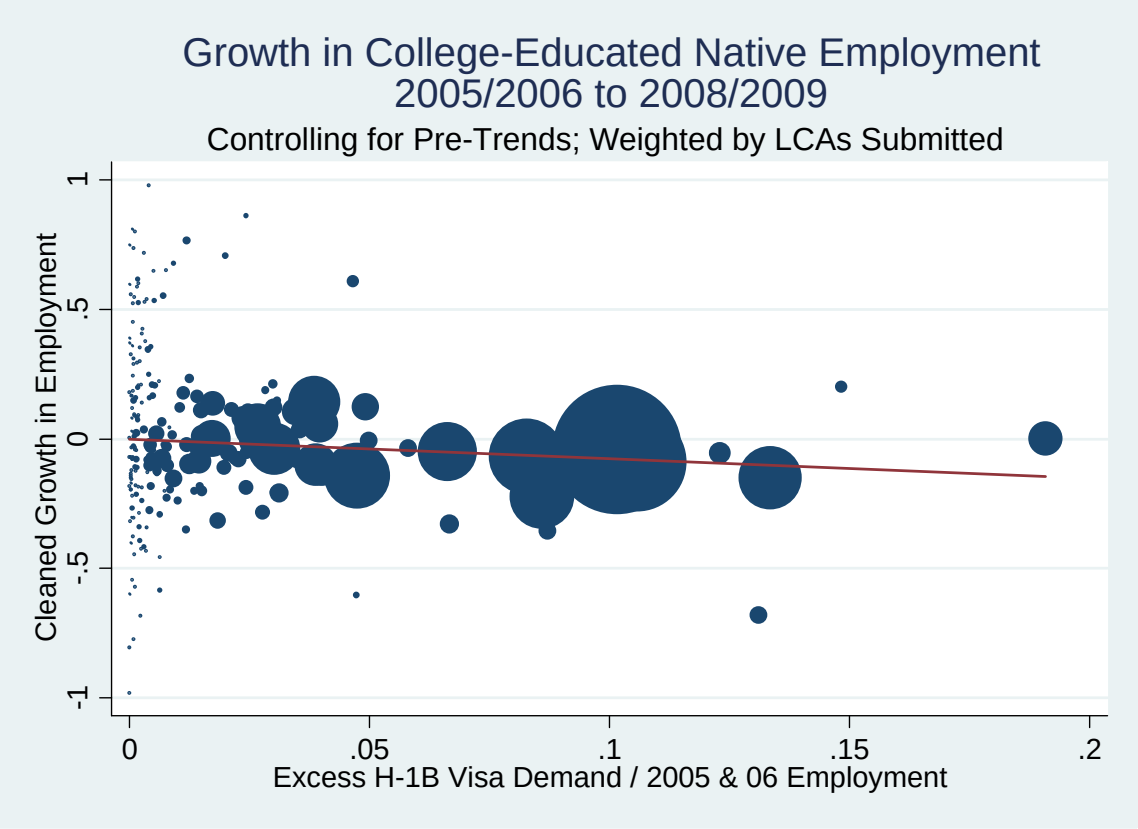
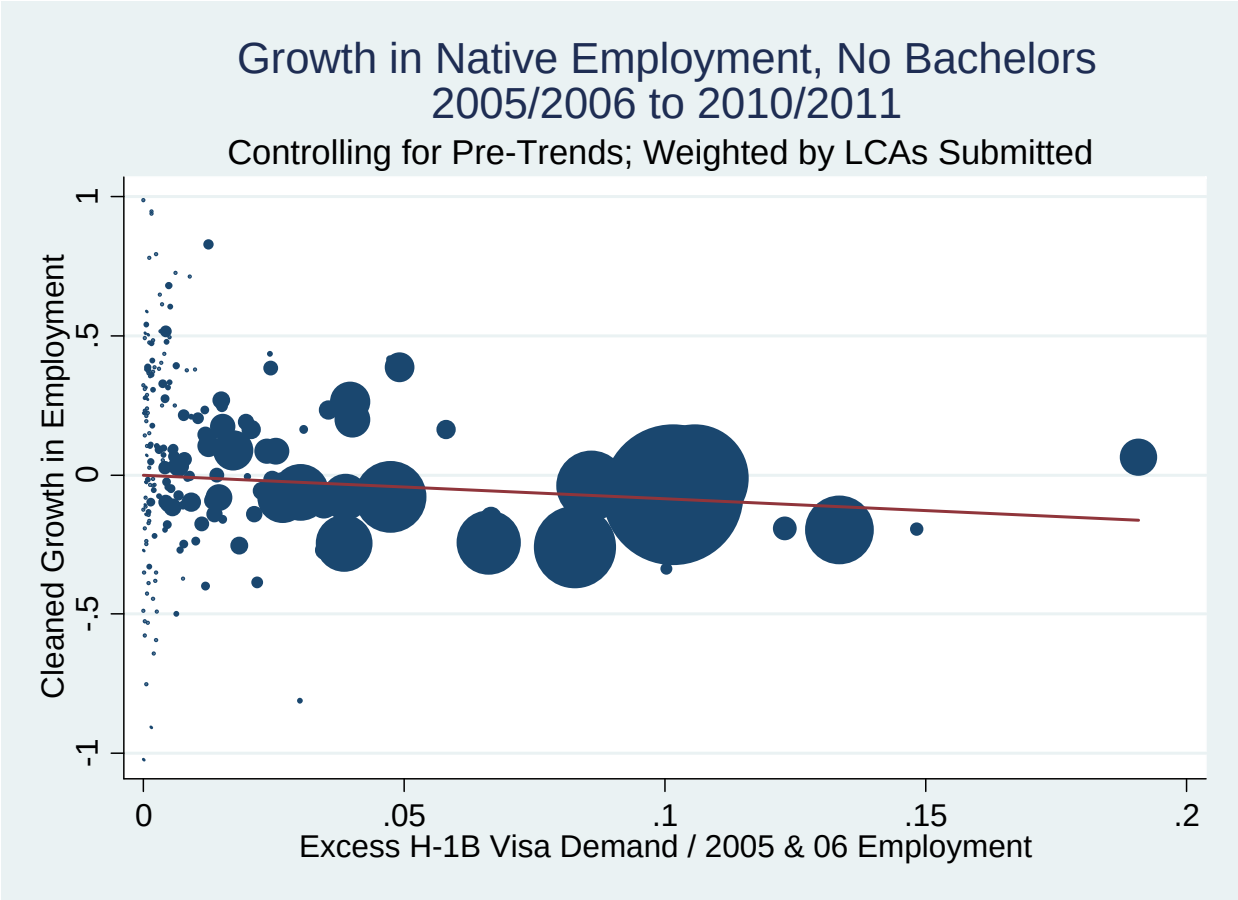

Histogram of Explanatory Variable
Weighted by LCAs Submitted, Outlier Removed
Fraction
0
.05
.1
.15
.2
.25
0
.05
.1
.15
.2
Excess D / 2005&06 Employment

Figure 5



The figure displays results from an underlying regression of Native College-Educated Employment Growth from 2005/06 to 2008/09 on normalized visa demand and pre-lottery native college-educated employment growth. Observations are weighted by firms' LCA demand. The vertical axis represents observed growth values, minus an amount predicted by the pre-lottery control variable.

Figure 6



The figure displays results from an underlying regression of Native Non-College-Educated Employment Growth from 2005/06 to 2010/11 on normalized visa demand and pre-lottery native non-college-educated employment growth. Observations are weighted by firms' LCA demand. The vertical axis represents observed growth values, minus an amount predicted by the pre-lottery control variable.

Table 1: Number of Cap-Dependent H-1Bs Granted by Occupation, April 2007 & 2008

	Average Employment, 2005 & 2006		Cap-Bound H-1B Visas Awarded, April 2007 & 2008	
Occupation Group	*Number*	*Percent*	*Number*	*Percent*
Computer-Related Occupations	2,227,420	3.22	77,977	65.11
Managers, Officials, and Occupations in Administrative Specializations	15,318,099	22.14	13,778	11.50
Occupations in Architecture, Engineering, and Surveying	1,595,252	2.31	13,476	11.25
Occupations in Medicine and Health	3,228,074	4.67	3,127	2.61
Occupations in Mathematics and Physical Sciences	774,037	1.12	2,271	1.90
Occupations in Social Sciences	143,100	0.21	2,218	1.85
Miscellaneous Professional, Technical, and Managerial Occupations	391,230	0.57	1,985	1.66
Occupations in Art	426,014	0.62	1,450	1.21
Occupations in Life Sciences	248,650	0.36	916	0.76
Occupations in Law and Jurisprudence	974,778	1.41	789	0.66
Occupations in Education	3,247,468	4.69	604	0.50
Miscellaneous	517,746	0.75	513	0.43
Occupations in Writing	207,505	0.30	387	0.32
Occupations in Entertainment and Recreation	127,576	0.18	133	0.11
Occupations in Religion and Theology	260,500	0.38	82	0.07
Occupations in Museum, Library, and Archival Sciences	106,016	0.15	51	0.04
Occupations Not Valid for H-1B Program	39,395,775	56.94	0	0.00
Total	*69,189,240*	*100.00*	*119,757*	*100.00*

Note: H-1B data are from the USCIS and include our estimate of all new H-1B issuances subject to the cap, April 2007 & 2008. Estimates exclude workers from Australia, Canada, Chile, Mexico, and Singapore, who have methods of entry to the US workforce that are not subject to the H-1B lottery. Employment data are from the 2005 and 2006 ACS and include full time employees. The table describes visas and employees in metropolitan areas only.

Table 2: H-1B Lottery and Pre-Lottery Employment and Wage Statistics in Computer-related Occupations Across 236 Metropolitan Areas used in Regressions

	Unweighted		Weighted by Firms' LCA Demand	
	Mean	*Std. Dev.*	*Mean*	*Std. Dev.*
Denied Computer-Related H-1B Visas (1000s) in Metro Areas	0.752	3.287	15.088	13.106
Denied H-1B Visas Normalized by 2005/06 Employment	0.016	0.036	0.081	0.059
2005/06 Employment (1000s)	18.545	39.947	173.352	113.334
2005/06 College-Educated Native Employment (1000s)	8.419	17.189	71.645	45.282
2005/06 Non-College-Educated Native Employment (1000s)	5.587	9.630	37.331	21.499
2005/06 College-Educated Native Wage (1000s)	73.914	15.665	90.791	12.192
2005/06 Non-College-Educated Native Wage (1000s)	59.076	12.434	73.499	8.753

Note: The data on denied H-1B computer-related visas are obtained from LCA and I-129 Data by subtracting approved visas from the total number of LCAs submitted by for-profit employers. The remaining statistics on the employment and wages of college and non-college educated natives in2005/06 are from the 1% ACS sample, including only people not resident in group quarters, not in school, age 18-65, who worked at least one week, received positive salary, and resided in a metropolitan area.

Table 3: Negative H-1B Supply Shock (2007-08) and Foreign College Educated Employment Growth as Measured in the ACS.
Computer-Related Occupations Only; Evidence across Metropolitan Areas

	Explanatory Variable: Negative H-1B-Supply Shock Relative to Total 2005/06 Employment (Variable d_c in the Text)			
	(1)	**(2)**	**(3)**	**(4)**
	Unweighted	**Weighted by Firms' H-1B Demand**	**Weighted by ln(H-1B Dependence)**	**Unweighted; Excludes Outlier**
Dependent Variable:				
Pre-Lottery Changes of Foreign College Educated Employees				
Growth Rate between 2000 and 2005/06	-7.986	0.988	-7.161	-12.001
	(5.796)	(1.701)	(5.131)	(8.495)
Post-Lottery Changes of Foreign College Educated Employees				
Growth Rate between 2005/06 and 2008/09	-6.129*	-1.051**	-4.921*	-8.974**
	(3.232)	(0.525)	(2.597)	(4.467)
Growth Rate between 2005/06 and 2009/10	-4.786	-1.258**	-3.733	-6.694
	(2.940)	(0.504)	(2.367)	(4.455)
Growth Rate between 2005/06 and 2010/11	-4.109	-0.940	-3.369	-6.142
	(2.773)	(0.818)	(2.347)	(4.049)

Note: Each cell displays the estimate of the coefficient on the explanatory variable d_c (the negative H-1B shock) from a different regression with the dependent variable described in the first column. Each of the post-lottery regression outcomes includes the pre-lottery trend of the dependent variable. Observations represent metropolitan area characteristics of computer-related occupations. Number of cities range from 179 to 205, depending upon regression. Standard errors are heteroskedasticity robust. Specification (1) includes all observations and does not weight cells, Specification (2) weights for the size of firms' demand for H-1B labor in the cell. Specification (3) weights the observations by the logarithm of firms' demand for H-1B labor, normalized by year 2000 native college employment in the cell. Specification (4) omits an outlier (Trenton, NJ).
*, ** significant at the 10, 5% confidence level

Table 4: Negative H-1B Supply Shock (2007-08) and Native Employment Growth as Measured in the ACS.
Computer-Related Occupations Only; Evidence across Metropolitan Areas

	Explanatory Variable: Negative H-1B-Supply Shock Relative to Total 2005/06 Employment (Variable d_c in the Text)			
	(1)	**(2)**	**(3)**	**(4)**
	Unweighted	**Weighted by Firms' H-1B Demand**	**Weighted by ln(H-1B Dependence)**	**Unweighted; Excludes Outlier**
Dependent Variable:				
Growth Rate of Native College-Graduate Employees				
Growth Rate between 2005/06 and 2008/09	-1.055	-0.582***	-0.971	-1.118
	(0.978)	(0.167)	(0.896)	(1.633)
Growth Rate between 2005/06 and 2009/10	-1.059	-1.031***	-1.015	-0.603
	(0.919)	(0.206)	(0.836)	(1.459)
Growth Rate between 2005/06 and 2010/11	-0.320	-1.312***	-0.403	0.920
	(1.389)	(0.288)	(1.296)	(2.007)
Growth Rate of Native Employees without Bachelor's Degrees				
Growth Rate between 2005/06 and 2008/09	-3.492	-0.148	-3.025	-5.574*
	(2.267)	(0.608)	(2.049)	(3.041)
Growth Rate between 2005/06 and 2009/10	-5.135*	-1.299***	-4.616*	-7.058*
	(2.827)	(0.280)	(2.565)	(4.058)
Growth Rate between 2005/06 and 2010/11	-4.965**	-0.793***	-4.456**	-7.154**
	(2.273)	(0.214)	(2.064)	(2.985)

Note: Each cell displays the estimate of the coefficient on the explanatory variable d_c (the negative H-1B shock) from a different regression with the dependent variable described in the first column. Each of regression includes the pre-lottery trend of the dependent variable. Observations represent metropolitan area characteristics of computer-related occupations. Number of cities ranges from 234-236, depending upon regression. Standard errors are heteroskedasticity robust. Specification (1) does not weight cells. Specification (2) weights for the size of firms' demand for H-1B labor in the cell. Specification (3) weights the observations by the logarithm of firms' demand for H-1B labor, normalized by year 2000 native college employment in the cell. Specification (4) omits an outlier (Trenton, NJ). *, **, *** significant at the 10, 5%, 1% confidence level

Table 5: Negative H-1B Supply Shock (2007-08) and Native Wage Growth as Measured in the ACS.

Computer-Related Occupations Only; Evidence across Metropolitan Areas

	Explanatory Variable: Negative H-1B-Supply Shock Relative to Total 2005/06 Employment (Variable d_c in the Text)			
	(1)	**(2)**	**(3)**	**(4)**
	Unweighted	**Weighted by Firms' H-1B Demand**	**Weighted by ln(H-1B Dependence)**	**Unweighted; Excludes Outlier**
Dependent Variable:				
Growth Rate of Wages Paid to Native College-Graduates				
Growth Rate between 2005/06 and 2008/09	-0.284	-0.153	-0.236	-0.363
	(0.232)	(0.125)	(0.216)	(0.375)
Growth Rate between 2005/06 and 2009/10	-0.626***	-0.258*	-0.554***	-0.789**
	(0.214)	(0.144)	(0.189)	(0.311)
Growth Rate between 2005/06 and 2010/11	-0.568*	0.034	-0.468*	-0.870**
	(0.309)	(0.120)	(0.273)	(0.402)
Growth Rate of Wages Paid to Native Employees without Bachelor's Degrees				
Growth Rate between 2005/06 and 2008/09	-0.530*	-0.113	-0.451*	-0.903***
	(0.287)	(0.134)	(0.262)	(0.317)
Growth Rate between 2005/06 and 2009/10	-0.303	0.100	-0.249	-0.620
	(0.293)	(0.187)	(0.274)	(0.400)
Growth Rate between 2005/06 and 2010/11	-0.189	0.016	-0.172	-0.230
	(0.277)	(0.163)	(0.257)	(0.466)

Note: Each cell displays the estimate of the coefficient on the explanatory variable d_c (the negative H-1B shock) from a different regression with the dependent variable described in the first column. Each of regression includes the pre-lottery trend of the dependent variable. Observations represent metropolitan area characteristics of computer-related occupations. Number of cities ranges from 234-236, depending upon regression. Standard errors are heteroskedasticity robust. Specification (1) does not weight cells. Specification (2) weights for the size of firms' demand for H-1B labor in the cell. Specification (3) weights the observations by the logarithm of firms' demand for H-1B labor, normalized by year 2000 native college employment in the cell. Specification (4) omits an outlier (Trenton, NJ). *, **, *** significant at the 10, 5%, 1% confidence level

Table 6: Negative H-1B Supply Shock (2007-08) and Native Wage Bill Growth as Measured in the ACS.

Computer-Related Occupations Only; Evidence across Metropolitan Areas

	Explanatory Variable: Negative H-1B-Supply Shock Relative to Total 2005/06 Employment (Variable d_c in the Text)			
	(1)	**(2)**	**(3)**	**(4)**
	Unweighted	**Weighted by Firms' H-1B Demand**	**Weighted by ln(H-1B Dependence)**	**Unweighted; Excludes Outlier**
Dependent Variable:				
Growth Rate of Wage Bill Paid to Native College-Graduates				
Growth Rate between 2005/06 and 2008/09	-1.230	-0.708***	-1.071	-1.415
	(1.004)	(0.225)	(0.905)	(1.656)
Growth Rate between 2005/06 and 2009/10	-1.417	-1.247***	-1.292	-1.084
	(0.883)	(0.263)	(0.796)	(1.418)
Growth Rate between 2005/06 and 2010/11	-0.323	-1.341***	-0.361	0.919
	(1.495)	(0.340)	(1.374)	(2.245)
Growth Rate of Wage Bill Paid to Native Employees without Bachelor's Degrees				
Growth Rate between 2005/06 and 2008/09	-3.332	-0.131	-2.886	-5.482*
	(2.191)	(0.670)	(2.041)	(2.964)
Growth Rate between 2005/06 and 2009/10	-4.609	-0.996***	-4.196	-6.559
	(2.812)	(0.365)	(2.635)	(4.199)
Growth Rate between 2005/06 and 2010/11	-4.331**	-0.674**	-3.946**	-6.261**
	(2.034)	(0.284)	(1.901)	(2.825)

Note: Each cell displays the estimate of the coefficient on the explanatory variable d_c (the negative H-1B shock) from a different regression with the dependent variable described in the first column. Each of regression includes the pre-lottery trend of the dependent variable. Observations represent metropolitan area characteristics of computer-related occupations. Number of cities ranges from 234-236, depending upon regression. Standard errors are heteroskedasticity robust. Specification (1) does not weight cells. Specification (2) weights for the size of firms' demand for H-1B labor in the cell. Specification (3) weights the observations by the logarithm of firms' demand for H-1B labor, normalized by year 2000 native college employment in the cell. Specification (4) omits an outlier (Trenton, NJ). *, **, *** significant at the 10, 5%, 1% confidence level

Table 7: Estimated Computer-Related Native Employment Consequences Due to H-1B Rationing

Top 11 Metropolitan Areas in 2009/10

Computed from ACS, Department of Labor, and USCIS Data				*Annual Native Jobs Lost by 2009/10 Due to H-1B Rationing (Calculated from Table 4 Estimates and Average 2005/06 Native Employment)*					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Metropolitan Area	**Yearly Employment, 2005/06**	**H-1Bs Denied per Year by the Lotteries, 2007-2008**	**Normalized Negative H-1B Supply Shock**	**College-Educated**		**No Bachelor's Degree**		**Total**	
				Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
New York-Northeastern NJ	168,330	17,105	0.102	3,790	6,655	3,939	21,400	7,728	28,055
Washington, DC/MD/VA	132,901	14,060	0.106	4,157	7,300	4,219	22,922	8,376	30,222
Los Angeles-Long Beach, CA	89,645	2,401	0.027	483	849	763	4,146	1,247	4,995
Chicago, IL	89,503	7,410	0.083	2,068	3,631	2,395	13,011	4,462	16,642
Dallas-Fort Worth, TX	80,640	3,821	0.047	991	1,740	1,647	8,948	2,637	10,687
San Francisco-Oakland-Vallejo, CA	70,102	2,704	0.039	591	1,038	585	3,181	1,177	4,219
Atlanta, GA	65,672	4,347	0.066	1,274	2,238	1,622	8,814	2,896	11,051
Boston, MA-NH	63,084	1,904	0.030	585	1,027	396	2,149	980	3,176
Seattle-Everett, WA	58,933	1,013	0.017	276	484	313	1,699	589	2,184
Philadelphia, PA/NJ	57,188	2,216	0.039	635	1,115	873	4,744	1,508	5,859
San Jose, CA	54,001	4,641	0.086	748	1,314	437	2,372	1,184	3,685
Total, 236 Metro areas	**2,188,258**	**88,693**	**0.041**	**24,280**	**42,642**	**34,708**	**188,582**	**58,988**	**231,224**

Note: Total computer-related employment is obtained from the 2005-2006 ACS. The number of denied computer-related H-1B visas is calculated as described in the text from LCA and I-129 data from the Department of Labor and USCIS, respectively. The number of computer-related jobs lost by natives is calculated using our estimates of the native employment growth impact of the negative H-1B shock from Table 4, second and fifth row. We multiply that effect by the initial computer-related employment in the metropolitan area and we obtain the estimated number of jobs lost.