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Buying Lottery Tickets for Foreign Workers: Lost Quota Rents Induced by H-1B Policy

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September 2022

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Abstract

The H-1B program allows firms in the United States to temporarily hire high-skilled foreign citizens. The government restricts foreign labor inflows and therefore generates potential rents typical of a quota. However, the US allocates H-1B status by random lottery. We develop a theoretical model demonstrating that this lottery creates a negative externality by incentivizing firms to search for more workers than can actually be hired and, in so doing, completely destroys quota rents. Moreover, some firms specialize in hiring foreign labor and contracting out those workers' services to third-party sites, and this outsourcing behavior both exacerbates lost quota rents and leads to an increased concentration of H-1B workers among a small number of firms. Simple numerical exercises suggest that the H-1B lottery and outsourcing result in an annual economic loss exceeding \$10,000 per new H-1B worker hired relative to what would occur under a quota alone.

Key Words: Skilled Workers, H-1B, Quota Rents, Outsourcing.

JEL Codes: J61, J68, F22

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1 Introduction

The H-1B program provides an important method for college-educated foreign citizens to secure temporary legal employment in the United States. Though available for workers in a number of occupations, the program is particularly popular among Science, Technology, Engineering, and Mathematics (STEM) workers. For example, United States Citizenship and Immigration Services (USCIS (2020a)) reports that computer-related workers alone accounted for 66.1% of H-1Bs issued in fiscal year (FY) 2019. Many economists credit the program (or foreign STEM workers more generally) for generating a substantial share of recent U.S. innovation, technology, productivity, wage, and GDP growth.¹ Such evidence led the National Academies of Sciences, Engineering, and Medicine (2017) to argue in its summary on the economic effects of immigration that “the prospects for long-run economic growth in the United States would be considerably dimmed without the contributions of high-skilled immigrants.”

Less sanguine views of skilled immigration and the H-1B program often focus on two concerns. The first is the possibility that infusions of skilled workers might reduce wages paid to subsets of native-born labor.² The second – as articulated by Costa and Hira (2020) – is that “Companies with an outsourcing business model rely on the H-1B program to build and expand a business model based on outsourcing jobs. In this arrangement, rather than being employed directly by the company that hired them, the H-1B workers ultimately work for third-party clients, either on- or off-site.”

Our paper develops a theoretical model arguing that the US government’s response to this first concern has created costs exacerbated by the second. Namely, lottery allocation of quota-restricted H-1Bs and domestic outsourcing behavior combine to generate search cost externalities that would not exist under alternative methods of H-1B allocation, and these externalities lead to a loss of quota rents.

In an effort to reduce potential labor market competition with skilled immigrants, the US limits the number of new H-1B entrants (at most firms) to just 85,000 per year. This cap (or quota) is far exceeded by interest in the H-1B program. At its peak to date, USCIS received more than 236,000 petitions for new H-1B status in the first week of application eligibility for fiscal year 2017. As with any quota, the H-1B cap generates the potential for

¹See Hunt and Gauthier-Loiselle (2010), Kerr and Lincoln (2010), Hunt (2011), Moser et al. (2014), Kerr, Kerr, and Lincoln (2015), Peri, Shih, and Sparber (2015), Bernstein et al. (2018), and Gunadi (2019).

²See Borjas and Doran (2012), Bound et al. (2015), Ma (2020), and Turner (2020). This is related to a worry that strong employer/employee links within the H-1B program might inhibit labor mobility and therefore provide a recipe for labor exploitation. Depew et al. (2017) and Hunt and Xie (2019), however, argue that H-1B workers are quite mobile, thus reducing the possibility for exploitation of this type.

rents.³ However, current US policy allocates new H-1B status through a random lottery, and this destroys quota rents that could have otherwise been retained as welfare or government revenue.

In particular, our theoretical model demonstrates that random allocation has generated two presumably unintended costs that would not exist in alternative systems (such as through firms’ willingness to pay in the presence of a quota, a wage floor, or a tax on H-1B employment). First, it has incentivized firms to search for (and extend offers to) far more workers than can actually be hired through the program. Any offer extended by one firm creates a negative externality on competing firms by reducing the chances that they will win the lottery and secure permission to hire the individuals they would like to employ. Second, some firms specialize in outsourcing services that contract out labor to other firms. Such specialization might carry economic benefits in a competitive free market, but given quota restrictions and lottery allocation, outsourcing specialists further increase the number of petitions for H-1B status. The lottery and outsourcing behavior therefore amplify costs associated with the H-1B quota. We provide simple numerical exercises estimating that the negative job search externality cost US firms more than \$1 billion during the late 2010s when firms submitted an extraordinarily high number of H-1B petitions on behalf of prospective employees. In other words, the government forfeited between \$12,000 and \$22,000 per new H-1B worker hired that could have been retained as tax revenue or that could be reserved as labor or firm welfare under alternative allocation methods.

These results – and our model in general – provide important insights for ongoing policy analysis. In February 2018, USCIS (2018) issued a policy memorandum that made it more difficult for employers to hire H-1B workers who they intended to place at third-party sites. This policy required “detailed statements from end-user clients, copies of client contracts, and work itineraries to demonstrate that non-speculative assignments were available throughout the entire requested period” (National Law Review (2020b)). Perhaps as a consequence, H-1B denial rates rose from 13% in FY 2017 to 24% the following year. Anderson (2020) and The National Foundation for American Policy (2020) report that increases in denial rates between FY 2015 and 2020 were much larger among Costa and Hira’s (2020) outsourcing firms such as Cognizant (52 percentage points), Infosys (57 pp.), and Tech Mahindra (32 pp.) than at non-outsourcing firms using the H-1B program heavily such as Amazon (15 pp.), Google (13 pp.), Microsoft (13 pp.), and Facebook (8 pp.). H-1B employers won a lawsuit challenging these rules in the US District Court for the District of Columbia in May 2020. As a result, USCIS rescinded the memorandum and issued less restrictive guidelines (National

³These quota rents are equivalent to the revenue that would be generated by a tax causing an equivalent decline in quantity.

Law Review (2020a) and USCIS (2020b)). The Department of Labor (DOL) and Department of Homeland Security (DHS) issued similar rule changes restricting the employment of H-1B workers at third-party sites in October 2020, but they were overturned in court during the following December.

Even more recently, DHS suspended the H-1B lottery during the waning days of the Trump administration. Instead, the new rule in DHS (2021) called for allocating new H-1B status to individuals earning the highest salary offers. On September 15, 2021, however, a United States district court overturned that order on the basis that then-Acting DHS Secretary Chad Wolf “was not lawfully appointed as Acting Secretary at the time DHS promulgated the rule.” Thus, the lottery remains in place, but the court did not rule against using an alternative in the future.⁴ Knowledge about how lottery allocation – as opposed to the quota itself – can be useful in informing continuing debates.

This paper also adds to the economics of immigration literature’s knowledge about lottery allocation. While past work including Kerr et al. (2010), Peri et al. (2015a), Sparber (2018), and Mayda et al. (2020) have argued that H-1B restrictions and the H-1B lottery harm aggregate productivity, wages, the selection of foreign employment, and firm outcomes, our paper is unique in arguing that the lottery allocation mechanism and outsourcing behavior combine to generate substantial quota rent losses associated with job search externalities. This inefficiency is not the simple deadweight loss that would typically arise due to an intervention into a well-functioning market. Rather, it is an additional cost specific to the lottery that would not arise through other allocation schemes.

Our paper is similarly related to a smaller literature on the H-1B program, outsourcing, and employment concentration. For example, our modeling of domestic outsourcing behavior (i.e., sending employees to third-party worksites within the United States) complements work by Glennon (2020), who finds that firms respond to H-1B restrictions by moving production to foreign affiliates. Also, one implication of our model is that the quota, lottery allocation, and outsourcing lead to an increased concentration of H-1B employment among a small group of employers. Mayda et al. (2018) perform triple difference regressions finding empirical evidence for this effect. We therefore build a theoretical foundation explaining those prior empirical results.

Firms in our model generate output according to a standard Constant Elasticity of Supply (CES) production function and face monopolistically competitive demand for their products. A single key assumption drives our results: While most “regular” firms experience increasing marginal costs associated with labor searches, a select group of “outsourcing” firms expe-

⁴See Anderson (2021) and *Chamber of Commerce of the United States of America v. United States Department of Homeland Security* (2021).

riences constant marginal costs, possibly because they have a large pool of potential H-1B workers already employed at overseas headquarters or affiliates.⁵ An important implication is that the changes in the H-1B quota do not generate proportional changes in the probability of winning the lottery since the quota also affects the number of petitions that firms submit. That is, a 1% decrease in the cap reduces the probability of winning by more than 1%, implying that the elasticity of the winning probability with respect to the cap is greater than 1. We provide a closed form solution demonstrating that this elasticity is positively related to the share of firm expenditures spent hiring H-1B workers in the economy and the premium paid to outsourced workers. We can also write it as a function of the win probability and the proportion of H-1B petitions filed in excess of actual H-1B demand. In any case, the higher this elasticity, the more the quota leads to higher search externalities and increased H-1B concentration.

Our theory and the externalities it identifies are broadly related to those arising in models from several different fields. Quota rents are perhaps most frequently examined in the international trade literature. Our model’s implications resemble those of Krueger’s (1974) seminal work on competitive rent seeking behavior’s destruction of quota rents. Our analysis shows that the combination of a lottery and a competitive outsourcing sector leads to a similar destruction of quota rents. Public finance economists (Morgan (2000), Landry et al. (2006) and Lange et al. (2007)) have examined the use of raffles in the voluntary provision of public goods. In that context, bidding externalities are potentially positive because they can help offset free rider problems associated with the voluntary provision of public goods. The implications of our model are the opposite since H-1B petitions impose negative externalities on competing firms. In this sense, our approach is more similar to the concept of a stock externality (Gordon (1954), Smith (1968), Brito and Intriligator (1987)) in which the actions of a firm to deplete a finite resource impose costs on other firms that would also like to access it. Our theory is perhaps even more closely related to all-pay auctions (Baye, Kovenock, and de Vries (1996)) in which firms simultaneously submit bids for a resource, all participating firms forfeit their bids, and only the top bidder acquires the resource. In this case, a firm’s decision to increase the value of its bid imposes an externality on other firms by reducing their chances of winning. An important distinction between such an all-bid auction and our model, however, lies in the role of willingness to pay. In an auction, a firm with the highest demand for a resource (labor, in our setting) can be guaranteed to win if its bid accurately reflects its willingness to pay. In our lottery setting, by contrast, a firm with

⁵Note, for example, that in FY 2019 more than half of H-1Bs granted for initial employment, and nearly three quarters of H-1Bs overall, were allocated to workers born in India, while Indian-based companies are frequently cited as outsourcing firms.

high demand can increase its chance of winning by submitting a large number of bids, but it cannot guarantee success.

2 Stylized Facts about the H-1B Program

This paper develops a theoretical model arguing that H-1B program design creates negative labor search cost externalities, destroys capturable quota rents, and leads to an increased concentration of H-1B workers among a small number of firms. To understand this behavior, we first describe the program and summarize H-1B employment trends.

The H-1B program provides an important channel for college-educated foreign citizens to work in the United States. USCIS grants individuals H-1B status for up to a three year initial period that can then be renewed for a total of six years. The government has always imposed a statutory limit on the number of new H-1Bs issued per fiscal year. That limit equaled 195,000 from FY 2001-2003 but it was effectively non-binding since it was never reached. The cap dropped to 65,000 for FY 2004 and has held at 85,000 since FY 2006 when the H-1B Visa Reform Act became operational and added 20,000 H-1Bs for people who have obtained a masters degree or more education from a US institution. The quota has been binding throughout this period. All employees of colleges, universities, and non-profit institutions are exempt from the cap, as are workers applying to renew their H-1B status.

USCIS grants H-1B status to individuals, not firms, but strong employer/employee links in the program can lead to confusion on this point. A firm wanting to hire an H-1B worker begins by filing a Labor Condition Application (LCA) with the US Department of Labor attesting that it will abide by specific work conditions (e.g., that it will pay H-1B workers a wage at or above the wage earned by similar U.S. workers or the prevailing wage). This form also contains basic information about the job including the wage, date of intended employment, occupation title, and work location. There is no limit to the number of LCAs a firm can file, a single LCA can be used for multiple open job positions, and there is no LCA filing fee. The LCA serves as a *de facto* government permission slip for a firm to include foreign workers in its job search. It provides a crude measure of a firm's intent to hire foreign labor with the caveat that the number of job openings with LCA approval will far exceed the number of job offers that firms eventually extend to foreign workers.⁶

A firm can extend a job offer to a qualified foreign-born worker if it has obtained an approved LCA. It must then file an I-129 petition applying for H-1B status on the individual's behalf. Unlike LCAs, I-129 forms are linked with specific individuals. Thus, these forms not only include information about the employer, but the prospective employee as well. Also

⁶Sparber (2019) describes this in more detail.

unlike LCAs, I-129 submissions require filing fees that begin at \$460 and might include additional fraud detection fees that vary across firms. The Consolidated Appropriations Act of 2016 (Public Law 114-113) created an additional \$4000 fee for firms employing 50 or more employees if more than 50% of those employees are on H-1B status.

In principle, USCIS grants H-1B status to individuals on a first-come first-served basis. In practice, however, the H-1B program is vastly over-subscribed and USCIS has allocated all cap-subject H-1Bs with a random lottery in recent years.

Numerical caps pertain to fiscal years that begin on October 1. Through FY 2020, USCIS accepted I-129 petitions beginning on the previous April 1. The number of cap-subject I-129 petitions submitted during the first week of April for FYs 2008, 2009, and 2014-2020 exceeded the total H-1B cap for the entire year. Figure 1 illustrates that USCIS received roughly 89,000 cap-subject petitions when H-1B limits exceeded the number of applications in FYs 2002 and 2003. In FYs 2008 and 2009, that number reached 123,000 and 163,000, respectively. The number surpassed 236,000 for FY 2017 before dipping to around 200,000 in FYs 2018-2020. Partly as a result of high demand, the Department of Homeland Security (DHS) began to require firms filing cap-subject petitions to first electronically register with USCIS during March preceding the fiscal year. USCIS (2020c, 2022) reported receiving 275,000 unique registrations for FY 2021; 308,613 for FY 2022; and a staggering 483,927 for FY 2023. The numerical analysis in this paper relies upon data before this change in registration procedure, and therefore refers to 2017 as the year of peak demand.

Unfortunately, Figure 1 provides a good measure of firms' actual demand for new H-1B workers only for FY 2002 and 2003. This is due to two data limitations. First – and most obvious – firms with an interest in hiring an H-1B worker after national limits have been exceeded will never petition USCIS for H-1B approval. USCIS cannot measure this demand. However, Mayda et al. (2018) estimate that in the absence of the reduced H-1B cap, demand would have been 16-26% higher than the 85,000 cap in FYs 2004-2007, and 22-33% higher in FYs 2008-2009. This would imply a maximum of new H-1B demand between 103,700 and 113,050 in each of these years, and yet firms applied for 163,000 new H-1B workers in FY 2009. This points to the second data limitation using I-129 petitions as a measure of H-1B demand. The theoretical model in Section 3 will show that petitions rise simply because firms compete against each other for a labor source that is constrained by artificial limits and allocated by lottery. That is, the H-1B cap and lottery create a job search cost for firms such that the number of jobs offered exceeds the number of employees actually demanded. This negative externality reduces welfare and destroys quota rents.

Another concern about the H-1B program – commonly expressed in the popular media and policy papers – is that it provides a vehicle for domestic outsourcing activities. Costa

and Hira (2021) argue that just 30 firms accounted for nearly 40% of H-1B issuances in fiscal year 2020, more than half of which used an outsourcing model. Using earlier data and analysis by Hira, Park (2015) reports that “In recent years, global outsourcing companies have dominated the program, winning tens of thousands of visas and squeezing out many American companies, including smaller start-ups. 13 outsourcing companies took nearly one-third of all H-1B visas in 2014.” North (2020) similarly argues that “outsourcing firms... control of [*sic*] 36 percent of the H-1B visas.” Loten (2020), Torres (2017), and Fernandez Campbell (2016) provide further anecdotes describing how although some companies hire H-1B workers directly, many do so through business services companies including Accenture, Cognizant, and Infosys.

More systematic evidence of this outsourcing behavior is not immediately available since administrative datasets on the H-1B program do not definitively identify outsourcing firms. Moreover, other firms might decide to provide outsourcing services even if that is not their primary business function. Instead, we use data on approved individual I-129 petitions from FYs 2002-2011 acquired through a Freedom of Information Act (FOIA) request to USCIS to construct several descriptive statistics illustrating a related firm behavior: Approved, cap-subject, H-1B workers are increasingly concentrated among fewer firms. For example, when H-1B issuances were unconstrained by the quota in FYs 2002 and 2003, 70% of for-profit firms seeking new H-1B workers filed only a single petition. These unique firm names accounted for 41% of all new cap-subject H-1Bs issued during that period. Contrast this outcome with FYs 2008 and 2009 when the cap had decreased to 85,000 and all new H-1Bs were allocated by random lottery. Unique firm names petitioning for a single cap-subject H-1B worker accounted for 62% of firms but one-fifth of new issuances. New H-1B employment was far more concentrated in a fewer set of firms during these lottery years.

Those summary statistics may be somewhat misleading in the sense that a single firm in the dataset can be represented by different name variants due to typos, misspellings, or alternative naming conventions. It is possible that firms took greater care to ensure consistent name spellings in later years, thus leading to a spurious change in the measured concentration of new H-1B hires between these time periods. We take two steps to correct and/or rule out this possibility. First, we employ an automated routine to correct misspellings based upon the Levenshtein edit distance between firm names (Reif (2010)). This method compares the number of characters in a firm name that would need to change for two firms to share a name. We choose a relatively high threshold value of 25% for this procedure: If 25% or fewer characters would have to change, we assume that the two names belong to the same firm, and we group workers accordingly.⁷ Second, we separately consider for-profit firms relative

⁷We also employ a 10% threshold and no correction at all. These differences do not affect our qualitative

to colleges, universities, and non-profit research institutions – employers exempt from H-1B limits throughout this time period – as a rudimentary control group.⁸

The top panel of Figure 2 displays the share of new H-1Bs awarded to employees of firms hiring five or fewer total H-1B workers in a given year (after applying the automated routine to correct for firm name variants). This value was above 50% in FYs 2002 and 2003 for cap-subject firms, but it declined precipitously after the quota became binding (in 2004) and has fluctuated between 25% and 30% since then. The share among cap-exempt firms, however, remained fairly static at 20%.

Figure 2 augments our FOIA evidence from 2002-2011 with aggregate statistics provided by the USCIS H-1B Employer Data Hub from 2009-2019. One limitation of this data is that it does not provide an identifier for whether a firm is bound by H-1B caps. Instead, we proxy for cap-exempt firms as those with “UNIV”, “COLLEGE”, or “INSTITUTE” in their names, except for those with “UNIVERSAL”. The two datasets reasonably resemble each other for the three fiscal years of overlap. The Data Hub data suggests a continuation of previous years’ trends: Very few H-1B employees have worked for firms hiring five or fewer total H-1B workers in recent years.

By contrast, the bottom panel displays the shares of new H-1Bs awarded to workers at firms hiring 250 or more total H-1B employees in a given year. This H-1B intensity has perhaps declined among cap-exempt employers over time, but it raised dramatically from about 10% in FY 2002 and 2003 to over 35% in 2011 for cap-subject firms. Data Hub statistics suggest that this share has usually been above 40% in recent years.⁹ Trends in shares reflect raw counts. Whereas the number of H-1Bs allocated to firms employing five or fewer H-1B workers declined by about 50% among cap-subject firms between the non-binding period (FYs 2002 and 2003) and 2011, that number tripled among firms hiring 250 or more H-1B workers. H-1B hiring has become a specialized endeavor.

Figure 3 complements our I-129 data with information from LCA filings. As noted above, LCAs might provide a measure of intent to hire foreign labor. This data is noisier. Specified work start dates are merely projections at best and might not correspond to actual projected start dates at all.¹⁰ LCAs provide no indication of whether the employer is cap

conclusions.

⁸Given the timing of H-1B petitions, we record all I-129 petitions beginning in April and moving forward as belong to H-1B caps for the fiscal year beginning in the subsequent October. Mayda et al. (2018) follow this strategy as well.

⁹Roughly 40% of H-1Bs are awarded to workers at firms employing more than 5 but fewer than 250 H-1B workers each year. This regularity has been steady throughout our time period, and the figure is available upon request.

¹⁰Firms need to have approved LCAs in March if they intend to file an I-129 petition in April, but they can only submit an LCA six months in advance of the stated work start date. Peri et al. (2015b) document pre-dating behavior in which firms file LCAs with stated start dates in September for work that is more

exempt. Moreover, LCAs are not linked to employees, so they will not indicate whether the worker will be seeking new (cap-subject) or continued (cap-exempt) H-1B status.

Despite these limitations, the documented trends for LCA filings in Figure 3 (after employing the automated name correction routine and cap-exempt firm proxy described above) mirror those of H-1B petitions in Figure 2. We graph trends across calendar years of stated work start dates. Among cap-subject firms, the top panel of Figure 3 shows a sustained decline in the proportion of LCAs filed by firms submitting five or fewer total LCAs per year, falling from over 17% in 2002 and 2003, and stabilizing at about 5.5 to 7.5% from 2012 through 2019. The figure hovers around 6.5 to 8.5% for cap-exempt employers throughout the period. The bottom panel shows that since 2012, roughly 75% or more of LCAs filed by cap-subject firms have originated with firms seeking 250 or more H-1B workers. This compares to a figure below 50% in years when statutory H-1B limits were high. The share among cap-exempt firms declines over this period, however.

Our paper contends that increasing H-1B concentration – unique among cap-subject firms – is not random. Rather, it reflects firms’ rational responses to restrictive limits on H-1B hiring. Though this concentration occurred before all cap-subject H-1Bs were allocated by lottery, we interpret this as evidence that H-1B outsourcing firms began to play a more dominant role in the program as soon as it became clear that new H-1B issuances would be restricted. Palagashvili and O’Connor (2021, p. 6) offer qualitative evidence in support of this view. They summarize a survey conducted among roughly 400 executives of small US technology firms by noting that “The responses from small startups indicate that changes to the H-1B visa program to make it more restrictive and costly will not necessarily lead small businesses to hire more Americans. Instead, small startups will continue to settle for hiring overseas contractors rather than hiring what they would prefer – foreign workers as employees.” The following section develops a theory to model domestic outsourcing behavior and its cost implications.

3 Theoretical Model

This section builds a theoretical model to understand how restrictive H-1B caps affect firm behavior. Before turning to the mathematics, it is helpful to understand the intuition that will drive the main results. The section then closes with simple graphs illustrating predicted welfare losses.

First, imagine a lottery contest. Suppose the government decreases the number of winners and therefore the probability of any single entry from winning. A competitor with a strong

accurately scheduled to begin in October.

interest in winning might rationally respond by increasing its number of entries. This further reduces the probability of any single entry from winning and therefore imposes an externality on other competitors. If all competitors behave this way then it will create a multiplier effect that generates and amplifies large costs. In the context of our paper, the competitors are firms that increase their number of lottery entries by offering an increasing number of jobs to foreign-born workers, many of whom will lose the H-1B lottery.

Second, entering the lottery is not a costless proposition. Firms wanting H-1B workers will need to conduct job searches, make job offers, complete government forms, and submit processing fees. Firms are heterogenous – some will find the procedure more cumbersome than others. Those finding the process to be particularly onerous might not participate at all.

Third, firms that fail to hire their desired number of H-1B workers directly are not completely shut off from the foreign labor market. They can indirectly hire such a worker by contracting with firms specializing in H-1B employment to provide the desired services. That is, they can meet their labor needs by contracting with outsourcing firms as Costa and Hira (2020) define the term.¹¹

With that intuition established, we begin the formal modeling by considering a firm, indexed by i , that faces a CES demand for its product and can produce x_i units using a combination of native and foreign labor. In stage 1, the firm chooses the number of H-1B applications, F_{iA} , so as to maximize expected profits. In stage 2, the lottery outcome is realized and the firm learns of the number of successful bids, $F_{iS} \leq F_{iA}$. The firm then chooses the number of immigrant workers (F_i) and native workers (N_i) to use. Thus, the firm – regardless of whether it specializes in providing outsourcing services or not – chooses to interact with other firms to either rent out or contract for immigrant workers in the second stage. We can solve the firm’s problem backwards starting from stage 2.

3.1 Stage 2

3.1.1 Setup

After the lottery outcome is realized, the firm learns its number of successful H-1B bids F_{iS} . It can hire up to this number of workers at immigrant labor wage w^F , which is the wage actually received by H-1B workers. It can choose to either rent out or contract for immigrant labor at a wage rate of w^O , which in equilibrium will be greater than w^F . The firm also

¹¹Our paper builds a theoretical model of outsourcing labor to third party sites within the United States. Complementary but distinct empirical analysis in Glennon (2020) finds that restrictive H-1B policies cause firms to offshore jobs to their foreign affiliates, while Olney and Pozzoli (2021) estimate a negative relationship between immigration and firm-level offshoring in a Danish context.

employs native-born workers at wage w^N .

3.1.2 Demand and Revenue

The firm produces a differentiated product and faces a CES demand curve derived from an underlying quasi-linear preference structure provided in Appendix A. Demand for good x_i is:

$$x_i = p_i^{-\sigma} \alpha_i \frac{E}{P^{1-\sigma}}, \quad (1)$$

where E is the total expenditure on all varieties and is constant; P is the price index for all the varieties of the good produced in this sector, and is constant from the firm's perspective;¹² α_i is a taste parameter; and σ is the elasticity of substitution across products.

The inverse demand function for the firm is:

$$p_i = \left(\frac{1}{\alpha_i} \frac{E}{P^{1-\sigma}} \right)^{1/\sigma} x_i^{-1/\sigma} \quad (2)$$

The firm's revenue generated by sales of its good (i.e., revenue excluding any potential income from renting out excess labor) is:

$$R_i = \left(\alpha_i \frac{E}{P^{1-\sigma}} \right)^{-1/\sigma} x_i^{\frac{\sigma-1}{\sigma}} \quad (3)$$

3.1.3 Production Function and Cost

Firms produce good x_i according to a CES production function that combines native and foreign labor with an elasticity of substitution of ϵ , augmented by a firm-specific productivity parameter (A_i):

$$x_i = A_i \left(N_i^{\frac{\epsilon-1}{\epsilon}} + F_i^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}} \quad (4)$$

Substituting (4) into (3), production revenue is:

$$R_i = \left(\frac{1}{\alpha_i} \frac{P^{1-\sigma}}{E} \right)^{-1/\sigma} \left[A_i \left(N_i^{\frac{\epsilon-1}{\epsilon}} + F_i^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}} \right]^{\frac{\sigma-1}{\sigma}} \quad (5)$$

The cost of production accounting for the net cost of outsourcing is:

$$C_i = w^N N_i + w^F F_i + (w^O - w^F) (F_i - F_{iS}) \quad (6)$$

¹²The constant E setup is useful for expositional simplicity but could be relaxed without affecting the thrust of our analysis.

Note that $F_i - F_{iS}$ is the difference between the actual number of foreign workers the firm uses in the production process and the number of successful H-1B bids it has received. When positive, it therefore represents “imported” labor. The firm contracts with third party providers to supply labor services at wage rate w^O . These third party providers are likely to be outsourcing specialists, but they may also be regular firms that simply won the right to employ more workers than it intended to hire. When negative in value, C_i includes the revenues firms receive from renting out their H-1B workers to firms desiring more labor.

3.1.4 Profit and Factor Expenditure Functions

Subsection 3.2 will describe search costs incurred in the first stage. In the firm’s second stage decision these costs are sunk. Its relevant profit function is then simply:

$$\Pi_i = R_i - C_i \quad (7)$$

Given the realized number of successful H-1B bids, F_{iS} , the firm chooses the optimal native (N_i) and foreign (F_i) employment to maximize (7). This gives us two first-order wage conditions:

$$\frac{\partial R_i}{\partial x_i} \frac{\partial x_i}{\partial N_i} = w^N \quad (8)$$

$$\frac{\partial R_i}{\partial x_i} \frac{\partial x_i}{\partial F_i} = w^O \quad (9)$$

We see from (9) that the marginal revenue product of immigrant labor is equal to the outsourcing wage at the optimum. This may be surprising given that the firm will generally use at least some labor from its own successful bids, in which case it would pay w^F instead of w^O . However, since H-1B workers can always be “exported” to other firms, the opportunity cost of using a worker in production is still given by w^O for regular and outsourcing firms alike.

The production function in (4) and wage conditions in (8) and (9) combine to deliver a standard marginal rate of technical substitution condition:

$$\frac{F_i}{N_i} = \left(\frac{w^N}{w^O} \right)^\epsilon \quad (10)$$

We next insert (10) into (8) and (9) to solve for the optimal expenditure on native and foreign-born labor:

$$w^N N_i = \frac{(w^N)^{1-\epsilon}}{(w^O)^{1-\epsilon} + (w^N)^{1-\epsilon}} \frac{\sigma-1}{\sigma} R_i \quad (11)$$

$$w^O F_i = \frac{(w^O)^{1-\epsilon}}{(w^O)^{1-\epsilon} + (w^N)^{1-\epsilon}} \frac{\sigma-1}{\sigma} R_i \quad (12)$$

These are standard CES factor expenditure functions, except with the opportunity cost of hiring foreign-born labor, w^O , being the relevant wage for immigrants.

3.1.5 Profits

We can plug expenditure functions (11) and (12) into the cost expression (6) to get:

$$C_i = \frac{\sigma-1}{\sigma} R_i - (w^O - w^F) F_{iS} \quad (13)$$

The firm's profits are then:

$$\Pi_i = \frac{1}{\sigma} R_i + (w^O - w^F) F_{iS} \quad (14)$$

The above expression is similar to the standard CES profit maximizing choice except that the second term captures the benefit of having more successful H-1B bids.

We take two steps to calculate the optimal level of output (x_i) in terms of the parameters of the model. First we substitute the cost expressions (11) and (12) into the production function (4). Then we insert the revenue function from (3). The resulting output functions become:

$$x_i = \frac{\sigma-1}{\sigma} A_i \left[(w^N)^{1-\epsilon} + (w^O)^{1-\epsilon} \right]^{\frac{1}{\epsilon-1}} R_i \quad (15)$$

$$x_i = \left(\frac{\sigma-1}{\sigma} A_i \right)^\sigma \left(\frac{1}{\alpha_i} \frac{P^{1-\sigma}}{E} \right) \left[(w^N)^{1-\epsilon} + (w^O)^{1-\epsilon} \right]^{\frac{\sigma}{\epsilon-1}} \quad (16)$$

Equation (16) gives us the firm's optimal choice as a function of wages as well as demand and productivity parameters from the firm and industry. This finally allows us to write profits, given by (14), as a function of parameters and factor prices:

$$\Pi_i = K_i \left[(w^N)^{1-\epsilon} + (w^O)^{1-\epsilon} \right]^{\frac{\sigma-1}{\epsilon-1}} + (w^O - w^F) F_{iS}, \quad (17)$$

where $K_i \equiv \left(\frac{\sigma-1}{\sigma} A_i \right)^{\sigma-1} \frac{1}{\sigma} \frac{1}{\alpha_i} \frac{P^{1-\sigma}}{E}$ is a constant from the standpoint of the firm. We will now be able to use (17) in the firm's first stage problem.

3.2 Stage 1 Problem

3.2.1 Probability Distribution and Density Functions

In Stage 1, the firm chooses the optimal number of H-1B applications, F_{iA} , so as to maximize expected profits, taking as given the optimal choices it will make in Stage 2. In order to write down the firm's expected profits when accounting for search costs, we need to specify the stochastic process that determines the successful number of bids, F_{iS} . This poses a potential problem because while we can follow standard practice in ignoring any integer constraint on F_{iA} , we would still somehow have to account for the fact that the distribution of F_{iS} will be binomial with a constant probability ρ of winning the lottery. We deal with this challenge by using a continuous version of the binomial distribution (Ilenko, 2013), the cumulative density function (CDF) of which is:

$$G(F_{iS}; F_{iA}) = I_{1-\rho}(F_{iA} - F_{iS}, 1 + F_{iS}), \quad (18)$$

where $I_{1-\rho}(\cdot)$ is the regularized incomplete beta function. The associated probability density function is:

$$g(F_{iS}; F_{iA}) = \frac{dI_{1-\rho}(F_{iA} - F_{iS}, 1 + F_{iS})}{dF_{iS}}, \quad (19)$$

which exists but does not have a simple closed form. This continuous binomial distribution is a generalization of the regular binomial distribution that is also defined for non-integer values of F_{iA} and F_{iS} through the use of gamma functions in place of factorial-based expressions.

3.2.2 Expected Profits

Given the probability distribution functions, we can write the firm's expected profits when accounting for search costs, $E[\pi_i]$, as:

$$E[\pi_i] = \int_0^{F_{iA}} \Pi_i(F_{iS}) dG(F_{iS}) - cF_{iA} - c_i \frac{1}{\lambda} F_{iA}^\lambda \quad (20)$$

The firm's cost of filing an H-1B petition is represented by cF_{iA} . Although the government varies these fees across firms as described above, we hold them constant for simplicity. By contrast, we allow the search costs associated with finding F_{iA} potential H-1B workers ($c_i \frac{1}{\lambda} F_{iA}^\lambda$) to vary, with c_i serving as a firm-specific search cost parameter. We assume that $\lambda > 1$ for most employers so that these regular firms face an increasing marginal cost of finding H-1B workers.¹³ Conversely – and to be discussed more thoroughly in the next sub-

¹³We choose this specific iso-elastic functional form for these costs for simplicity and ease of interpretation.

section – we assume that a select group of outsourcing firms face constant marginal search costs ($\lambda = 1$), which will motivate their decision to specialize in providing outsourcing services.

By substituting the second-stage maximum profit condition (17) into the first-stage expected profit function (20), we get:

$$E[\pi_i] = K_i \left[(w^N)^{1-\epsilon} + (w^O)^{1-\epsilon} \right]^{\frac{\sigma-1}{\epsilon-1}} + (w^O - w^F) \rho F_{iA} - c F_{iA} - c_i \frac{1}{\lambda} F_{iA}^\lambda, \quad (21)$$

where ρF_{iA} is the mean of the binomial distribution. The marginal expected profit from filing an H-1B petition is then:

$$\frac{\partial E[\pi_i]}{\partial F_{iA}} = (w^O - w^F) \rho - c - c_i F_{iA}^{\lambda-1} \quad (22)$$

The first term represents the marginal benefit of a bid, which equals the premium an employer can earn by renting a worker to another firm ($w^O - w^F$) multiplied by the probability that the bid will be successful (ρ). The latter two terms represent the marginal costs associated with searching for a perspective worker and filing a petition.

For regular firms in which $\lambda > 0$, we can set this expression equal to zero and solve for its optimal number of H-1B petitions:

$$F_{iA} = \left[\frac{(w^O - w^F) \rho - c}{c_i} \right]^{\frac{1}{\lambda-1}} \quad (23)$$

Intuitively, this value is increasing in the expected premium, $(w^O - w^F) \rho$, and decreasing in both the application cost c and the search cost parameter c_i . Perhaps surprisingly, the optimal number of bids is entirely independent of the firm's actual needs, which would depend on its production costs and demand for its output. This is because the firm's ability to rent out or contract for labor as needed fixes the benefit of a successful bid to equal $w^O - w^F$ at the firm's optimum.

3.2.3 Outsourcing Firms

In principle, any firm can rent out its labor to other firms. However, we exogenously separate firms into two types: regular firms (with each firm i filing F_{iA} petitions) and outsourcing firms that specialize in providing labor to third party sites (with each firm j filing F_{jA}^O petitions). We assume that these firm types differ in that regular firms have increasing marginal search costs (driven by $\lambda > 1$) as described above. Outsourcing firms, on the other hand, face a

Qualitatively, any increasing marginal cost function would give us similar results.

constant marginal search cost ($\lambda = 1$) equal to c_X . On the surface, this dichotomy might appear to constitute a *Deus ex machina* assumption, but we believe it accurately reflects the reality noted in Section 1 that many outsourcing specialists are headquartered overseas (particularly in India) and are likely to have a large pool of potential H-1B workers already on their payroll abroad. Thus, they would not face the same challenges as domestic firms when looking more people to work in the US. With this assumption, and after making the appropriate F_{jA}^O , c_X , and $\lambda = 1$ substitutions into (21), we see that profits for outsourcing firms are linear in the number of H-1B petitions filed. For these firms, the marginal profit function becomes:

$$\frac{\partial E[\pi_i]}{\partial F_{jA}^O} = (w^O - w^F) \rho - c_X - c \quad (24)$$

Outsourcers will never file an H-1B petition – and will therefore cease to exist – if the expression in (24) is negative. Since this outcome is inconsistent with real world observation, we largely dismiss it as a curiosity except to note that in the equilibrium identified in the next subsection, the sum of H-1B bids filed by outsourcing firms would also necessarily equal zero in this scenario (i.e., $\sum_j F_{jA}^O = 0$). Conversely, the expression seemingly suggests that outsourcing firms will submit an infinite number of petitions if $(w^O - w^F) \rho > c + c_X$. Note, however, that this explosion in applications would drive down the probability that any one petition will be selected in a lottery with a fixed number of available H-1B positions. That is, ρ would collapse until (24) is no longer positive. Thus, the only stable equilibrium in which outsourcers exist occurs where $\frac{\partial E[\pi_i]}{\partial F_{iA}} = \frac{\partial E[\pi_i]}{\partial F_{iA}^O} = 0$ for regular and outsourcing firms alike. Whereas regular firms file H-1B petitions according to (23) above, outsourcers do so with perfect elasticity such that the premium for renting out an H-1B worker is characterized by:

$$(w^O - w^F) = \frac{c + c_x}{\rho} \quad (25)$$

3.3 Equilibrium

3.3.1 Equilibrium Concept

In the above analysis, we assume the firm faces uncertainty about the number of successful bids it receives (F_{iS}) but not about other values such as the probability of success (ρ) and the wage it will have to pay to H-1B workers, whether employed directly or through its decisions to contract for or rent out labor (w^O). This requires a rational expectations equilibrium concept, where firms' choices regarding the number of submitted H-1B petitions are optimal given the realized wages and ρ in the second stage. We also assume that there is no aggregate

uncertainty. Ultimately, the number of petitions filed, the probability of success, and wages paid are endogenous variables determined by the size of the H-1B quota and the model's cost and elasticity parameters.

3.3.2 Equilibrium Conditions

The total supply of immigrant labor is fixed by the H-1B quota, Ω . The supply of native workers is also assumed to be constant and is equal to \bar{N} . We can write the outsourcing wage in terms of the native wage by combining the optimal expenditure functions in (11) and (12) and then summing over all firms. This delivers a marginal rate of technical substitution relation that is the aggregate analogue to the firm-level equivalent expressed in (10):

$$\frac{\Omega}{\bar{N}} = \left(\frac{w^N}{w^O} \right)^\epsilon \quad (26)$$

We can also sum over firms' foreign labor expenditures in (12) and simplify to get:

$$w^O \Omega = \frac{(w^O)^{1-\epsilon}}{(w^O)^{1-\epsilon} + (w^N)^{1-\epsilon}} \frac{\sigma - 1}{\sigma} E \quad (27)$$

The model is closed by setting the successful number of bids equal to the actual H-1B quota:

$$\rho \left(\sum_i F_{iA} + \sum_j F_{jA}^O \right) = \Omega \quad (28)$$

Here, we separate the number of H-1B petitions (F_{iA}) submitted by regular firms i and those (F_{jA}^O) filed by outsourcing firms j . We can now use equations (23) and (25)-(28) to determine the endogenous variables F_{iA} , $\sum F_{jA}^O$, w^O , w^N , and ρ . Note that the distribution of H-1B petitions across outsourcers is indeterminate because these firms make no economic profits from outsourcing activities and are therefore willing to provide any number of workers in equilibrium.

3.3.3 Solving for the Equilibrium

To solve for the equilibrium values of our endogenous variables, we first recall that the perfectly elastic bid-supply of outsourcing firms identified in (25) determines the outsourcing premium – a net price, of sorts, for renting out H-1B workers. One can rearrange this expression to deliver the equilibrium probability of a successful bid: $\rho = \frac{c_X + c}{w^O - w^F}$. Success probabilities rise in proportion to outsourcing firms' marginal search costs and H-1B filing fees. The more difficult it is to find foreign workers, the fewer applications will be submitted, and hence the probability of winning will be larger. If the outsourcing premium ($w^O - w^F$)

is large, then firms will be incentivized to submit more H-1B applications, thus reducing the probability of winning any one individual bid.

We can then combine the outsourcing premium condition in (25) with the optimal H-1B petition condition in (23) to solve for the number of bids (F_{iA}) submitted by a regular firm. The resulting Equation (29) intuitively demonstrates that a firm submits fewer H-1B applications as its own marginal costs of extending a job offer rise. It will submit more applications if outsourcing specialists' marginal search costs are high since these costs would be passed along to regular firms in the form of higher outsourcing fees.

$$F_{iA} = \left(\frac{c_X}{c_i} \right)^{\frac{1}{\lambda-1}} \quad (29)$$

Next we can combine (25), (26), and (27) to determine the outsourcing wage as a function of the H-1B quota, native employment, and the elasticity parameters of the model:

$$w^O = \frac{\sigma-1}{\sigma} E \left[\Omega + (\bar{N})^{\frac{\epsilon-1}{\epsilon}} (\Omega)^{\frac{1}{\epsilon}} \right]^{-1} \quad (30)$$

From (30), w^O is increasing in the labor expenditure of the H-1B sector, which is given by $\frac{\sigma-1}{\sigma} E$. It is decreasing in the constrained supply of H-1B workers, the quota Ω . It is also decreasing in the supply of native labor, \bar{N} , as long as native and immigrant workers are more substitutable than what would be implied by Cobb-Douglas production (i.e., if $\epsilon > 1$).

Finally, we can determine the total number of H-1B applications filed by outsourcing firms ($\sum F_{iA}^O$) by using the simple supply and demand framework in (28). Consistent with the discussion above, this sum total in (31) increases if the outsourcing premium is high. It decreases if marginal search costs, application fees, or the sum of regular firms' filings are high.

$$\sum_j F_{jA}^O = \frac{\Omega}{c_X + c} (w^O - w^F) - \sum_i F_{iA} \quad (31)$$

The search costs that arise due to lottery allocation and outsourcing crucially depend upon the extent to which the quota induces firms to submit excess H-1B petitions. We examine this in Section 4, but first we turn to a graphical illustration of the job search externality.

3.4 Graphical Illustration

Our analysis emphasizes the externalities generated by the H-1B lottery and outsourcing behavior, not by the quota itself. The lottery entails costs in addition to the more conventional

deadweight loss inefficiency resulting from quantitative restrictions. Figure 4 provides an illustration of the counterfactuals that we consider for the stylized case such that marginal search costs for regular firms are so high that all hiring is performed by outsourcing firms.¹⁴

The left panel illustrates a free market equilibrium for H-1B workers. Assume that foreign workers supply their labor with perfect elasticity at wage w_0^F . Since all hiring is performed by outsourcers in this diagram, firms face constant marginal search cost $c_X + c$. The intersection between firms' demand for H-1B workers and the marginal cost of *hiring* them (the wage plus the search cost) determines the equilibrium level of H-1B employment at F^* .

The middle panel supposes that the government has an interest in limiting the number of new H-1B hires to Ω . Any intervention for achieving this outcome will generate a readily-identifiable deadweight loss inefficiency represented by the triangle with base $F^* - \Omega$ and height $(w_1^F + c_X + c) - (w_0^F + c_X + c)$. Box C (which is the same size as Box A) represents total search costs, while boxes A and B represent what the international trade literature refers to as quota rents: The rents people could earn if they had the exclusive rights to buy at a cheaper external price and resell at the more expensive domestic price. These quota rents are simply transfers of surplus from firms to some other entity.

Consider how different policies would affect the distribution of these quota rents. For example, the government could impose a tax of $w_1^F - w_0^F$ on firms for each H-1B worker hired. Quota rents A and B would then be transferred from firms to the government in the form of tax revenue. Alternatively, the government could institute an H-1B minimum wage equal to w_1^F . Under this policy, the quota rents would be awarded to H-1B workers in the form of higher wages. The most direct method of achieving the government's H-1B employment target, however, would obviously be to enact a quota equal to Ω representing the total number of new H-1B workers that can be hired. If workers continue to be allocated according to firms' willingness to pay, then the quota rents accrue to H-1B workers just as under a minimum wage plan. Importantly, all of these scenarios represent a counterfactual to current US policy. In each case, the marginal *search* cost of a hired worker is the same as it would be without government intervention (i.e., the free market diagram in the left panel). The intervention simply raises the marginal cost of hiring a worker to $w_1^F + c_X + c$. Foreign workers earn this amount, less the marginal cost of searching.

Contrast these outcomes with current US policy illustrated in the third panel. In this scenario, the government imposes an H-1B quota but allocates workers according to a random lottery. Note that the deadweight loss triangle induced by the quota is identical to that

¹⁴We impose this to simplify the graphical illustration of the search costs arising from the lottery and outsourcing in the context of a quota. It does not illustrate how the quota leads to a rising concentration of H-1Bs at outsourcing firms. We perform that numerical exercise in 5.3.

from the alternative scenarios presented in the middle panel. The unique feature of lottery allocation is that it breaks the one-for-one link between the number of workers with job offers and the number who are employed. Firms extend offers to Ω/ρ individuals for just Ω available slots. Thus, the marginal search cost for a successful hire rises to $\frac{cx+c}{\rho}$.

Firms pay H-1B workers the free market wage of w_0^F . Box C therefore continues to represent the total search cost for *hired* H-1B workers, but it no longer represents total search costs overall. That value must incorporate search costs for everyone who received a job offer. Since the market clearing outsourcing wage must equal w^O , we know that the vertical distance $w^O - w_0^F$ equals $\frac{cx+c}{\rho}$, just as predicted in Equation (25). In other words, the lottery and outsourcing amplify the costs associated with a quota. Quota rents – firms’ free market surplus in boxes A and B – are now entirely wasted on unnecessary search costs when they would have been distributed as welfare to foreign workers or as tax revenues to the government under alternative allocation systems.¹⁵ This waste – not the deadweight loss inefficiency – is the negative search cost externality that we seek to identify in this paper. Our numerical exercises in Section 5 estimate these quota rent losses. Parameters like $\frac{cx+c}{\rho}$, w^F , and w^O are unobservable, however, so we will instead rely upon other methods to assess the search costs associated with excess demand for H-1B workers. The quota will be useful in backing out parameters necessary for that exercise.

4 Results: Theoretical Implications

Our theoretical model described in Section 3 generates predictions for how the H-1B quota, lottery, and domestic outsourcing behavior affect search externalities and H-1B employment concentration. This section begins by demonstrating that domestic outsourcing exacerbates negative externalities associated with the lottery. It then describes how a tightening of the quota would affect both concentration and search externalities in this environment.

4.1 Search Cost Implications of Outsourcing Firms

As long as the H-1B quota is binding, outsourcing firms cannot affect the total number of workers actually hired, so they play no role in determining the deadweight loss inefficiency common to all quota systems discussed in Section 3.4. We therefore focus instead on how

¹⁵In our setup, the outsourcing sector is competitive and earns zero equilibrium profits. This is analogous to competitive rent-seeking in the trade quota literature, which also leads to the complete destruction of quota rents (Krueger, 1974). If there were imperfect competition among the outsourcing firms, this imperfect competition distortion would to some degree counteract the lottery externality so that a portion of quota rents would be preserved as pure profits for these firms.

outsourcing firms affect the search cost externality represented by lost quota rents.

One way to think about this issue is to consider possible policy actions and responses. The government could impose restrictions, for example, that would raise the search costs for outsourcing firms, c_X . This higher value for c_X would reduce regular firms' use of the services provided by outsourcing firms. This service has value since it allows firms in the H-1B sector to effectively find immigrant labor at a lower cost than would be otherwise possible, but excess bids generate negative externalities. The net effect of such a restriction is therefore not obvious, *a priori*. By focusing on a continuous metric such as c_X to evaluate the effect of such restrictions, we can evaluate externality implications using simple differentiation. The total costs of bidding, C , including both the cost of the application and the search costs, are:

$$C = \sum_i \left[c F_{iA} + c_i \frac{1}{\lambda} F_{iA}^\lambda \right] + \sum_j (c + c_X) F_{jA}^O \quad (32)$$

The first sum in (32) captures the costs incurred by regular firms and the second reflects those incurred by outsourcing firms. We then develop the implications of raising the marginal search costs of outsourcing firms in (33) by turning to the total application behavior described in (29) and (31), aggregate costs outlined in (32), and then differentiating. The key implication clearly outlined here is that an increase in the search costs of the outsourcing firms *reduces* aggregate H-1B search costs.

$$\frac{dC}{dc_X} = - \sum_i F_{iA} < 0 \quad (33)$$

The intuition for this result is straightforward. We can think of the total application cost as being equal to the total number of bids – both by regular and outsourcing firms – multiplied by the average cost per H-1B application. Consider the effect of an increase in c_X that increases $c_X + c$ by 1%. From the outsourcing firms' condition in (25), we see that this would lead to a 1% increase in the probability of a successful bid. Therefore, from the supply and demand condition in (28), this leads to a 1% decrease in the total number of bids as well.

In terms of average costs, a 1% increase in $c_X + c$ translates into a 1% increase in the (constant) average cost for outsourcing firms. However, it translates into a less than 1% increase in the cost of regular firms: the 1% increase in $c_X + c$ increases the marginal application cost in equilibrium for regular firms by 1%, but it does not correspondingly increase the costs on all the applications up to the marginal ones. Hence, taken together, we have a less than 1% increase in the average application costs of all firms and a 1% decrease

in the total number of applications. As a consequence, the total costs decrease when c_X increases.

The government would not eliminate the H-1B search externality by prohibiting outsourcing. However, our results altogether imply that a larger outsourcing sector (i.e., a lower search cost for the outsourcing sector) worsens the negative externality generated by the lottery system by encouraging a higher number of bids. While the outsourcing firms could in principle be beneficial because they allow firms to find a larger number of workers at a lower search cost, this potential benefit is not realized in the presence of the behavioral response induced by the lottery.

4.2 The H-1B Quota, Search Externalities, and H-1B Concentration

This subsection describes how a tightening of the H-1B quota would affect both the search cost externality (lost quota rents) and H-1B employment concentration that arise in an environment characterized by lottery allocation. Although our primary interest is in lost quota rents, the intuition of the predictions is more clearly illustrated by beginning with a discussion of concentration.

First, note that Equation (29) implies that the total number of H-1B petitions filed by regular firms ($\sum_i F_{iA}$) is entirely independent of the quota (Ω). By contrast, the hiring behavior of outsourcing firms identified in (31) is tied to the quota. This equation is therefore key in understanding how government decisions to tighten H-1B restrictions will affect the number and concentration of H-1B petitions filed by outsourcing firms.

Next, we differentiate the outsourcing wage in (30) with respect to the quota to illustrate the intuitive prediction in Equation (34) that increasing (i.e. loosening) the quota would decrease the outsourcing wage, w^O .

$$\frac{dw^O}{d\Omega} = -\frac{\sigma-1}{\sigma} E \frac{1 + \frac{1}{\epsilon} (\bar{N}/\Omega)^{\frac{\epsilon-1}{\epsilon}}}{\left[\Omega + (\bar{N})^{\frac{\epsilon-1}{\epsilon}} (\Omega)^{\frac{1}{\epsilon}} \right]^2} < 0 \quad (34)$$

Finally, we can differentiate the aggregate number of outsourcers' bids in (31) and multiply by -1 to get:

$$-\frac{d\sum_j F_{jA}^O}{d\Omega} = -\frac{1}{\rho} - \frac{\Omega}{c_X + c} \frac{dw^O}{d\Omega} \quad (35)$$

We see from this expression that in principle, a tightening of the H-1B quota could either increase or decrease the number of bids by outsourcing firms and therefore could either

increase or decrease the concentration of bids amongst these firms. This is because two competing effects are at play. The first is the direct effect of the quota, Ω ; the second is the effect through the probability of securing a successful bid, ρ .

Consider the first channel captured by $-\frac{1}{\rho} < 0$. There is a mechanical relationship such that the win probability of success equals the quota divided by the total number of bids. Holding the probability constant, any decline in the quota would be offset by a decline in H-1B applications equal to $-\frac{1}{\rho}$. In economics terms, a lower quota means that firms are restricted to hiring fewer H-1B workers. Thus, there is a reduced need to rely on the services of the outsourcing firms. Conversely, if Ω was large, then at a constant ρ the industry would hire a larger number of workers and would rely on the outsourcing firms to avoid the otherwise increasing search costs.

The second channel, represented by $-\frac{\Omega}{c_X+c} \frac{dw^O}{d\Omega} > 0$, recognizes that the probability of success will not remain constant. Thus, there is an indirect effect that operates through this probability. Since a lower Ω will reduce ρ , it means that to hire a given number of H-1B workers in the aggregate, the number of bids has to be larger and firms will need to search for more workers. These increasing search costs faced by regular firms therefore raise the demand for the services of the outsourcing firms.

This probability channel is a lottery externality. To see why, consider a rather artificial but nonetheless useful counterfactual. Suppose that instead of individual firms choosing their optimal values of F_{iA} in a decentralized manner, a social planner chooses the bids for each firm. In this scenario, the social planner is still subject to the lottery system but makes the decisions on the behalf of firms. It should be apparent that the social planner would have no reason to make more aggregate bids than there are H-1B quota slots. Any petition filed in excess of Ω entails social costs in the form of search and bid costs that offer no corresponding social benefit. The externality here arises from the fact that when a firm makes a bid, it internalizes the potential benefit to itself but not the cost to other firms in the form of a reduced probability of success. Hence, any probability of success less than one reflects an inefficient use of aggregate resources that arises only in a lottery environment.

There is no particular reason why one of the channels discussed above must dominate the other *a priori*. In order to get a better sense of whether an H-1B quota would increase or decrease the number of applications submitted by outsourcing firms (i.e., the sign of equation (35)), we can write down an alternative expression by differentiating the supply and demand condition in (28) with respect to Ω :

$$-\frac{d \sum_j F_{jA}^O}{d\Omega} = \frac{1}{\rho} \left(\frac{d\rho}{d\Omega} \frac{\Omega}{\rho} - 1 \right) \quad (36)$$

The right hand side of this equation includes a term representing the elasticity of the win probability with respect to the H-1B quota, $\frac{d\rho}{d\Omega} \frac{\Omega}{\rho}$. This elasticity, which we henceforth represent with ψ , is the key parameter that drives the main implications of the H-1B quota and lottery allocation in our model. The left hand side of (36) is positive so long as $\psi > 1$. In economics terms, the random allocation of H-1B status implies that a lower H-1B cap will cause an increasing concentration of H-1B employment among outsourcing firms when the elasticity of the win probability with respect to the quota is greater than one. The intuition of this result is straightforward. An elasticity of one would imply that the total number of bids remains constant when the quota is decreased so that the probability of success also decreases proportionately.

These insights now let us consider how the quota affects the costs of bidding. Recall that Equation (32) identified these costs and that the first summation in that equation (which reflects hiring costs of regular firms) is independent of the quota. Thus, the quota affects search costs only through outsourcers' behaviors. By combining these implications with the equilibrium outsourcing premium in (25), we see that the H-1B quota affects the total costs of H-1B searches according to (37):

$$-\frac{dC}{d\ln(\Omega)} = (w^O - w^F) \Omega (\psi - 1) \quad (37)$$

Equation (37) highlights the central implication of our model. Lottery allocation and outsourcing behavior are responsible for generating a search externality and lost rents associated with the quota. These losses would not occur under alternative allocation methods. As with H-1B employment concentration, lost quota rents only arise when the elasticity of the win probability with respect to the quota (ψ) is above one. That is, if firms increase their bids in an effort to win the lottery. In reality, and as we will show numerically in the next section, the total number of bids likely *increases* due to the quota. Interpreting this through the lens of the model, it implies a greater use of outsourcing firms, a greater concentration in bids, and higher search cost externalities beyond the losses that would occur under alternative allocation mechanisms.

5 Results: Numerical Exercises

The elasticity of the win probability with respect to the quota, $\psi = \frac{d\rho}{d\Omega} \frac{\Omega}{\rho}$, is the key parameter for determining many of the model's economic predictions. Its size is an empirical question that cannot be answered through regression analysis. In what follows, we present different conceptual approaches to measuring this elasticity, as well as different numerical estimates

for its value implied by the data. We close by using this information to quantify the H-1B quota's effect on lost quota rents and H-1B employment concentration that arise in the context of lottery allocation and domestic outsourcing.

5.1 Win Elasticities

We gain insight into the elasticity of the win probability with respect to the quota by re-expressing it as a ratio of log differentials, $\psi = \frac{d \ln(\rho)}{d \ln(\Omega)}$, and comparing two different eras: One with a high and non-binding quota, and one with restricted H-1B inflows allocated by lottery. An advantage of this approach is that it simplifies the elasticity. The log win probability differential reduces to $\ln(\rho) - \ln(1)$, where ρ now represents the win rate under the lottery scenario. One disadvantage of this approach is that non-lottery outcomes (that is, values of $\rho = 1$) exist for a range of Ω values. Thus, although we observe an H-1B cap of $\Omega = 85,000$ during the lottery era that far exceeds the high, non-binding, H-1B cap of $\Omega = 195,000$ from a period of H-1B certainty, it would be inappropriate to simply calculate the log quota differential as $\ln(85,000) - \ln(195,000)$.

As a solution to this limitation, we re-express the elasticity as a function of the change in log H-1B filings, not as a function of the quota. To do so, first let $\bar{F} = \sum_i F_{iA} + \sum_j F_{jA}^O$ represent the aggregate number of cap-subject H-1B petitions submitted. Then consider a simple partial differentiation of the log-linearized expression of the mechanical relationship between the probability of winning, the size of the quota, and the aggregate number of applications in (28):

$$d \ln(\Omega) = d \ln(\rho) + d \ln(\bar{F}) \quad (38)$$

Altogether, these assumptions allow us to rewrite our elasticity of interest as a function of the win probability when the quota is binding and the change in log H-1B petitions filed between the two periods:

$$\psi = \frac{d \ln(\rho)}{d \ln(\Omega)} = \frac{\ln(\rho)}{\ln(\rho) + d \ln(\bar{F})} \quad (39)$$

Unfortunately, measurement of \bar{F} presents two of its own challenges. First, the number of desired H-1B filings is a latent variable (as described in Section 2). Second, \bar{F} changes over time due to both quota-induced supply shocks and demand shocks. We are only interested in the former. That is, $d \ln(\bar{F})$ conceptually represents the percentage-change in H-1B petitions attributable to lottery allocation under a binding quota (a supply constraint), not from the actual demand for H-1B labor.

We can overcome these challenges. Suppose that real demand for H-1B workers, D , can be measured and that $\phi = \frac{\bar{F}-D}{\bar{F}}$ represents excess H-1B filings as a share of total filings – i.e., the percentage of H-1B petitions submitted solely in an attempt to win the H-1B lottery. We consider three approaches to measuring $d \ln(\bar{F})$. All three reduce our key elasticity (ψ) to a function of just two parameters: the win probability during the lottery year (ρ) and excess H-1B filings as a share of total filings (ϕ).

5.1.1 Win Elasticities: Method 1

Our first method for calculating the percentage-change in lottery-induced filings assumes that in the absence of a lottery, the number of filings would equal the size of the quota. In the presence of a lottery, however, excess filings beyond measurable demand exist. One must still remove any demand-driven increase in filings that have occurred over time. Thus, this approach compares excess filings beyond the quota ($\bar{F} - D + \Omega$) filed in lottery years relative to the quota itself.

One way to conceptualize the counterfactual that this exercise captures is that it represents a pollyannaish view of the lottery: It compares excess filings above the quota to a world in which firms never file any H-1B petitions above the quota because they know they will never be able hire these workers. This would be a world in which firms exhibit no strategic behavior after the quota is reached; they make no attempt to submit additional H-1B petitions in order to secure a better chance of hiring the number of workers they actually desire. Firms do not even bother demanding any real workers beyond the quota since they know they cannot be hired.

Another way to consider this counterfactual is to recognize that it measures the rise in total filings (removing contributions from trends in demand) relative to the maximum number that could be filed with a certainty of winning the lottery (i.e., such that $\rho = 1$). In any case, we substitute the expression $d \ln(\bar{F}) = \ln(\bar{F} - D + \Omega) - \ln(\Omega)$ into (39), simplify the elasticity, and express it as a function ρ and ϕ :

$$\psi = \frac{\ln(\rho)}{\ln(\rho + \phi)} \quad (40)$$

This expression – as with alternatives below – allows us to compute win probability elasticities for values of ρ and ϕ suggested by the data. Moreover, it allows us to graph values of ψ as a function of ρ and ϕ without appealing to claims of knowing what the actual demand for H-1B workers equals.

5.1.2 Win Elasticities: Method 2

The second approach to estimating ψ assumes that in the absence of a lottery, the number of filings would equal the actual demand for H-1B workers, D . We know from other studies, however, that the number of actual submissions filed, \bar{F} , far exceeds the level of actual demand. If we attribute all of these excess filing to the lottery, then $d \ln(\bar{F}) = \ln(\bar{F}) - \ln(D)$. Since $\phi = \frac{\bar{F} - D}{\bar{F}}$, we can rearrange so that $D = \bar{F} * (1 - \phi)$. Substituting this into the $d \ln(\bar{F})$ term and simplifying yields:

$$\psi = \frac{\ln(\rho)}{\ln(\rho) - \ln(1 - \phi)} \quad (41)$$

5.1.3 Win Elasticities: Method 3

The final approach to measuring demand-induced changes to H-1B filings results in a win probability elasticity much like the second. Recognizing that we need to calculate a change in \bar{F} at a constant level of demand, we can write this (in an elasticity form) as:

$$\frac{d\bar{F}|_{D=\bar{D}}}{\bar{F}} = \left(\frac{d\bar{F} - dD}{\bar{F}} \right) \quad (42)$$

Next, we can approximate the left hand side with a log differential. We can also break apart the right hand side by approximating differentials with discrete changes between the lottery and non-lottery filing (F_0) and demand (D_0) outcomes.

$$d \ln(\bar{F}) = \left[\frac{(\bar{F} - F_0) - (D - D_0)}{\bar{F}} \right] \quad (43)$$

Finally, by recognizing that filings and demand are equivalent in a world without a lottery, this differential simplifies to:

$$d \ln(\bar{F}) = \left(\frac{\bar{F} - D}{\bar{F}} \right) = \phi \quad (44)$$

Thus, our third approach to approximating lottery-induced changes in H-1B petitions results in a win probability elasticity with respect to the lottery of:

$$\psi = \frac{\ln(\rho)}{\ln(\rho) + \phi} \quad (45)$$

5.1.4 Win Elasticities Predicted by Petition Data

The three methods above used to approximate the elasticity of the win probability with respect to the quota are by no means exhaustive. For example, one might prefer to use a discrete measure of $\%\Delta\rho = \rho - 1$ as opposed to the log differential $d\ln(\rho) = \ln(\rho)$. Similarly, $\left(\frac{\bar{F}-D}{D}\right) = \left(\frac{\phi}{1-\phi}\right)$ represents yet another possible (discrete) way to measure the growth in filings above demand. However, we will see that all three methods in this paper deliver strikingly similar implications. Note, for example, that since $\phi \approx -\ln(1-\phi)$ when ϕ is small, the methods used to approximate the elasticities in (41) and (45) result in similar values when firms submit few H-1B applications in excess of real demand. Furthermore the elasticity in (40) is equivalent to that in (41) when H-1B demand is equal to the quota.

We calculate specific elasticities and graphically display ψ estimates for a range of ρ and ϕ values using equations (40), (41), and (45). Table 1 provides calculations suggested by the data for three years. The first two – 2008 and 2009 – were the first fiscal years in which all H-1Bs were allocated by lottery. Though only 85,000 new H-1Bs were available in those years, USCIS received more than 120,000 petitions during the first week of the application period for 2008 and roughly 163,000 for the following year. These numbers almost certainly exceed actual demand for new H-1B labor due to the lottery. Mayda et al. (2018) perform triple difference regressions exploiting variation in H-1B policy application across firms and individuals to estimate that H-1B employment was 22%-33% lower in FY 2008 and 2009 than what would have occurred in the absence of a quota. If we take these values as measures of actual demand, and if 85,000 represents actual H-1B employment, then this implies that firms demanded between 103,700 and 113,050 real H-1B workers in those years – figures much lower than the number of H-1B petitions filed. This alone illustrates that firms are conducting H-1B searches above and beyond their actual demand for foreign labor and that $\phi > 0$.

Table 1 also includes calculations for 2017 – the peak year for H-1B submissions prior to the DHS pre-registration policy for FY 2021 and beyond. This necessitates an important caveat: 2017 is beyond the sample period included in the Mayda et al. (2018) analysis. Trends in employment demand might imply that even a 33% increase in real demand above the quota could be a lower-bound estimate for that year. Thus, our resulting estimate of excess filings might be larger than reality for 2017.

The columns of Table 1 are distinguished by the year of observation and hence the number of H-1B filings and the probability of winning. The first three use the upper-bound Mayda et al. (2018) demand estimate of 33% above the quota for 2008, 2009, and 2017; Columns (4)-(6) use the lower-bound 22% figure. We use the three methods for computing the change in log H-1B filings described above. The top panel of Table 1 computes filings relative to

the 85,000 H-1B quota (Method 1). The middle panel measures filing differences relative to estimated real H-1B demand (Method 2). The bottom measures excess relative to total filings (Method 3).

The table reports a range of estimates for the elasticity of H-1B win probability with respect to the quota. At a minimum, we estimate a value of 1.29 in 2008 when excess H-1B filings were comparatively modest and we assume that real demand for foreign labor was high. The elasticity is always smallest when measuring excess filings relative to total filings (bottom panel), which delivers quantitatively similar results to using Method 2's computation of excess filings relative to demand (middle panel). Elasticities are highest when calculating filings relative to the quota (top panel). Not surprising, the largest elasticity estimates arise in 2017 when the number of H-1B petitions was exceedingly high. Most importantly, however, all values are comfortably above one, implying that lottery allocation causes H-1B restrictions to generate lost quota rents associated with negative job search externalities, and it increases H-1B employment concentration among outsourcing firms. These effects would not occur under a quota alone and are entirely distinct from the deadweight loss inefficiency common among alternative forms of government intervention into the labor market.

Next, we turn to algebraic and graphical analysis for understanding the interplay between ϕ , ρ , and ψ . This is somewhat difficult to do in the sense that the parameter values are endogenously determined by the model – this is not a typical comparative statics exercise in which one simply changes an exogenous variable in order to examine the consequences of a shock. Nonetheless, we believe the mathematics and graphs are informative both about how the endogenous variables are related to each other and are helpful in identifying elasticity values consistent with real world data.

It is straightforward to show that the elasticity ψ is increasing in both ϕ and ρ , conditional upon $\phi \in [0, 1-\rho]$ and $\rho \in [0, 1]$, where the former range restriction arises from an assumption that real H-1B demand in lottery years equals the size of the quota at a minimum. Let us consider the intuition behind these results in turn. The first is almost tautological. It implies that if excess filings are low, then a change to the quota will lead to an almost proportional change in the win probability. High values of ψ , in contrast, arise when firms file a large number of H-1B petitions in excess of demand, thus implying that the win probability is highly responsive to quota restrictions. The importance of this result becomes more apparent when recognizing that the elasticity of the win probability with respect to the quota is guaranteed to be greater than one so long as any firm submits more H-1B petitions in excess of their actual demand for H-1B workers. Moreover, any elasticity above one is indicative of a negative externality induced by the quota and lottery that is sufficiently large to induce an increase in the total number of bids. Even a small proportion of H-1B petitions

filed in excess of actual H-1B demand would be enough to generate such costs.

The reasoning behind the positive relationship between ρ and ψ is somewhat more complicated. The result implies that the responsiveness of the win probability to a quota shock is high if the win probability itself is also high. Behaviorally, this means that when firms are confident that they can win the lottery, they respond to quota restrictions by trying to game the system, so to speak. That is, they conduct an excess number of searches and extend multiple offers in an attempt to secure their desired number of workers. Collectively, this causes the actual win probability to drop precipitously. For a more mechanical understanding, first note that $1 - \rho$ is the maximum possible value of ϕ . It follows that the larger value that ρ takes, the closer any fixed value of ϕ is relative to its maximum and the more important firms' behavioral responses become. In other words, the phenomenon of excess H-1B petition filings is more relevant to the responsiveness of the win probability to the quota when the win probability itself is large.

Figure 5 plots the elasticity estimates as a function of the percentage of excess H-1B applications that arise from the Methodologies 1-3 (moving from the left panel through the right) described above. Each graph displays contour plots for different values of ρ increasing in increments of 0.05 from a minimum of $\rho = 0.30$ (light colored) to a maximum of $\rho = 0.75$ (dark). Each panel also includes point estimates implied by observed win probabilities and the number of excess H-1B filings implied by the given methodology. The red line corresponds to the assumption that real H-1B demand is 22% above the quota; the blue line assumes demand is 33% higher than the quota. Graphs share the same vertical axis scale and are displayed side-by-side for comparison purposes.

Not surprisingly, all three methods demonstrate that the win elasticity with respect to the quota is high when firms submit a large number of petitions in an effort to win the lottery (i.e., when ϕ is low). Methods 2 and 3 produce quantitatively similar estimates, though Method 3 has the advantage of producing estimates that are the least sensitive to differences in ϕ and ρ values. Using real world data, it implies a minimum elasticity estimate of 1.29 (when assuming that demand is 33% higher than the quota) and a maximum of about 2.25. Even at the lowest values, elasticity estimates are large enough to imply that the quota and lottery generated negative search cost externalities. Note that elasticity estimates are always highest when using Method 1. Differences are particularly apparent when excess petition filings are high. Despite these disparities, however, we will see below that all three methods produces very similar estimates for search cost externalities resulting from the quota and lottery.

5.1.5 Win Elasticities Predicted by Wage Data

Table 1 provides a range of reasonable estimates of the win probability elasticity based upon H-1B filing behavior, but we can also gain insight into its value by appealing to wage data. This has the further benefit of also delivering an estimate of the marginal search costs of outsourcing firms.

First, we rewrite the elasticity of the probability with respect to Ω in terms of shares and basic elasticities. Using (34), we get:

$$\psi = \frac{d\rho}{d\Omega} \frac{\Omega}{\rho} = \frac{w^O \Omega}{w^O \Omega + w^N \bar{N}} \frac{w^O/w^F}{w^O/w^F - 1} \left[1 + \frac{1}{\epsilon} (w^O/w^N)^{\epsilon-1} \right] \quad (46)$$

Next, we rearrange the marginal rate of technical substitution equilibrium from (26) and insert the relative wage into the bracketed expression. If we then assume that native and foreign labor is relatively substitutable so that ϵ is large,¹⁶ then equation (46) simplifies to:

$$\psi \approx \frac{w^O \Omega}{w^O \Omega + w^N \bar{N}} \frac{w^O/w^F}{w^O/w^F - 1} \quad (47)$$

The first term is the share of wages paid to H-1B workers in the sectors of the economy that employ them. The higher this value, the larger the probability elasticity. As H-1B workers become more important to the production process, firms become more responsive to changes in the H-1B quota and are more likely to respond by aggressively changing their number of excess H-1B filings. The second term is a transformation of the outsourcing premium w^O/w^F . The probability elasticity decreases as reliance upon outside labor becomes more expensive and this wage gap rises. At its limit, the second term in (47) approaches one so that the win probability elasticity with respect to the quota is governed solely by H-1B workers' share of income.

If we could measure these values, we could then back out an estimate for our key probability elasticity. Unfortunately, however, those values – like the measures described above – are unknowable. For example, we cannot observe the wages of H-1B workers in representative datasets, and given the small size of the H-1B program relative to the US economy, we believe it would be a mistake to insert a literal measure of total H-1B expenditures as a share of the national wage bill into equation (47). Similarly, the ratio $\frac{w^O}{w^F}$ is conceptual and reflects the gap between what employers earn from renting out their workers and what they

¹⁶Dustmann and Preston (2012), Manacorda, Manning, and Wadsworth (2012), Ottaviano and Peri (2012), and Borjas, Grogger, and Hanson (2012) provide extensive discussion about this parameter and challenges in measuring it. The lowest estimates – and hence greatest complementarity – in the literature that we are aware of come from Manacorda, Manning, and Wadsworth (2012). They find a minimum value of $\epsilon = 4.6$ and a baseline value of $\epsilon = 7.8$. Ottaviano and Peri (2012) prefer a value of $\epsilon = 20$, whereas some Borjas, Grogger, and Hanson (2012) values suggest perfect substitutability ($\epsilon = \infty$).

actually pay their H-1B workers. This is unobservable.

Despite these limitations, we can turn to proxies in the data for insight. First, we note the USCIS (2020a) evidence that H-1B workers are highly concentrated among computer-related occupations. Further, Mayda et al. (2018) report that 91% of new H-1B recipients are under the age of 40. Motivated by these stylized facts, we turn to the 2008 and 2009 American Community Surveys (ACSs) and calculate that foreign-born labor accounted for 40% of wages paid to college-educated employees under age 40 in computer-related occupations. We then substitute this value for our first term in (47).

Second, let us suppose that the conceptual wage gap discussed above is similar to the gap in wages paid by regular firms and those paid by low-wage H-1B employers. Consider different behaviors in the H-1B petitioning process. Wage offers exhibit a well-populated mode at \$60,000 per year. This reflects legislation passed in the H-1B Visa Reform Act of 2004 that exempts H-1B dependent employers from additional legal obligations and government scrutiny if they only employ workers at a wage of \$60,000 or higher. We allow this value to serve as a *de facto* minimum wage and substitute it for w^F . For w^O , we instead use the average wage offer to new H-1B workers receiving more than \$60,000 in fiscal years 2008 and 2009. After removing extreme outliers, this amounts to \$83,500 and implies an outsourcing premium of $w^O/w^F \approx 1.39$.¹⁷

After substituting this into the second term of (47), we get an estimate of the probability elasticity with respect to the quota of $\psi = 1.43$. This is consistent with the lower range of our elasticity estimates in Table 1 calculated by exploiting differences in firm H-1B filing behavior over time. Most importantly, it still delivers an elasticity greater than one. The condition required for search cost externalities and increased H-1B concentration as a result of the lottery is therefore easily satisfied through evidence from both H-1B petition and wage data.

Wage data also allows us to conduct one further back-of-the-envelope calculation: An estimation of the implied bid and search costs for an outsourcing firm. Specifically, if we assume a lottery success rate of 0.50 (fairly consistent with the lottery in 2009) and a $w^O - w^F$ wage gap of \$23,500, equation (25) implies that $c_X + c = \$11,750$. If we take a literal interpretation of application cost and we assume a \$4,500 cost near the upper range of the H-1B filing fees discussed in Section 2, it implies that an outsourcing firm's marginal cost of searching for and extending an offer to a worker, c_X , equals roughly \$7,250.

¹⁷Note also that in his February 2016 testimony to the US Senate, Hira (2016) argued that firms heavily relying upon H-1B workers generate profit margins of 20-25%, figures broadly consistent with the premium we find here.

5.2 Search Cost Externalities

Recall that Equation (37) describes how lottery allocation and outsourcing behavior are responsible for generating a search externality and lost quota rents that would not arise under alternative allocation methods. We have already discussed how to calculate proxies for many of the terms in this equation. For example, data suggests a wage gap value of $(w^O - w^F) = \$23,500$ and quota $\Omega = 85,000$. Total costs are then a function of the win probability elasticity with respect to the quota, ψ . This in turn depends upon the method used to compute ψ outlined in Section 5.1. Interestingly, the value of win probability itself plays no role in identifying these costs when using Methods 2 and 3. Not surprisingly, all three find that excess filings increase search externalities.

Consider Figure 6. Panels display estimated search costs in millions of dollars as a function of the percentage of excess filings (ϕ). Panels are distinguished by their use of Methods 1 through 3 (from left to right) for calculating the elasticity ψ . Graphs also include point estimates for search costs implied by observed data for each fiscal year in which a lottery allocated all cap-subject H-1Bs. Table 1 additionally provides a subset of these calculations. Recall that Mayda et al. (2018) estimate that actual H-1B demand was 22% to 33% above the quota for fiscal years 2008 and 2009. Red dots correspond to estimates using the 22% figure; blue dots assume the 33% value. Note that since data beyond 2009 were not included in the Mayda et al. (2018) analysis, the point values in 2014 and beyond represent out-of-sample estimates.

As with our estimates of ψ , smaller estimated search cost externalities arise when real demand is particularly high above the quota (left panel of Table 1 and indicated in blue in Figure 6), when using Method 3 for calculating ψ , and when the win probability is high (69% in 2008). They are largest when assuming low levels of real demand, Method 1's calculation of ψ , and low win probabilities. Nonetheless, results are similar across methods. Our most conservative estimates imply that even when excess filings were a modest 8.4% of all H-1B petitions submitted for fiscal year 2008, firms' strategic behavior resulted in at least a \$169 million search cost externality, or about \$2,000 per new H-1B worker hired.¹⁸ Costs were substantially higher in 2009 when nearly 31% of firms' H-1B submissions were filed in excess of demand: The estimated quota rents lost via this externality range between \$612 million and \$1.057 billion for that year – roughly \$7,000 to \$12,000 per hire. If real H-1B demand remained at a constant 33% above the quota for years in the late 2010s, then estimated annual search costs exceed \$1 billion in that period regardless of the method used for estimating the win elasticity. In 2017 when losses were maximized, for example, our

¹⁸Since currency figures are derived from nominal wage premia from 2008 and 2009, it would be reasonable to interpret these outcomes as reflecting losses in real 2008 or 2009 dollars.

estimates imply a search cost externality of \$12,000 to \$22,000 per new H-1B worker. Given that firms must actually search for these workers and file paperwork with the government on their behalf, the estimate seems quite reasonable.

It is important to reiterate that these costs arise purely because the lottery induces firms to search for an excess number of eligible H-1B workers to meet their target hiring goal. They are not costs associated with losing workers that firms actually wish to hire. This can be seen, for example, by the absence of an externality cost at a value of $\phi = 0$. If all H-1B petitions submitted by firms are for workers those firms intend to hire, then externalities associated with attempts to win the lottery do not exist. The data, however, strongly implies that firms engage in strategic behavior, resulting in large costs to society. More specifically, Table 1 suggests that the US government forfeited \$1.042 billion to \$1.879 billion in 2017 that could have been retained as tax revenue or distributed as welfare to foreign workers under alternative methods of restricting H-1B flows. Instead, the strategic behavior induced by the lottery destroys those rents.

5.3 Concentration Implications

The H-1B lottery not only generates unnecessary search cost externalities, it also leads to an increased concentration of H-1B employment among a small set of firms. To quantify this, let $\theta = \frac{\sum_j F_{jA}^O}{\bar{F}}$ represent the share of H-1B approvals awarded to outsourcing firms. By combining the response in outsourcers' filings identified in (36) with the identity in (38), we can determine how the H-1B quota restriction affects the proportion of H-1B approvals granted to H-1B outsourcing specialists:

$$-\frac{d\theta}{d \ln(\Omega)} = (\psi - 1)(1 - \theta) \quad (48)$$

This expression states that H-1B concentration among outsourcing firms increases linearly with the win elasticity ψ and is positive so long as $\psi > 1$, which – as we have seen above – is likely. Furthermore, the marginal change in this share decreases as the share itself approaches one.

To get a sense of the magnitude of these predictions, we first need to consider possible values of θ from the data. There is no one definition for what constitutes an H-1B outsourcing firm or the proportion of H-1Bs such firms hire. Individuals and organizations generally opposed to the H-1B program argue that at least a third of cap-subject H-1B workers are hired by outsourcing firms.¹⁹ Thus, $\theta = 0.33$ serves as a useful lower bound. We also examine

¹⁹See North (2020) and Park (2015).

an upper bound of $\theta = 0.60$ to reflect the percentage of firms that pay H-1B workers low wages according to Costa and Hira (2020).²⁰

Table 1 presents our estimates for the change in the outsourcing employment share for 2008, 2009, and 2017 at these values of θ . Focusing on the first three columns (which assume that aggregate H-1B demand was 33% higher than the quota in lottery years) and the middle panel of estimates (which uses Method 2 – described above to measure the change in H-1B petitions as excess H-1B filings relative to demand), we estimate that the lottery caused the proportion of H-1Bs awarded to outsourcing firms to rise by 4 to 6 percentage points in 2008, depending upon the assumed starting value of θ . This effect is much larger and sometimes exceeds 50 percentage points in 2009 and 2017 when the probability of winning the lottery was much lower and the elasticity of the win probability with respect to the quota was much larger. Our third method (bottom panel) for calculating the change in log H-1B filings produces the lowest elasticity estimates. It therefore also produces the most muted response in the share of H-1Bs awarded to outsourcing firms. At its maximum, this method predicts that outsourcers controlled 24% more of the H-1B market in 2009, and 37% more of the market in 2017, than they would have in the absence of a lottery.

Further insight into these magnitudes comes from considering that the top 1% of H-1B employers accounted for 24.3% of new H-1B employment in 2002 and 2003 when the H-1B cap was high and not binding, and 36.7% of H-1Bs in the 2008 and 2009 lottery years. If we think of these firms as outsourcers, then this implies a 12.4 percentage point increase in θ . If we broaden our definition to include the top 5% of H-1B employers, then θ rose by nearly 20 percentage points (from 0.380 to 0.577) between these two periods. Thus, these descriptive statistics fall within the range of estimates predicted by our theoretical model.

6 Conclusion

The H-1B program allows highly-educated foreign-born individuals to temporarily work in the United States. The government limits the number of new H-1Bs that can be distributed each year. Demand for the program is high, and the government allocates H-1B status through a random lottery. H-1B petitions peaked at over 236,000 in 2017 when only about a third of petitioners won the lottery.

Past research has estimated several losses induced by the H-1B quota and lottery distribution. By restricting the skilled labor force, the quota reduces US productivity and wages

²⁰Namely, the authors find that “Sixty percent of H-1B positions certified by the U.S. Department of Labor are assigned wage levels well below the local median wage for the occupation” and that “three-fifths of all H-1B jobs were certified at the two lowest prevailing wage levels in 2019.”

paid to American-born workers. Firm outcomes such as sales and profits have declined as well. H-1B employment is increasingly concentrated among a smaller set of firms. Since firms receive permission to hire only those who win the lottery, lottery allocation prevents employers from selecting the foreign workers whom they most desire. Some firms have responded by moving operations overseas.

This paper adds to the existing evidence by modeling heretofore undocumented costs induced by the quota and lottery: Firms waste resources and destroy quota rents by searching for workers who cannot legally be hired. Indeed, firms search for far more workers (and submit H-1B petitions on their behalf) than they truly intend to hire. They do this knowingly in an attempt to better their chances of securing enough workers who will win the lottery and satisfy actual H-1B demand. Moreover, the lottery has given rise to outsourcing firms that specialize in hiring H-1B labor for the purpose of renting their employees to firms seeking the specialized services that H-1B workers can provide. This exacerbates negative search cost externalities.

We estimate that lottery allocation and outsourcing behavior cost American firms \$169 million in search costs in 2008, more than \$600 million in 2009, and more than \$1 billion in the late 2010s when the probability of winning the lottery was very low (and hence, excess H-1B petitions were very high). That amounts to a loss of over \$10,000 per H-1B worker hired in 2017. Importantly, these are not the typical deadweight losses that would exist under other methods of reducing H-1B labor inflows. Rather, they are lost quota rents due to the strategic behavior of firms responding to lottery allocation.

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A Partial Equilibrium Setup

This appendix provides more detail as to the underlying assumptions on preferences that would rationalize the partial equilibrium model in the main text. We assume that the representative consumer has the following quasi-linear utility over the aggregate H-1B sector good, X , and a numeraire good that represents all other goods, m :

$$U = m + \gamma \times \log(X), \quad (49)$$

where γ is constant and where:

$$X = \left[\sum_i (\alpha_i)^{\frac{1}{\sigma}} (x_i)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \quad (50)$$

The household is subject to a budget constraint:

$$m + PX = I + \Pi + w_N \bar{N} + w_F \Omega, \quad (51)$$

where I is total income excluding the H-1B sector and is exogenous given the partial equilibrium setting; Π are the total profits of the H-1B sector; and P is the price index for the aggregate H-1B sector output:

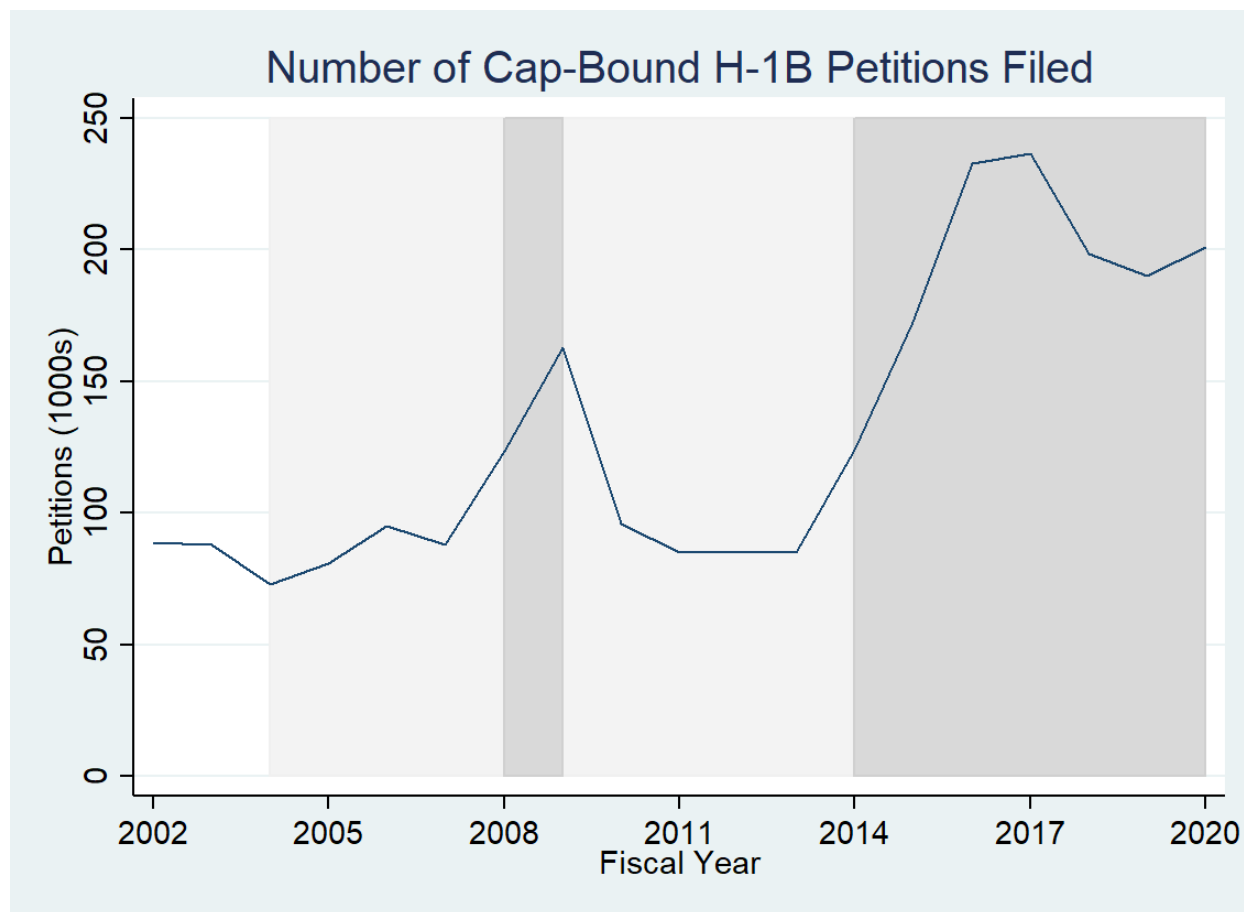
$$P = \left[\sum_i \alpha_i (p_i)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \quad (52)$$

Note that while we include both native and immigrant H-1B wages in (51) – taking the representative household to include immigrant workers – the analysis would be basically identical if we only focused on native households. Maximizing (49) subject to (31) gives us:

$$PX = \gamma \quad (53)$$

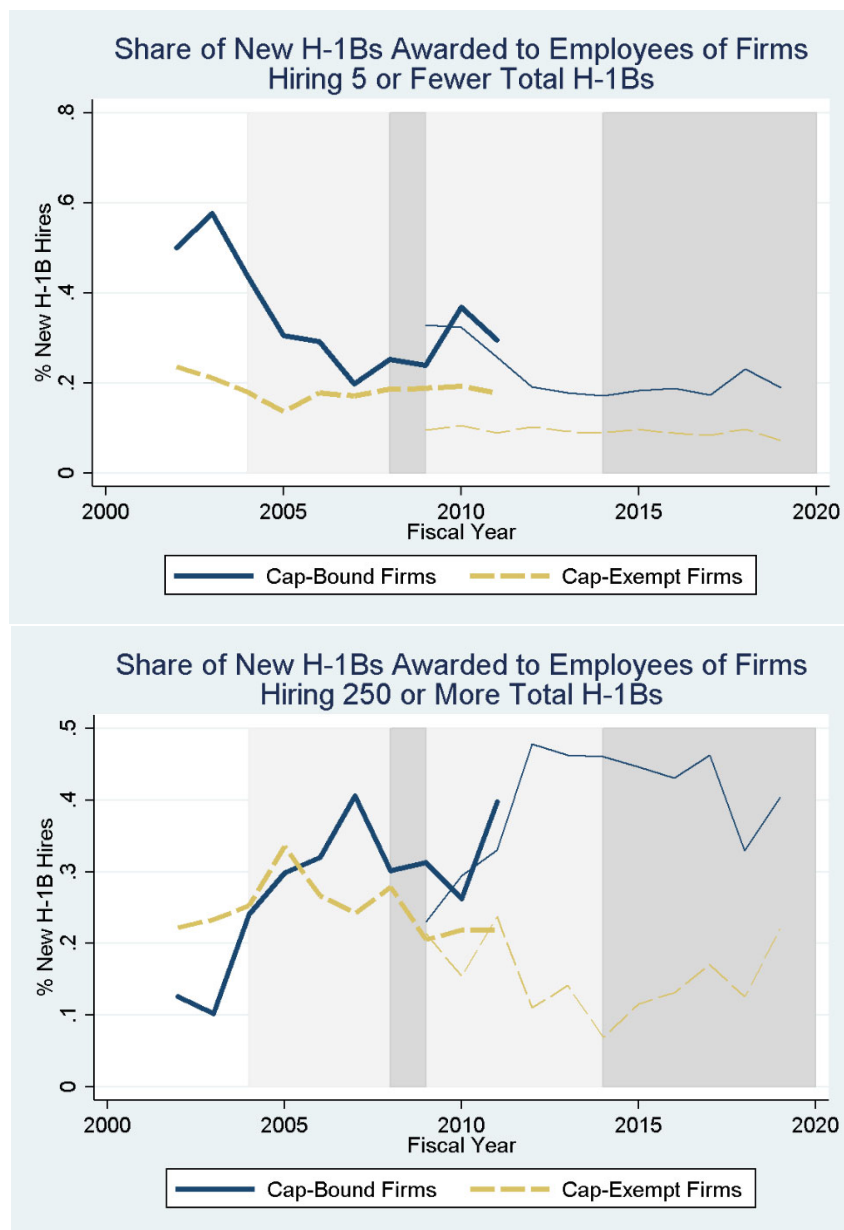
This rationalizes our constant E assumption since $PX = E$. The constant E here depends on the assumption of log substitutability. This constant E setup is helpful for expositional clarity and simplicity, but could easily be relaxed without changing the thrust of our overall analysis. Finally, we could find the optimal choice of each variety x_i within (50), and this would give us the standard CES demand in (1).

Figure 1



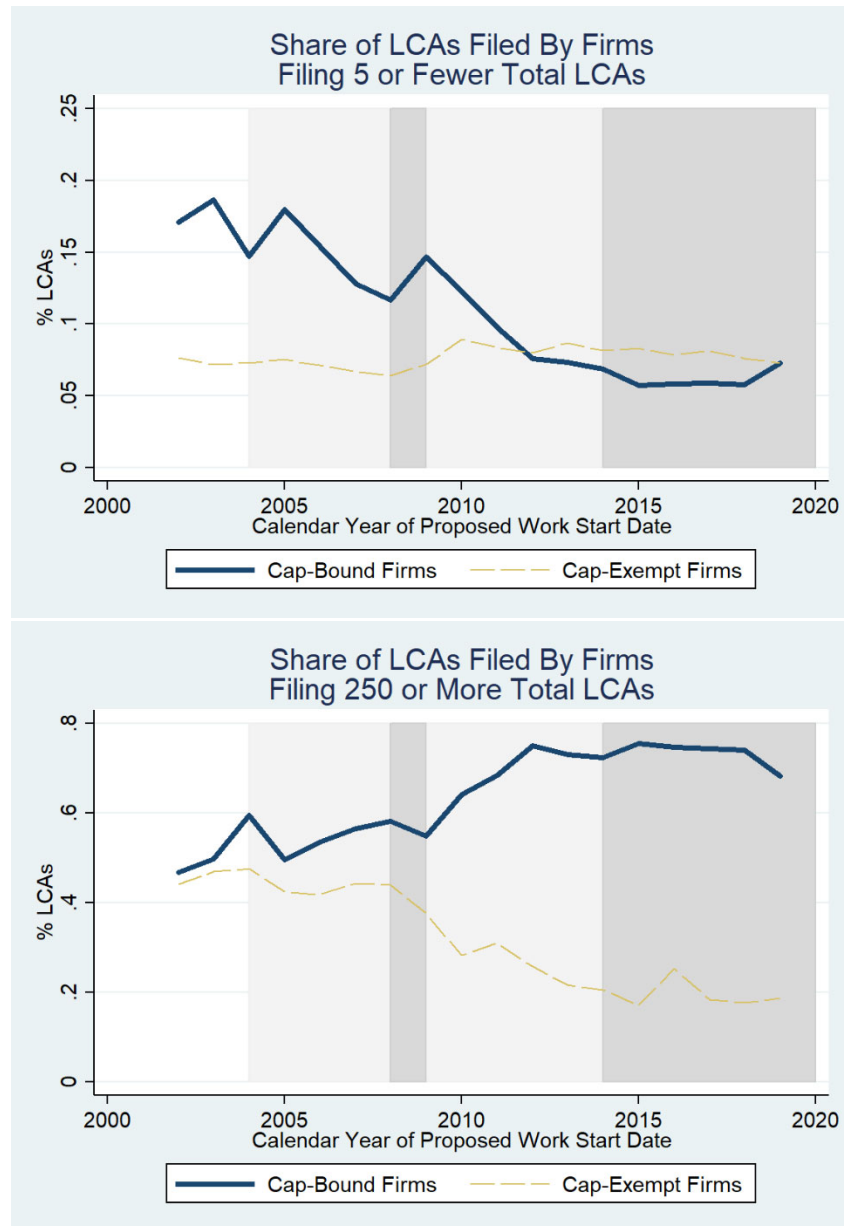
This figure displays the number of I-129 petitions filed for cap-bound H-1B workers in fiscal years 2002-2020. Years with a binding H-1B cap lightly shaded. Years in which USCIS allocated all cap-bound H-1Bs by random lottery are darkly shaded. Sources include USCIS (2007, 2018b, 2019), DHS (2011, 2018), and Office of the Federal Register (2011). Figures in FY 2011-2013 reflect the caps in those years that were reached several months after USCIS started accepting petitions.

Figure 2



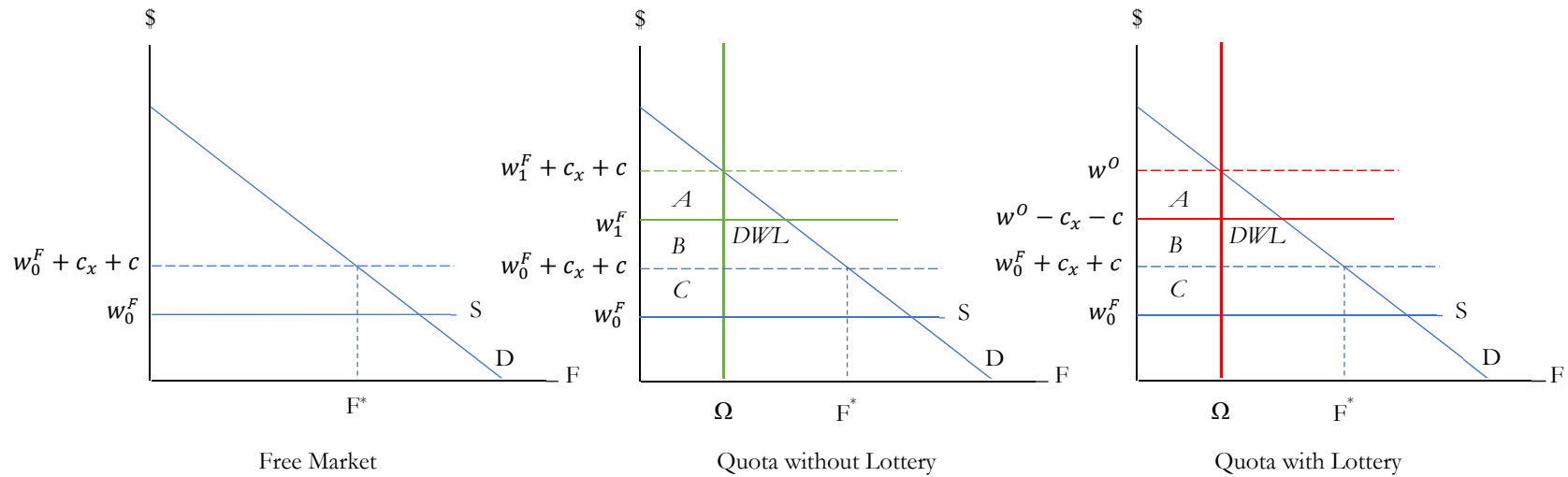
This figure displays the percentage of new H-1B workers hired at firms employing five or fewer total H-1B workers (top panel) and 250 or more total H-1B workers (bottom panel) for a given fiscal year. Years with a binding H-1B cap lightly shaded. Years in which USCIS allocated all cap-bound H-1Bs by random lottery are darkly shaded. Data is based upon I-129 petitions: Data used in bold curves come from a FOIA to USCIS; data used in regular curves come from the USCIS Data Hub.

Figure 3



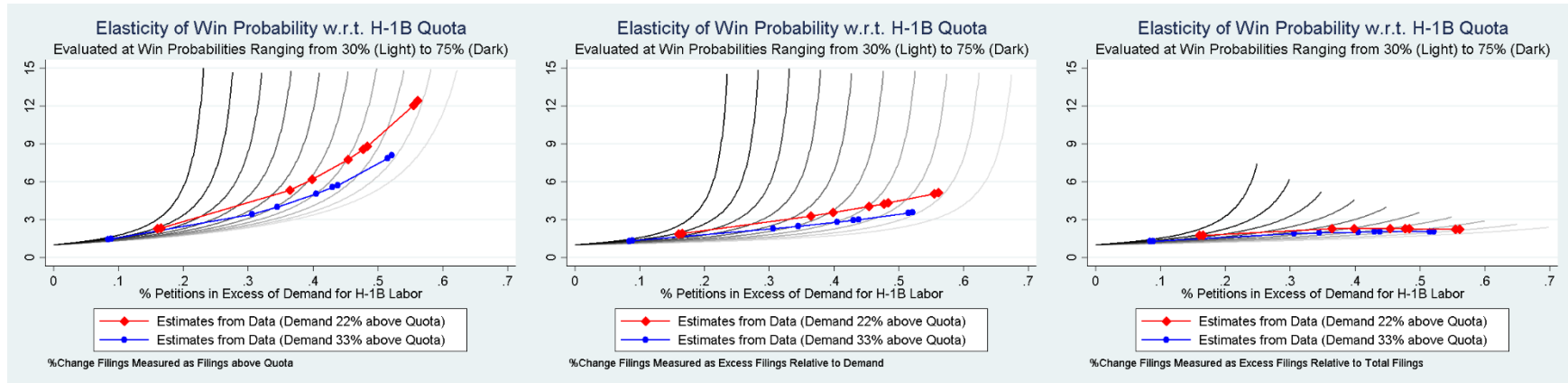
This figure displays the percentage of LCAs filed at firms filing five or fewer LCAs (top panel) and 250 or more LCAs (bottom panel) for a given fiscal year. Years with a binding H-1B cap lightly shaded. Years in which USCIS allocated all cap-bound H-1Bs by random lottery are darkly shaded. Data is based upon LCA filings.

Figure 4



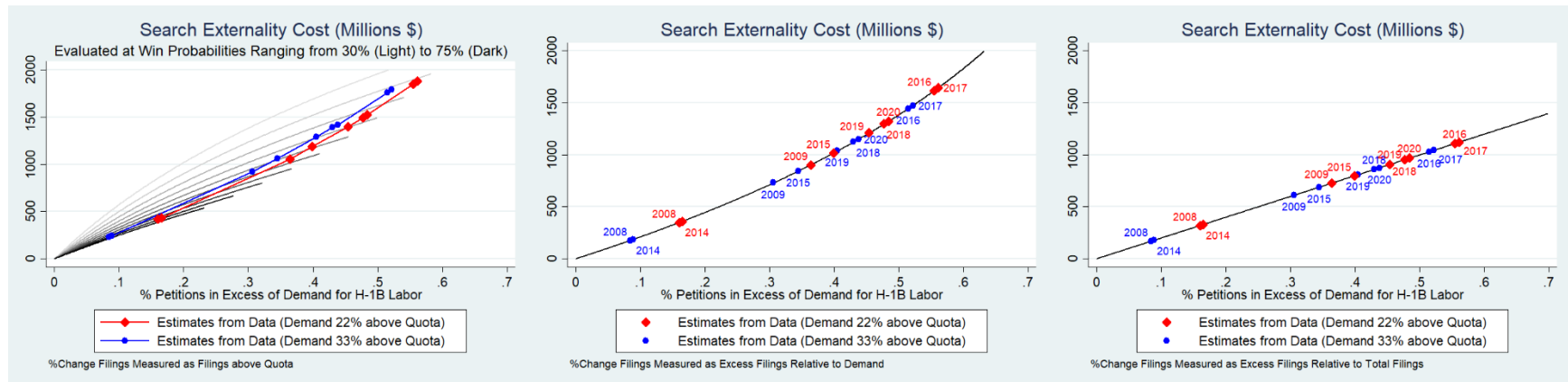
Each graph displays the Supply (S) and Demand (D) of foreign-born H-1B labor (F) and identifies equilibrium wages (w) given marginal costs (c) of performing a job search and a possible H-1B quota (Ω). The left panel illustrates a free market equilibrium. The center displays outcomes with a quota and willingness to pay H-1B allocation. The right shows outcomes with a quota and lottery allocation. The latter two graphs yield predictable deadweight loss triangles (DWL). Without a lottery, the quota transfers surplus (A and B) to H-1B workers. With a lottery, that surplus is completely absorbed by additional search costs. See the text for more details.

Figure 5



This figure displays estimates for the elasticity of the H-1B win probability with respect to the quota (ψ) as a function of the win probability (ρ) and petitions filed in excess of demand for H-1B labor (ϕ). Plausible values of ϕ range from zero to $1 - \rho$. Panels differ in the methods used to compute the percentage change in filings due to the quota.

Figure 6



This figure displays estimates for the search cost externality generated by the H-1B quota as a function of the H-1B win probability (p , middle panel only) and petitions filed in excess of demand for H-1B labor (ϕ). Plausible values of ϕ range from zero to $1 - p$. Panels differ in the methods used to compute the percentage change in filings due to the quota.

Table 1

Implied Demand Shock	33%			22%		
Assumed Real Demand	113,050			103,700		
Year of Observation	2008	2009	2017	2008	2009	2017
Applications	123,480	163,000	236,444	123,480	163,000	236,444
Win Probability (ρ)	68.8%	52.1%	35.9%	68.8%	52.1%	35.9%
Excess Filings	10,430	49,950	123,394	19,780	59,300	132,744
% Excess Filings (ϕ)	8.4%	30.6%	52.2%	16.0%	36.4%	56.1%
$\Delta \ln(\text{Filings})$ Measured as Filings above Quota						
$\Delta \ln(\text{Filings})$	0.12	0.46	0.90	0.21	0.53	0.94
$\Delta \ln(\Omega)$	-0.26	-0.19	-0.13	-0.16	-0.12	-0.08
Elasticity (ψ)	1.45	3.45	8.10	2.27	5.34	12.42
Search Cost Externality (\$m)	231	923	1,791	418	1,057	1,879
Externality per Hire (\$)	2,720	10,863	21,074	4,916	12,437	22,106
$\Delta \theta$, at $\theta=1/3$	0.08	0.31	0.60	0.14	0.35	0.63
$\Delta \theta$, at $\theta=3/5$	0.05	0.18	0.36	0.08	0.21	0.38
$\Delta \ln(\text{Filings})$ Measured as Excess Filings Relative to Demand						
$\Delta \ln(\text{Filings})$	0.09	0.37	0.74	0.17	0.45	0.82
$\Delta \ln(\Omega)$	-0.29	-0.29	-0.29	-0.20	-0.20	-0.20
Elasticity (ψ)	1.31	2.28	3.59	1.88	3.27	5.14
Search Cost Externality (\$m)	176	731	1,474	349	903	1,646
Externality per Hire (\$)	2,074	8,599	17,340	4,103	10,628	19,369
$\Delta \theta$, at $\theta=1/3$	0.06	0.24	0.49	0.12	0.30	0.55
$\Delta \theta$, at $\theta=3/5$	0.04	0.15	0.30	0.07	0.18	0.33
$\Delta \ln(\text{Filings})$ Measured as Excess Filings Relative to Total						
$\Delta \ln(\text{Filings})$	0.08	0.31	0.52	0.16	0.36	0.56
$\Delta \ln(\Omega)$	-0.29	-0.34	-0.50	-0.21	-0.29	-0.46
Elasticity (ψ)	1.29	1.89	2.04	1.75	2.27	2.22
Search Cost Externality (\$m)	169	612	1,042	320	727	1,121
Externality per Hire (\$)	1,985	7,201	12,264	3,764	8,549	13,193
$\Delta \theta$, at $\theta=1/3$	0.06	0.20	0.35	0.11	0.24	0.37
$\Delta \theta$, at $\theta=3/5$	0.03	0.12	0.21	0.06	0.15	0.22

The first rows of the table reflect estimates of real H-1B demand from Mayda et al. (2018). The second set of rows display the observed number of H-1B filings according to USCIS, plus the implied win probabilities and excess filings implied by the data and estimated real demand. The remaining sets of rows show the search cost externality (measured in millions of dollars), externality per H-1B hire (in dollars), the change in H-1B concentration at outsourcing firms (θ), and component measures caused by the quota, lottery allocation, and outsourcing according to the three methodologies outlined in the main text.