

Substitution between Groups of Highly-Educated, Foreign-Born, H-1B Workers*

Chad Sparber (Colgate University)

August 2018

Abstract

Highly-educated foreign-born workers can secure legal US employment through the H-1B program. The annual cap on H-1B issuances varies across individuals' US educational experience, H-1B work history, and employer type. Caps are met quickly in most but not all years. This paper exploits these differences to identify whether firms substitute across different sources of highly-educated, foreign-born, H-1B labor. New H-1B workers without advanced degrees from US universities substitute with new H-1B workers possessing advanced US degrees. We find no evidence for substitution with established H-1B workers.

Key Words: Skilled Workers, H-1B Status, Immigration.

JEL Codes: J61, F22

*Address: Chad Sparber, Department of Economics, Colgate University, 13 Oak Drive, Hamilton, NY 13346, csparber@colgate.edu. The author is grateful for funding provided by the National Science Foundation, grant 1535580.

1 Introduction

The H-1B program allows US firms to temporarily hire foreign-born workers in occupations that require highly specialized knowledge. The program is controversial among economists, policy-makers, and the public. On the one hand, it might allow firms to engage in economic activity that would be impossible to pursue through domestic labor alone. Moreover, H-1B workers tend to work in Science, Technology, Engineering, and Mathematics (STEM) fields that are responsible for much of the country's technological and productivity growth. On the other hand, some worry that foreign workers are perfectly substitutable with native-born Americans and therefore reduce domestic wage and employment opportunities. Partly in response to these concerns, current policy limits the number of new H-1B workers that can be hired each year. This policy presumes that when firms face restrictions to hiring new H-1B workers, they will substitute toward US labor sources. Less-considered is the possibility that firms will substitute toward other production inputs such as alternative sources of foreign labor.

This paper does not assess how immigration affects native-born workers. Rather, it uses triple-difference estimation and administrative H-1B data to analyze how H-1B caps affect wage offers to H-1B recipients. Theory predicts that H-1B restrictions will cause wage offers to substitutable foreign labor inputs to rise so long as their labor supply is not perfectly elastic. By examining the wage effects induced by H-1B caps, this paper therefore provides a unique methodology for identifying whether firms substitute between different subsets of highly-educated foreign-born workers

The paper's identification strategy is driven by H-1B program design. H-1B status is awarded to individuals (not firms) for up to a three year period and is renewable to a total of six years. Current policy allows 65,000 new H-1B issuances to employees of for-profit firms per year. An additional 20,000 issuances are available for individuals who have obtained a masters degree or more education from a US university. After the date on which the "general" 65,000 quota has been filled (that is, the last date of receipt, or LDR), for-profit firms wanting to hire an H-1B worker face limited options. Two potential sources include new workers with advanced US degrees so long as the 20,000 "advanced" quota has not yet been met, and established H-1B workers currently working at for-profit firms. In contrast, prospective employees of colleges, universities, and

other non-profit research institutions (henceforth “non-profit” firms) are exempt from H-1B quotas.¹ Program design therefore segments individuals who possess otherwise-similar education, skills, ethnic heritage, and other characteristics into separate markets: Highly-educated foreign-born workers seeking to enter the US labor market through H-1B employment at non-profit institutions can be hired at any time. Similar workers seeking first-time H-1B employment at for-profit firms can do so only if permits are still available.²

H-1B policy, coupled with administrative data on accepted H-1B job offers approved by United States Citizenship and Immigration Services (USCIS) acquired through a Freedom of Information Act (FOIA) request, provides a natural experiment for identifying how policy-induced scarcity affects wages paid to H-1B workers. *A priori*, simple difference-in-difference methodology would seemingly be appropriate. Filled H-1B job offers (i) on date (t) could serve as the unit of observation. Offers from for-profit firms would serve as the treatment group; offers from non-profit research firms would be the control. The treatment occurs after the LDR when for-profit firms wanting to hire H-1B workers face limited options.

Unfortunately, however, standard difference-in-difference estimation is not possible. The filing period for new for-profit H-1B status fluctuates according to demand, implying that permit scarcity is particularly acute in some years. Quotas pertain to fiscal years (which begin on October 1), but an individual can apply for H-1B status up to six months in advance (April 1). Table 1 illustrates that prospective employees of for-profit firms had more than four months to secure an H-1B permit for fiscal year (*FY*) 2006. In 2007, that period reduced to just 56 days. The shortage was so severe for fiscal years 2008, 2009, and 2014 through the present that the number of applications exceeded the number of available permits during the first week of the filing period and all permits were distributed by random lottery. These regularities lead to several limitations of difference-in-difference estimation. First, full-lottery years cannot be used in difference-in-difference panel analysis because wage offers are only observed on the LDR, not before or after that date. Second, fluctuation in H-1B scarcity suggests that the value of H-1B status could vary across years – the LDR might have little effect on H-1B offers during years in which it occurs late in the application period. Third, firms and individuals anticipate the LDR. This might affect wage offers around the LDR so that no discrete before-and-after date can be used in estimation.

¹In this non-profit / for-profit dichotomy, employees of non-profit firms that do not conduct research are bound by H-1B restrictions, and are therefore classified as for-profit.

²Note that workers transitioning from non-profit to for-profit employment for the first time are subject to the H-1B cap.

This paper instead adopts an estimation approach that emphasizes graphical illustration of wage offers to H-1B workers near the general LDR of FY 2007 relative to the same date one year prior (i.e., offers for FY 2006). Since policy and other factors could act to alter the composition and quality of H-1B hires after the last date of receipt, it is important for the analysis to be conducted for narrowly-defined groups of workers that nonetheless exhibit enough data variation to facilitate meaningful statistical identification. This paper examines two groups consistent with the ones discussed above: new H-1B workers with advanced degrees from US colleges and universities and established H-1B workers without advanced US degrees who have demonstrated US work experience.

Figures 1 and 2 provide descriptive evidence and motivation for pursuing this approach. The horizontal axes represent the number of days since April 1, the first date in the H-1B application period for the following fiscal year. Vertical axes display the cumulative moving average wage of H-1B job offers – cleaned of covariate effects such as age and education – relative to the final average wage in 2006.³ Each graph displays trends separately for fiscal years 2006 and 2007 (or, equivalently, calendar years 2005 and 2006) to illustrate how the average wage of a fiscal year cohort of workers evolves over the application period.⁴

Figure 1 provides evidence for new H-1B workers with an advanced US degree. The left panel graphs trends for for-profit firms, while the right does so for colleges, universities, and non-profit research institutions. Wage offers from for-profit firms are high at the start of the application period in both fiscal years, but average wages decline in subsequent weeks. Fiscal year 2007 saw a pronounced reversal with rising wages near May 26, 2006 – the last date of receipt for the 65,000 general H-1Bs in that year. These high premiums eventually subsided, but the cumulative average wage offer – unexplainable by covariates – was about 4% above that of similar workers for FY 2006 by the time the last date of receipt for advanced degree recipients was reached on July 26, 2006. Importantly, the right panel demonstrates no such behavior for US advanced degree recipients with job offers at non-profit firms.

Figure 2 illustrates cumulative average wage for job offers to established H-1B workers without an ad-

³To compute these values, we first regress individual wages on indicators for age, education, field of study, occupation, birth country, city of residence, and date. We then calculate the cumulative wage attributable to date and the regression residual, divided by the average wage paid to the particular group of H-1B workers in fiscal year 2006.

⁴We prefer cumulative wage figures to either simple average wage or moving average wage graphs. Cumulative wages are more illustrative of trends in typical behavior than these alternatives. The former would exhibit tremendous day-to-day volatility obscuring trends. The latter would not reflect changes in overall average wages driven by fluctuations in the volume of H-1B issuances. Cumulative wages reflect both price (wage) and quantity (employment) effects and are less susceptible to swings in value attributable to just a few individuals.

vanced US degree. These workers can be hired at any time in the year. Trends for fiscal years 2006 and 2007 mirror each other at both for-profit and non-profit firms and are relatively stable. This suggests that effects of H-1B restrictions could be different for new and established H-1B workers.

The empirical analysis in the following sections will more formally analyze the phenomena illustrated in these figures through the context of economic theory and regression analysis. The evidence argues that as the general H-1B cap was reached for FY 2007, the for-profit wage premium associated with offers to advanced US degree holders rose 5% relative to the prior year. This implies that firms substituted toward these workers when foreign labor without advanced US degrees became unavailable. Conversely, regressions find no evidence that firms responded to the general cap by substituting toward established H-1B labor.

Importantly, regression estimates are stable across different empirical strategies. Robustness checks reveal that the main conclusions are insensitive to the inclusion/exclusion of groups over-represented in the H-1B program (namely, Indians and computer-related workers), countries whose citizens have viable H-1B alternatives, and employees of firms that might use the H-1B program to facilitate offshoring activities. Results are further reinforced in regressions using fixed effects to control for firm-level idiosyncrasies. These checks help to ensure that wage estimates reflect price effects generated by H-1B scarcity and not changes in the quality or characteristics of foreign-born workers or the firms hiring them. The next section provides a more detailed discussion of the H-1B program and the related literature. Subsequent sections develop a theory, describe the data, perform the empirical estimation, and conclude.

2 Motivation

The H-1B program is an important channel through which highly-educated foreign-born individuals obtain legal employment in the United States. To secure H-1B status, an individual must first obtain a job offer from a firm possessing an approved Labor Condition Application (LCA) attesting that the foreign employee will not earn less than the prevailing wage. The firm then files an I-129 petition to USCIS to secure H-1B status for the worker. Individuals seeking H-1B status to work at a for-profit company for the first time are subject to a cap on new issuances. Individuals seeking to change jobs, renew employment, or work for colleges, universities, and other non-profit research institutions are not. Applications received on the

last date of receipt (when the number of applications for new for-profit employment exceeds the number of available permits) are processed and approved by random lottery. All new permits were allocated by lottery in fiscal years 2008, 2009, and 2014 through the present. Regardless of the specific year, for-profit firms are constrained on the sources of potential H-1B workers they can hire after the LDR.

Economists debate the effects of highly-educated foreign-born workers on American labor markets and the economy. In a simplified textbook supply and demand setting, an increase in the supply of laborers possessing a particular set of skills (college-educated foreign-born labor, for example) should decrease the wage paid to similar workers in the short run (college-educated native-born labor, for example). Indeed, this is what Borjas (2003, 2013) argues when he finds that immigration has substantially reduced wages paid to native-born workers with similar education and experience levels. However, many economists contend that immigration has only a negligible – or perhaps even positive – effect on labor market outcomes for native-born workers.

For this to be true, the textbook supply and demand model would have to be missing some important nuance. At least three possibilities have been proposed: The first – expressed in Ottaviano and Peri (2008, 2012), Peri and Sparber (2009, 2011), Amuedo-Dorantes and De La Rica (2011), and Manacorda, Manning, and Wadsworth (2012) – is that immigrants are imperfectly substitutable with natives of similar educational attainment because the two groups supply differentiated skills. This helps protect native-born workers from labor market competition and wage losses.⁵

The second – perhaps unique to the market for highly-educated workers – is that highly-educated immigrants generate long-run productivity gains and economic growth. For example, Jones (2002) argues that scientists, engineers, and research and development activities are essential in creating growth-promoting technological spillovers. If true, then the consequences of highly-educated foreign-born labor inflows are not governed solely by potential skill-complementarities; such inflows also expand a scarce resource with positive externalities. Whether this occurs is another source of contention. Evidence that immigrants generate productivity gains can be found in Hunt and Gauthier-Loiselle (2010), Kerr and Lincoln (2010), Peri, Shih, and Sparber (2015a, 2015b), and Moser, Voena, and Waldinger (2014). Evidence for nonexistent or negative

⁵See Borjas, Grogger, and Hanson (2008, 2011) for studies challenging this conclusion.

effects can be found in Borjas (2009), Borjas and Doran (2012), and Doran, Gelber, and Isen (2014).

A third possibility is that firms respond to immigration shocks by substituting toward or away from many production inputs. For example, Ottaviano, Peri, and Wright (2013) and Olney (2012) examine offshoring activities. Firms seeking foreign labor might employ such workers domestically or at operations abroad, whereas native-born workers might or might not enter into that decision-making process. A positive migration shock might therefore simply cause firms to substitute away from offshoring operations. Similarly, Lewis (2011, 2013) argues that firms respond to immigration by adjusting their capital and technological processes to suit the workforce's skills. These types of adjustments serve to mitigate native-born labor market responses to foreign-born labor shocks.

This paper is most directly related to this third strand of the literature. Comparatively little work has examined how immigration affects wages paid to immigrants. More precisely, economists have limited understanding of whether firms substitute particular groups of foreign-born labor for others. Many well-known studies including those cited above assume that workers are perfectly substitutable within nativity and skill groupings. If that assumption is invalid, then it will impede economists' ability to recognize the full ramifications of policy attempts to curb new immigration inflows.

Typical approaches to assessing labor substitutability or the macroeconomic consequences of immigration might directly estimate how an increase in the foreign-born share of the labor force affects native-born workers' skills, wages, or productivity. Alternatively, they might measure how the relative supply of native and foreign labor affects relative wages. Scholars' methodological choices have led to differing conclusions and have fueled much of the academic debate. No one methodology is immune to criticism. Spatial analyses performed across regions (Card (2009), Peri, Shih, and Sparber (2015b)) are subject to omitted variables and reverse causality concerns even when they employ instrumental variable strategies and thorough robustness checks.⁶ National-level analyses that group workers into education and experience skill-cells (Borjas (2003, 2013), Ottaviano and Peri (2012)) are sensitive to decisions about how those cells are constructed, result in a small number of observations, and require assumed parameter values to infer general equilibrium results. A promising new line of research is exploiting variation caused by H-1B lotteries (Doran, Gelber, and Isen

⁶See Jaeger, Ruist, and Stuhler (2018) for a recent critique of the shift-share instrument commonly used for identification in cross-region analysis.

(2014), Peri, Shih, and Sparber (2015a)), but this approach must respond to challenges regarding sample size, coverage, and true randomness.

This paper provides two important contributions to the literature. First, it fills this gap by assessing whether firms substitute between groups of H-1B workers. It uses administrative data on accepted H-1B job offers to explore how capping the supply of new, highly-educated, foreign-born, H-1B workers at for-profit firms affects the wage paid to other H-1B workers that for-profit firms can hire. *A priori*, the sign on this effect is ambiguous. The cap on new H-1B employment will cause wages of substitutable labor groups to rise. This is the effect presupposed by H-1B opponents who argue that H-1B workers substitute for underemployed native-born skilled labor. But substitutable groups might include foreign-born labor sources as well. Conversely, the cap on new H-1B employment will cause wages of complementary labor groups to fall. This is the effect more consistent with economists who hold more sanguine views on the effects of immigration on native-born workers. Second, it performs this analysis by relying upon a unique approach to assessing substitution. Rather than rely upon spatial analysis, variation across skill groupings, or small lotteries, the analysis in this paper uses triple difference estimation and administrative data on job offers. Identification is driven by policy and aggregate H-1B scarcity – factors exogenous to firms.

Though these innovations contribute to the literature, it is important to acknowledge the limitations of the empirical approach as well. One disadvantage is that the methodology can only use wage data to assess whether firms are substituting across different groups of H-1B workers. It is not suitable for providing specific elasticity of substitution parameter estimates. Quantity responses cannot be measured: New employment of H-1B workers with advanced US degrees is capped and time invariant (on an annual basis for the time period considered), and a single established H-1B worker could accept multiple job offers in any given year. A second drawback is that the data is limited to administrative information on H-1B job offers. Thus, it is not possible to estimate wage effects or substitutability for other labor groups including native-born employees and alternative foreign-labor sources such as recent foreign-born graduates of US universities on OPT status or employees of firms with a presence in multiple countries who can work in the US on L status. A third is that the analysis relies on evidence from a brief time period, thus making it difficult to say anything definitive about external validity to other years.

A larger area of concern is that the analysis assumes a competitive marketplace in wage determination, but there are at least four reasons to believe that the H-1B program might limit the mobility of highly-educated foreign-born workers even though an existing H-1B employee can legally change employers. First, firms might be deterred from hiring H-1B workers due to fees that could cost employers more than \$2000 in 2007.⁷ Second, the USCIS website notes that “there is no automatic 10-day or other grace period for terminated employees holding H-1B status, so once the individual is no longer in a lawful nonimmigrant status, he/she usually must depart from the United States.”⁸ Thus, workers face huge risks from potential unemployment spells. Third, the H-1B program allows firms to sponsor their employees for permanent residency (a green card), and a worker might not want to jeopardize this possibility by exploring new employment opportunities. Finally, H-1B status is temporary in nature, thereby decreasing the time available to look for new work. All of these characteristics combine to reduce mobility and have led critics to call the H-1B program a form of “indentured servitude” (Hira 2010, Matloff 2013). Such market power would allow firms to systematically underpay H-1B workers and undercut the wages for similarly-skilled native-born workers.

Again, mixed evidence on market power and mobility exists. Recent work by Mukhopadhyay and Oxborow (2012) estimates that green card holders earn a massive 25% wage premium over foreign-born temporary workers. One might surmise that this is a result of vastly underpaying immobile temporary workers (see such arguments in Center for Immigration Studies Backgrounders by Miano 2007 or Matloff 2008, for example). However, alternative analyses suggest that H-1B workers are reasonably mobile and well-paid. In terms of mobility, Depew, Norlander, and Sorensen (2013) find that “during periods of full employment, inter-firm mobility [of Indian Information Technology H-1B workers] is comparable to other estimates in the literature obtained from presumably more mobile workers in other labor markets, suggesting that competitive market forces provide some check against firms dramatically underpaying these workers.” In terms of wages, Lofstrom and Hayes (2011) find that although H-1B workers earn 3.1% to 11.6% less than US-born workers within STEM fields, the regularity reverses itself when controlling for age, educational attainment, occupation, and industry. Conditional on these factors, new H-1B workers in Information Technology earn a 6.7%

⁷Fee schedules are available in I-129 instructions and G-1055 forms. Revised forms for July 30, 2007 require a minimum \$320 filing fee plus additional funds that vary depending upon a firm’s type, usage of the H-1B program, and possible fraud prevention fee. Depew, Norlander, and Sorensen (2013) note that in 2013 fees rose to between \$2000 and \$5225 and that “the forms required have an estimated paperwork burden of 3 hours and 45 minutes.” The Labor Condition Application, cited above, is a related form required to hire an H-1B worker. However, there are no filing fees with this form.

⁸See USCIS (2010).

wage premium, and the premium nearly doubles to 11.7% for H-1B renewals.

In the context of this paper, limited H-1B mobility across firms could bias wage estimates toward zero. One might suspect that this would be less likely to play a role in determining initial wage offers to new H-1B applicants who would be eager to work for firms offering the best job match, and more likely to affect wage offers to established workers wishing to continue steady US employment. Despite this and other potential challenges, however, the data and empirical methodology provide an opportunity to analyze the important but under-explored issue of foreign-labor substitutability from a unique perspective.

3 Theory

This section provides a simple theory of production in a perfectly competitive environment to provide context for the empirical results. Suppose firm output (Y) is characterized by the following constant elasticity of substitution production function:

$$Y = \left(\beta \cdot H^{\frac{\sigma-1}{\sigma}} + (1-\beta) \cdot L_3^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

$$\text{where } H = \lambda \cdot L_1 + (1-\lambda) \cdot L_2$$

In this setting, L_1 , L_2 , and L_3 are three separate groups of workers that a firm expects it will be able to hire. L_1 and L_2 are perfectly substitutable with each other and combine to create a composite labor input H , with λ representing the relative importance of the first labor group. This composite input combines with L_3 to generate firm output according to the constant elasticity of substitution function in (1). β describes the relative weight of H and L_3 in production, while $\sigma \in (0, \infty)$ governs substitutability: H and L_3 are perfect complements if $\sigma = 0$ and perfect substitutes if $\sigma = \infty$.

Firms seek to maximize output for a given year based on the number of workers it expects to hire. They

pay a wage (w) equal to a worker's marginal product of labor. Mathematically, the three labor groups earn:

$$\begin{aligned} w_1 &= \lambda \cdot \beta \cdot \left(\frac{Y}{H}\right)^{1/\sigma} \\ w_2 &= (1 - \lambda) \cdot \beta \cdot \left(\frac{Y}{H}\right)^{1/\sigma} \\ w_3 &= (1 - \beta) \cdot \left(\frac{Y}{L_3}\right)^{1/\sigma} \end{aligned} \tag{2}$$

Since production in (1) exhibits constant returns to scale in its labor inputs, the share of income paid to labor will sum to one. The income shares paid to H , L_1 , L_2 , and L_3 are characterized by:

$$\begin{aligned} H &: \eta = \beta \cdot \left(\frac{Y}{H}\right)^{\frac{1-\sigma}{\sigma}} \\ L_1 &: \eta \cdot \phi = \beta \cdot \left(\frac{Y}{H}\right)^{\frac{1-\sigma}{\sigma}} \cdot \frac{\lambda \cdot L_1}{H} \\ L_2 &: \eta \cdot (1 - \phi) = \beta \cdot \left(\frac{Y}{H}\right)^{\frac{1-\sigma}{\sigma}} \cdot \frac{(1 - \lambda) \cdot L_2}{H} \\ L_3 &: \theta = (1 - \beta) \cdot \left(\frac{Y}{L_3}\right)^{\frac{1-\sigma}{\sigma}} \end{aligned} \tag{3}$$

News about the aggregate availability of workers can change expected employment for the firm. Let us interpret L_1 as new H-1B workers without an advanced US degree. News in April and May of 2006 suggested that firms would see a bigger, exogenous, negative supply shock for FY 2007 than they had previously anticipated. We can interpret this as an unexpected decline in L_1 and this information can identify whether other subsets of H-1B workers are more like group L_2 or L_3 . To do so, calculate the elasticity of wages with respect to L_1 :

$$\frac{d \ln(w_2)}{d \ln(L_1)} = \frac{-(1 - \eta) \cdot \phi}{\sigma} < 0 \tag{4}$$

$$\frac{d \ln(w_3)}{d \ln(L_1)} = \frac{\eta \cdot \phi}{\sigma} > 0 \tag{5}$$

Expression (4) implies that if news reveals that the supply of L_1 available to the firm has been reduced, then the wages of perfectly substitutable workers in L_2 will rise. Expression (5) implies that the wages of complementary workers in L_3 will fall. If all groups are perfectly substitutable with each other, then $\sigma = \infty$

and all wage effects approach zero.

Two groups of H-1B workers that could be hired after the general LDR for FY 2006 were new H-1B workers with advanced US degrees and established H-1B workers without advanced US degrees. Whether firms substituted toward these two groups when they were no longer able to hire new H-1B workers without advanced US degrees is an empirical question. The analysis below will ascertain whether substitution occurred by identifying the wage consequences that arise when news of impending limits on new H-1B hiring are approaching. In the context of the perfectly competitive theoretical model developed in this section, the wage effects identify whether labor groups are substitutes or complements. One caveat to that interpretation, however, is that empirical estimates will be biased toward zero in non-competitive environments that limit labor mobility across firms. In that case, regressions identifying wage gains would continue to signal that substitution occurred, but null results should be interpreted simply as lack of evidence for substitution as opposed to proof that groups are complementary.

4 Data

Foreign-born specialty workers seeking H-1B status for new or continuing employment must have first obtained a job offer from a US firm and then submitted an I-129 petition to USCIS. The I-129 form contains a wealth of information about the individual (e.g., country of birth, education level, etc.) and the job offer (e.g., the wage, occupation, etc.). A FOIA request provided individual-level I-129 data. This paper refers to these forms as filled job offers (i), and they serve as the unit of analysis.

One limitation of the data is that although it provides the date (t) on which USCIS received the I-129 petition, the date on which work is scheduled to begin is unknown. However, numerical limits on new permit issuances apply to fiscal years, which begin on October 1. Petitions can be filed as early as six months in advance of the start date. Given the popularity of the H-1B program, this implies that USCIS receives a flood of H-1B applications beginning on April 1. Motivated by this regularity, this paper assumes that all petitions filed in April through September are for the fiscal year that begins in the following October.

The empirical exercise will identify effects based off of differences between fiscal years 2006 and 2007 (that is, H-1B hiring activity in April through September of calendar years 2005 and 2006). There are several

reasons for pursuing this strategy. Both years faced reasonably high H-1B demand, but the application period lasted long enough that most permits were not awarded by lottery. However, H-1B scarcity was much more acute in the latter year. Table 1 reveals that the general H-1B filing period for 2007 was nearly two and a half times longer than for 2006, as was the filing period for advanced US degree holders. News in April and May of 2006 suggested that firms would see a bigger negative supply shock for FY 2007 than they had previously anticipated, with several legal advice websites releasing information about the number of permits remaining.⁹ Moreover, the previous discussion of Figures 1 and 2 documented that acute scarcity in the availability of new H-1B workers appears to have had a wage effect on job offers from for-profit firms to new employees with advanced US degrees in 2007. This phenomena does not appear at non-profit firms or in 2006 when scarcity was less severe.

These factors suggest that comparison of outcomes between 2006 and 2007 can provide a unique method for identifying labor market outcomes arising from H-1B scarcity. Though they motivate much of the analysis, they do not provide full guidance for more sophisticated estimation. As a step toward identifying systematic evidence, consider additional illustrative evidence gleaned from the regression specification:

$$\ln(\text{wage}_{it}^{jk}) = \alpha^{jk} + \beta^{jk} \cdot X_{it}^{jk} + \delta_t^{jk} \cdot \text{date}_t + e_{it}^{jk} \quad (6)$$

Equation (6) regresses the log of an individual’s accepted wage offer i at date t on a vector of demographic controls (X_{it}^{jk}) and a vector of indicators specific to day-month-year dates (date_t). Regressions are performed separately for employees of different firm types $j = \{\text{for-profit, non-profit}\}$ and H-1B category $k = \{\text{new workers with an advanced US degree, established workers without an advanced US degree}\}$. This allows coefficient estimates to vary across firm and H-1B type. Skills of job candidates might vary throughout the year; the model controls for this by including indicators for educational attainment, field of study, age, occupation, country of birth, and employer’s city. The coefficients on the date fixed effects (δ_t^{jk}) therefore identify the sector-specific wage paid to an individual on a given date that cannot be explained by available

⁹It is unclear how regularly USCIS posted updates on H-1B counts. USCIS (2006, page 5) noted that “The current count on all nonimmigrant caps can always be found on the USCIS website at: <http://www.uscis.gov/graphics/services/tempbenefits/cap.html>”, but that website is now defunct. The Oh Law Firm (Oh 2006) maintains an archive that posted ten cap updates between April and June for fiscal year 2007. Those dates and counts can be found at other legal web sites as well.

information about the characteristics of an individual or his/her employer.

After running the relevant regressions, we calculate the average log-wage predicted by date alone for each week in a given year. We then compute the predicted wage difference between for-profit and non-profit employment. Figure 3 presents the results for new H-1B workers with an advanced US degree. The displayed period begins with the first week of April – the first week of the application period. It ends on August 10 – the LDR for general H-1Bs in FY 2006. Since the LDR for advanced US degree holders occurred on July 26, 2006, average wage calculations are not available beyond that date for FY 2007. The figure gives special attention to the week ending on May 26. Recall that May 26, 2006 is the last date of receipt for general H-1B applications to begin work in FY 2007. In contrast, there nothing particularly notable about May 26, 2005. Given the unique implications of May 26, 2006 to for-profit firms, this paper is essentially interested in whether the one-year difference (or wedge) in estimated date fixed effects, $\delta_t^{jk} - \delta_{t-365}^{jk}$, is particularly large in magnitude among for-profit firms near that date.

Not surprising given the evidence in Figure 1, the left panel of Figure 3 demonstrates that the average predicted log-wage declines in the weeks following the first date of the application period for both fiscal years 2006 and 2007. Somewhat surprisingly, this value then rises in both years leading up to May 26. However, the wedge between these years also rises. The right panel of Figure 3 graphs the value of this wedge. It also provides a two-standard-error band based upon a bootstrapping routine that performs repeated estimation of (6) by sampling with replacement. The graph reveals that the wage difference between for-profit and non-profit firms for FY 2007 was significantly different from that for 2006 one week prior to and three weeks after May 26. This suggests that this month-long period of heightened H-1B scarcity encouraged firms to increase wage offers to new H-1B workers who could be hired.

Contrast these results with effects on established H-1B workers in Figure 4. For-profit versus non-profit gaps in wage offers exhibit random noise in both 2006 and 2007. No discernible pattern emerges, suggesting that the effect of H-1B scarcity did not impact this group in the same way. In the context of the theoretical model above, this preliminary evidence suggests that new H-1B workers possessing advanced US degrees are like group L_2 and substitute for new H-1B workers without advanced US degrees, whereas established workers might be like group L_3 and complement new H-1B employment (or, at a more basic level, are simply

not substitutable with new H-1B workers).¹⁰

5 Empirical Evidence

5.1 Triple-Difference Estimation

The illustrative exercise in Section 4 motivates the more formal regression analysis in this section. Firm substitution to alternative labor sources can manifest itself in different ways. Policy-induced shocks to the labor supply of one group could affect the demand for alternative labor sources either positively or negatively. So long as the labor supply curve is not perfectly elastic, these consequences should appear as wage effects. To examine these wage consequences and labor substitutability implied by them, we divide the H-1B application period into three segments for each year: (1) The early period occurring more than one week before May 26; (2) The news era one week before through three weeks after May 26; and (3) The post-news period more than three weeks after May 26. Wage offers will vary across fiscal year, periods within each year, and the profit-status of firms. The triple difference specification in (7) exploits differences between for-profit H-1B job offers and otherwise similar non-profit offers for fiscal years 2006 and 2007.

$$\begin{aligned}
\ln(wage_{ijt}^k) = & \gamma_0^k + \gamma_1^k \cdot F07_t + \gamma_2^k \cdot Forprofit_{ijt}^k + \gamma_{3,News}^k \cdot News_{ijt}^k + \gamma_{3,Post}^k \cdot Post_{ijt}^k & (7) \\
& + \gamma_{4,News}^k \cdot News_{ijt}^k \cdot Forprofit_{ijt}^k + \gamma_{4,Post}^k \cdot Post_{ijt}^k \cdot Forprofit_{ijt}^k \\
& + \gamma_{5,News}^k \cdot News_{ijt}^k \cdot F07_t + \gamma_{5,Post}^k \cdot Post_{ijt}^k \cdot F07_t \\
& + \gamma_6^k \cdot Forprofit_{ijt}^k \cdot F07_t \\
& + \gamma_{7,News}^k \cdot News_{ijt}^k \cdot Forprofit_{ijt}^k \cdot F07_t \\
& + \gamma_{7,Post}^k \cdot Post_{ijt}^k \cdot Forprofit_{ijt}^k \cdot F07_t \\
& + \beta^k \cdot X_{ijt} + \delta_t^k \cdot date_t + \varepsilon_{ijt}^k
\end{aligned}$$

The left hand side of (7) records the log-wage of an accepted job offer to individual i on date t (defined

¹⁰For this subset of H-1B workers, it would be possible to extend the date range through the end of the calendar year. Week-by-week differences remain insignificant, however. For comparison purposes, we fix the date range to be the same for Figures 3 and 4.

by day, month, and year) to work for a firm of profit-status j . Regressions are run separately for H-1B groups k as described above. Suppressing the k superscripts for simplicity, parameters γ_0 through γ_3 reflect a constant and level terms for FY 2007 ($F07$), for-profit firms ($Forprofit$), and period of the year ($News$ and $Post$). Parameters γ_4 through γ_6 reflect double-difference terms for the pertinent interactions between profit-status, fiscal year, and period of the year. The effect of the triple-difference interaction of all three terms is captured by the γ_7 coefficients.

The vector X controls for demographic features including indicator variables for educational attainment, field of study, age, occupation, country of birth, and employer’s city. Inclusion of these observable characteristics allows the model to better compare workers hired early in the H-1B filing period to those hired near or after May 26. Thus, estimated triple-difference wage effects represented by γ_7 only reflect knowledge about the limited availability of new H-1B hires in for FY 2007 and not a change in the quality or characteristics of job candidates. Relatedly, δ_t^k represents date fixed effects. When present in the model, these terms will absorb any time-specific factor affecting all groups of workers that might be present in the data including macroeconomic trends and/or the possibility that candidates receiving offers in April 2005 are systematically better (or worse) workers than those receiving offers in May 2006. These terms also absorb effects otherwise identified by γ_1 , γ_3 , and γ_5 – coefficients that are therefore not displayed in regression output tables. Finally, the error term is represented by ε and regressions cluster standard errors by country of birth.

One underlying assumption in (7) is that a permit quota applied to for-profit firms would generate effects similar to a permit quota applied to non-profit firms. Since H-1B caps do not apply to non-profit firms, this narrow assumption cannot be validated. More broadly, however, the model assumes that market forces affect wages paid by non-profit and for-profit firms alike. Past work and alternative data can provide insight on this assumption. Anecdotal support is available in 2010-2012 American Community Survey (ACS) data: academic fields of study that earn high wages in for-profit firms (e.g., engineering, mathematics and computer science, economics) also earn high wages in non-profit firms. A simple bivariate regression across degree fields reveals an elasticity of 0.79 between wages paid at non-profit and for-profit firms that is significantly different from both zero and one.¹¹ This correlation is obviously not causal, but it is consistent with non-profit

¹¹See the appendix for further detail.

responsiveness to market forces.

The results for regressions of the triple-difference specification in (7) when $k = \text{new H-1B workers with advanced US degrees}$ are in Table 2.¹² The most important coefficients are the γ_7 terms. These values will equal zero if for-profit and non-profit firms maintain constant but unique trends in wage offers. Significant coefficients indicate that wage gaps deviated from predictable trends.

Column 1 presents results without date fixed effects. To interpret the results, consider the evolution of the wage gap between offers to new for-profit and non-profit H-1B workers. This for-profit wage premium (γ_2) is large and significant, amounting to 22 log-points in FY 2006, even when controlling for the full set of demographic characteristics such as age, educational attainment, and field of study. The premium was 5.2% higher (γ_6) in the beginning of the FY 2007 filing period. Consistent with the illustrative evidence above, this wage premium rose an additional 4.7% ($\gamma_{7,News}$) as news about H-1B scarcity was being revealed near May 26, 2006, relative to the same time period of the previous year. However, this added effect was temporary. The for-profit wage premium experienced an insignificant 3.3% reversal ($\gamma_{7,Post}$) three weeks beyond this date, also relative to the same time period of the previous year. The cumulative average wage premium paid to new for-profit H-1B workers versus non-profit labor was 5.3% higher in FY 2007 than 2006 and is significantly different from zero at the 1% confidence level.¹³

Column 2 will serve as a baseline comparison for further robustness checks. It includes date fixed effects to account for any activity occurring in a given day, month, and year that affects all types of firms and workers. The model therefore absorbs coefficients on year (γ_1), season (γ_3), and season-within-year (γ_5) wage determinants. Results with and without these demanding date fixed effects are remarkably similar. The triple-difference estimate of $\gamma_{7,News}$ suggests that for-profit firms increased wage offers to new H-1Bs with advanced US degrees by 5% in response to news about reaching the last date of receipt for general H-1Bs for FY 2007. The post-news-period coefficient remains insignificant but negative in sign. The cumulative average wage effect for new H-1B hires at for-profit firms decreases to a 3.6% gain.

We have interpreted the significant wage increases in Columns 1 and 2 Table 2 as evidence that acute H-

¹²Point estimates for β , γ_1 , γ_2 , and γ_3 are omitted but available upon request.

¹³This estimate incorporates the wage premium beginning from April 1 in fiscal year 2007 relative to 2006 and the effect from the news and post-news periods. Formally, this estimate equals $\gamma_6 + \gamma_{7,News} \cdot (\% \text{ For-profit hires in the } News \text{ period}) + \gamma_{7,Post} \cdot (\% \text{ For-profit hires in the } Post \text{ period})$.

1B scarcity in 2007 caused wages paid to new H-1B workers with advanced US degrees to rise, thus indicating substitution between new H-1B workers with and without advanced US degrees. Another possibility, however, is that heightened scarcity for FY 2007 simply shifted the timing of hiring such that offers to the highest ability workers occurred earlier in the hiring cycle at for-profit firms. Though inclusion of the demographic controls in X should help account for shifts in the quality or characteristics of job candidates over time, robustness checks can provide further support.

The remaining columns retain date fixed effects but employ alternative sample selection criteria to test the robustness of results. Column 3 recognizes that five countries (Australia, Canada, Chile, Mexico, and Singapore) have country-specific H-1B alternatives due to various trade agreements. Thus, for-profit firms wishing to hire workers from these countries have more certainty in their ability to do so, and such individuals do not receive the same treatment that citizens of other countries do.¹⁴ Removal of people born in those countries results in estimates consistent with prior specifications. The for-profit wage premium rises during the period when firms receive news about H-1B scarcity and then it eventually falls. The cumulative average effect remains at a 3.6% wage increase.

Column 4 explores the role of Indian-born individuals since they comprise roughly half of new H-1B issuances to for-profit firms each year. Similarly, Column 5 explores the role of computer-related workers since they comprise roughly two-thirds of new H-1B issuances to for-profit firms each year. Estimates are again robust to the exclusion of these individuals – it is reassuring that these groups are not driving the results.

In principle, one could conduct similar analysis focusing exclusively on residents of countries with H-1B alternatives, Indians, or computer-related workers. In practice, however, this is not possible. In the first case, the overall number of observations is quite small. In the latter two cases, the number of observations in one or more untreated group becomes too small. In that context, it is especially important to recognize that the results are robust to the exclusion of these workers despite the compositional changes of the relevant samples.

The collective results of Table 2 are consistent with labor substitution between new H-1B workers with

¹⁴Canadians and Mexicans qualify for TN status. Australians qualify for the E-3 work permit. Citizens of Singapore and Chile receive preferential H-1B treatment.

and without advanced US degrees. Wage increases near the last date of receipt for FY 2007 are due to news about aggregate H-1B scarcity and not compositional changes to the pool of job offer recipients. It remains somewhat curious, however, as to why the wage premium rises only around the last date of receipt and not beyond three weeks after it. Perhaps the two most obvious possibilities are that the key parameter estimates are wrongly capturing either a shift in worker composition or macroeconomic dynamics. However, the model accounts for these possibilities. In the former case, the demographic controls in X and the sample selection robustness checks help to rule out compositional change. In the latter case, day-month-year fixed effects control for phenomena that occur in particular dates. Interaction terms estimate for-profit wage gains relative to non-profit job offers and allow for trends to differ between these sectors. The regressions estimate breaks from those trends and interpret them as occurring due to news and not to other factors. If macroeconomic factors are at play, they would have to be of the sort preferring for-profit over non-profit employment for FY 2007 but not 2006.

A third possibility is that news about H-1B scarcity in May 2006 caused not a shift in quality of workers, but rather a shift in urgency to hire them. Faced with pressures to secure quick job offer acceptances before the 20,000 advanced US degree quota was met, firms might have increased wage offers in response to workers' increased bargaining power. This is a form of substitution in the sense that firms increased their valuation of this labor source, even if only temporarily. The next subsection will explore the role of firms more thoroughly. Before doing so, however, we first turn to regressions for $k =$ established H-1B workers without an advanced US degree to examine whether firms also substituted toward this labor source.

Results for this exercise are in Table 3. Columns repeat the previous specifications but for this different subset of H-1B workers. Unlike with the case of new H-1B hires with an advanced US degree, we find no evidence that firms increased wage offers to established H-1B workers in response to news about H-1B scarcity. Overall, established for-profit workers actually experience a significant cumulative 2% wage decline in FY 2007. This heterogeneity in effects across groups of H-1B workers is interesting for several reasons. First, it helps to further ensure that the results for new H-1B hires with advanced US degrees were not driven by macroeconomic dynamics. It seems unlikely that macroeconomic conditions would increase the wage premium for one group of foreign-born for-profit workers while decreasing the premium for another.

Second, it implies that the degree to which firms substitute toward alternative foreign-born labor sources varies across groups. In the context of the theoretical model, the results would imply that while new H-1B workers with and without advanced US degrees are substitutable with each other and correspond to groups L_1 and L_2 from the model, new and established H-1B workers without advanced US degrees complement each other and correspond to groups L_1 and L_3 . Alternatively, it might be the case that workers' dependence upon employers for permanent residency (green card) sponsorship precludes established labor from exploiting their enhanced bargaining power in the form of securing wage raises, whereas new H-1B workers are able to capitalize on their bargaining power when choosing their first job.

5.2 Firm Influence

As noted in the introduction, H-1B status is awarded to individuals, not firms. However, the design of the H-1B program creates a strong employer-employee link. H-1B employment and wage offers are made by specific firms that must have first obtained an approved LCA. H-1B employment has increasingly become concentrated among fewer firms over time.¹⁵ Mobility might be limited because employers can sponsor H-1B workers for permanent residency status. Moreover, the worker's H-1B status is no longer valid if a job separation occurs.

These phenomena require the empirical analysis to include a greater consideration of firms. Fortunately, the H-1B dataset includes the name of each individual's employer that can be incorporated into the analysis. Unfortunately, this information is incomplete. There is a large amount of measurement error due to misspellings and typos. Moreover, the data does not include other helpful information such as industry, sales volume, total employment, or headquarters location, nor does it provide identification numbers that would facilitate a merge with other data sources. We nonetheless proceed with two important exercises.

The first concern is that results could be driven by a select few firms. For example, in his February 2016 testimony to the US Senate, Ron Hira (2016) argued that 15 of the top 20 for-profit H-1B employers use the program to facilitate offshoring efforts and were responsible for hiring more than 190,000 new H-1B workers from fiscal years 2005 through 2014. It is important to examine whether these firms – which may have distinct motivations for hiring H-1B workers – are driving results. To do so, regressions remove employees of

¹⁵See Mayda, Ortega, Peri, Shih, and Sparber (2018).

the offshoring firms identified by Hira (2016, Table 2).¹⁶ These firms represent 15% of new for-profit H-1B hiring for fiscal years 2006 and 2007, a smaller proportion than Hira’s calculations for 2014. Moreover, they represent just 2% of for-profit H-1B hiring of new H-1Bs with advanced US degrees.

The results are in Table 4. For ease of comparison, columns (1) and (4) redisplay estimates from the baseline specifications for new H-1B workers with advanced US degrees and established H-1B workers without advanced degrees, respectively. Columns (2) and (5) omit these offshoring firms. Coefficient estimates are robust to the exclusion of these firms. Estimates are very similar to baseline results in part because the decline in observations is quite small. Firms potentially using the H-1B program to facilitate offshoring behavior are not driving wage results.

A second concern is that wage offers depend upon the characteristics of the firms extending them.¹⁷ As noted, the dataset does not have information on firm characteristics but does have noisy information on firm name. One solution is to therefore include firm fixed effects. This too has limitations. Single firms can enter the dataset under several different names due to misspellings, typos, and alternative conventions for recording the name (e.g., IBM, IBM Corp, and IBM Global Services IGS India PVT constitute three separate entries). Many firms have just one or few entries – use of the full dataset in conjunction with firm fixed effects can lead to estimation of a variance matrix that is nonsymmetric or highly singular. Finally, estimates would not be identified within firm in the sense that some people within a firm experience a treatment near the LDR for FY 2007 while others do not. Rather, it is that all hires within a particular for-profit firm near that date experience the treatment whereas hires at non-profit firms do not.¹⁸ Nonetheless, Table 4 pursues estimation with firm fixed effects.¹⁹

Column (3) presents results for new H-1B hires with advanced US degrees. To avoid the problem of a singular covariance matrix, firms hiring fewer than 50 total H-1B workers during the time period of this

¹⁶More specifically, the analysis removes observations with variants of the following firm names: Tata Consultancy, Cognizant Tech, Infosys Limited, Wipro Limited, Accenture LLP, Tech Mahindra, IBM, Larsen & Toubro, Syntel Consulting, Igate Tech (including Patni), Computer Sciences Corp, HCL Americas, Deloitte & Touche LLP, Capgemini (including Kanbay), and Mindtree Limited.

¹⁷For example, see evidence for wage premiums paid by exporting and multinational firms in Bernard et al. (2007) and Huttunen (2007).

¹⁸For a recent example of within-firm estimates of labor substitutability, consult Jaeger (2016). Using German employer/employee data, he estimates within-firm wage effects arising from unexpected deaths. This negative supply shock has a positive effect on wages of coworkers within occupation, and a negative one on workers in different occupations.

¹⁹The analysis does not employ manual or automated routines to group names of likely-identical firms since this could also generate measurement error. Instead, we take only minimal steps to harmonize firm names and rely primarily on the information provided in the H-1B data.

study are removed from the dataset. This drastically reduces the number of observations by about two-thirds. Interestingly, however, the main triple-difference point estimate ($\gamma_{\tau,News}$) rises in magnitude and significance. The for-profit wage premium increased by 5.9% compared to the prior year when firms learned about acute H-1B scarcity near May 2006. Also interesting, the triple-difference point estimate for the post-news period ($\gamma_{\tau,Post}$) falls in magnitude and is near zero, suggesting that the for-profit premium paid to new H-1B workers with advanced degrees in late June were comparable among hires for fiscal years 2006 and 2007. The cumulative for-profit wage premium was 3.8% higher in the latter year.

Column (6) presents results for established H-1B workers without advanced US degrees. In this case, triple difference point estimates for both $\gamma_{\tau,News}$ and $\gamma_{\tau,Post}$ appear to be precisely-estimated zeros. Unlike in the baseline specification, regressions with firm fixed effects find no evidence for a cumulative decline in the for-profit wage premium paid to these workers.

As noted, the regressions in Columns (3) and (6) excluded firms hiring fewer than 50 H-1B workers in fiscal years 2006 and 2007. The choice of this specific cutoff value was arbitrary but largely inconsequential. Figure 5 illustrates this by displaying the point estimates and standard error bands of $\gamma_{\tau,News}$ using different threshold values for firm exclusion. The left panel presents estimates for new H-1B workers with an advanced US degree; the right is for established H-1B workers without one. Regressions are performed using different cutoff values in increments of five and displayed on the horizontal axes. Values for $\gamma_{\tau,News}$ are on the vertical axes. Among new hires with advanced US degrees, point estimates hover near 5% and are usually significant at a 90% significance level. Among established H-1B labor, point estimates are always near zero and never close to being significant. Altogether, regressions accounting for the influence of firm behavior support baseline conclusions. Near the date of last receipt for general H-1B workers, firms substituted toward new H-1B workers with advanced US degrees as evidenced by higher wage offers. We find no evidence that firms substituted toward established H-1B workers.

5.3 Event Study

May 26 is not an arbitrarily-chosen “magic” day such that new H-1B employees of for-profit firms randomly earned higher premiums near that date for FY 2007 compared to FY 2006. Rather, it was the last date of

receipt for FY 2007 only. Regressions in Tables 2-4 were split into three periods because data summaries suggested a for-profit wage premium near that date that later subsided. As an alternative approach to estimating the effects of H-1B scarcity, one could instead employ a more flexible triple-difference event study framework. This subsection pursues this approach by estimating the week-by-week for-profit versus non-profit wage premium in FY 2007 relative to the same week in 2006. This methodology also serves, in effect, to provide a sort of falsification test examining whether May 26 marks an appropriate delineation point for different outcomes across the two years.

Define ω as the number of weeks pre or post May 26 such that May 26 is the last day of week $\omega = 0$. April 1-7 constitutes the first week, $\omega = -7$. Equation (8) then alters the triple-difference specification in (7) to allow week-by-week coefficients.

$$\begin{aligned}
\ln(\text{wage}_{ijt}^k) &= \gamma_0^k + \gamma_1^k \cdot F07_t + \gamma_2^k \cdot \text{Forprofit}_{ijt}^k + \sum_{\omega=-7} \gamma_{3,\omega}^k \cdot \text{week}_\omega & (8) \\
&+ \sum_{\omega=-7} \gamma_{4,\omega}^k \cdot \text{week}_\omega \cdot \text{Forprofit}_{ijt}^k \\
&+ \sum_{\omega=-7} \gamma_{5,\omega}^k \cdot \text{week}_\omega \cdot F07_t \\
&+ \gamma_6^k \cdot \text{Forprofit}_{ijt}^k \cdot F07_t \\
&\sum_{\omega=-7} \gamma_{7,\omega}^k \cdot \text{week}_\omega \cdot \text{Forprofit}_{ijt}^k \cdot F07_t \\
&+ \beta^k \cdot X_{ijt} + \delta_t^k \cdot \text{date}_t + \varepsilon_{ijt}^k
\end{aligned}$$

The model in (8) is analogous to the prior specification in (7), but it replaces broadly-aggregated period indicators (*News* and *Post*) with week-by-week dummy variables (subscripted by ω). The presence of date fixed effects will absorb all γ_1 , γ_3 , and γ_5 terms. γ_2 is colinear with the $\gamma_{4,\omega}$ terms, and γ_6 is colinear with the $\gamma_{7,\omega}$ terms. The vector of $\gamma_{7,\omega}$ values represents the week-specific for-profit versus non-profit wage premium in FY 2007 relative to 2006. Those point estimates and confidence intervals are displayed in Figures 6 and 7. Standard errors are clustered by country of birth.

The left panel of Figure 6 includes the full sample of new H-1B workers with advanced US degrees. Results are similar to the baseline analysis of Table 2, Column (2). The for-profit wage premium in FY

2007 relative to the same week in FY 2006 was significantly positive beginning two weeks before May 26 and ending three weeks after.²⁰ The average new H-1B worker with an advanced US degree saw a 3.10% increase in the for-profit wage premium in FY 2007 relative to 2006. The right panel includes firm fixed effects and excludes firms hiring fewer than 50 total H-1B workers during the period. The general shape of the graph matches that of the left panel, though with a flatter profile leading up to May 26 and less evidence for significant coefficients.

Figure 7 displays estimates for established H-1B workers without an advanced US degree. Results contrast with those of new H-1B workers. The for-profit wage premium in FY 2007 is statistically indistinguishable from that of 2006 in all but one week. Point estimates using the full sample (left panel) are generally negative, culminating in a 2.2% decline in the average for-profit wage premium in 2007. Estimates using firm fixed effects and the more limited sample of employers continue to cluster closely around zero. We see no evidence that firms substituted toward established H-1B workers for FY 2007 relative to 2006.

6 Conclusions

Caps on the number of new H-1B workers that for-profit firms are allowed to hire were reached before the start of the fiscal year for FYs 2006 through 2009 and 2014 through today. That scarcity could change the value of H-1B work status. Whereas most analyses of the H-1B program focus on how immigrants affect native-born labor, this paper instead assesses how H-1B limits affect the wage offers extended to H-1B workers themselves. It uses triple-difference and event-study frameworks that exploit three sources of variation. First, H-1B caps apply to employees of for-profit firms but not to colleges, universities, and non-profit research institutions, thereby segmenting the market into two sectors. Second, H-1B demand was high in fiscal years 2006 and 2007, but was particularly acute in the latter year. Third, regressions exploit differences in job offers throughout the year. The last date of receipt occurred on May 26, 2006 for FY 2007 – much earlier than for the previous year. Regressions examine whether hiring behaviors around that day were different across these years.

The analysis identifies significant wage estimates implying that market forces play a role in determining H-

²⁰Specifically, estimates are significant at 10% two weeks before and after, significant at 5% one week before and after, and significant at 1% three weeks after May 26. Estimates are insignificantly different from zero during the week of May 26.

1B wage offers. Importantly, H-1B scarcity had heterogenous effects across different groups of H-1B workers. As new H-1B workers without advanced degrees became unavailable, firms substituted toward new H-1B workers with advanced degrees in the form of offering higher wages. They did not, however, extend higher wage offers to established H-1B workers without advanced US degrees complement each other. This could be because established workers complement new H-1B hires, or it could be due to institutional constraints that limit job mobility of established workers. In any case, attempts to alter future inflows of new H-1B labor should be expected to have a varied impact across foreign workers.

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A Appendix

A.1 Wage Correlations across Academic Fields of Study

The 2010-2012 ACS²¹ provides data on variables that facilitate the comparison of average (log) wages paid to for-profit and non-profit workers by primary academic field of study. Individuals included are native-born civilian employees, age 18-65, who do not reside in group quarters, and who have obtained a bachelor's degree or more education and are not currently enrolled in school. The sample is further restricted to individuals working for private for-profit or non-profit organizations. Figure A1 displays a simple bivariate scatter plot of average wages paid by field of study. STEM degrees are marked with an X; non-STEM degrees are marked with an O.²² A line of best fit across all fields of study reveals that a 1% increase in the wage paid to for-profit workers is associated with a 0.79% increase in wages paid to non-profit employees with the same field of study. The coefficient is significantly different from both zero and one.

More systematic support for the claim that market forces affect wages paid by non-profit firms is available in the literature on academic labor markets. Ellison (2010), Hamermesh, and Pfann (2011), and Hilmer, Hilmer, and Ransom (2012) are among recent authors who have found that academic wages are affected by the quantity and/or quality of publications (among other factors), while Katz (1973) provided an early study documenting wage variation across academic departments. Although it is not certain that quotas would affect for-profit and non-profit H-1B wages similarly, it is reassuring to know that academic wages reflect returns to skills and are influenced by market pressures.

²¹Ruggles et al. (2015).

²²Economics is the highest-earning non-STEM degree in the for-profit sector; actuarial science (a business degree) is the highest-earning non-STEM degree in the non-profit sector.

Table 1: Final Receipt Date by Fiscal Year

Fiscal Year	General		Advanced Degree	
	Final Receipt Date	Days in Filing Period	Final Receipt Date	Days in Filing Period
2004	February 17, 2004	323	NA	NA
2005	October 1, 2004	184	Not Reached	548
2006	August 10, 2005	132	January 17, 2006	292
2007	May 26, 2006	56	July 26, 2006	97
2008*	April 3, 2007	3	April 30, 2007	30
2009*	April 7, 2008	7	April 7, 2008	7
2010	December 21, 2009	265	July 9, 2009	100
2011	January 26, 2011	301	December 22, 2010	266
2012	November 22, 2011	236	October 19, 2011	202
2013	June 11, 2012	72	June 7, 2012	68
2014*	April 5, 2013	5	April 5, 2013	5
2015*	April 7, 2014	7	April 7, 2014	7
2016*	April 7, 2015	7	April 7, 2015	7
2017*	April 7, 2016	7	April 7, 2016	7
2018*	April 7, 2017	7	April 7, 2017	7
2019*	April, 6 2018	6	April, 6 2018	6

*Indicates fiscal years in which all cap-bound H-1Bs were allocated by lottery.

Table 2: $\ln(\text{Wage})$, New H-1B Workers with Advanced US Degrees

	(1)	(2)	(3)	(4)	(5)
Omitted Workers:	NA	NA	Countries with H-1B Alternatives	Indian- Born	Computer-Related Occupations
Date Fixed Effects:	No	Yes	Yes	Yes	Yes
News Period * For-Profit * FY07	0.047* (0.025)	0.050* (0.027)	0.056* (0.029)	0.065* (0.037)	0.058** (0.029)
Post News Period * For-Profit * FY07	-0.033 (0.020)	-0.040 (0.025)	-0.042* (0.025)	-0.017 (0.025)	-0.035 (0.024)
For-Profit * FY07	0.052*** (0.019)	0.037* (0.022)	0.036 (0.023)	0.020 (0.028)	0.036* (0.021)
News Period * For-Profit	0.008 (0.014)	0.008 (0.015)	0.014 (0.015)	0.010 (0.019)	0.020 (0.016)
Post News Period * For-Profit	0.038*** (0.012)	0.035*** (0.011)	0.041*** (0.011)	0.039*** (0.015)	0.047*** (0.012)
For-Profit Firm	0.223*** (0.020)	0.227*** (0.019)	0.223*** (0.021)	0.220*** (0.024)	0.230*** (0.025)
Average $\Delta \ln(w)$, For-Profit in FY 2007	0.053***	0.036***	0.036***	0.033***	0.040***
Observations	49,365	49,365	47,420	29,991	34,855
R-squared	0.332	0.341	0.334	0.363	0.354

News period = one week before through three weeks after May 26. Post-news period = more than three weeks after May 26. All models include indicators for educational attainment, field of study, age, birthplace, occupation, and metropolitan area. Column (1) also includes indicators for News Period, Post News Period, and Fiscal Year 2007, plus interactions between News and Post with 2007. Standard errors cluster on country of birth. Cluster-robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table 3: $\ln(\text{Wage})$, Established H-1B Workers without Advanced US Degrees

	(1)	(2)	(3)	(4)	(5)
Omitted Workers:	NA	NA	Countries with H-1B Alternatives	Indian-Born	Computer-Related Occupations
Date Fixed Effects:	No	Yes	Yes	Yes	Yes
News Period * For-Profit * FY07	-0.021 (0.016)	-0.019 (0.016)	-0.016 (0.019)	-0.014 (0.020)	-0.017 (0.017)
Post News Period * For-Profit * FY07	-0.015 (0.021)	-0.013 (0.021)	-0.013 (0.024)	0.006 (0.019)	-0.011 (0.023)
For-Profit * FY07	-0.008 (0.019)	-0.008 (0.019)	-0.011 (0.022)	-0.022 (0.016)	-0.001 (0.023)
News Period * For-Profit	0.060*** (0.014)	0.060*** (0.014)	0.060*** (0.016)	0.058*** (0.017)	0.062*** (0.014)
Post News Period * For-Profit	-0.012 (0.011)	-0.015 (0.012)	-0.015 (0.012)	-0.015 (0.014)	-0.018 (0.014)
For-Profit Firm	0.283*** (0.024)	0.284*** (0.024)	0.282*** (0.027)	0.289*** (0.029)	0.310*** (0.028)
Average $\Delta \ln(w)$, For-Profit in FY 2007	-0.021***	-0.020***	-0.022***	-0.019***	-0.011
Observations	148,112	148,112	135,660	78,719	75,556
R-squared	0.330	0.334	0.323	0.384	0.366

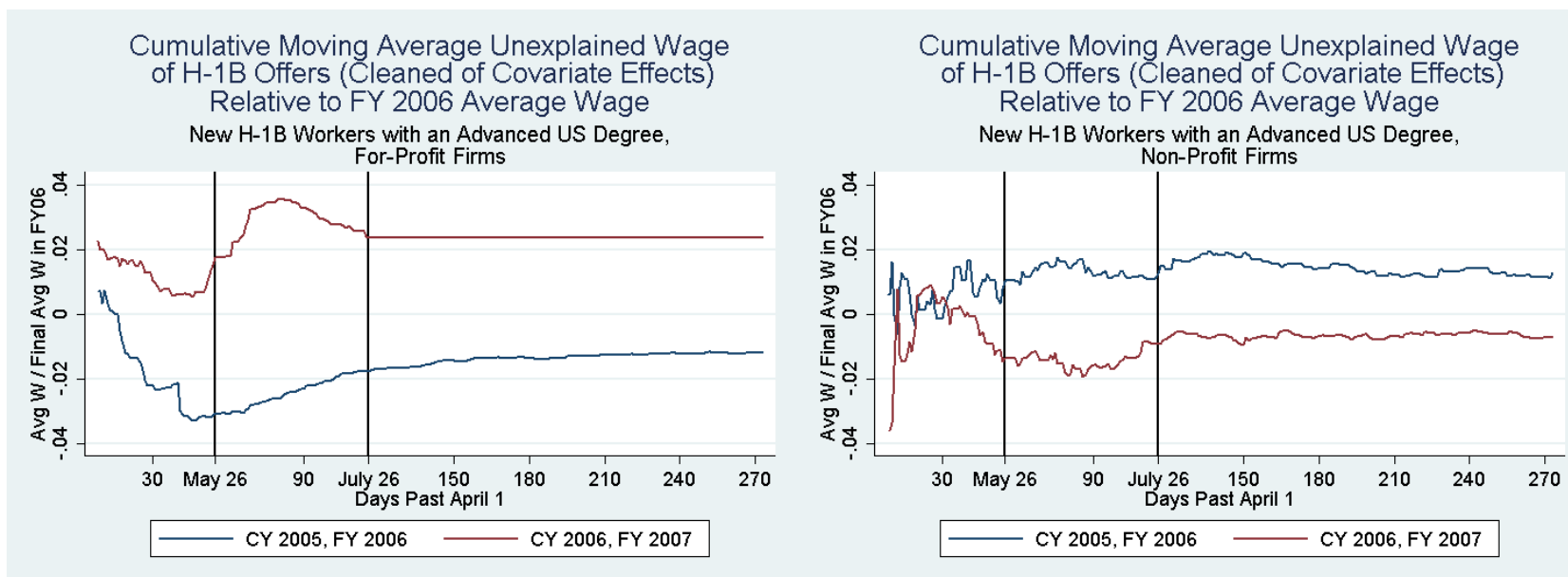
News period = one week before through three weeks after May 26. Post-news period = more than three weeks after May 26. All models include indicators for educational attainment, field of study, age, birthplace, occupation, and metropolitan area. Column (1) also includes indicators for News Period, Post News Period, and Fiscal Year 2007, plus interactions between News and Post with 2007. Standard errors cluster on country of birth. Cluster-robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table 4: ln(Wage), Firm Controls

Sample:	(1)	(2)	(3)	(4)	(5)	(6)
	<u>New Advanced Degree Hires</u>			<u>Established Workers, No Adv. Degree</u>		
Omitted Workers:	NA	Offshoring Firms	Firms Hiring <50 H-1Bs	NA	Offshoring Firms	Firms Hiring <50 H-1Bs
Firm Fixed Effects:	No	No	Yes	No	No	Yes
News Period * For-Profit * FY07	0.050* (0.027)	0.055* (0.028)	0.059** (0.027)	-0.019 (0.016)	-0.019 (0.017)	0.002 (0.028)
Post News Period * For-Profit * FY07	-0.040 (0.025)	-0.039 (0.026)	-0.004 (0.029)	-0.013 (0.021)	-0.015 (0.021)	-0.002 (0.015)
For-Profit * FY07	0.037* (0.022)	0.035 (0.022)	0.018 (0.020)	-0.008 (0.019)	-0.004 (0.020)	0.003 (0.016)
News Period * For-Profit	0.008 (0.015)	0.007 (0.015)	-0.016 (0.023)	0.060*** (0.014)	0.062*** (0.015)	-0.000 (0.011)
Post News Period * For-Profit	0.035*** (0.011)	0.036*** (0.011)	0.037*** (0.013)	-0.015 (0.012)	-0.014 (0.011)	-0.003 (0.014)
For-Profit Firm	0.227*** (0.019)	0.222*** (0.019)		0.284*** (0.024)	0.280*** (0.023)	
Average $\Delta \ln(w)$, For-Profit in FY 2007	0.036***	0.035***	0.038***	-0.020***	-0.017**	-0.004
Observations	49,365	48,558	18,229	148,112	137,301	55,092
R-squared	0.341	0.343	0.665	0.334	0.341	0.625

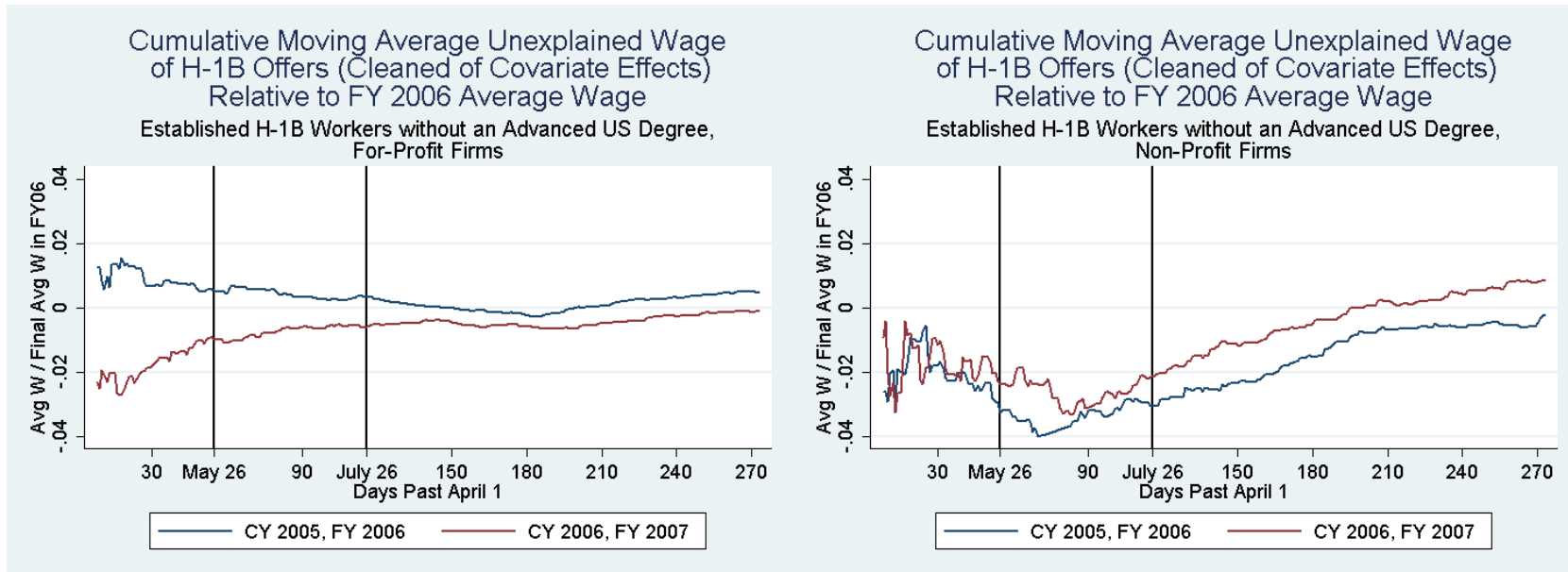
News period = one week before through three weeks after May 26. Post-news period = more than three weeks after May 26. All models include date fixed effects and indicators for educational attainment, field of study, age, birthplace, occupation, and metropolitan area. Standard errors cluster on country of birth. Cluster-robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10

Figure 1: Cumulative Moving Average Wage, New H-1B Workers with an Advanced US Degree



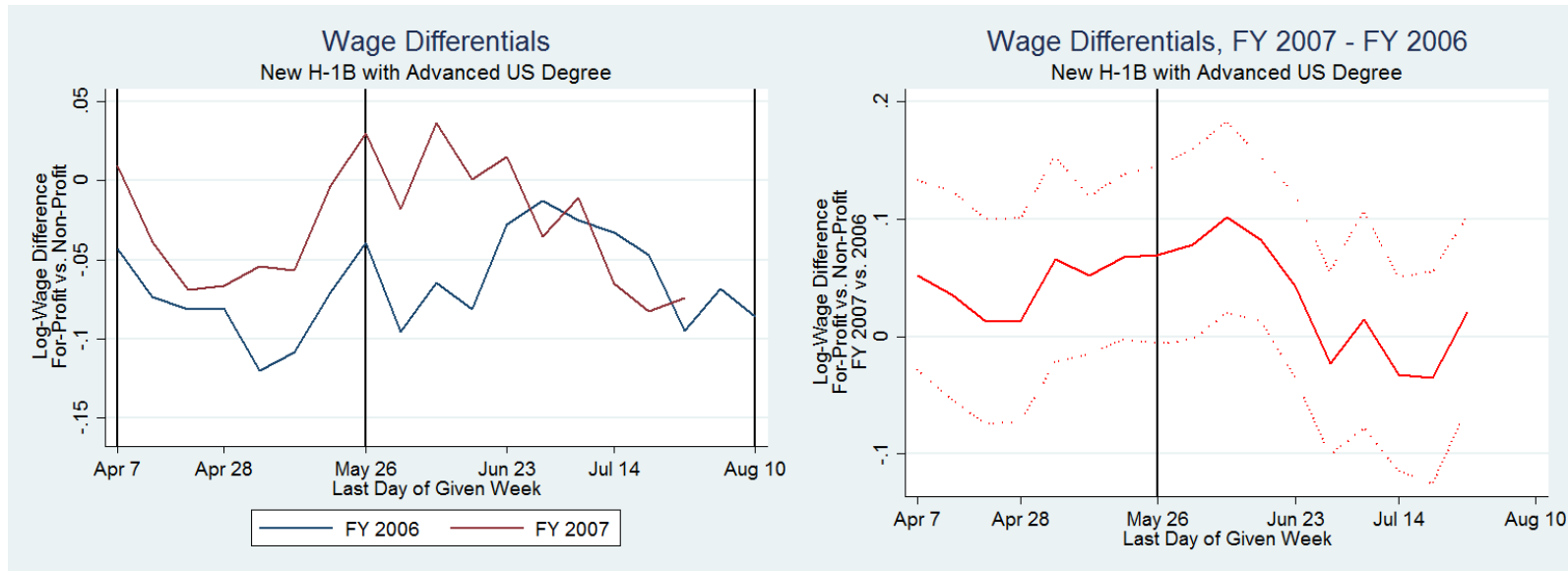
Figures represent cumulative average wages – relative to the average wage paid to new H-1B workers with an Advanced US Degree in Fiscal Year (FY) 2006 – after accounting for age, education, field of study, occupation, birth country, and city of residence. May 26, 2006 was the last date of receipt for general H-1B applications in FY 2007. July 26, 2006 was the last date of receipt for advanced US degree applications in FY 2007.

Figure 2: Cumulative Moving Average Wage, Established H-1B Workers without an Advanced US Degree



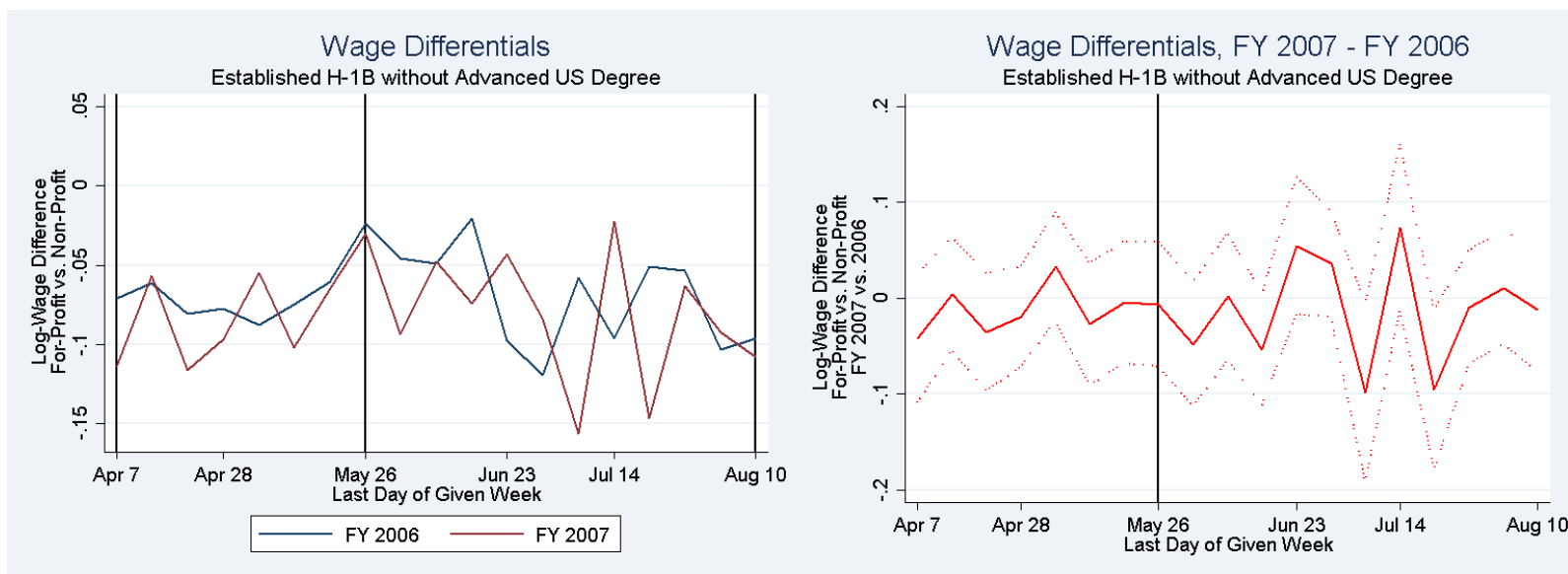
Figures represent cumulative average wages – relative to the average wage paid to established H-1B workers without an Advanced US Degree in Fiscal Year (FY) 2006 – after accounting for age, education, field of study, occupation, birth country, and city of residence. May 26, 2006 was the last date of receipt for general H-1B applications in FY 2007. July 26, 2006 was the last date of receipt for advanced US degree applications in FY 2007.

Figure 3: Week-by-Week For-Profit Wage Premium, New H-1Bs with an Advanced US Degree



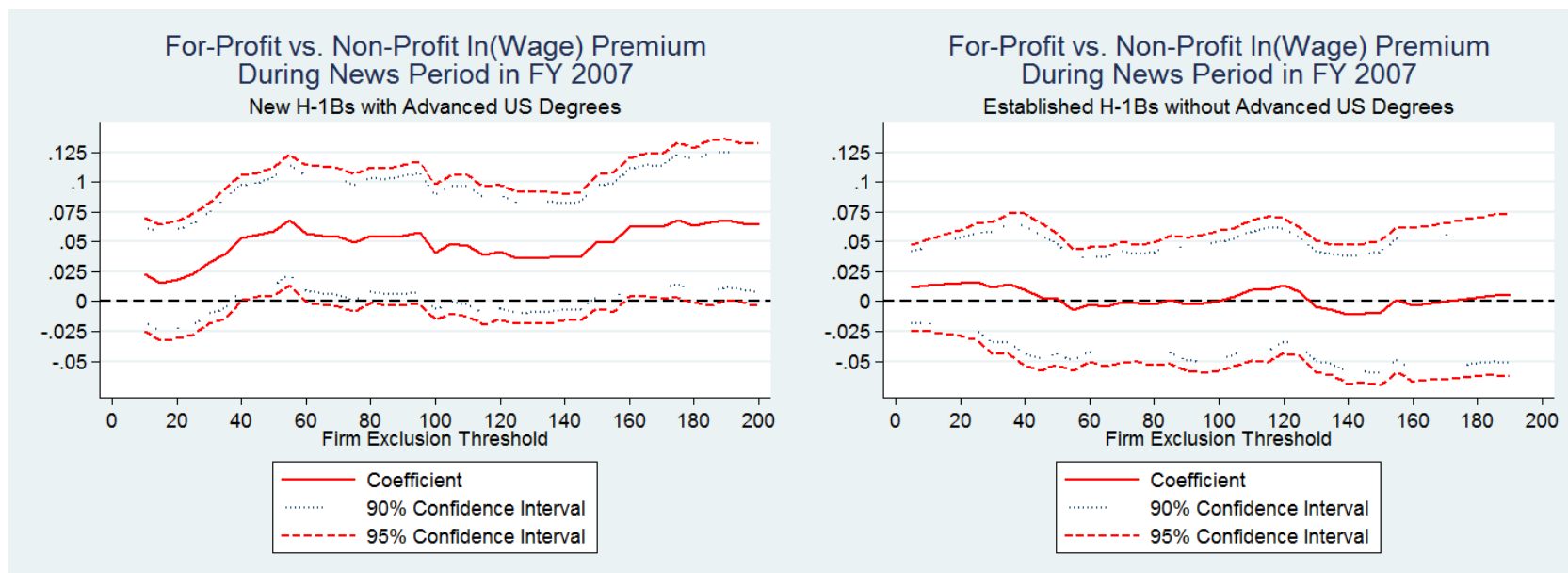
Left panel displays week-by-week differences in the for-profit wage premium paid to H-1B workers as described by the methodology in the text. The right panel displays the gap in this premium between fiscal year (FY) 2006 and 2007, plus a two-standard-error band. May 26, 2006 was the last date of receipt for general H-1Bs in FY 2007.

Figure 4: Week-by-Week For-Profit Wage Premium, Established H-1Bs without an Advanced US Degree



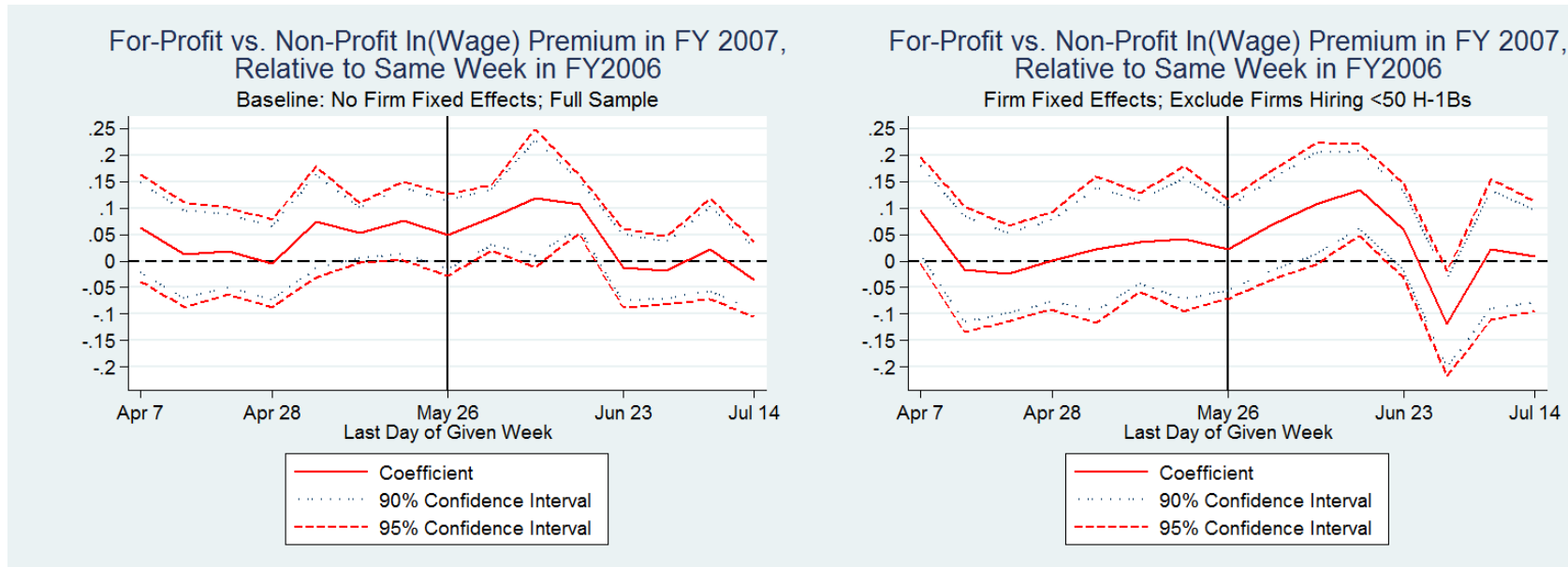
Left panel displays week-by-week differences in the for-profit wage premium paid to H-1B workers as described by the methodology in the text. The right panel displays the gap in this premium between fiscal year (FY) 2006 and 2007, plus a two-standard-error band. May 26, 2006 was the last date of receipt for general H-1Bs in FY 2007.

Figure 5: Robustness of News-Period Triple Difference Estimates to Firm Exclusions



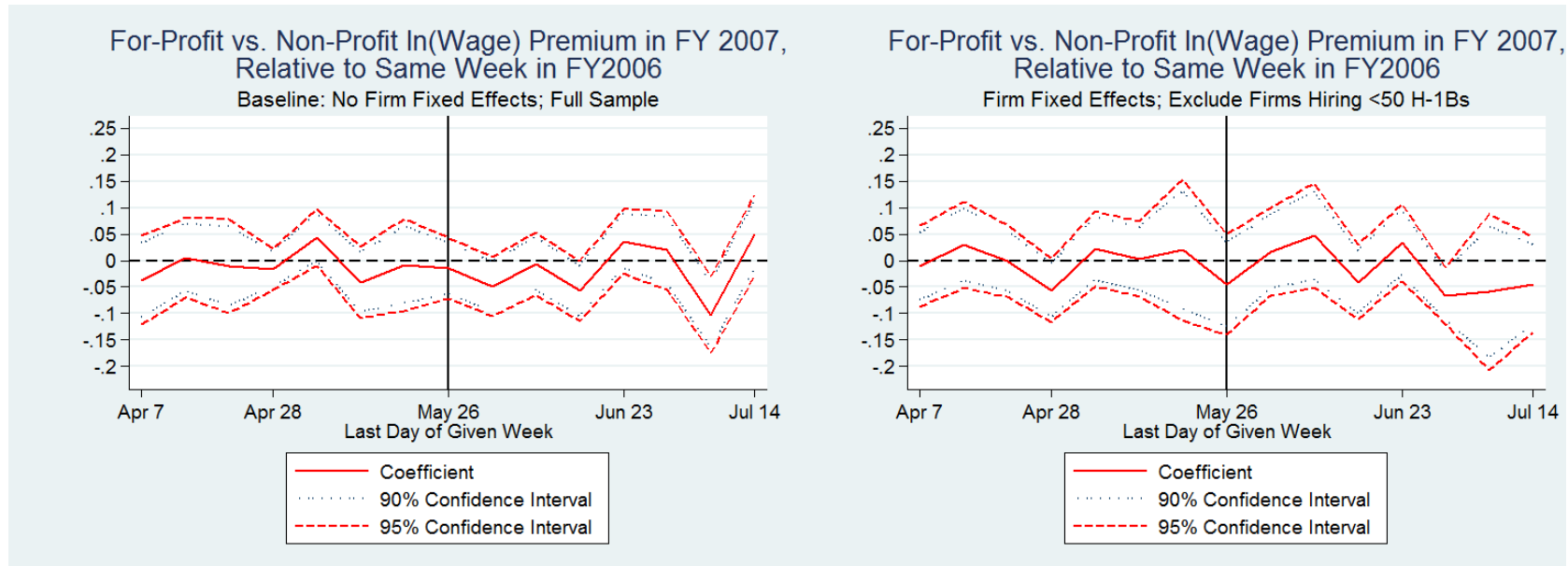
Figures display $\gamma_{7,News}$ triple difference coefficients and standard error bands for News Period * For-Profit * FY07. Estimates come from regressions excluding firms that hire fewer than the number of H-1B workers indicated on the horizontal axis. News period = one week before through three weeks after May 26. All models include date and firm fixed effects and indicators for educational attainment, field of study, age, birthplace, occupation, and metropolitan area. Standard errors cluster on country of birth.

Figure 6: Event Study Results, New H-1Bs with an Advanced US Degree



Graphs display week-by-week event study coefficients for the for-profit wage premium in fiscal year (FY) 2007 relative to 2006. The left panel provides baseline results for the whole sample of new H-1B workers with advanced US degrees; the right panel includes firm fixed effects but excludes firms with fewer than 50 H-1B hires over the period. The methodology is described in the text. May 26, 2006 was the last date of receipt for general H-1B applications in FY 2007.

Figure 7: Event Study Results, Established H-1Bs without an Advanced US Degree



Graphs display week-by-week event study coefficients for the for-profit wage premium in fiscal year (FY) 2007 relative to 2006. The left panel provides baseline results for the whole sample of established H-1B workers without advanced US degrees; the right panel includes firm fixed effects but excludes firms with fewer than 50 H-1B hires over the period. The methodology is described in the text. May 26, 2006 was the last date of receipt for general H-1B applications in FY 2007.

Appendix Figure A1: Wages by Field of Study and Employer Type

