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ABSTRACT

US universities have attracted hundreds of thousands of international students each year for the last decade. Some of these remain in the US after graduating and contribute to the high skilled labor supply in US labor markets. In this paper, we identify and estimate by how much one more international master's (or bachelor's) student increases the skilled labor supply of the US in the short-run. To estimate this "transition rate" we implement an instrumental variable estimation using quasi-random variation in the tuition charged to international students by public US universities in the year that they likely started their studies. We find that attracting an additional international student to a US university increases the local labor supply by about 0.23 employees for master's students and about 0.11 for bachelor's students. These averages conceal an important difference. While non-STEM bachelor's and master's students had negligible transition rates into US employment, STEM Master students have had significant transition rates around 0.2, especially after the 2008 reform of Optional Practical Training for STEM graduates.

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1 Introduction

The internationalization of higher education across OECD countries has become a major feature of globalization. In less than 50 years, the number of students completing their higher education in a foreign country has increased by a factor of more than 6. The number of international students enrolled in higher education institutions located in OECD countries amounted to 3.3 million in 2015 (OECD, 2018) and to 5.3 million worldwide in 2018. The US has long been the top destination for those wishing to complete their education abroad. In 2015, US universities hosted 907,000 international undergraduate and graduate students, representing about two-thirds of total foreign-student enrollment in higher education in OECD countries. That year also saw the largest flow of new foreign students in the US, with the number of F-1 visas, the typical visa of a foreign student in the US, reaching a total of 644,000. That number has declined since then. However, except for the year 2020, when the effects of Covid were at its strongest, it has always been larger than 400,000[1]. Many master's and PhD programs in the sciences, engineering, mathematics, and economics would be much less successful and productive without the active participation of foreign undergraduate and graduate students (see Chellaraj et al., 2008). The high number of international students eager to enroll in US universities gives those institutions the possibility of selecting high quality students and generating highly valuable human capital for the US economy if some of these students remain in the US after graduation.

Admission of international students by US universities is based on academic qualities and not on labor market needs. However, by attracting and educating international students, US universities play an important role in generating potential supply of highly educated workers in the US and in their local economy. The size and significance of this contribution depends on how many of them graduate, remain and find a job in the US at least in the short run. While international students usually pay for their education with higher tuition fees than natives (especially in public universities) and cross-subsidize domestic students (Shih, 2017), the full impact of international students' human capital on the US economy depends on whether they transition into US labor markets, at least for a while. Thus, the positive local economic spillovers from the high human capital of these graduates depends on the rate of their transition into employees.

In this paper, we estimate the increase in the short-run high-skilled labor supply in response to an exogenous increase in the number of foreign graduates from US

[1]In year 2020 due to Covid disrupting international travel, only 120,000 F1 visas were issued for educational purposes

bachelor's and master's programs. This parameter captures the short-run impact of international master's or bachelor's student enrollment in US universities on the master's- or bachelor's-educated labor supply in the US. At one extreme, if all international students find a way to work in the local economy of the university from where they graduated, attracting more international students will have a strong impact on the high skilled labor supply available to local firms. At the other extreme, if they all leave and return to their country or origin or move to another foreign country, none of the skilled labor supply increase and productive spillovers that these students will generate will be realized in the US. This would imply a smaller positive contribution of universities at both the local and national level.

Since we focus on the transition of foreign graduates into their first jobs, which are obtained mainly through the Optional Practical Training program (discussed below) and which last between a few months and 2-3 years, our analysis captures short-run transitions of international students into the US labor market, rather than their long-term presence. Several of these students may leave the US labor market within few years. Nevertheless, these short-run transitions have a direct impact on the supply of human capital, as well as on the long-run probability of these workers settling, living and working permanently in the US. We calculate a "short-run transition rate" within US states and within the US as a whole for both master's and bachelor's students by estimating the coefficient on the number of international graduates in a regression with first-time OPT workers in the US (or in the same state) as the dependent variable, aggregating individuals by graduating university, major and year. We instrument for the number of international graduates with the exogenous and idiosyncratic part of the non-resident tuition in the university where they studied, measured two to four years before graduation. We limit our analysis to public university graduates, which covers the majority of foreign students, where the tuition fees for out-of-state students are different from those for in-state students. This allows us to identify a quasi-random component in out-of-state fees relative to in-state tuition.

A few studies have produced estimates of transition rates of international graduates into employment in the US. Peri and Basso (2016) used data from the American Community Survey (ACS) and could only identify *likely* students on F-1 visas in 50 US states and 277 Metropolitan areas. They estimated simple partial correlations between the number of local college-educated foreign workers and foreign college students five year earlier in the same state. This simple correlation analysis finds a very low transition rate (close to 0.05 and not statistically significant) from international graduates to workers in the US. The large imprecision of ACS data, the fact that they consider a five-year interval and the fact that they do not account for local labor

market conditions or demand factors makes it hard to interpret this coefficient as the true impact of international graduates on US labor supply.

Ruiz (2014), using data on F-1 visas and OPT requests, calculates that about one-third of graduating students transition to an OPT position and that of those, about 50% do this within the metropolitan area where they studied [2]. Those coefficients are simple averages and do not account for local labor market conditions and the omitted common effects that these can have on attracting students and generating labor demand. Nevertheless, they provide a insightful picture of the growth in international students from 2001 to 2015 and their growing concentration in several locations. Finally Demirci (2019) shows, using data on F-1 visas, that the probability of international master's graduate transitioning to US workers increased by 5 to 7 percentage points after the 2008 extension of the maximum duration of OPT. This study is not focused on providing an unbiased measure of the transition from foreign graduates into workers, only on identifying the change in this coefficient from before to after the 2008 reform. Our work also sheds new light on the role of the OPT reform in facilitating the transition to the job market and finds a positive impact of such reforms.

Our paper introduces three key innovations relative to these previous contributions. First, we merge two rich sources of data, at the university/major/year level, that provide very detailed information on students, expenditures, and tuition in all public US universities and on the first job in the US of international students who graduated from these public universities. The first data are from the Integrated Postsecondary Education Data System (IPEDS) and include data on international students in US universities from 1997 to 2017, capturing in a complete way the exact number of all international students enrolled and graduating in each year from each university, by major. We only consider students in public universities, both because this captures the majority of students and, more importantly, because public universities set a different tuition fee for in-state and out-of-state, including international, students. This allows us to use the idiosyncratic differences between these fees as a source of variation in the enrollment (supply) of international students without being correlated to native students fees. The second dataset includes all international students obtaining US employment with the Optional Practical Training program (OPT) by university, major and year from 2003 to 2017. Those data were obtained through a Freedom of Information Act (FOIA) request, and we matched them with the IPEDS data by name of the university, major and year with a success rate of around 80%.

[2] Ruiz and Budiman (2018) update the study to include data up to 2016 and confirm the main finding of Ruiz (2014).

Second, relative to those earlier papers, the information contained in the job and education data allows us a match more precisely and at a much more detailed unit of analysis: the university/majors/year. Peri and Basso (2016) and (Ruiz, 2014) only matched at the geographical unit level (city, state) and the first paper did not even have information about the university of graduation. We introduce much less error, in matching on university names and major codes and we can control much more carefully for university and major level differences in quality of students and quality of education as well as for local labor market characteristics.

Third and most importantly, previous estimates cannot be interpreted as the causal relationship between the number of international graduates and the number of new international workers entering the US economy. Our instrumental variable approach enables this interpretation. Omitted variables affecting location of foreign students, their graduation rates and their local labor market conditions generate a bias. Hence, the partial correlation of international students with foreign labor supply (their transition rate to employment) can be affected by local unobserved factors that jointly influence the location of international students and US or local employment. This leads to a bias in the estimation of the transition rates. The expected sign of the bias in the estimation of transition rates of international students is ambiguous. On the one hand, international students may be attracted by booming areas or sectors with good job opportunities when choosing a university. On the other hand, international students may favor universities located in low-price, low-rent areas which may not exhibit strong labor markets, since these students are planning to study and not to work, at least in the short-run. Which confounding factors dominate and influence the overall direction of the bias is primarily an empirical issue.

To address these sources of bias our identification strategy is based on an instrumental variable approach. We use as an instrument the quasi-random component in the tuition fees charged to international students at public universities, after controlling for in-state fees, measures of university quality and other proxies of local funding. We discuss the sources of variation of this residual non-resident fee and show that it is uncorrelated to several pre-trends at the university and at the local level. We also show that, in line with the existing literature on the location choices of international students, these students tend to enroll more in universities charging lower non-resident fees, all else equal (Beine et al., 2020; González et al., 2011). Specifically, we find a negative correlation between the residual and international enrollment and graduation two to four years later, and we show that our instrument is reasonably strong.

Using this identification strategy, our main findings are as follows. First, our

preferred IV estimates suggest that transition rates of international students to the local labor markets are in the vicinity of 0.22 for master's graduates and 0.11 for bachelor's graduates. The typical IV estimates are higher than those using OLS regressions which, similarly to Peri and Basso (2016), delivers transition rates close to zero. Nevertheless, while higher, our IV estimates still point to significant leakage of US-produced human capital away from the US labor market, as four-fifths of US-educated master's graduates do not even work in the US in the short-run. Additionally, we find that there is a clear heterogeneity between STEM and non-STEM students. While non-STEM students exhibit transition rates not significantly different from zero, STEM students have a local transition rate close to 0.25 for master's graduates and 0.16 for bachelor's graduates.

Second, we obtain similar patterns of transitions rates at the national level and the within-state level. The national transition rates, while slightly higher than the within-state rates, suggest the existence of significant losses of human capital for the US labor market as a whole. Most foreign graduates who remain in the US transition to a first job in the same state where they got their degree. Finally, exploring some of the potential factors that may be associated with the transition of international students into US labor markets, we show that the 2008 OPT reform, which extended the possibility to work in the US under OPT up to 29 months for students graduating with a STEM major, increase the transition rates at the national level for STEM master's graduates by around 8 percentage points.

Besides the studies closely related to this paper and cited above, our analysis is related to three additional areas of the literature. The first is the literature analyzing the growing role of international students and foreign skilled workers in US higher education, science and technology. Bound et al. (2015) emphasize the crucial role of immigrants in the development of the information technology sector in the US and, through it, their contribution in generating economic growth. Kerr and Lincoln (2010), Peri et al. (2015), Hunt and Gauthier-Loiselle (2010) document the importance of skilled immigration for US innovation, patenting and productivity growth. Chellaraj et al. (2013) show the role of international students on increasing the quality of US universities. Our paper quantifies how the growing education of international students in US colleges contributes to US human capital, and potentially to all the benefits identified by those studies.

The second area of the literature we connect to, especially in the elaboration of the identification strategy, focuses on the choice of university for an international student. As reviewed by Kahanec and Kralikova (2011), an extensive literature has analyzed the various factors affecting the choice of international students across universities. The literature has stressed the importance of various factors, such as the language of

instruction (Perkins and Neumayer, 2014; Abbott and Silles, 2015; González et al., 2011), the quality of the educational institutions (Van Bouwel and Veugelers, 2013; Beine et al., 2014), the economic prospects and return to skills (Rosenzweig, 2006; Rosenzweig, 2008; Kato and Sparber, 2013; Shih, 2016), the existence of networks (Beine et al., 2014; Dreher and Poutvaara, 2011), the cost of living (Beine et al., 2020; González et al., 2011) and the level of tuition fees.

In our analysis, we exploit the idiosyncratic variations of college tuition for international students, connecting to those studies finding that higher tuition fees discourage attendance or divert attendance elsewhere. Beine et al. (2020) find that tuition fees negatively affect the probability that international students enroll in Italian universities. Using reform-induced variation in tuition fees across German Landers, Alecke et al. (2013) show that first-year students tend to relocate from universities in Landers that increased tuition to those located in Landers with stable tuition. Baer (2018) shows a similar phenomenon in public US universities, where tuition on out of state students resulted in lower presence and, after two years, lower numbers of graduating international students[3].

Finally, our work relates to a significant area of the urban/regional literature, which focuses on estimating the impact of local universities on the local supply of human capital and its potential positive externality on production. Moretti (2004) uses the presence of a land grant college in a US county as instrument in determining the share of college graduates in the local labor force and its local impact; Anselin et al. (1997), Lee (2019), and Kantor and Whalley (2014) show the positive effect of starting or expanding a university on local employment, innovation and firm productivity. In our case, the ability of US universities to attract foreign talent will be an important booster for the local supply of human capital if a fraction of those student work locally.

The rest of the paper is organized as follows. Section 2 presents the data, Section 3 presents the identification strategy and method to estimate transition rates from universities to the labor market. Section 4 presents our results. It first highlights the estimated transition rates at the national- and state-level and then shows extensions and the variation in transition rates before and after the 2008 OPT reform. Section 5 concludes.

[3]Let us also notice that Bound et al. (2020) emphasized the role of international students in US universities as a way to increase revenues in response to decline in state appropriation to fund public universities. To address this source of variation we control in our analysis for the part of each university's budget coming from state appropriations.

2 Data

One of the contributions of this study is to create a new database that enables us to precisely document the transition rates of international graduates from university to their first job. We combine two sources of administrative data. The first source is the Integrated Postsecondary Education Data System (IPEDS) from the National Center for Education Statistics. The second one consists of the complete data on OPT (Optional Practical Training) employment authorizations given to international students, obtained via a FOIA request.

2.1 Data on international graduates

The Integrated Postsecondary Education Data System (IPEDS) dataset allows us to measure the number of international students. Those are defined in the data as "non-resident aliens", namely persons who are not U.S. citizens, have a temporary visa, and do not have the right to remain in the country indefinitely. IPEDS counts the degree-seeking students during the fall of each academic year and also measures the number of students graduating in each year by degree type (bachelor's, master's and PhD), major and separating "international" from "domestic" students. Domestic enrollments and graduations are the count of "resident" individuals, which include U.S. citizens and permanent residents.

Additionally, the IPEDS data allow us to separately measure the average tuition fees paid by international and domestic students between 2001 and 2017. Those fees are the average fees "on the books" for the university in each academic year, and they are differentiated between in-state and out-of-state/international students. We separately observe yearly fees paid by bachelor's students and by master's students.

Our data capture the number of graduates by major, university and year, both at the master's and at the bachelor's level. 50% of new international graduates over this period graduate from a master's degree. While we can expect that most of the master's graduates seek to transition into the job market, either in the US or in another country, this is not the case for bachelor's graduates, since a significant share will continue their education at the graduate level. Unfortunately, we do not know the number of bachelor's graduates transitioning into a master's program. The transition rates for bachelor's graduates into jobs are therefore affected by the fact that a significant percentage of them continues their education at the graduate level. Therefore, our data is more likely to capture with a higher degree of precision the transition of master's graduates to jobs in the US, relative to the transition of bachelor's graduates.

Our instrumental variable strategy relies on the IPEDS data. We first use data on the public university-major-year specific bachelor's and master's-level tuition fees for international students, and we regress these on in-state tuition fees, university quality, university public funding and additional fixed effects. The residuals from this regression provide idiosyncratic variation in out-of-state fees that we use to predict the number of new international bachelor's and master's students and the international bachelor's (master's) graduates 4 (2) years later. Tuition fees are decided by the university each year. They differ significantly over time and across universities and they are different, within university, for in-state and out-of-state students. While some variation is driven by financial, cyclical and economic factors, there is a large amount of idiosyncratic variation in out-of-state tuition, especially after controlling for those systematic factors. We will show that variation seems uncorrelated with pre-enrollment variables and mostly exogenous to local demand conditions.

2.2 OPT data on international graduates

Optional Practical Training (OPT) is a temporary employment authorization for international students under F-1 visa. It represents the overwhelming mode of entry in the US labor market for foreign graduates, even those who will later obtain H1-B, L, or O visas or green cards. It enables international students to work up to 12 months in a job directly related to their major area of study. Since 2008, students who graduated in a STEM major can apply for a 17-month extension (24-month since 2016) of their employment authorization.

We capture the entry of international graduates into the US labor market via the full list of OPT employment authorizations granted to F-1 students with a terminal degree between 2003 and 2017. This list was obtained through a Freedom of Information Act request to the US Citizenship and Immigration Services (USCIS).[4]

For each international student who obtained authorization to work as Optional Practical Training (OPT), these data contain information about the university from which they graduated, the year of graduation, their major, the degree they received, the location of their job, and their employment starting date. We use this information to construct the dependent variable of our analysis which is the count of bachelor's (master's) graduates by university, major and year who enter the labor market through the OPT program. Then, by using the location of their first employment, we can generate a count of graduates finding jobs in the US or in the same US state where their school is located. This will allow us to estimate national and local transition rates.

[4]We are grateful to Jeremy Neufeld who generously shared the data with us.

We merge the data on graduates from IPEDS with the OPT employment data by university, type of degree, major and year. For a given university, the name reported in each dataset may slightly differ. We fix this issue by checking by hand each one of the 3,209 universities included in the OPT dataset. After so doing, we match 81% of the universities included in the OPT data and 90% of OPT recipients with the corresponding information included in IPEDS. We match majors using four-digit cip-codes, which are extremely accurate and do not show any significant typo or mis-match.

One limitation of our OPT data is that we cannot easily distinguish between pre- and post-completion OPTs. Only post-completions OPTs are relevant to measure the transition rates after graduation. Pre-completion OPTs are used by international students for internships or to work in a part-time job to finance their studies. Pre- and post-completion OPTs are not distinguished in the data, but we know that pre-graduation OPTs are usually rare and short. The reason is that the pre-completion OPT time will be subtracted from the total, hence reducing post-completion working opportunities. Therefore, among the 1,048,575 OPT employment authorizations given to F-1 students between 2003 and 2017, we only keep OPTs whose duration is equal or longer than 12 months. We think this is a conservative choice which will, if anything, likely omit some post-completion OPTs.

A second limitation of the OPT data relates to the information on employer locations for the graduates' first jobs. This information is not included before 2008 and is sometimes missing after 2008. This implies that before 2008, we can only estimate the national transition rate, not local transition rates. This also prevents us from estimating the impact of the 2008 OPT reform on in-state transition rates. After 2008, the information is included for 70% of observations. Our estimation of the local transition rate builds on the assumption that the probability that the job information information is missing is independent from the probability of finding job locally. In appendix A.4 we show that the percentage of missing job location information is uncorrelated with many university characteristics and with our IV. This reassures us that there is not a systematic bias in those missing values and that, in any case, it is orthogonal to the IV variation.[5]

Another significant limitation of using only OPT data is that, while OPT is the fastest and easiest option for international students with F-1 visas to enter the US labor market, it is not the only option. Many students who later will transition to longer lasting visas such as H-1B, L or permanent residence start with an OPT.

[5]In particular, we look at the correlation between the share of missing information about the job location in each cell and the level of a set of key variables such as the number of graduates, the level of tuition fees, and the value of our generated instrument.

However, they can also start working in the US with an H-1B visa or a green card directly. Nevertheless, these types of visas are more demanding, more restricted and usually more expensive. Failing to count students who transition into the US labor market through these channels would imply that our transition rate is somewhat underestimated. However, since only a very small fraction of international students get a working (H1-B) visa or a green card right out of college, it is likely that this measurement error is small. In 2017, more than 80% of F-1 graduates who entered the US labor market did it with an OPT. Additionally, all major university International Scholar offices recommend applying for an OPT as the most straightforward path to employment[6], [7].

Figure 1 shows the number of international master's students graduating from US universities and the number of new post-completion OPTs issued in each year between 2003 and 2017. The number of new master's graduates doubled between 2003 and 2017. During the same period, the number of new post-completion OPTs issued in each year increased by a factor 3, before decreasing in 2017. The ratio of OPT hires to international graduates was between one-fourth and one-third for master's graduates. This ratio already provide a naive estimate of the short-run transition rate for international graduates into initial employment in the US.

There is also a strong correlation between the two numbers across space. Figure 2 plots the number of international master's graduates by year and state on the horizontal axis and the corresponding number of post-completion OPTs for master's graduates in the same state and year on the vertical axis. The high correlation reflected in Figure 2, with a slope of about 0.25, suggests a state-level correlation rate that is in line with the US-level correlation and consistent with a transition rate of between 0.2 and 0.3 employees per one additional international master's graduate.

A naive approach would suggest that the transition rate of international students from university to the labor market is simply the ratio of the two numbers, between 0.25 and 0.33 depending on the year. However, these estimates might be biased by omitted variables and endogeneity issues due to the endogenous location choices of students before and after graduation. One of the main purposes of our empirical analysis is to provide consistent estimates of these transition rates in the presence of these endogeneity concerns.

[6] see for instance https://iss.washington.edu/work/f1-employment/opt/

[7] Since 2004, the cap on H-1B visas in the US has been binding, which makes it even more likely that the first transition occurs on an OPT permit during our period of analysis.

3 Estimating the "transition rate" from graduates to skilled workers

A correct estimate of the transition rate of international students from universities to local labor markets is crucial to evaluate how much the attractiveness of American universities to international students translates into human capital available to US labor markets. In particular, the parameter we estimate answers the following question: If one international student is exogenously added to a US university, how many more skilled new workers will be available to national and local labor markets in the year of their graduation? We call this parameter the "transition rate" from graduation to labor markets. It measures the probability of transition of an exogenously added international student (i.e. not attracted by labor demand reasons) to the local or US labor market.

To calculate this transition rate, we need to identify variation in the number of international students in US universities that is independent of local or US-wide factors affecting both the probability of attending a US university and the probability of finding a (local) job. If persistent positive local labor market conditions, for instance, both promote the expansion of a university enrollment and improve the job opportunities of its graduates a few years later, the positive correlation between the number of international graduates and the number of new workers may be driven by demand forces, not by the increase in the supply of international students. Thus, we would overestimate the effect of one more exogenous student on high-skilled employment. In an opposing example, if economic decline attracts international students by making local housing more affordable, but makes it harder for graduates to find a job and forces them to leave the country at graduation, a naive correlation will underestimate the transition rate. To address these issues, we construct an instrument whose variation affects the probability for an international student to enroll and graduate in an US public university but is not correlated with local demand and price conditions.

3.1 Estimated equation

In order to estimate transition rates, we estimate the following equation separately for bachelor's and master's graduates, where the unit of observation is a cell defined by university, major and year:

$$FE_{umt} = \alpha_{um} + \alpha_t + \beta FG_{umt} + \varepsilon_{umt} \tag{1}$$

The left-hand size variable FE_{umt} of equation (1) represents the number of foreign

bachelor's (or master's) graduates of university u in major m who are hired as workers in year t in the area (or in the whole US). The right-hand side variable of interest is FG_{umt}, the number of international graduates from university u in major m in the same year t.

In its simplest form, we include in equation (1) a set of university-by-major fixed effects (α_{um}) and a set of year (α_t) fixed effects. The first group of fixed effects imply that our coefficient is only identified on yearly variations in the number of post-completion OPTs associated with yearly variations in the number of new international graduates, not on level differences. This captures the comovement of new skilled employment with changes in number of international students. The year fixed effects control for aggregate trends.[8]

As mentioned above, our main dependent variable counts all international students in a university who transitioned to a job located within the same state as the university. This estimation enables us to characterize how international university graduates translate into local skilled labor supply, and therefore how local universities, by educating foreign students, contribute to the human capital of their state. We also investigate transition rates at different levels of geographic aggregation. We construct alternative dependent variables, calculating transition rates of students who transitioned into a job anywhere in the US, and of students who transitioned into a job in a given radius around their university to study the effects of foreign graduates on even more local labor markets.

A couple of comments are in order. First, a β close to zero means that after graduation, very few international graduates integrate into the labor market, either at the national or the local level, depending on the specification. Conversely, transition rates close to 1 suggest that the share of foreign graduates working in the US or in the state from which they graduated is high, which implies only a small loss of human capital for the economy. By construction, transition rates will be higher at the national level, as only a subset of international student who find a job in the US will find it in the state of their university.

3.2 Identification strategy

We estimate bachelor's (master's) graduate-to-employee transition rates within the US or within state in the same framework shown in equation 1. For national transi-

[8] In Appendix A.2, we also check the estimates using alternative structures of the fixed effects for robustness.

tion rates, the outcome is OPT employment anywhere in the US, while for within-state transition rates, it is OPT employment in the same state as the graduate's university. Comparing the transition rates estimated at the state and national level tells us about the degree of internal mobility of international graduates within the US. From a state university point of view, the estimated local transition rate also gives a measure of the human capital spilling out of the state. The smaller the local transition rates, the smaller the impact of US universities on local economy in terms of productivity and productivity spillovers.

As already noted in the data section, one could very simply calculate a short-run transition rate for each university-major-year as the ratio of foreign employed in a year divided by international graduates in that year. Alternatively, one could identify such a rate only on variations of those two variables by estimating equation (1) using OLS and controlling for fixed effects (averages by university and major). Neither of those two coefficients, however, would identify the more interesting policy parameter. This parameter would ideally measure, for one exogenously added international student in a US university, what fraction would transition to be a US worker in the short-run. Such a coefficient would be identified only if we have variations in university foreign graduates that are exogenous to US-sector and US-location specific factors that affect the university enrollment decisions and the local probability of being employed after graduation.

The omitted variables in equation (1) can generate bias in either direction. On the one hand, positive economic trends in sectors, majors, or areas may generate "pull" for international students who are deciding whether or not to study in the US. If, say, a boom in US information technology sectors, attracts more international students to enroll in a degree in electrical engineering in the US, and in turn increases the probability of hiring them few years later, this would generate a positive bias in the OLS estimate of equation (1). In such a case, the estimated transition rate would capture the role of the demand pull affecting both enrollment and employment rather than the pure impact of an exogenous variation in the number of foreign graduates.

On the other hand, once a student has decided to study in the US, they may choose (other things equal) a university in a more affordable, less expansive location to minimize their costs of living. After all, the current wage prevailing in the location is not expected to affect the student's decision, but local prices are. If such locations are also characterized by weaker labor markets, this omitted variable would generate a downward bias in the OLS estimate of the transition, especially at the local level. International students may be financially constrained and highly sensitive to the cost of living (Beine et al., 2020) and, in the US, the high cost of education can make them more sensitive to local prices (Baer, 2018; Batalova and Israel, 2021). Therefore the

choice of specific university based on local costs of living can be important. If the location choice is negatively driven by cost considerations rather than by the labor demand pull, OLS estimations of equation (1) would underestimate the transition rate if local prices are positively correlated with local labor demand.

To interpret the estimation of β in equation (1) as the transition rate of one exogenous (master's or bachelor's) graduate into local employment, we need to address these omitted variable issues. To do so, we use as instrumental variable the variations in the cost of attending a US public university for a foreign student, focusing on the part not correlated with local demand and university characteristics. In our benchmark IV estimations, our instrument is the residual non-resident tuition after controlling for resident tuition, measures university quality and funding sources, and local economic conditions. The tuition is a direct cost for international students that potentially affects their attendance decision, and while it can be correlated with local economic conditions or university quality, once we control for resident tuition and local characteristics, the remaining variation over time is likely idiosyncratic and uncorrelated with local conditions.

There is no purely "random variation" in our IV. However, we follow the spirit of recent papers such as Borusyak and Hull (2021) that encourage the econometrician to separate the non-random variation of the explanatory variable and then test whether the remaining part is quasi-random. In that spirit, we proceed in two steps. In a first step, we extract quasi-random variation in the tuition fees charged to international students for a given university, major and year, after controlling for in-state tuition fees, measures of quality of the university, state appropriations and a set of fixed effects capturing local trends. As a test of validity, we check that this residual is uncorrelated with the number of international students admitted in the years before the tuition is changed (pre-trend). In a second step, we use this quasi-random variation as an instrument to predict the number of international bachelor's (master's) graduates in a university, major and year, 4 (2) years after the fees were charged, i.e. when students enrolled responding to tuition costs are expected to graduate from the bachelor's or master's programs, respectively.

There is existing evidence that international students are sensitive to variations in fees. Beine et al. (2020) find that higher tuition fees decrease the number of international students enrolling in Italian universities. Using reform-induced variation in tuition fees across German Landers, Alecke et al. (2013) show that first-year male students tend to relocate from universities in tuition-raising states to those located in states that do not raise tuition. Studying a reform that increased the tuition fees charged to international students in the German Lander of Baden-Württenberg, Vortisch (2022) finds evidence of a 2% decrease in the enrollment rate of all international

students in universities located in this Lander, with a larger decrease among Asian and African students. A report from the Migration Policy Institute (Batalova and Israel, 2021) found that in 2018, the university tuition costs were one of the top four considerations for international students when deciding wheter to study in the US.

The first stage in the 2SLS estimation is represented by the following equation:

$$FG_{umt} = \delta_{um} + \delta_t + \gamma(\text{Quasi-Random Fees}_{u,t-x}) + \zeta_{umt} \tag{2}$$

.

where FG_{umt} is, as in equation 1, the number of international graduates from university u in major m in year t and Quasi-Random Fees$_{u,t-x}$ is the idiosyncratic component of out-of state-tuition fees x years before graduation, which should not be correlated with university quality and funding. We use $x = 4$ for bachelor's students and $x = 2$ for master's students. In order to extract this Quasi-Random component, we regress the observed level of tuition fees charged to international students on a set of fee determinants identified in the existing literature. Let us remind the reader that in our analysis, we focus only on US public universities. These institutions charge different rates for in-state and out-of-state students, generating Quasi-Random changes in out-of state tuition relative to in-state tuition.

We control for the level of fees charged to in-state students which is correlated to observed and unobserved time-varying quality and funding of the university. Additionally, we explicitly control for state appropriations, the part of the public university budget that is funded by the state. This may have an indirect impact on fees (Deming and Walters, 2018) and total enrollment. We control for past levels of enrollment of foreign and native students to capture a feedback effect from the past attractiveness of prices, as well as past levels of graduation of both groups. Finally, we include three measures of resources devoted to education by the university to control for local resources and the quality of education: The ratio of faculties per student, the ratio of expenditures per student and the ratio of endowments per student. Equation 3 shows our specification aimed at isolating the idiosyncratic part of the variation in out-of-state tuition fees, which we call the "stage 0" of the IV approach:

$$\begin{aligned}\text{Out-of-state fees}_{umt} = \delta_{s(u)} + \delta_t + \gamma_1 \text{In-state Fees}_{ut} + \gamma_2 \text{State appropriations}_{ut} + \\ \gamma_3 \text{Int Graduates}_{u,t-2} + \gamma_4 \text{Native Graduates}_{u,t-2} + \gamma_5 \text{Resources}_{u,t} + \nu_{umt}.\end{aligned} \tag{3}$$

. We then use $\widehat{\nu_{umt}}$ as variable (Quasi-Random Fees$_{ut}$) in the first stage equation (2). Since the instrument is a constructed variable, we bootstrap the standard errors

in the IV estimation. As a robustness check, we will alternatively use the actual out-of-state fees as an instrument for the number of international graduates.

4 Results

In this section, we present the main estimates of within-state and within-US transition rates. As described above, these coefficients capture the impact of changes in the number of international students on labor supply in the state or the US. Larger transition rates imply a larger positive contribution of these students to the state and/or US economies. Other studies (e.g. Conzelmann et al. (2022)) have quantified the local contribution of universities by measuring local production and local consumption of graduates. Those effects, for international students, depend on the in-state transition rate that we estimate.

4.1 Instruments: Strength and validity

Table 1 reports the estimation results of the "stage 0" equation (3) predicting variation in the tuition fees charged to international students separately for bachelor's (Column 1) and master's (Column 2) students. These fees are, unsurprisingly, strongly correlated with in-state tuition fees. State appropriations are also negatively correlated with out-of-state tuition for bachelor's students. While out-of-state tuition is somewhat correlated with the enrollment of native and international students in the previous year, the correlation fades away in two years. Once we control for in-state tuition the correlation of out of state tuition with measure of inputs per student is not significant.

The residuals of these regressions are the constructed IV. If the instrument is valid, these residuals should predict the number of international graduates 2 to 4 years after, but they should not predict the past number of international graduates or past international student enrollment. Such a correlation would imply some spurious association between school trends affecting both tuition and enrollment. For instance if unobserved and persistent improvement of school quality or placement attract foreigners and allows tuition increases this would generate such correlated trends.

We proceed with a validity test followed by a strength test. First, we check that the extracted residual variation in out-of-state tuition is uncorrelated with past flows of enrolled and graduated students, namely that the trend of enrollment before the tuition changes are not correlated with those changes. The results reported in Table 2 show that the extracted residual variation exhibits little correlation with

past enrollment flows of native and international students. This is consistent with no persistent trends of omitted variables.

Second, we test the strength of the instrument by analyzing whether (2- or 4-period) lagged residual variation in tuition fees (master's or bachelor's) obtained from equation 3 are negatively correlated with the level of *enrollment* of international students. Table A1 in the Appendix reports the estimates of the impact of lagged innovations on foreign enrollment, both at the bachelor's and master's levels. The results show a negative and very significant predictive power of this residual variation. Reassured that our instrument passes validity and strength tests, we now show the 2SLS results.

4.2 Impact on short-term local labor supply

Table 3 shows the basic estimates of our main coefficient of interest: the short-term transition of international graduates to the in-state labor market. We report the OLS estimates (in column 1 and 3) and IV estimates (in column 2 and 4) separately for international bachelor's (columns 1 and 2) and master's (columns 3 and 4) students. The first stage coefficients, displayed in the second row of the table, show that the residual variation in out-of-state tuition fees predicts negatively and very significantly (see the F-stats of 146 and 25) the number of international bachelor's or master's graduates 4 or 2 year later, respectively.

The IV estimates of Table 3 suggest that in-state transition rate is about 11.5 percentage points for international bachelor's students and about 23 percentage points for master's student. In other terms, about one out ten foreign bachelor's graduates and one in four foreign master's graduates takes a first job in their US state of graduation. These numbers are significantly higher than previous estimates in the existing literature. For instance, Peri and Basso (2016) use a method more similar to our OLS estimates and find transition rates to local employment at the state and metropolitan area levels that are not significantly different from zero. They describe these estimates as an almost total loss of foreign human capital for local economies. Our IV estimates are higher and imply significantly positive local transition, but they still suggest the existence of significant "leakages" of human capital at the state-level: More than 70 percent of locally educated foreign master's and about 90 percent of bachelor's graduates do not translate into high skilled supply in state.

Estimates using OLS are reported in columns (1) and (3) of Table 3. They are significantly lower than IV estimates (and similar to Peri and Basso (2016), which did not use IV). They suggest that omitted variable and endogeneity issues lead to a significant *negative* bias in the estimates of transition rates. One plausible explanation

for the negative bias is the endogenous location of international students in response to the local cost of living. If international students, all else equal, are attracted to US states with relatively low costs of living and this is correlated with weak labor markets, naive OLS regressions may generate negatively biased coefficients. Since students care more about low local prices than high local wages, this generates an opposite bias of what usually discussed for working immigrants, who are attracted by booming areas with high wages. Empirical analyses of the impact of immigration on native employment often finds positive OLS bias of the effect (see among others Borjas, 2003;Card, 2001;Peri, 2012 and Peri, 2016).

To provide evidence consistent with this explanation of the bias, whereby international students seek out low-cost areas with relatively weak labor markets when choosing a US university, we show the relationship between the number of new international students and the level of housing rents across metropolitan areas and over time. Rents are usually positively correlated with labor market conditions, and are the most relevant component of local prices, especially for students. We investigate this relationship by regressing the change in the number of enrolled students in a given metropolitan area on the change in the average rents in the same city. Figure 3 shows the scatterplot and regression line for this relationship. A ten-dollar increase in average weekly housing rents is associated with a decrease of about 18 international students enrolled in the city. This is a strong and significant correlation and it confirms the tendency of international students to be attracted in location where prices are decreasing, which are also likely areas with weakening labor markets. By overlooking the endogenous location of international students, OLS estimates of transition rates such as those of Peri and Basso (2016) tend to underestimate the rate of transition of exogenously distributed international graduates into local labor markets. The scatterplot gives us a clear idea of how strong that negative bias can be.

Table 4 shows our estimates of all transition rates, all estimated using 2SLS, including larger or smaller geographical areas of the first job. The estimated transition rates for the US labor market (columns 1 and 4) are very similar to those obtained for the in-state transition rates (shown in 3), suggesting limited rate of transitions of international graduates into out-of-state jobs in the US.

Confirming the evidence provided by Conzelmann et al. (2022), the majority of international university graduates who work in the US transition to initial jobs within the same state. Column 2 and 6 show transition rates of international bachelor's and master's graduates to other states. Those coefficients are very close to zero, and for master's graduates, they are not significantly different from 0. Columns (3) and (7) imply that about two-thirds of first US jobs of bachelor's graduates and half of the

first US jobs of Masters 4 have an employers within 10 Kilometers from the university of graduation. This implies that in most cases, the first job is found in the same city where the university is located.

4.3 Heterogeneity between STEM and non STEM majors

One important dimension in the transition of international students in US college and master's programs into employment is the STEM versus NON-STEM definition of their major. First, foreign students and workers have been disproportionately concentrating in STEM areas (see Peri et al. (2015) and Bound et al. (2015)). Due to an increase in STEM workers, demand-driven technological progress and the computerization of the US economy, and because the few long-term available H-1B visas were concentrated in STEM (Peri et al., 2015), it is possible that the short-term transition rates for STEM graduates were larger than for non-STEM ones.

Additionally, over the period we investigate, there were important reforms of the OPT program that specifically targeted STEM graduates. In particular, in 2008, the OPT program was extended to a maximum duration from 12 to 29 months for students graduating in STEM majors. This was meant to improve access for international graduates to an initial job in the US. At the same time, H-1B visas became rationed and harder to obtain in response to a reduction in the cap in H-1B in 2004. Starting in 2007, the quota of H-1B visas was filled very early in the year. The demand for these visas increased, leading the administration to assign them through a lottery of early applicants. This may imply an even smaller number of newly graduate transitioning into employment directly through H-1B visas.

Table 5 displays the US labor market transition rates estimated separately for STEM and non-STEM majors (first and second row), before and after the 2008 reform. These coefficients show whether transition rates differ across major type and before versus after the reform. The transition rates for non-STEM students are virtually zero and not statistically significant. For STEM students, they are statistically significant at the 5% level only after 2008. In the case of STEM master's graduates they are precisely estimated and they increase almost by a factor of 2 after the OPT reform. In the case of bachelor's students, the estimated transition rate is very imprecise before the reform. The precisely estimated transition rates for foreign master's graduates are consistent with the 2008 reform promoting the transition of more STEM master's graduates into US employment, relative to non-STEM graduates, whose length of OPT did not change. These non-STEM graduates can be considered the "control group" for this policy.

The transition rates for STEM master's graduates increased substantially after

2008 when an extended period of 17 months for these graduates could make them more willing to take an initial job in the US. Demirci (2019) finds a similar increase (in the order of 6-8 percentage points) in foreign graduates transitioning to US jobs after the 2008 reform.

In Table 6, we explore additional sources of heterogeneity in transition rates. First, we distinguish between universities located in large and small Metropolitan Statistical Areas (MSAs), splitting the size of MSAs at the median of the sample. Next, we look at the role of education quality as captured by the university's Carnegie classification. The estimated transition rates show several interesting patterns. First, universities in large MSAs generate larger in-state transition rate for international master's graduates (not for bachelor's graduates). Better opportunities in larger cities can be part of the explanation for these differences, especially in highly professional and specialized jobs.

This result is in line with the findings of Conzelmann et al. (2022) who show that urban and suburban areas tend to retain a larger share of college graduates. Additionally, the transition rates for international bachelor's graduates are higher from research intensive institutions (column 4). This does not apply to master's graduates, whose transition rates from non-research universities are large but estimated with a large degree of imprecision. Summarizing these results, one international bachelor's student exogenously allocated to a research university and one master's student exogenously allocated to a school in a large city are likely to exhibit larger transition rates to in-state employment than other groups.

4.4 Robustness

4.4.1 Excluding large states

One concern might be that our IV estimates are driven by a few states with very prestigious and large public universities such as California or New York. To address these concerns, we provide IV estimates on different samples while excluding, one at a time, those largest states. The states with largest public university population are California, Florida, Texas, New York and New Jersey. Table 7 provides the estimates of the local transition rates for bachelor's graduates while Table 8 provides those for master's graduates. Overall, the results show that the estimated transition rates are very stable across samples and that no single state omission changes the estimated coefficients by much.

4.4.2 Using simpler IV

The IV approach we use is based on the construction of an instrument that tries to isolate quasi-random variation. However, such a constructed instrument, exhibits variation that might be harder to understand intuitively.

As an alternative, Table 9 reports estimates of transition rates for master's graduates using directly observed (2-year lagged) out-of-state tuition fees as an instrument. If most of the identifying variation of the out-of state tuition fee is uncorrelated with the systematic variables we condition on, then the estimates will be similar. Column (1) in Table 9 reports the benchmark estimates of Table 3 for comparison purposes. For the sake of comparison and given that the first step of our IV procedure uses determinants of tuition fees, we include these determinants in the structural equation (equation 1). In columns (2) to (4), we use different sets of controls, depending on their significance in the estimation.

First, the IV estimates of local transition rates using the different instruments are extremely similar and stable. In particular, IV estimates using tuition fees as an instrument yield a transition rate for foreign master's graduates that is virtually identical to our benchmark estimate. This is not too surprising, since out-of-state tuition fees were not strongly correlated to local conditions. Second, the results show that observed tuition fees are reasonably strong instruments for the number of international graduates, with a significant and large negative impact on the number of international graduates that is similar to those one obtained using only the innovation part of the IV.

5 Conclusion

The US is home to many world-class universities. It is not surprising, therefore, that the US represents the main destination country for international students wishing to complete their higher education. From 2000 and 2015, between 500,000 and one million of international students graduated each year from American universities with a bachelor's or a master's degree.

These students represent a potentially valuable investment for the US educational system if they enter US labor markets after graduation. This article quantifies how many skilled workers will be available in the short-run to the US or to the state economy for each international student exogenously added to one of its public universities, which we call the transition rate. While universities do not explicitly enroll students on the basis of their labor market potential, the transition rates that we estimate partially determine the contribution of US universities to the local supply

of high-skilled workers.

To estimate these transition rates, we use new university-level data on international graduates merged to individual data on Optional Practical Training (OPT) permits. These permits represent the primary way for students on F-1 visas to transition into the US labor market. Using these data, we estimate the transition rates from education to employment for international graduates from US public universities. Our specific contribution is to estimate these transition rates while accounting for endogeneity and omitted variable bias from local demand shock which may affect jointly enrollment and labor demand.

To account for these issues, we use an IV strategy based on innovations of tuition fees paid by the international students, after controlling for in state-tuition, other local factors and university specific characteristics. We show that these innovations have a strong predictive power (negative correlation) with the enrollment and subsequently graduation of international students both at the bachelor's and master's levels. We also provide an estimate of the transition rates at the national level and within state and local economies.

We find that about 23% (12%) of international master's (bachelor's) graduates transition in the short-run to a within-state job, so that one more foreign master's (bachelor's) graduate increases the local supply of skilled workers by about 0.23 (0.12) workers. Furthermore, evidence suggests that most of the foreign graduates who transition into US employment find their first job within the state of their university.

These estimates have important implications for labor markets and immigration policy. For example, in 2020, the number of foreign enrollment (graduate and masters) dropped from 400,000 students on F1 visa to about 100,000 due to Covid. Our estimates imply that this loss of 300,000 students will translate in 30,000 to 60,000 fewer foreign bachelor's and master's graduates working in the US between 2022 and 2024. Clearly this will worsen the shortages that the US labor market is already experiencing.

Our results also point out the existence of a significant heterogeneity in transition rates into employment between STEM and non-STEM graduates. In particular, we find that STEM graduates have significant positive transition rates into US employment, while non-STEM graduates have transition rates are not statistically different from zero Moreover, the results suggest that the 2008 OPT reform that extended the duration of the OPT work permit from 12 to 29 months for STEM graduates led to an increase in the transition probability of STEM graduates. From a policy perspective, policies that make it easier for international graduates to transition into local and US employment would allow the US to reap the positive economic benefits

of a larger supply of skilled labor.

In a methodological contribution, we find evidence that international students seek out lower-cost areas when choosing a university, and that these areas are associated with weaker labor markets. This endogenous university choice by students leads naive OLS estimates of the transition rates to underestimate the probability of staying and working in the US. Our estimates of transition rates, especially for foreign master's graduates, are therefore significantly larger than those found previously in the literature that used a naive OLS. Still, our findings show that only 10 to 20% of foreign graduates work in the US even in the short run, likely due to visa and policy restrictions. This significantly dampens the local returns to human capital investments that US universities generate by training international students.

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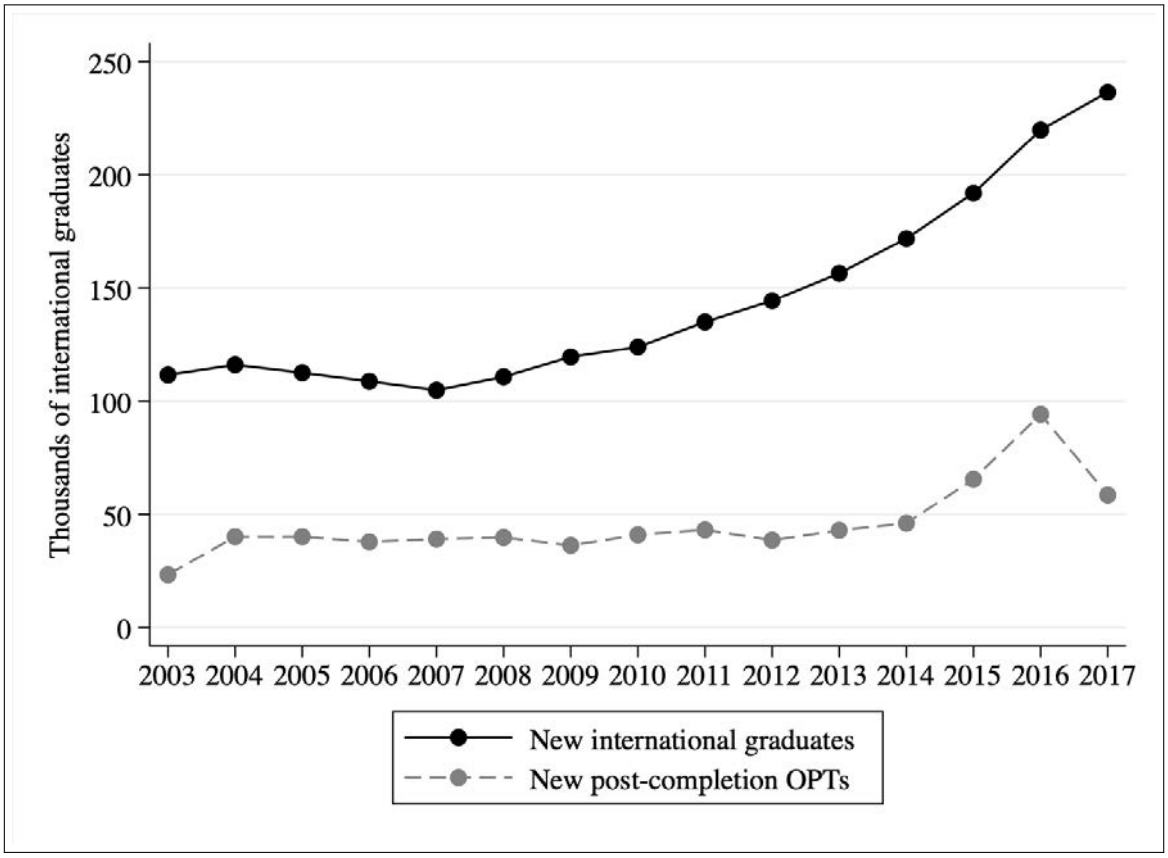
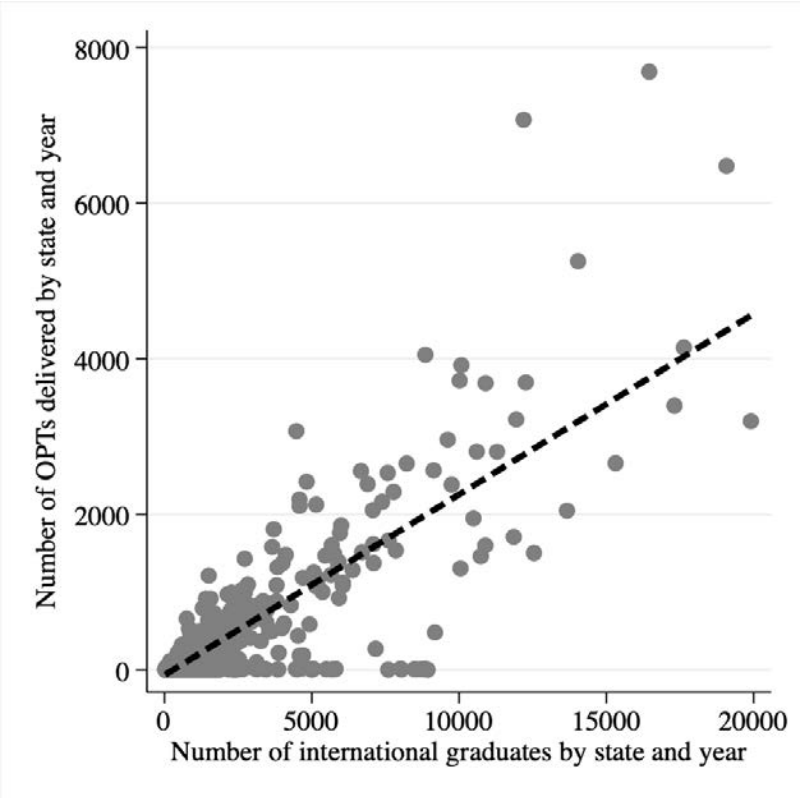
6 Figures

Figure 1: Evolution of international master's graduates and post-completion OPTs



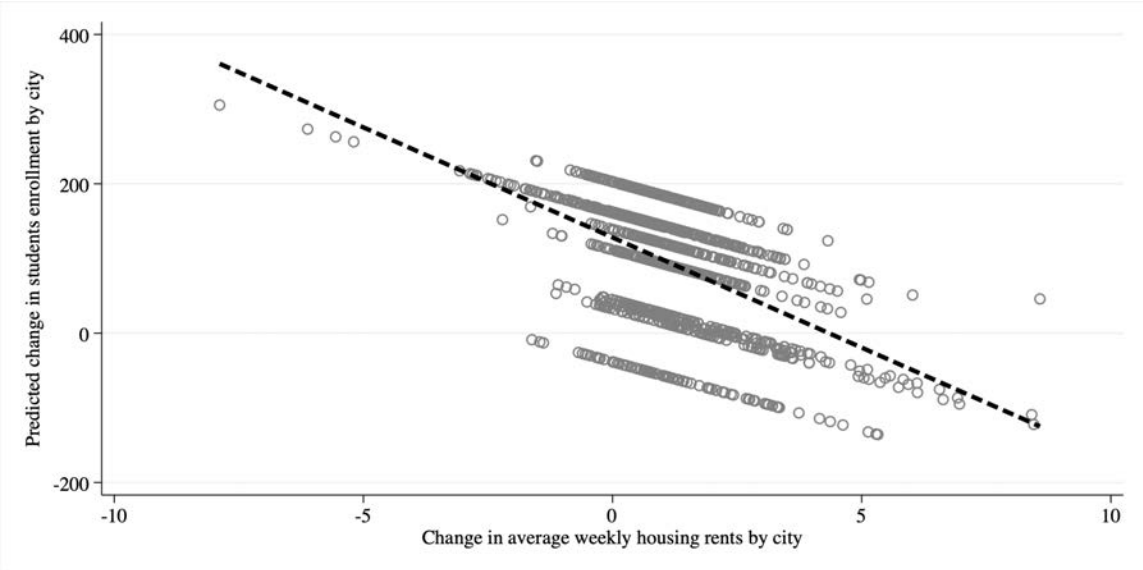
Notes: This graph presents the evolution of the number of international bachelor's and master's graduates from US universities and the evolution of the number of new post-completion OPTs issued on each year between 2003 and 2017. Source: IPEDS and USCIS.

Figure 2: Relationship between the number of international graduates and the number of OPTs by state and year.



Notes: This graph plots the relationship between the number of OPTs and the number of international students graduated by year and state. Period : 2008-2017. Source: IPEDS

Figure 3: Relationship between housing rents and international student enrollment



Notes: This graph plots the relationship between the year-to-year change in the number of enrolled international students in city c and the year-to-year change in the average rents in this city. The dashed line gives the regression line from the following estimated equation : ΔNber of New For. Students$_{ct}$ $=$ $\beta\Delta$(Average Housing rents$_{ct}$) $+$ α_c $+$ α_t $+$ ϱ_{ct}. The estimated β is -18.29, with a standard error (clustered at the city level) equal to 8.61.

7 Tables

Table 1: Estimation of the determinants of out-of-state tuition fees.

Dependent variable:	Out-of-state tuition fees	
	(1)	(2)
	Bachelor's	Master's
In-State tuition fees	1.4883***	1.2812***
	(0.0119)	(0.0107)
State appropriations	-66.1001***	53.2346***
	(1.9584)	(14.2277)
International enrollees per univ 1 year before	0.5432***	-0.0967***
	(0.0216)	(0.0310)
US enrollees per univ 1 year before	0.0096***	0.3122***
	(0.0031)	(0.0142)
International graduates per cell 2 years before	-0.4666	0.8899
	(1.4190)	(0.8395)
Native graduates per cell 2 years before	0.2256	-0.3393
	(0.1575)	(0.2621)
Endowments per student	0.0636***	0.0011
	(0.0011)	(0.0012)
Number of faculties per student	1,239.4147	4,574.9354***
	(871.5708)	(1,703.4989)
Expenditures per student	0.0022	-0.0056***
	(0.0017)	(0.0015)
State × Carnegie FE	Yes	Yes
Year FE	Yes	Yes
Observations	337,354	192,302
R-squared	0.8904	0.8925

Notes: Estimation period: 2003-2017. Standard errors are clustered at the university x major level. ***, ** and * denote significance at 1, 5 and 10% levels. Sources: IPEDS and USCIS.

Table 2: Exogenous component of tuition fees and past number of enrollees and graduates.

Dependent variable:	Predicted residuals from equation (3)			
	(1)	(2)	(3)	(4)
	Bachelor's		Master's	
International enrollees per univ 4 years before	0.2827	-	-0.2709	-
	(0.2965)		(0.5955)	
Native enrollees per univ 4 years before	0.1122**	-	-0.0188	-
	(0.0532)		(0.1261)	
International enrollees per univ 6 years before	0.5153	-	0.3080	-
	(0.3963)		(0.5599)	
Native enrollees per univ 6 years before	-0.0020	-	0.2919*	-
	(0.0435)		(0.1565)	
International graduates per cell 4 years before	-	9.1588*	-	2.3263
		(5.2930)		(2.0127)
Native graduates per cell 4 years before	-	0.1634	-	0.2909
		(0.7654)		(0.6376)
International graduates per cell 6 years before	-	3.0953	-	0.7226
		(2.9841)		(1.8452)
Native graduates per cell 6 years before	-	0.7520	-	-1.1170*
		(0.6996)		(0.6034)
University × Major FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
Observations	295,266	295,302	138,334	138,375
R-squared	0.4332	0.4232	0.5979	0.5939

Notes: This table presents the relationship between innovations of tuition fees (see equation (3) and past number of international graduates. Estimation period: 2003-2017. Std err are clustered by cell defined by state and category in Carnegie Ranking.***, ** and * denote significance at 1, 5 and 10% levels. Source: IPEDS.

Table 3: Impact of foreign graduates on short-term local labor supply.

Dependent variable:	Number of OPTs in same state			
	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)
	Bachelors'		Masters'	
Number of international graduates	0.0466***	0.1157***	0.1377***	0.2316***
	(0.0006)	(0.0130)	(0.0011)	(0.0535)
First stage:				
Predicted residuals from equation (1)	-	-0.2110***	-	-0.1661***
		(0.0173)		(0.0326)
University × Major FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	72,054	72,054	65,474	65,474
First stage F statistic	-	149.6	-	25.99

Notes: OLS and IV estimates of international students transition to the local labor supply defined at the state level. Estimation period: 2008. ***,** and * denote significance at 1, 5, and 10% levels. Sources: IPEDS and USCIS.

Table 4: Impact on local labor supply: alternative geographic definitions.

Dependent variable:	Number of OPTs in							
	the US	other states	10km radius	60km radius	the US	other states	10km radius	60km radius
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Bachelor's				Master's			
Number of international graduates	0.1434***	0.0277***	0.0958***	0.1073***	0.2028*	-0.0288	0.0950***	0.1038***
	(0.0168)	(0.0087)	(0.0101)	(0.0116)	(0.1094)	(0.0958)	(0.0225)	(0.0309)
University × Major FE	yes	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes	yes
Observations	72,054	72,054	72,054	72,054	65,474	65,474	65,474	65,474
First stage F statistic	146.4	146.4	146.4	146.4	25.63	25.63	25.63	25.63

Notes: IV estimates of international students' transition rates to local labor supply. Estimation period: 2003-2017. ***, ** and * denote significance at 1, 5 and 10% levels. Sources: IPEDS and USCIS.

Table 5: Impact of STEM and non-STEM foreign graduates on the local labor supply.

Dependent variable:	Number of OPTs			
	before 2008	after 2008	before 2008	after 2008
	(1)	(2)	(3)	(4)
	Bachelor's		Master's	
Number of international graduates in STEM majors	0.3787	0.1438***	0.1239*	0.2055**
	(0.5952)	(0.0115)	(0.0741)	(0.1010)
Number of international graduates in non-STEM majors	-0.0301	0.0506	0.0166	0.0005
	(0.0760)	(0.0412)	(0.0721)	(0.3942)
University x Major FE	Yes	Yes	Yes	Yes
Yeara FE	Yes	Yes	Yes	Yes
Observations	25,786	70,814	17,115	61,114
First stage F-statistic	0.225	8.309	1.711	4.796

Notes: Table reports IV estimates of transition to local labor market defined at the state level for STEM and non-STEM international graduates before and after the 2008 OPT reform. All specifications control for university x major fixed effects. Sources: IPEDS and USCIS.

Table 6: Heterogeneity in the contribution to the short-term local labor supply.

Dependent variable:	Number of OPTs in same state					
	(1)	(2)	(3)	(4)	(5)	(6)
	Bachelor's			Master's		
Number of international graduates	0.1157***			0.2316***		
	(0.0130)			(0.0535)		
Number of international graduates in large MSAs		0.1183***			0.2320***	
		(0.0090)			(0.0485)	
Number of international graduates in other cities		0.1304**			0.0816	
		(0.0634)			(0.1185)	
Number of international graduates in top 2 carnegie universities			0.1335***			0.2080***
			(0.0100)			(0.0424)
Number of international graduates in other universities			0.0392			0.3018**
			(0.0430)			(0.1466)
University × Major FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	72,054	72,054	72,054	65,474	65,474	65,474
First stage F statistic	146.4	6.331	24.61	25.63	4.865	4.770

Notes: This table investigates the heterogeneity in the contribution to the short-term local labor supply. All specifications are estimated with a 2SLS procedure where we instrument the number of international graduates with the predicted residuals from equation (1). Sources: IPEDS and USCIS.

Table 7: Robustness: contribution of bachelor to the short-term local labor supply leaving out one state at a time.

Dependent variable:	Number of Bachelors' OPTs in same state					
Sample:	Main	Excluding CA	Excluding FL	Excluding TX	Excluding NY	Excluding NJ
	(1)	(2)	(3)	(4)	(5)	(6)
Number of international bachelor's graduates	0.1157***	0.1004***	0.1157***	0.1214***	0.1213***	0.1146***
	(0.0130)	(0.0158)	(0.0135)	(0.0123)	(0.0128)	(0.0131)
University × Major FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	72,054	64,135	69,492	66,042	67,577	70,846
First stage F statistic	146.4	78.09	133.9	161.7	152.6	144.2

Notes: This table presents the contribution of bachelor students to the short-term local labor supply. Source: IPEDS and USCIS.

Table 8: Robustness: contribution of master graduates to the short-term local labor supply leaving out one state at a time.

Dependent variable:	Number of master OPTs in same state					
Sample:	Main	Excluding CA	Excluding FL	Excluding TX	Excluding NY	Excluding NJ
	(1)	(2)	(3)	(4)	(5)	(6)
Number of international masters' graduates	0.2316***	0.1192**	0.2350***	0.2324***	0.1850***	0.2192***
	(0.0535)	(0.0483)	(0.0520)	(0.0401)	(0.0467)	(0.0492)
University × Major FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	65,474	59,768	62,679	59,166	62,363	64,343
First stage F statistic	25.63	14.41	27.90	50.97	31.24	29.14

Notes: This table presents the contribution of master students to the short-term local labor supply. Source: IPEDS and USCIS.

Table 9: Robustness check comparing the contribution to the short-term local labor supply with traditional IVs.

Dependent variable:	Number of master OPTs in same state			
	(1)	(2)	(3)	(4)
Number of international graduates	0.2316***	0.2206***	0.2228***	0.2265***
	(0.0535)	(0.0703)	(0.0752)	(0.0775)
First stage:				
Predicted residuals from equation (1)	-0.1661***			
	(0.0525)			
Out-of-state tuition fees 2 years before		-0.1223***	-0.1147***	-0.1142***
		(0.0322)	(0.0321)	(0.0328)
University × Major FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	65,474	67,133	67,133	65,788
First stage F statistic	25.99	14.41	12.75	12.10
Controls:				
State app. and in-state tuitions	-	Yes	Yes	Yes
Nat. & Int. graduates 2 years before	-	-	Yes	Yes
Faculties, expenses & endowments per stud.	-	-	-	Yes

Notes: This table compares estimates of the contribution to the short-term local labor supply. Column (1) reports the results obtained with the main estimation procedures. Columns (2) to (4) replicates the estimation with another 2SLS procedure using out-of-state tuition fees as instrumental variable. They progressively includes additional controls to make estimates comparable. Source: IPEDS and USCIS.

A Appendix

A.1 Robustness checks on the instrumentation procedure

Table A1: Relationship between innovations of fees and enrolment.

Dependent variable:	Number of international enrollees					
	(1)	(2)	(3)	(4)	(5)	(6)
	Bachelor's			Master's		
IV (1 year lag)	-0.0016***	-0.0013*	-0.0008	-0.0030***	-0.0028***	-0.0012
	(0.0003)	(0.0007)	(0.0007)	(0.0010)	(0.0010)	(0.0010)
Observations	13,777	13,777	13,777	10,452	10,452	10,452
University fixed effects	Yes	Yes	-	Yes	Yes	-
Major fixed effects	-	Yes	-	-	Yes	-
University x Major fixed effects	-	-	Yes	-	-	Yes

Notes: This table presents the relationship between predicted residuals from equation (1) and international students' enrolment. All specifications control for year fixed effects. Source: IPEDS

A.2 Robustness checks on the impact on short-term local labor supply

In table A2, we investigate the robustness of the results presented in Table 3 to different fixed effects specifications. This table successively presents local transition rates estimated with IV specifications for bachelor's and master's students. Columns (1) and (5) replicate the estimations presented in Table 3 where we control for year fixed effects and university $\times$ major fixed effects.

Columns (2) and (6) separately introduce year, major and university fixed effects. Therefore, we exploit variations between universities, majors and years after removing specific variations associated with each year, major and university. Point estimates are slightly smaller but not statistically different from the previous ones. If anything, this suggests a small heterogeneity across cells.

Columns (3) and (7) separately control for university fixed effects and major $\times$ year fixed effects. Here we exploit variations between universities within cells defined by year and major of education. Point estimates are roughly similar.

Finally, columns (4) and (8) control for major fixed effects and university × year fixed effects. Therefore, we exploit variations between majors within cells defined by university and year. Point estimates are smaller than the estimates obtained with other specifications. This difference reflects the heterogeneity of the transition rate across majors that we have already documented in section 4.3. of the paper.

Table A2: Robustness: comparing estimates with different fixed effects specifications.

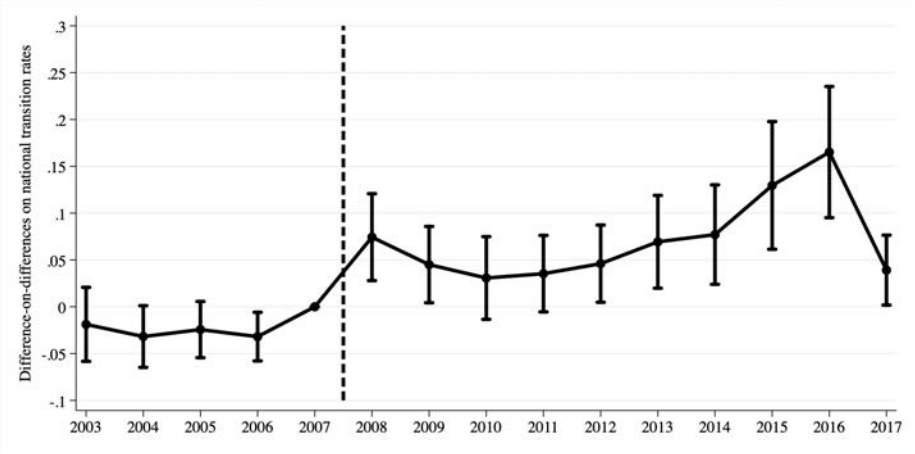
Dependent variable:	Number of OPTs in same state							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Bachelor's				Master's			
Number of international graduates	0.1175***	0.1049***	0.0963***	0.0562***	0.2295***	0.2070***	0.2167***	0.1513***
	(0.0130)	(0.0183)	(0.0178)	(0.0013)	(0.0529)	(0.0632)	(0.0715)	(0.0034)
First stage:								
Predicted residuals from equation (3)	-0.0002***	-0.0002***	-0.0002***	-0.2305***	-0.0002***	-0.0002***	-0.0002***	-0.2856***
	(0.0000)	(0.0000)	(0.0000)	(0.0033)	(0.0000)	(0.0001)	(0.0001)	(0.0046)
Observations	72,054	75,624	75,291	75,278	65,474	67,411	67,022	66,924
First stage F statistic	149.6	37.07	35.69	4847	25.99	12.17	10.03	3826
Year fixed effects	Yes	Yes	-	-	Yes	Yes	Yes	-
Major fixed effects	-	Yes	-	Yes	-	Yes	-	Yes
University fixed effects	-	Yes	Yes	-	-	Yes	Yes	-
University × Major fixed effects	Yes	-	-	-	Yes	-	-	-
Year × Major fixed effects	-	-	Yes		-	-	Yes	-
Year × University fixed effects	-	-	-	Yes	-	-	-	Yes

Notes: Different fixed effects specifications for IV estimates of international students transition to the local labor supply defined at the state level. Estimation period: 2003-2017.***, ** and * denote significance at 1, 5 and 10% levels. Sources: IPEDS and USCIS.

A.3 Diff-in-diff estimates of the 2008 OPT reform on the national transition rates

Figure A1 plots the estimates of the difference between national transition rates for STEM and non-STEM master's graduates. Since job location is not available in the post-completion OPT data before 2008, the transition rates can be estimated only at the national level. The dashed line refers to the timing of the 2008 OPT reform that extended the duration of the temporary work permit from 12 to 29 months for only STEM graduates. The difference in the national transition rates is mostly positive after the 2008 reform, confirming at the national level the results obtained for the within-state transition rates in section 4.3.

Figure A1: Impact of 2008 OPT reform on national transition rates.



Notes: This graph plots the estimated differences in the national transition rates between STEM and non STEM master's graduates over the 2003-2017 period. OPT reform occurred in 2008.

A.4 Missing data and sample selection

A final concern relates to potential sample selection bias due to missing data on OPTs. In some cells, we do not have the full information about the job location of international graduates, even after 2008. Therefore, measures of the number of OPTs are not based on the same level of information. One concern might be that cells with a relatively higher number of missing values about the job location have some specific features in terms of tuition fees the number of international graduates that could affect the transition to the labor market.

To check whether this issue might affect our results, we provide some additional pieces of evidence related to the amount of missing information about the job location. First, in Table A3, we check whether our instrument is correlated with the share of missing values about the job location, either at the city or state level. The results show no systematic relationship between the exogenous variation in out-of-state tuition fees and missing job location data. Figures A2, A3, A4 and A5 complement these results showing, for visual inspection, the possible correlation, both for bachelor's and master's graduates, between out-of-state fees and missing informaiotn on jobs. Figure A2 and A3 provide a plot of the data with missing information about the location at the city level, while Figures A4 and A5 report the same thing, but for missing information at the state level. The data plots do not display any visible pattern of correlation between our instrument and the share of missing information

Table A3: Relationship between IV and the share of missing values for job location by cell.

Dependent variable:	Share of missing values for job location by cell			
	City	State	City	State
	(1)	(2)	(3)	(4)
	Bachelor's		Master's	
IV	-0.00018	-0.00018	-0.00022	-0.00023
	(0.00017)	(0.00017)	(0.00016)	(0.00016)
University × Major FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	17,897	17,897	20,847	20,847
R-squared	0.48272	0.48303	0.45732	0.45792

Notes: This table presents the relationship between our IV and the share of missing values for job location by cell as defined by university, major and year. This relationship is separately estimated for bachelor and master graduates. Standard errors are clustered at the university x major cell. Source: IPEDS and USCIS.

about job location.

Finally, we repeat this analysis but with the instrumented variable, the number of international graduates, rather than our instrument. Figures A6-A9 report the plots, which again show no visible pattern of correlation between the number of graduates and the share of missing values for job location. All in all, this makes us confident that our results are not driven by some patterns in the missing information about job location forthe OPTs.

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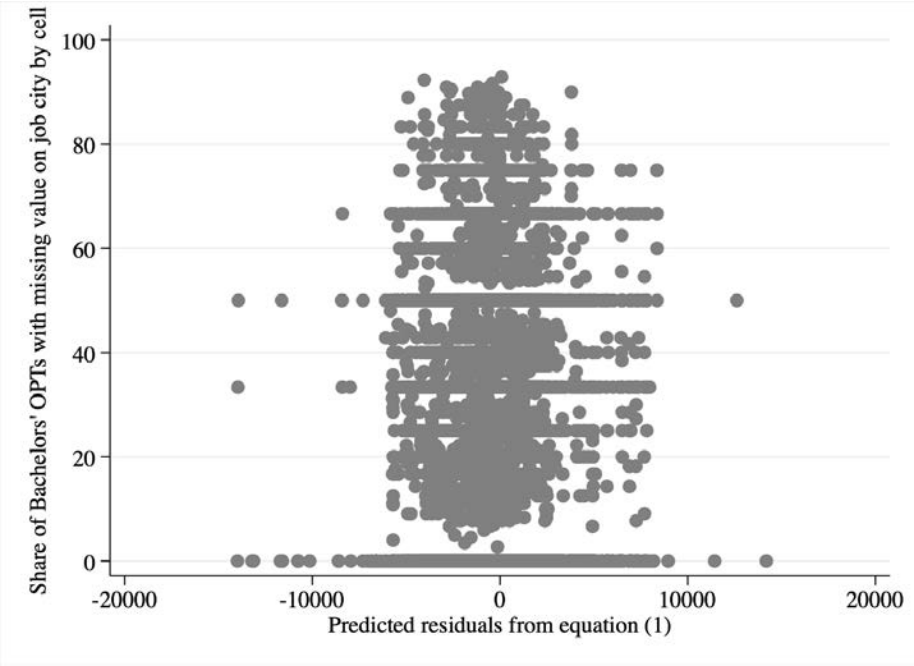
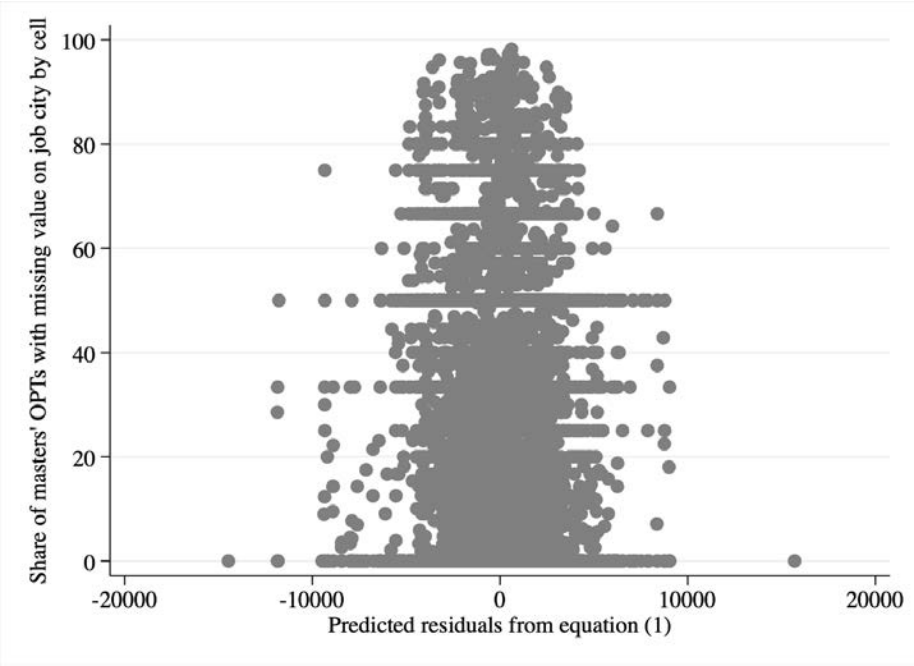
Figure A2: Correlation between our IV and the share of missing values for job city by cell for bachelor's graduates.



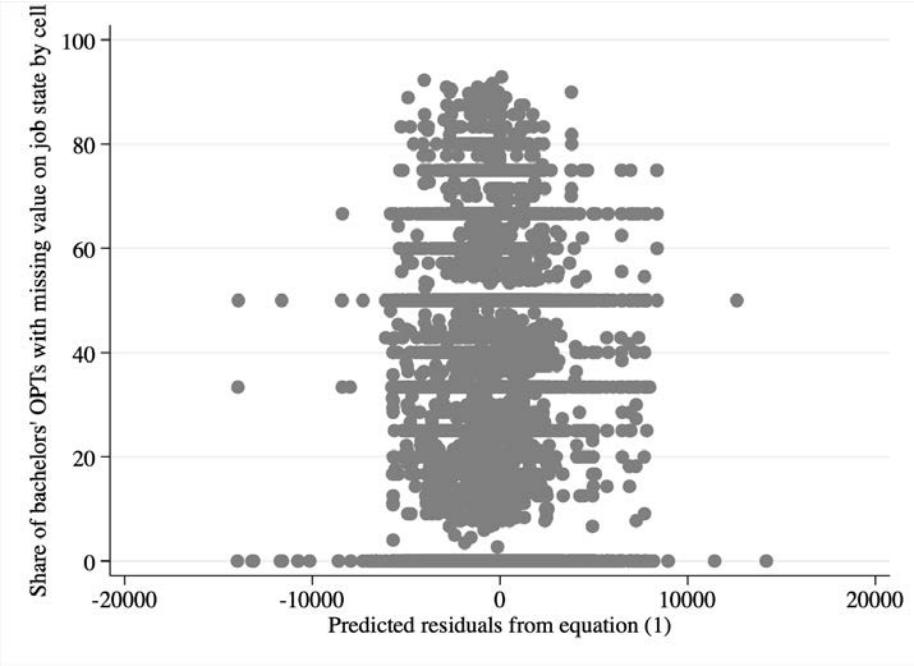
Notes: This graph plots the relationship between our IV and the share of missing values for job city by cell for bachelor's graduates. Source: IPEDS

Figure A3: Correlation between our IV and the share of missing values for job city by cell for master's graduates.



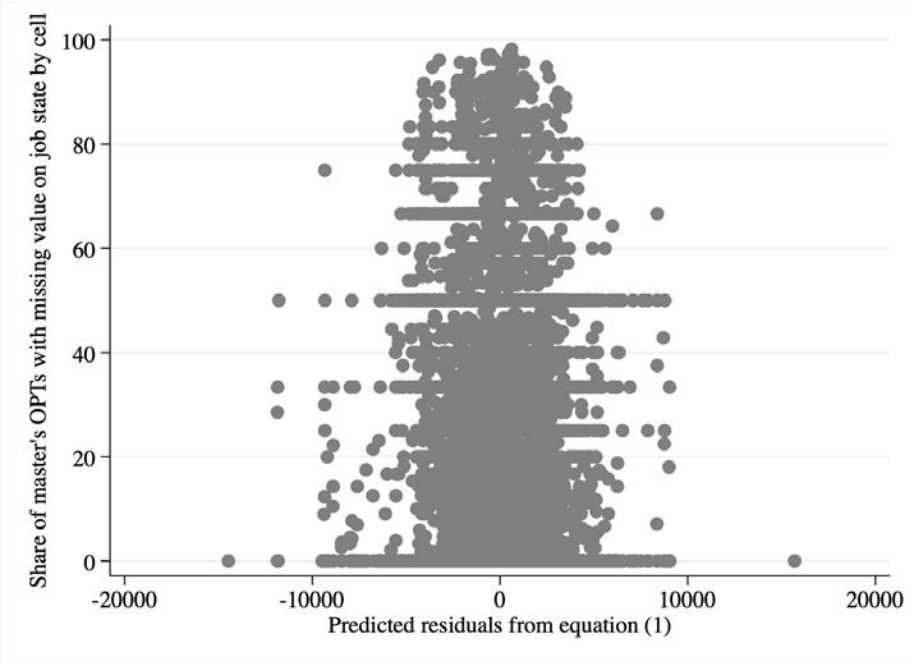
Notes: This graph plots the relationship between our IV and the share of missing values for job city by cell for master's graduates. Source: IPEDS

Figure A4: Correlation between our IV and the share of missing values for job state by cell for bachelor's graduates.



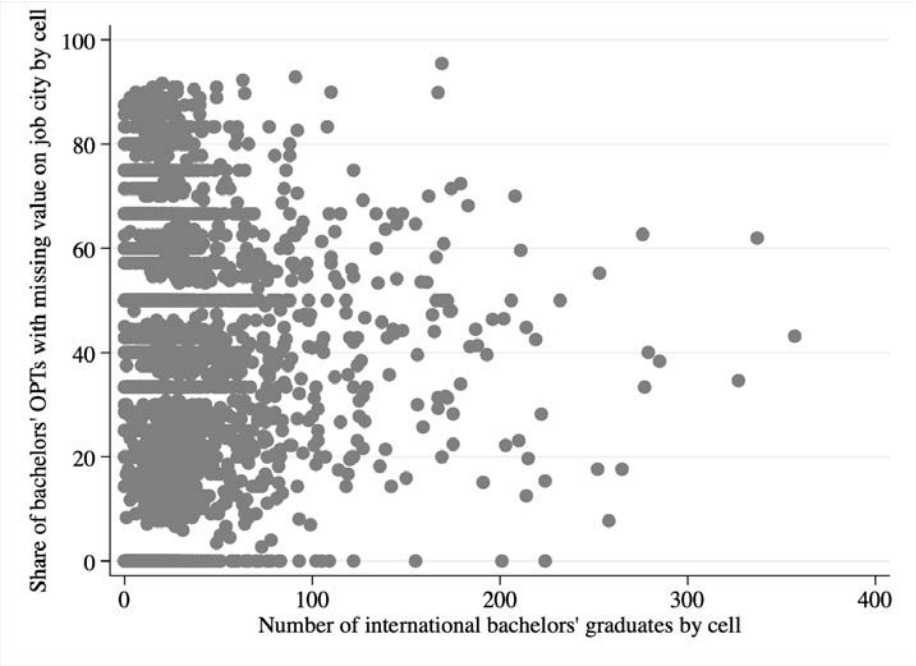
Notes: This graph plots the relationship between our IV and the share of missing values for job state by cell for bachelor's graduates. Source: IPEDS

Figure A5: Correlation between our IV and the share of missing values for job state by cell for master's graduates.



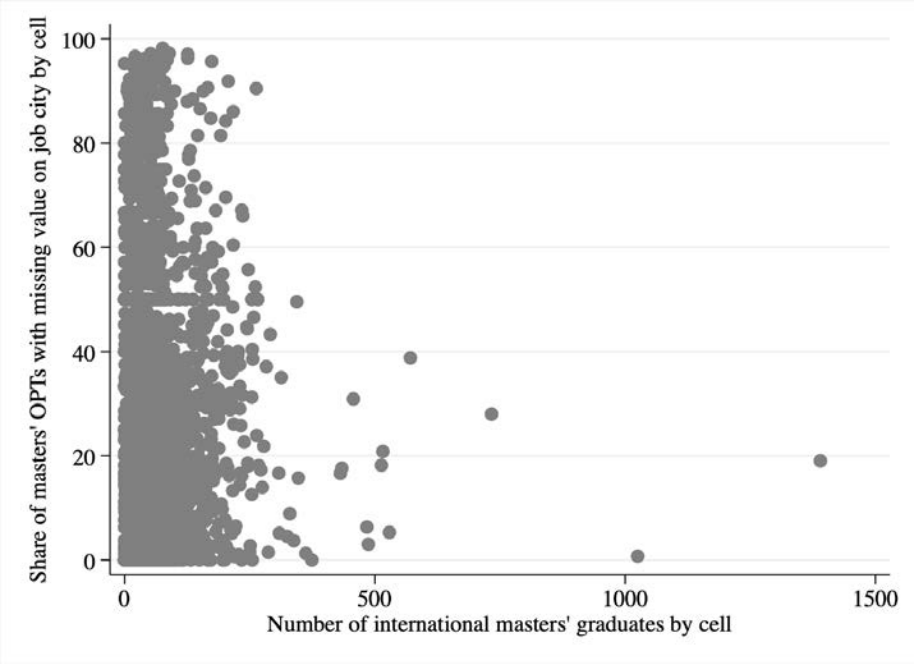
Notes: This graph plots the relationship between our IV and the share of missing values for job state by cell for master's graduates. Source: IPEDS

Figure A6: Correlation between the number of international bachelor's graduates and the share of missing values for job state by cell for bachelor's graduates.



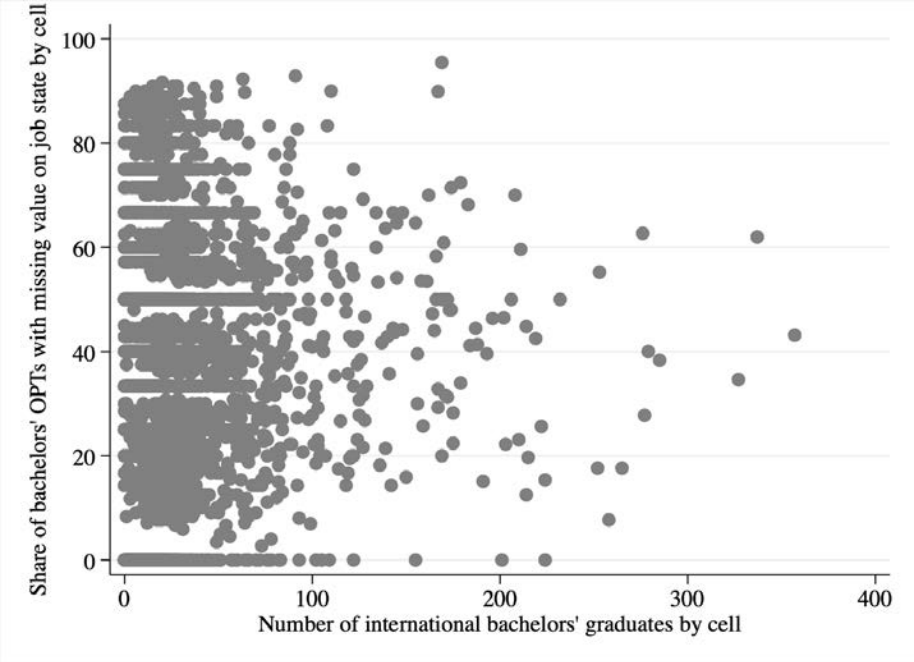
Notes: This graph plots the relationship between our IV and the share of missing values for job city by cell for bachelor's graduates. Source: IPEDS

Figure A7: Correlation between the number of international master's graduates and the share of missing values for job state by cell for master's graduates.



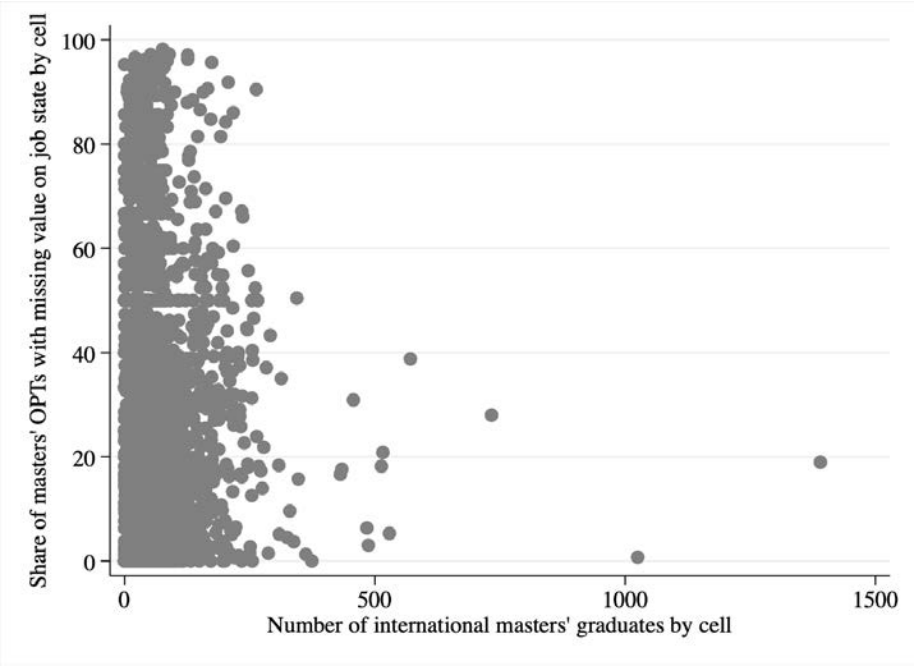
Notes: Source: IPEDS

Figure A8: Correlation between the number of international bachelor's graduates and the share of missing values for job state by cell for bachelor's graduates.



Notes: Source: IPEDS

Figure A9: Correlation between the number of international master's graduates and the share of missing values for job state by cell for master's graduates.



Notes: This graph plots the relationship between the number of international master's graduates and the share of missing values for job state by cell for master's graduates. Source: IPEDS