A Worker Worth the Wait

Information Asymmetry and Adverse Selection in the Labour Market of International Students

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What happens if employers are given more time to try out workers before making final wage commitments? The theory of information asymmetry predicts that workers of higher quality enter the labour market. I test this prediction using a 2008 policy intervention in the US labour market. Employers in the US can hire international students for short durations without acquiring costly work visas. The intervention increased this duration from 12 to 29 months for students in a well-defined list of degree programs. I study its effects using data on all international students enrolled in master's degree programs in the US under F-1 visas over 12 years. A difference-in-difference-in-differences strategy shows that, consistent with theory, employers were 21 percentage points (63 percent) more likely to spend $3,000 to $7,000 in work visas costs for students in the labuor market who enrolled in listed degree programs after the intervention. (JEL D81, D82, D83, J08, J61)

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The theory of information asymmetry facilitates the study of workers' migration between labour markets. It predicts that, if employers in a labour market cannot accurately assess the quality of migrant workers, workers of high quality would be less likely to migrate into the market. Conversely, reducing information asymmetry could result in workers of higher quality entering the market. The literature has extensively debated whether a worker's education reduces information asymmetry by signaling their quality to employers at the time of hiring. Studies also provides ample evidence that, the longer a worker works for an employer, the more accurately the employer observes the worker's quality. Accordingly, existing models predicted decades ago that allowing employers more time to try out workers prior to making final wage commitments ought to result in workers of higher quality migrating into the labour market. Nevertheless, hardly any empirical test of this prediction exists.

I test the prediction using a natural experiment in the labour market of international students. Employers in the US can hire international students by securing work visas— a cost of $3,000 to $7,000 per visa petition borne solely by employers. Given the sizable cost, employers would only sponsor the work visa petitions for workers of high quality. Students may also obtain work authorizations, which allow employers to hire them without securing costly work visas, though for a limited number of months. Importantly, an employer may use the period of authorization to assess whether a worker is worth sponsorship. In April 2008, the government announced that students enrolled in any university degree program from a well-defined list would be allowed to extend their work authorizations for up to 29 months compared to the prevailing limit of 12 months. In essence, the intervention allowed employers more time to assess worker before committing to spnsor them. I study the effects of this policy intervention using data on all international students enrolled in master's degree programs in the US under F-1 visas over 12 years. I find that, after the policy announcement, listed degree programs drew a higher proportion of international students. Students enrolled in listed degree programs after the announcement were also more likely to obtain work authorizations, suggesting that they intended to enter the labour market and benifit from the policy intervention. However, the policy intervention affected not only students enrolling after the announcement, but also retroactively affected students already enrolled in the listed degree programs at the time of the announcement. The effect of the policy intervention on those retroactively treated cannot be attributed to selection since these students could not have chosen their degree programs in response to the policy intervention. Such direct

effects, regardless of their underlying mechanism, would be common to both groups of students— those retroactively treated, as well as treated students who enrolled after the policy announcement, whereas only the latter can exhibit a selection effect. After removing any direct effect common to all treated students, I find that employers were 21 percentage points (63 percent) more likely to sponsor students enrolling after the policy announcement who could avail extensions— an effect I attribute to the improved quality of the students. I also find evidence that employers waited longer before sponsoring treated students. Thus, the results corroborate the hypothesis that allowing employers more time to try out workers prior to making final wage commitments results in workers of higher quality migrating into the labour market.

The remainder of this article adheres to the following layout. Section I positions this article in the literature on information asymmetry in the labour market, presents a model, and derives from it a falsifiable prediction (Proposition 1). Section II details the nature of the policy intervention which afford the opportunity for empirical hypothesis testing. Section III describes the data, defines some terminology (such as eligible and treated students), and presents an overview of the data. The next three sections lay out the central arguments of this paper. Section IV examines evidence of selection into listed degree programs and into the labour market. Section V carries out a test of the main prediction presented in Section I (Proposition 1). Section VI investigates whether employers took longer to assess treated students before making final wage offers. Finally, Section VII presents concluding discussions.

I Information Asymmetry in the Labour Market

Akerlof's (1970) theory information asymmetry has found applications in various domains, including the study of labour markets. Information asymmetry in the labour market arises because an employer cannot know a worker's quality with certainty at the time of hiring. The asymmetry exists between workers and potential employers, but can also exist between a worker's current employer and other potential employers. Having had time to observe the worker, a current employer knows more about the worker's quality than other employers in the labour market. Such asymmetry, Greenwald (1986) argues theoretically, keeps workers of high quality from switching jobs. Transnational migrants face analogous asymmetries. Katz and Stark (1987) predict that, if employers in the destination country cannot accurately assess the quality of migrant workers, workers of high quality are less likely to migrate.

Conversely, reducing information asymmetry can reduce adverse selection. Spence (1973) proposes that education serves as a signal[1] of worker quality, reducing information asymmetry. The author argues that employers decide whether to hire a worker based on their education, among other factors, and then update their beliefs about the accuracy of the signal after observing the performance of those hired. Implicitly, the author acknowledges the value of the initial period[2] of employment in gauging the quality of workers. Katz and Stark (1987) acknowledge it explicitly . The literature provides some evidence that employers learn more about workers who have spent more time in the labour market. Farber and Gibbons (1996), as well as Altonji and Pierret (2001) find that, with time, the correlation between wages and measures of quality unobservable to employers increases. Thus, the authors argue that a worker's initially unobserved quality becomes more observable over time.

It follows, then, that reducing information asymmetry by allowing employers more time to try out workers prior to finalizing wage commitments could result in workers of higher quality choosing to enter the labour market. Below, I follow Katz and Stark (1987) in developing a more formal model of the self-selection of migrant workers under information asymmetry.

I.A A Model of Selection Under Information Asymmetry

Suppose there are two labour markets m_0 and m_1. Let q be the quality of a worker in m_0 such that $0 \leq q \leq 1$. The worker can work for the duration of their lifetime $l > 0$, and their quality q does not change over this period. Suppose employers in both m_0 and m_1 can fully observe q. Then, the worker with quality q at m_0 receives a wage rate— wage per unit time— of $w_0(q)$ such that $\frac{\delta w_0(q)}{\delta q} > 0$. In m_1, after deducting any cost of migration, the worker receives the wage rate $w_1(q)$ such that $\frac{\delta w_1(q)}{\delta q} > 0$. In deciding whether or not to migrate, the worker compares their earnings over their lifetime l in m_0 and m_1. The worker opts to migrate if and only if:

$$w_1(q)l > w_0(q)l$$

[1]For further discussion on education's value as a signal, see: Hungerford and Solon (1987), Jaeger and Page (1996), Frazis (2002), Hussey (2012), and Arteaga (2018).

[2]For further discussion on employers' learning of worker quality over time, see: Greenwald (1986), Farber and Gibbons (1996), Waldman (1996), Bauer and Haisken-DeNew (2001), Lange (2007), and Schönberg (2007).

If the wage rate in neither labour market changes over time, the worker need only compare the wage rates. So, I can write the full migration condition as:

$$w_1(q) > w_0(q)$$

Now, suppose that employers in m_0 can fully observe q, but due to information asymmetry, employers in m_1 believe that the quality of workers from m_0 is $\bar{q}$, where $0 < \bar{q} < q$. For instance, $\bar{q}$ may be the average quality of migrant workers in m_1. Since employers in m_1 can only observe $\bar{q}$, they offer the same wage $w_1(\bar{q})$ to all workers from m_0. So, the worker from m_0 with quality q migrates to m_1 if and only if:

$$w_1(\bar{q}) > w_0(q)$$

Let the function Φ represent the degree of information an employer in the destination labour market m_1 can possess about the quality of individual migrant workers, where $0 \leq \Phi \leq 1$; $\Phi = 1$ means the employer is fully informed, and $\Phi = 0$ means that the employer is entirely uninformed. Here, Φ is a function of time t such that $\frac{\delta\Phi(t)}{\delta t} > 0$. At time t, the employer takes the worker's quality to be $q_t = q + (q - \bar{q})\Phi(t)$. So, with time, the employer observes the quality of the worker more accurately. Since $\frac{\delta\Phi(t)}{\delta t} > 0$, $\frac{\delta q_t}{\delta t} = (q - \bar{q})\frac{\delta\Phi(t)}{\delta t} > 0$ for $q > \bar{q}$ (workers of quality above that initially assumed), and $(q - \bar{q})\frac{\delta\Phi(t)}{\delta t} < 0$ for $q < \bar{q}$ (workers of quality below that initially assumed).

Now, I allow the employer to observe the worker before making a final wage commitment. Suppose the employer has a maximum initial observation period of $t_{max} \leq l$ prior to finalizing a wage offer. The employer may not change wage rates beyond t_{max}. I can, then, decompose a migrant worker's earnings into that which the worker earns in the initial period of employment leading up to t_{max}, and that which the worker earns in the period after t_{max} leading up to l. The migration condition[3] becomes:

$$\int_0^{t_{max}} w_1(q_t)\delta t + w_1(q_{t_{max}})(l - t_{max}) > w_0(q)l$$

[3]Here, I assume the employer can continuously update wage offers until t_{max}. Consider the special case where the initial wage offer lasts throughout the interval $t \in \{0, t_{max}\}$. The migration condition for this special case is: $w_1(\bar{q})t_{max} + w_1(q_{t_{max}})(l - t_{max}) > w_0(q)l$

Proposition 0. *A worker who migrates for certain values of the maximum initial observation period t_{max} and lifetime l might not migrate for other values of these parameters.*

See Appendix A for proof.

Now, consider decisions of permanent migration, where the worker compares earnings over an indefinite lifetime in m_0 and m_1. Evaluating the limit of the migration condition as $\lim_{l\to\infty}$, I get:

$$\lim_{l\to\infty}\left[\int_0^{t_{max}} w_1(q_t)\delta t + w_1(q_{t_{max}})(l - t_{max})\right] > \lim_{l\to\infty} w_0(q)l$$

which simplifies to:

$$w_1(q_{t_{max}}) > w_0(q)$$

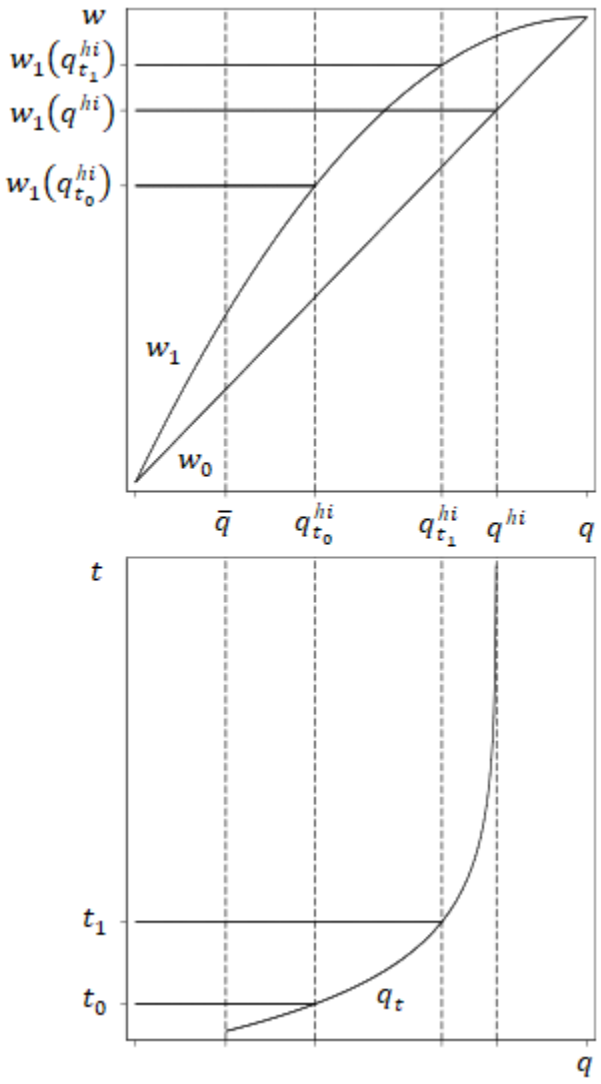
Explicitly, the full migration decision function becomes:

$$\begin{cases} \text{migrate} & \text{if } w_1(q_{t_{max}}) > w_0(q); \\ \text{not migrate} & \text{if } w_1(q_{t_{max}}) < w_0(q); \\ \text{undefined} & \text{if } w_1(q_{t_{max}}) = w_0(q) \end{cases}$$

Assumptions of Non-Linearity and Intersection of Wage Functions: Following Katz and Stark (1987), I assume that at least one of $w_0(q)$ or $w_1(q)$ is non-linear in q, and that these functions intersect at three points at least.

The assumptions ensure that there exists a continuous interval $\left\{q^{hi}_{min}, q^{hi}_{max}\right\}$ of workers in m_0, such that $0 \leq \bar{q} < q^{hi}_{min} < q^{hi} < q^{hi}_{max} \leq 1$, and $w_1(q^{hi}) > w_0(q^{hi})$. So, all workers in this interval migrate to m_1 under full information symmetry. The assumptions also ensure that $w_0(q^{hi})$ and $w_1(q^{hi})$ are both defined for all values of q^{hi} in the interval.

Proposition 1. *A worker of quality q^{hi} who does not migrate to labour market m_1 for a given maximum initial observation period t_{max} will migrate for a sufficiently large increase in t_{max}.*



Proof of Proposition 1. *Suppose* $t_{max} = t_0$. *If the worker of quality* q^{hi} *does not migrate, it implies that* $w_1(q^{hi}_{t_0}) < w_0(q^{hi})$. *Moreover,* $\frac{\delta q_t}{\delta t} > 0$ *for* $q^{hi} > \bar{q}$, *and* $\frac{\delta w_1(q)}{\delta q} > 0$. *So,* $\frac{\delta w_1(q^{hi}_t)}{\delta t} > 0$. *Since* t_{max} *can take the vaue of any positive real number, and* $\Phi(t)$ *is defined for all such values, there exists a* $t_* > t_0$ *such that* $w_1(q^{hi}) > w_1(q^{hi}_{t_*}) = w_0(q^{hi})$. *The worker will migrate for any* $t_1 > t_*$ *because* $w_1(q^{hi}_{t_1}) > w_0(q^{hi})$.

■

Appendix A presents the proof for an alternate formulation of Proposition 1.

II The Natural Experiment

For many international students, education serves as a pathway to foreign employment (Kwok and Leland 1982; Rosenzweig, Irwin, and Williamson 2006). Several countries allow international students to work within the countries' borders after the students complete their studies. Host countries regulate international students' entry into their labour markets, as well as the duration of their stay there. In the US, an employer can hire an international student by securing an H-1B work visa[4] for them. A work visa, if approved, allows an employee to work in the US for up to six years. However, each work visa petition costs about \$3,000-\$7,000[5], and employers, by law, ought to bear the entire cost. Moreover, a petition does not guarantee approval of work visa. The US issues up to 65,000 work visas every year, and an additional 20,000 for applicants who have graduate degrees from US institutions. Since the number of petitions exceeds the number of visas available, the government allocates visas by lottery. Given the cost and uncertainty of obtaining the visas, sponsorship of work visa represents a substantial investment. Employers would sponsor only workers of high value, if at all.

Employers can also hire international students without acquiring work visas, though for shorter durations. A regulation called Practical Training[6] allows students with F-1 visas to obtain work authorization for a limited number of months. Despite contrary connotations associated with the word *training*, authorized students can work full-time. Work authorizations cost students about \$500[7] each. Importantly, an employer who hires a student worker under work authorization can use the authorization period to assess whether the worker is worth sponsorship.

In April 2008, United States Citizenship and Immigration Services (2008) announced

[4]The H-1B visa is the most popular one among students who enter the US labour market after completing university education in the country, and has been at the center of policy debates (See Wasem (2012), Issa (2017), Lofgren (2017), and Trump (2017)). Migrants entering the US for employment may also enter under the E-3 visa (applicable only to citizens of Australia), H-1B1 visa (applicable only to citizens of Chile and Singapore), or other visas such as L-1, O-1, and R-1.

[5]Cost as of 2017 (United States Citizenship and Immigration Services 2018a)

[6]While most international students study in the US under the F-1 visa, some study under the J-1 or M-1 visas. Only students under F-1 visas qualify for Practical Training. Upon a student's request, the government may grant restricted work authorization (Curricular Practical Training) prior to them completing their studies. Nevertheless, only one percent of students obtain authorization before graduation (Wasem 2012).

[7]Cost as of 2018 (United States Citizenship and Immigration Services 2018b)

a policy intervention applicable to a clearly defined list of degree programs.[8] The intervention allowed students graduating from any program on the list to extend their work authorizations for a total of 29 months compared to the prevailing limit of 12 months. All other students under F-1 visas remained entitled to 12-month work authorizations. The policy intervention affords employers more time to try out certain student workers before deciding whether to sponsor them.[9]

The announcement stated the following motivation for the policy intervention:

> Because... [H-1B work visas are] greatly oversubscribed,... [students with work authorizations] often are unable to obtain [them] within their authorized period of stay in... F-1 [student] status, including the 12-month [authorization] period, and thus are forced to leave the country. The inability of U.S. employers, in particular in the fields of science, technology, engineering and mathematics, to obtain H-1B [work visas] for highly skilled foreign students and foreign nonimmigrant workers has adversely affected the ability of U.S. employers to recruit and retain skilled workers... (United States Citizenship and Immigration Services 2008)

[8]During the 2008 announcement, the United States Citizenship and Immigration Services (2008) introduced another policy that benifited students transitioning from F-1 student visas to an H-1B work visas. The policy targeted students whose work visa petitions were approved to come into effect on a given date, but whose student visas expired before it. Prior to the announcement, the government required such students to leave the US before their student visas expired, and return only when the work visas were activated. A student's obligation to leave the US could disrupt their employer's operations. United States Citizenship and Immigration Services (2008) addressed the situation by "[extending] the authorized period of stay, as well as work authorization, of any F-1 student who is the beneficiary of a timely-filed H-1B [work visa] petition that has been granted..., or remains pending..." Unlike the policy allowing for the extension of work authorization, this policy targeted all students with work visa petitions rather than a subset of them. In my analysis, its effects, if any, are eliminated by cohort fixed effects in models which control for them.

[9]In May 2011 and May 2012, the United States Department of Homeland Security announced the addition of more degree programs to the list. In March 2016, the department announced the revision of the duration of authorization from a total of 29 to 36 months. The 2011 and 2012 changes do not afford valid natural experiments for the estimation of selection effects. The analysis assumes that no student enrolled before the announcement could choose their program based on whether it allowed a 29-month authorization. However, students who enrolled after the 2008 announcement (but before the 2011 or the 2012 ones) had the choice. The 2016 announcement, on the other hand, would offer a valid natural experiment because no student enrolling before the announcement could choose their program based on whether it allowed a 36-month authorization. However, I cannot reliably study the effects of the 2016 announcement because I do not have data for students enrolling after September 2016.

Prior to the policy intervention, an employer risked not being able to retain a sponsored worker beyond 12 months if the US government denied the work visa. Regardless of a student's quality, this risk could discourage an employer from sponsoring the student. So, given a student of any quality, an employer would be more likely to sponsor the student if they could extend authorization. An emperical test of Proposition 1 will need to separate such direct effects of the policy intervention from that of self-selection. Here, the policy is useful because it affected not only students enrolling after the announcement, but also those already enrolled at the time of announcement. Its retroactive nature allows for the identification of self-selection (See Section V).

III Data and Definitions

I use data from the entire population of master's degree students (over 982,000) entering the US with F-1 visas between January 2004 and September 2016. The data originate from the Student and Exchange Visitor Information System maintained by the US Department of Homeland Security. The dataset contains information on students' age, gender, schools, degree programs, cost of the programs, program start dates, country of citizenship, work authorization, and sponsorship. I am able to determine whether the policy intervention affected the student by comparing each student's degree program with those on the list of programs targeted by the policy intervention.

When the data were extracted from the Student and Exchange Visitor Information System, some students observed in the data were still enrolled. Records of authorization are not complete for all students starting their programs after September 2014. Likewise, the data would not accurately reflect sponsorship status for all students who graduated by the time of data extraction. The records of sponsorship are not complete for all students starting their programs after September 2012.

Each student falls into different groups based on three dimensions— their time of enrolment, whether they enrolled in a listed degree program, and whether they obtained work authorization. Below, I define some key terminology:

> **Periods of Enrolment:** I define a cohort as a group of students whose study programs began in the same month of the same year. I also categorize students into pre-announcement (*before*-announcement), peri-announcement (*dur-*

ing-announcement), or post-announcement (*after*-announcement) groups. Pre-announcement students are those who graduated *before* the policy announcement. Peri-announcement students are those who were enrolled when the policy was announced, but had not graduated; the announcement occurred *during* their period of enrolment. Post-announcement students are those who enrolled *after* announcement. In defining pre-announcement and peri-announcement students, I assume that master's degree programs in the US are four semesters long. Then, peri-announcement students are those who enrolled after September 2006 but before the announcement, and pre-announcement are those enrolled on or before September 2006. The analysis rests on a distinction between the pre-announcement, peri-announcement, and post-announcement students. The policy intervention left pre-announcement students unaffected. It affected only the peri-announcement and post-announcement students who enrolled in listed programs, making them eligible to avail extensions. Crucially, the policy intervention could have influenced the choice of degree program of a post-announcement student, but not that of a pre-announcement or a peri-announcement student. I also define staggered-year, where each year starts in April and ends in the following March. In the year-wise analyses that follow, staggered-years simply reflect that the announcement occurred in the month of April. Similarly, I divide a calendar year into four quarters.

Eligible and Treatment Groups: I define eligible students as those who had the choice to avail the extension by acquiring authorization. They are students enrolled in a listed program in the peri-announcement or post-announcement period. A treatment student is an eligible student who acquired authorization. The policy intervention allowed students to *extend* their work authorizations. Only the authorized among the peri-announcement and post-announcement students in listed degree programs— the treated among the eligible— could avail the extensions.

Table 1 describes some features of the data. Females accounted for 43 percent of the students, and the average student was 26 years old. The policy intervention affected a large population of students. Out of all master's degree students, 41 percent enrolled in listed degree programs. A substantial portion of students entered the US labour market. About 56 percent of students obtained work authorizations, and 33 percent acquired work visa sponsorships. Out of the sponsored, 82 percent were authorized. The average person who acquired sponsorship did so in about three years (1,103 days) from the date of enrollment, though with considerable variation (standard deviation

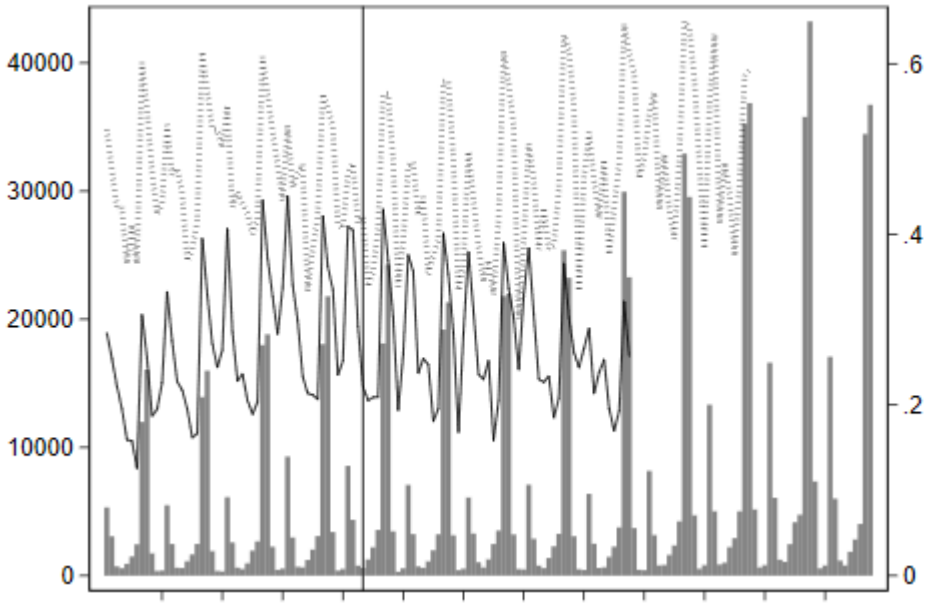
Table 1: Descriptive Statistics

	Variable	Mean	Standard Deviation	Observations
	Age	25.85	4.91	982,777
	Female	0.43	0.49	982,777
	Listed	0.41	0.49	982,777
	Authorized	0.56	0.50	747,111
	Sponsored	0.33	0.47	550,318
Conditional on Sponsorship:	Authorized	0.56	0.50	747,111
	Days from enrollment to sponsorship	1,103	510	182,499
Number of:	Schools			1,973
	Programs			1,504
	Countries			225

of 510 days). The dataset does not contain information on whether a student availed extension.

Figure 1 shows a distinct seasonality in some variables. Enrolment (shown with bars) has increased over the years. It peaks twice a year: at the beginning of the spring semester (January), and at the beginning of the fall semester (August and September). Out of all master's degree students, 12 percent enrolled in January, 32 percent in August, and 34 percent in September. No other month of the year accounts for more than five percent of enrolment. The proportion of students acquiring work authorizations (dotted line) and the proportion securing work visa sponsorships (solid line) follow the same seasonality.

Figure 1: Enrolment, Authorization, and Sponsorship over Time



X-axis shows month of enrolment starting at January 2004; markers are placed at every 12 months. Y-axis on the left shows frequency. It presents the scale for the bar graph, which shows the number of students enrolled in each month. Y-axis on the right shows proportions. It presents the scale for the line graphs. The dotted line shows the proportion of students in each month who acquired work authorizations. The solid line shows the proportion of students in each month who acquired work visa sponsorships. The vertical line marks the announcement of the policy intervention.

IV Selection

Before proceding to test whether the policy intervention drew students of higher quality into the US labour market, I investigate some priliminary questions. I check whether there is evidence that the policy induced self-selection, and whether responses to the policy intervention are consistent with the expected mechanism.

IV.A Selection into Listed Degree Programs

Did the policy intervention make the listed programs more attractive to international students? As a result of the intervention, certain students who intended to study and work in other countries could have decided to study in the US. I do not observe students' intensions or their forgone choices of labour markets. Nevertheless, I can examine whether the probability of students enrolling in listed degree programs changed following the announcement. I estimate variants of the following pre-post style model:

$$listed_{im} = \sum_{p} (\varphi_p \; period_p) + e_m + e_{im} \tag{1}$$

where the dependent variable $listed_{im}$ indicates whether a student i enrolled in a listed degree program in a given calendar month m. The variable $period_p$ indicates a student enrolled in a given period. The parameters φ_p represent the marginal probabilities of students in each period p enrolling in listed degree programs, where period refers to pre/peri/post, staggered-year, or quarter. Month-of-year fixed effects e_m control for seasonality. The term e_{ic} represents the unobserved error.

Table 2 shows ordinary least squares estimates of the φ_p parameters in model (1) for the peri-announcement and post-announcement periods. As expected, the probability of enrolment in listed degree programs increased by less than two percentage points in the peri-announcement period, and the estimate is not statistically significant. The figure represents a four percent increase in the proportion of students enrolled in listed programs. In the post-announcement period, the probability increased by about 23 percentage points— equivalent to a 55 percent increase in the proportion of students enrolled in listed programs. The estimate is statistically significant.

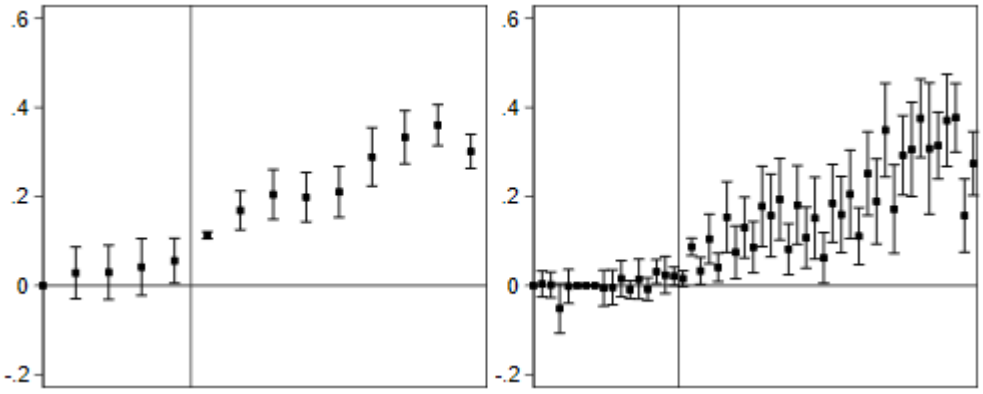
I now test the parallel trends assumption implicit in the specification in table 2. Figure 2 visualizes the ordinalry least squares estimates of the φ_p parameters in model (1) along with 95 percent confidence intervals using the staggered-year and cohort definitions of period. It provides evidence that students' probability of enrolment in listed programs was increasing slightly over time until the policy announcement. Immediately following the announcement, the probability began to increase rapidly. The results provide evidence that the policy intervention attracted students to listed degree programs.

Table 2: Probability of Enrolment in Listed Degree Programs

Variables	Listed (1)
Peri-Announcement	0.015
	(0.008)
Post-Announcement	0.226
	(0.053)
Month-of-Year Fixed Effects	Yes
Observations	982,777
Adjusted R^2	0.068
Mean of Dependent Variable	0.412

Sample includes only those students whose programs started between January 2004 and September 2016. Standard errors in parentheses are clustered at the cohort and degree program levels.

Figure 2: Probability of Enrolment in Listed Degree Programs over Time



The plots show students' probability of enrolling in listed degree programs over time. The x-axis in the left column denotes each successive staggered-year (April to March). The x-axis in the right column denotes each successive quarter. The vertical line marks the announcement of the policy intervention. Square dots represent estimates of the φ_p parameters in model (1), and capped vertical lines passing through the dots represent the 95 percent confidence intervals, both to be read against the y-axes. The scale of the y-axes might vary for each plot. Regressions control for month-of-year fixed effects. Sample includes students who enrolled between January 2004 and September 2016. Standard errors are clustered at the cohort and degree program levels.

IV.B Selection into the Labour Market

Did post-announcement students enrolling in listed programs intend to enter the labour market and benefit from the possibility of extending authorization? If so, they would be more likely to acquire authorization. Peri-announcement students made the decision to enter the US and enroll in their degree programs of choice during a policy regime with 12-month authorizations. The policy intervention could also influence their decision to enter the labour market as reflected in their acquisition of authorization. I want to specify a linear model to test for such effects. The model must consider that the probability of acquiring authorization changes with time, either due to seasonality, or due to changes in the state of the US economy. The probability could also differ between students of listed and unlisted degree programs, even in absence of any policy intervention. I account for potential biases due to such factors by controlling for cohort and listing fixed effects. Thus, I estimate variants of the following difference-in-differences style model:

$$authorized_{icl} = \sum_{p} (\gamma_p \; period_p \times listed_l) + \varepsilon_c + \varepsilon_l + \varepsilon_{icl} \tag{2}$$

where the dependent variable $authorized_{icl}$ indicates whether a student i in a given cohort c, enrolled in a given degree program of a given listing status l, obtained work authorization. The variable $listed_l$ indicates whether a student enrolled in a listed program. The variable $period_p$ indicates a student enrolled in a given period p, where period refers to pre/peri/post-announcement, staggered-year, or quarter. The parameters γ_p represent the marginal probabilities of students in listed degree programs in each period acquiring authorization. The specification controls for cohort fixed effects ε_c, and listing fixed effects ε_l. The term $\varepsilon_i cl$ represents the unobserved error.

Table 3 shows ordinary least squares estimates of the γ_p parameters in model (2) for the peri-announcement and post-announcement periods. The estimates provide no evidence that the policy intervention influenced the probability of peri-announcement students in listed degree programs acquiring work authorization. The increase in the probability is less than one percentage point, and not statistically significant. Contrarily, post-announcement students in listed programs experienced an increase of 10 percentage points in the probability of acquiring authorization. The figure is statistically significant, and equivalent to 18 percent of the probability of the average student acquiring authorization.

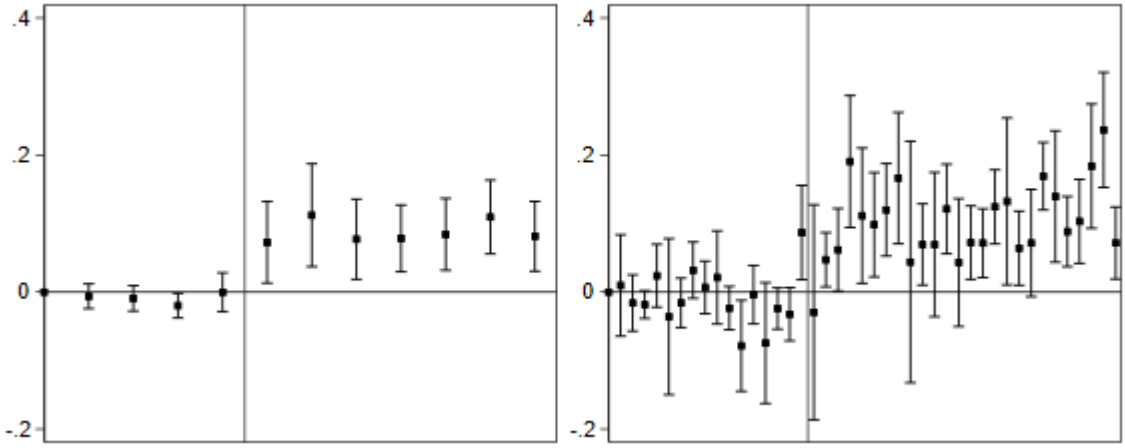
Table 3: Probability of Students in Listed Degree Programs Acquiring Work Authorizations

Variables	Authorized (1)
Peri-Announcement X Listed	0.008
	(0.007)
Post-Announcement X Listed	0.100
	(0.033)
Cohort Fixed Effects	Yes
Listing Fixed Effects	Yes
Observations	747,111
Adjusted R^2	0.054
Mean of Dependent Variable	0.557

Sample includes only those students whose programs started between January 2004 and September 2014. Standard errors in parentheses are clustered at the cohort and degree program levels.

I now test the parallel trends assumption implicit in the specification in table 3. Figure 3 visualizes the ordinary least squares estimates of the γ_p parameters in model (2) along with 95 percent confidence intervals using the staggered-year and quarter definitions of period. It provides evidence that the probability of students in listed programs acquiring authorization stayed stable over time until the policy announcement. Immediately after the announcement, the probability began to increase.

Figure 3: Probability of Students in Listed Degree Programs Acquiring Work Authorizations over Time



The plots show the probability of students listed degree programs acquiring work authorizations over time. The x-axis in the left column denotes each successive staggered-year (April to March). The x-axis in the right column denotes each successive quarter. The vertical line marks the announcement of the policy intervention. Square dots represent estimates of the γ_p parameters in model (2), and capped vertical lines passing through the dots represent the 95 percent confidence intervals, both to be read against the y-axes. The scale of the y-axes might vary for each plot. Regressions control for cohort and listing fixed effects. Sample includes students who enrolled between January 2004 and September 2014. Standard errors are clustered at the cohort and degree program levels.

I interpret a students' acquisition of authorization as a reflection of their decision to enter the labour market. The results provide evidence that, post-announcement, the possibility of extending authorization attracted students desirous of entering the labour market. The results suggest that the policy intervention did not, on average, influence the decision of the peri-announcement students in listed programs to enter the labour market.

V The Quality of Those Selecting into the Labour Market

Section IV provides evidence that the policy intervention made listed degree programs more attractive, and that a portion of post-announcement students enrolling in listed programs intended to enter the US labour market and benifit from the possibility of extending authorization. However, did the intervention draw students of higher quality into the labour market?

I measure a student worker's quality as their probability of acquiring work visa sponsorship. I estimate the marginal change in the probability of authorized post-announcement students in listed degree programs securing sponsorships after controlling for several sources of bias.

The policy could affect the probability of acquiring sponsorship in several ways. Prior to the policy intervention, an employer faced the risk of not be able to retain a sponsored worker for more than 12 months if the visa was denied. The ability to extend authorization dampens this risk. So, an employer would plausibly be more likely to sponsor a student who can extend authorization, regardless of their quality. Likewise, a worker who extends authorization and continues working also has more time to improve. An employer could have more incentive to sponsor such a worker rather than hire a replacement. I refer to such effects as the direct effects of the policy intervention in contrast to selection effect. The retroactive nature of the policy intervention allows me to seperately estimate the direct effects and the selection effect. The authorized among both peri-announcement and post-announcement students in listed degree programs— the treated among the eligible— would experience the direct effects. However, only the post-announcement out of the treated students can exhibit the selection effect.

Changes in the demand for migrant workers in the US labour market could affect the probability of a student worker receiving sponsorship, biasing estimates. Assuming that students in each cohort experience the same economic environment, I can remove such biases with cohort fixed effects. By design, the policy intervention targeted technical industries. The list included only degree programs pertaining to science, technology, engineering, and mathematics. So, even within the same cohort, changes in the technical industries might influence labour market outcomes for students enrolled in listed programs differently compared to the outcomes of those enrolled in unlisted programs. Therefore, I control for unobserved characteristics fixed to stu-

dents enrolled in listed and unlisted programs in each cohort using cohort-listing fixed effects.

The policy intervention did not introduce the option to acquire work authorization in a regime where no such provision existed. All students had the choice to obtain authorization, regardless of whether or not they could extend it. Students who obtained authorization could differ from the rest. I account for such differences, and the possibility of the differences varying over time, by controlling for cohort-authorization fixed effects. I also allow for unobserved differences between authorized and unauthorized students in listed and unlisted degree programs by controlling for listing-authorization fixed effects. Thus, I estimate variants of the following difference-in-difference-in-differences style model:

$$
\begin{aligned}
&sponsored_{icla} = \\
&\quad \alpha\ peri\text{–}or\text{–}post\text{–}announcement_c \times listed_l \times authorized_a + \\
&\quad \beta\ post\text{–}announcement_c \times listed_l \times authorized_a + \\
&\quad \epsilon_{cl} + \epsilon_{ca} + \epsilon_{la} + \epsilon_{icla}
\end{aligned}
\tag{3}
$$

where the dependent variable $sponsored_{icla}$ indicates whether a student i belonging to a given cohort c, enrolled in a degree program of a given listing status l, and with the given authorization status a, obtained work visa sponsorship. The variable $peri\text{–}or\text{–}post\text{–}announcement_c$ indicates a student who enrolled in either the peri-announcement or the post-announcement period, while $post\text{–}announcement_c$ indicates a student who enrolled in the post-announcement period. The variable $listed_l$ indicates whether a student enrolled in a listed program. The variable $authorized_a$ indicates an authorized student. The parameter α represents the aggregate direct effect experienced by both authorized peri-announcement and post-announcement students in listed degree programs. The parameter β represents the selection effect. The specification controls for cohort–listing fixed effects ϵ_{cl}, cohort-authorization fixed effects ϵ_{ca}, and listing-authorization fixed effects ϵ_{la}. The term ϵ_{icla} represents the unobserved error.

I modify model (3) to test the implicit parallel trends assumption. If the effects α and β in model (3) originated from the policy intervention, the probability of authorized students in listed degree programs receiving sponsorship would not fluctuate during the pre-announcement period. To test for such stable trends, I estimate:

$$
\begin{aligned}
&sponsored_{icla} = \\
&\sum_{p} (\theta_p \; period_p \times listed_f \times authorized_a) + \\
&\epsilon_{cl} + \epsilon_{ca} + \epsilon_{la} + \epsilon_{icla}
\end{aligned}
\tag{4}
$$

where the variable $period_p$ indicates a student enrolled in a given period p. The parameters θ_p represent the marginal probabilities of authorized students in listed degree programs acquiring sponsorship in each period.

Table 4 shows ordinary least squares estimate of the aggregate direct effect α and the selection effect β in model (3). The first column presents estimates for the primary specification. The estimate of α has a magnitude of three percentage points. It does not offer suffiient evidence of direct effects. On the contrary, the estimate of β provides evidence that the policy intervention led to student workers of higher quality entering the US labour market. After removing the direct effects, authorized post-announcement students in listed degree programs— the post-announcement among the treated— were 21 percentage points more likely to receive sponsorship. The figure amounts to 63 percent of the average probability of sponsorship and is statistically significant.

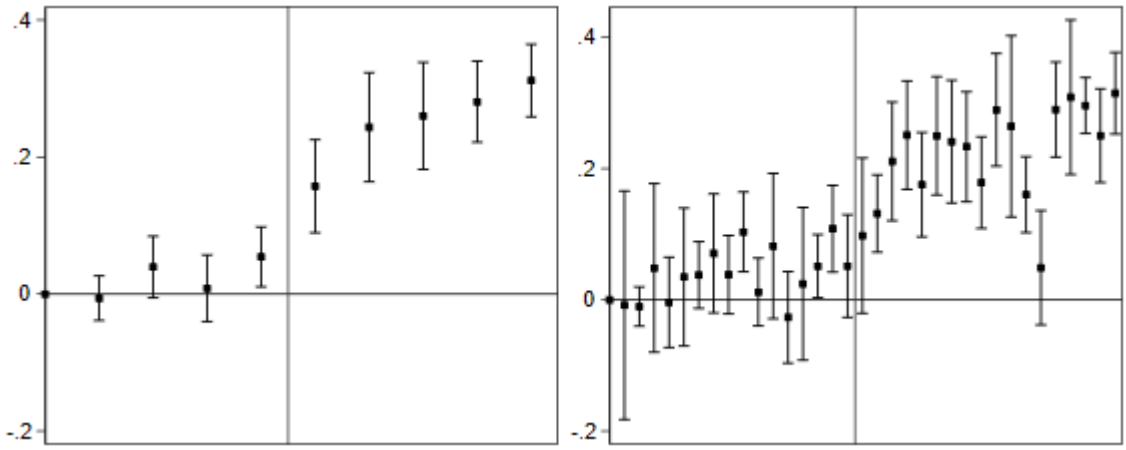
Figure 4 visualizes the ordinary least squares estimates of the θ_p parameters in model (4) along with 95 percent confidence intervals using the staggered-year and quarter definitions of period. It provides evidence that the probability of authorized students in listed programs acquiring sponsorship stayed stable over time until the policy announcement. Immediately after the announcement, the probability began to increase. The trend allows me attribute the estimated effects to the policy intervention.

Table 4: Probability of Students in Listed Degree Programs with Work Authorization Acquiring Work Visa Sponsorships

Variables	Sponsored (1)
Peri-or-Post-Announcement X Listed X Authorized	0.026
	(0.010)
Post-Announcement X Listed X Authorized	0.211
	(0.038)
Cohort-Listing Fixed Effects	Yes
Cohort-Authorization Fixed Effects	Yes
Listing-Authorization Fixed Effects	Yes
Observations	550,318
Adjusted R^2	0.231
Mean of Dependent Variable	0.332

Sample includes only those students whose programs started between January 2004 and September 2012. Standard errors in parentheses are clustered at the cohort and degree program levels.

Figure 4: Probability of Students in Listed Degree Programs with Work Authorization Acquiring Work Visa Sponsorships over Time



The plots show the probability of authorized students in listed degree programs acquiring sponsorships over time. The x-axis in the left column denotes each successive staggered-year (April to March). The x-axis in the right column denotes each successive quarter. The vertical line marks the announcement of the policy intervention. Square dots represent estimates of the θ_p parameters in model (4), and capped vertical lines passing through the dots represent the 95 percent confidence intervals, both to be read against the y-axes. The scale of the y-axes might vary for each plot. Regressions control for cohort-authorization, cohort-listing, and listing-authorization fixed effects. Sample includes students who enrolled between January 2004 and September 2012. Standard errors are clustered at the cohort and degree program levels.

A more accurate analysis would distinguish between those who extended authorization and those who acquired but did not extend it. The limitation notwithstanding, the evidence is consistent with the hypothesis that allowing employers more time to try out workers before making final wage offers leads to workers of higher quality migrating into the labour market.

VI Time to Wage Revision

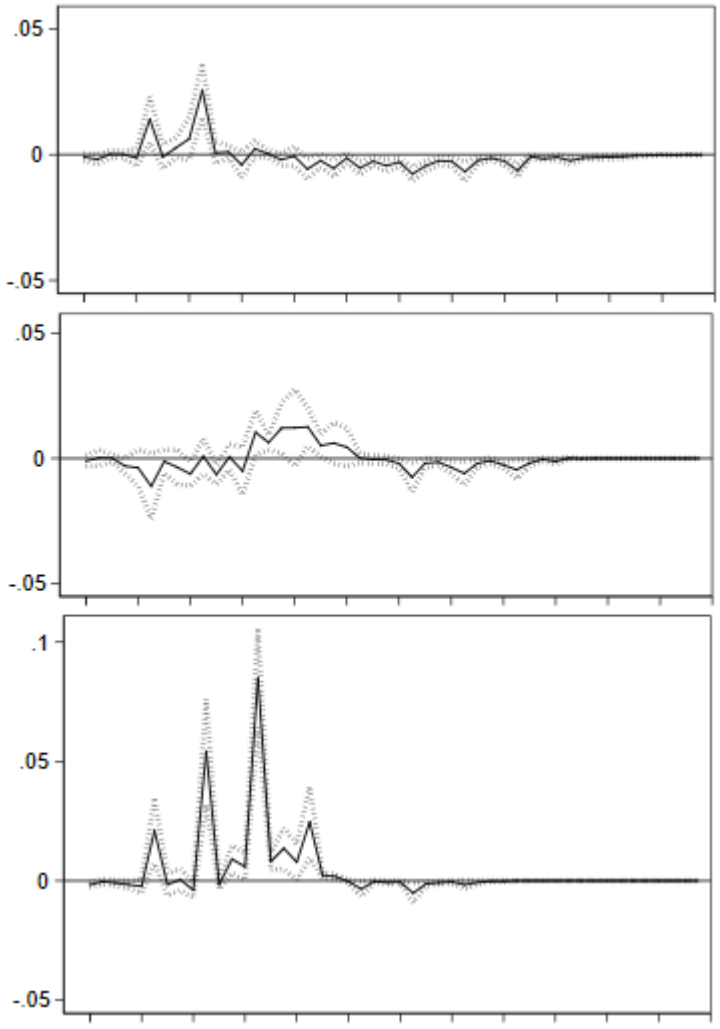
Section V provides evidence that the policy intervention brought student workers of higher quality into the US labour market. If the effect follows from improved information symmetry, employers should have taken longer to assess treated students—both peri-announcement and post-announcement— before deciding whether to sponsor them. I would expect that treated students were more likely to avail the extension. The dataset does not contain information on extensions, but other authors have provided some commentary. Demirci (2018) has found that, after 2008, master's degree students in listed fields held work authorizations for about 100 days more. More accurately, if the model explains the data, I would expect to find that employers took longer to decide whether to sponsor treated students. If an employr decided not to sponsor a student, I do not observe when they reached the decision. Nonetheless, if they decided to sponsor the student, I observe the date when the employer filed the student's work visa petition. Treated students who acquired sponsorships ought to have acquired them later. I am interested in the duration between a student worker's first day of work, when their employer begins observing them, and the date of sponsorship. Since the dataset does not contain information on the first day of work, I approximate the duration by taking the number of days between their enrolment and the filing of their work visa petition. Duely acknowledging these limitations, I estimate the following modification of models (3) and (4) for a set of dependent variables:

$$
\begin{aligned}
&sponsored^{q}_{icla} = \\
&\quad \kappa^{q}_{pre}\ pre_c \times listed_l \times authorized_a + \\
&\quad \kappa^{q}_{peri}\ peri_c \times listed_l \times authorized_a + \\
&\quad \kappa^{q}_{post}\ post_c \times listed_l \times authorized_a + \\
&\quad \omega^{q}_{cl} + \omega^{q}_{ca} + \omega^{q}_{la} + \omega^{q}_{icla}
\end{aligned}
\tag{5}
$$

where the dependent variable $sponsored^{q}_{icla}$ *indicates whether a student* i *belonging to a given cohort* c*, enrolled in a degree program of a given listing status* l*, and with the given authorization status* a*, acquired sponsorship in the* q^{th} *quarter since enrolment. The variables* pre_c*,* $peri_c$*, and* $post_c$ *indicate pre, peri, and post-announcement students respectively. The parameters* κ^{q}_{pre}*,* κ^{q}_{peri}*, and* κ^{q}_{post} *represent the marginal change in* $sponsored^{q}_{icla}$ *for authorized students in listed degree programs in each period— pre, peri, or post-announcement. The specification controls for cohort–listing fixed effects* ω^{q}_{cl}*, cohort-authorization fixed effects* ω^{q}_{ca}*, and listing-authorization fixed effects* ω^{q}_{la}*. The term* ω^{q}_{icla} *represents the unobserved error. The superscript* q *denotes that the dependent variable* $sponsored^{q}_{icla}$*, the parameters, fixed effects, and the unobserved error are unique to each value of* q*.*

Estimating the κ^{q}_{pre}, κ^{q}_{peri}, and κ^{q}_{post} parameters in model (5) for each value of q sheds light on how likely pre, peri, and post-announcement students were to acquire sponsorship on the q^{th} quarter after enrolment. Figure 5 visualizes the ordinary least squares estimates of the parameters, along with 95 percent confidence intervals, for each value of q. It shows that authorized pre-announcement students in listed degree programs were most likely to acquire sponsorship on the 10^{th} quarter after enrolment. For authorized peri-announcement students in listed programs, the probability was highest in the 18^{th} quarter after enrolment. Likewise, for authorized post-announcement students in listed programs, the probability was highest in the 14^{th} quarter. The probability of treated students acquiring sponsorship between the 12^{th} and 18^{th} quarter after enrollement is positive and largely distinct from zero given the 95 percent confidence level. Though this analysis does not test the equality of κ^{q}_{pre} and κ^{q}_{peri}, or that of κ^{q}_{pre} and κ^{q}_{post}, it provides some evidence that a sizable proportion of treated students acquired sponsorship six months to two years later than authorized pre-announcement students in listed degree programs. The results are consistent with employers taking longer to assess treated students.

Figure 5: Probability of Students in Listed Degree Programs with Work Authorization Acquiring Work Visa Sponsorship on a Given Quarter After Enrolment



The plots show the probability of authorized pre, peri, and post-announcement students in listed degree programs acquiring sponsorship on a given quarter after enrolment. The x-axis denotes each quarter after enrolment, with markers placed at the first quarter, and every fourth quarter subsequently. The solid lines represent estimates of the κ^q parameters in model (5), and the dotted lines represent the 95 percent confidence intervals, both to be read against the y-axes. The scale of the y-axes might vary for each plot. The top panel plots κ^q_{pre}, the middle one plots κ^q_{peri}, and the bottom one plots κ^q_{post}. So, the figure shows coefficients obtained from 48 regressions, each represented by a point on the x-axis. The regressions control for cohort-listing, cohort-authorization, and listing-authorization fixed effects. Standard errors are clustered at the cohort level.

VII Concluding Discussions

Using a 2008 policy intervention in the US labour market, I find evidence consistent with the theory of adverse selection under information asymmetry. Allowing employers more time to assess workers prior to making final wage commitments seems to improve the quality of workers in the labour market. Self-selecting students who acted to benefit from the policy intervention saw an increase of 21 percentage points (63 percent) in the probability of acquiring work visa sponsorships owing to their higher quality. Since each work visa petition costs roughly $3,000 to $7,000, the effect indicates a substantial improvement in qualilty.

Investigators may extend the analysis in this paper using the 2016 policy intervention once new data becomes available in the Student and Exchange Visitor Information System. The 2008 announcement allowed certain students to extend the duration of authorization by 17 months after the initial 12 months, whereas the 2016 policy allowed students to extend it by 23 months after the initial 12 months. The difference ought to allow investigators to infer whether the slope of the information function Φ in Section I is constant, increasing, or decreasing in time.

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A Appendix

Proof of Proposition 0. *I provide a proof by contradiction.*

Assume that a worker who migrates for given values of t_{max} and l migrates for any value of these parameters. Take a worker who migrates, and for whom $w_1(q_t) \neq w_1(q_{t_{max}})$. So, the migration condition holds for the worker. The migration condition simplifies to:

$$\int_0^{t_{max}} w_1(q_t)\delta t - w_1(q_{t_{max}})t_{max} > [w_0(q) - w_1(q_{t_{max}})]l$$

Consider the left hand side of the inequality. It must be that $\int_0^{t_{max}} w_1(q_t)\delta t - w_1(q_{t_{max}})t_{max} < 0$ because $w_1(q_t) \neq w_1(q_{t_{max}})$. Since $l > 0$, it is required on the right hand side that $w_0(q) - w_1(q_{t_{max}}) < 0$ if the migration condition is to hold. So, dividing the simplified migration condition by $w_0(q) - w_1(q_{t_{max}})$, I get:

$$0 < \frac{\int_0^{t_{max}} w_1(q_t)\delta t - w_1(q_{t_{max}})t_{max}}{w_0(q) - w_1(q_{t_{max}})} < l$$

However, since l is defined for all positive real numbers, there exists an l_* such that:

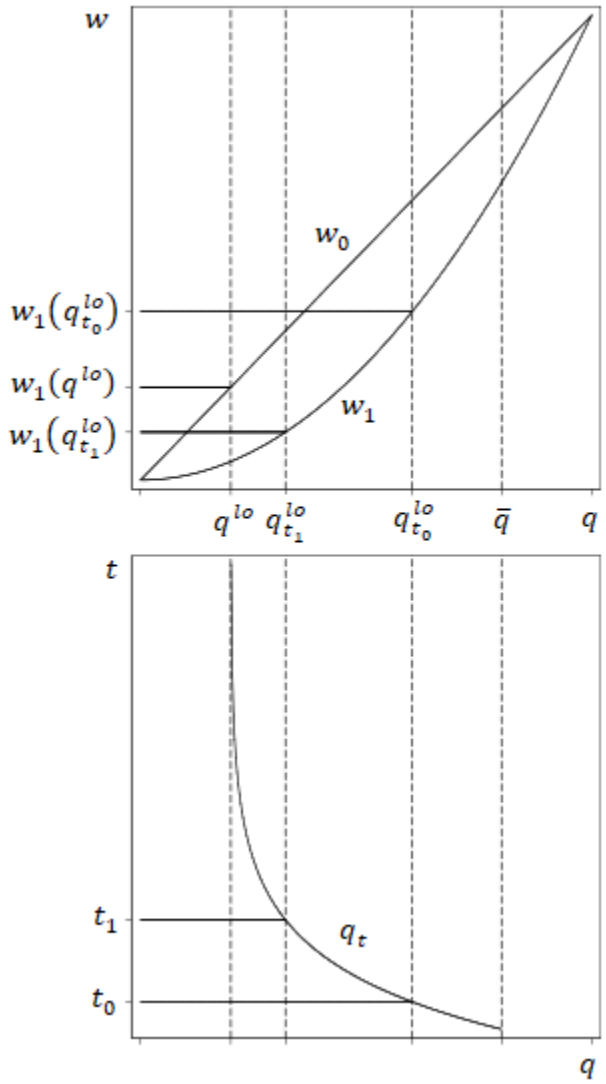
$$0 < l_* < \frac{\int_0^{t_{max}} w_1(q_t)\delta t - w_1(q_{t_{max}})t_{max}}{w_0(q) - w_1(q_{t_{max}})}$$

The migration condition can not hold for l_*.

■

The assumptions of non-linearity and intersection of wage functions ensure that there exists a continuous interval $\left\{q^{lo}_{min}, q^{lo}_{max}\right\}$ of workers in m_0, such that $0 \leq q^{lo}_{min} < q^{lo} < q^{lo}_{max} < \bar{q} \leq 1$, and $w_1(q^{lo}) < w_0(q^{lo})$. So, no worker in this interval migrates to m_1 under full information symmetry. The assumptions also ensure that $w_0(q^{lo})$ and $w_1(q^{lo})$ are both defined for all values of q^{lo} in the interval.

Proposition 1 (Alternate Formulation). *A worker of quality q^{lo} who migrates to labour market m_1 for a given maximum initial observation period t_{max} will not migrate for a sufficiently large increase in t_{max}.*



Proof of Proposition 1 (Alternate Formulation). *Suppose* $t_{max} = t_0$. *If the worker of quality* q^{lo} *migrates, it implies that* $w_1(q_{t_0}^{lo}) > w_0(q^{lo})$. *Moreover,* $\frac{\delta q_t}{\delta t} < 0$ *for* $q^{lo} < \bar{q}$, *and* $\frac{\delta w_1(q)}{\delta q} > 0$. *So,* $\frac{\delta w_1(q_t^{lo})}{\delta t} < 0$. *Since* t_{max} *can take the vaue of any positive real number, and* $\Phi(t)$ *is defined for all such values, there exists a* $t_* > t_0$ *such that* $w_1(q^{lo}) < w_1(q_{t_*}^{lo}) = w_0(q^{lo})$. *The worker will not migrate for any* $t_1 > t_*$ *because* $w_1(q_{t_1}^{lo}) < w_0(q^{lo})$.

■