



International college students' impact on the US skilled labor supply [☆]

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ABSTRACT

While US universities attract millions of international students, we do not know how many of them work in the US after graduating. In this paper we implement an instrumental variable estimation, using quasi-random variations in the tuition charged, and we estimate that between 2003 and 2017 one more international master (or bachelor) student, attracted by a university, increased the US skilled labor supply in the year of graduation by about 0.23 (0.08) employees. Only for STEM students such effect on labor supply was positive and significant, especially after the 2008 Optional Practical Training reform.

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1. Introduction

The internationalization of higher education across OECD countries has become a major feature of globalization. The number of students completing their higher education in a foreign country amounted to 5.3 million worldwide in 2018. The US has long been the top destination for foreign students: 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. The high num-

ber of international students eager to enroll in US universities gives those institutions the possibility of selecting high quality students generating valuable human capital for the US economy, provided some of these students remain in the US after graduation. In this paper we estimate the impact of foreign graduates on the short-term labor supply of skilled workers in the US.

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 stay and find a job in the US at least in the short run. Therefore, 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 bachelor's and master's programs. 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. We calculate a "short-run transition rate" within US states or within the US as a whole for both master's

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and bachelor's students. This is done by estimating the coefficient on the number of international graduates in a regression where first-time OPT workers in the US (or in the same state) are the dependent variable, aggregating individuals by graduating university, major and year. In order to account for endogeneity and omitted variables issues, we instrument for the number of international graduates using 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 universities, 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 addressed the question of the transition of foreign students from college to the labour market in the US. Using data from the American Community Survey (ACS) and identifying foreign students likely to be on F-1 visas in 50 US states and 277 Metropolitan areas, Peri and Basso (2016) find a very low transition rate (close to 0.05 and not statistically significant) from international graduates to workers in the US. 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.¹

An important limitation of these studies is that, by failing to account for the effects of omitted local labor market conditions, their 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. Omitted variables affecting location of foreign students, their graduation rates and their local labor market conditions generate a bias. 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 they 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. Our main contribution is to provide an instrumental variable approach allowing for a causal interpretation.

We merge two rich sources of data, at the university/major/year level. One provides very detailed information on students, expenditures, and tuition in all public US universities. The other includes the first job in the US of international students. The first is 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. The second dataset (obtained with a FOIA request) includes all international students on an F1 visa, obtaining US employment with the Optional Practical Training program (OPT) by university, major and year from 2003 to 2017. The two datasets are merged using name of the university, major code and year, with a success rate of around 80%. This is a more precise

match and a more detailed unit of analysis compared to previous papers.

Our identification strategy predicts the number of foreign students with the quasi-random component in the tuition fees charged to out-of-state students at public universities, after controlling for in-state fees, past enrollment, measures of university quality and other proxies of local funding. We show that this prediction is uncorrelated to the pre-trends of several variables measured at the university and at the local level. Additionally as a falsification exercise, we provide evidence that the residual variation in tuition fees does not predict enrollment and graduation of native students. We also show that, in line with the existing literature on the location choices of international students, non-resident tuition fees, are a significant determinant of university choice, all else equal (Beine et al., 2020; González et al., 2011). Such an instrument is plausibly exogenous and reasonably strong.

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 0.23 for master's graduates and 0.08 for bachelor's graduates. We also find that 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 less than one fourth of US-educated master's graduates do not work in the US in the short-run. These transition rates are significantly lower than those reported for native graduates. For instance in a recent paper Conzelmann et al. (2022) show that the transition rate for native college graduates into labor markets of the metropolitan area where the college was, are between 0.5 and 0.67. Therefore, Native college graduates' transition to local employment is 5–6 times larger than foreign bachelor graduates'. Second, 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 0.18 for master's graduates and 0.11 for bachelor's graduates. Third, we obtain similar transitions rates at the national level and within-state, suggesting non significant internal mobility of foreign graduates within the US. Finally, in line with Demirici (2019), we find 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, is associated with higher transition rates at the national level for STEM master's graduates by about 6.5 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.² Second, especially in the elaboration of the identification strategy, we connect to the literature analyzing the various factors affecting the choice of international students across universities.³ Our results are in line with studies finding a negative impact of costs of living (Beine et al., 2020; González et al., 2011) and tuition fees (Beine et al., 2020, Alecke et al., 2013, Baer, 2018, Vortisch, 2022) on the location choice of foreign students. Finally, our work relates to 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.⁴

² See Bound et al. (2015), Kerr and Lincoln (2010), Peri et al. (2015), Hunt and Gauthier-Loiselle (2010) and Chellaraj et al. (2013) among others.

³ See for a review Kahanec and Kralikova, 2011.

⁴ See Moretti (2004), Anselin et al. (1997), Lee (2019) and Kantor and Whalley (2014).

¹ Ruiz and Budiman (2018) update the study to include data up to 2016 and confirm the main finding of Ruiz (2014).

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.

2. Data

One of the contributions of this study is to create a new database that enables us to measure precisely 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 individual data on F1 visas and OPT (Optional Practical Training) employment authorizations given to international students, obtained from the US Citizenship and Immigration Services (USCIS) within the Department of Homeland Security, through a FOIA request.

2.1. Data on international graduates and tuition fees

The Integrated Postsecondary Education Data System (IPEDS) dataset allows us to measure the number of international students enrolled and graduating in the US. Those are defined 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. The number of domestic enrollments and graduations is the count of "domestic" individuals, which include U.S. citizens and permanent residents.

Our data capture the number of graduates by major, university and year, both at the master's and at the bachelor's level. The transition rates for bachelor's graduates into jobs are affected by the fact that a subset of these students continue their education at the graduate level. Some of them will transition to jobs after a graduate degree and not at time of graduation. As a result, our data captures 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.

Additionally the IPEDS data allow 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 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. 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. Our instrumental variable strategy relies on these idiosyncratic variations.

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 for those who will later obtain H1-B, L, or O visas or green cards. It enables international college graduate 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 2017.⁵ 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 entering 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.

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 mismatch.

We conduct several adjustments to overcome some limitations of the OPT data. First, since we cannot easily distinguish between pre- and post-completion OPTs, 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 based on the observation that pre-graduation OPTs are usually rare and short.⁶ A second limitation is that information on employer locations is not included before 2007 and is sometimes missing after 2007. We therefore estimate local transition rates only for the post-2007 period. After 2007, the information is included for 70% of observations. Our estimation of the local transition rate builds on the implicit assumption that the probability that the job information is missing is independent from the probability of finding job locally. In checks not included in the paper, we show that the percentage of missing employer information is uncorrelated to many characteristics of the university.

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. Nevertheless, it should be emphasized that alternative visas are more demanding, more restricted and usually more expensive. In 2017, more than 86% of foreign graduates who entered the US labor market did it with an OPT, confirming that this represents the main channel of transition to the labor market.⁷

⁵ This list was obtained through a Freedom of Information Act request. We are grateful to Jeremy Neufeld who generously shared the data with us.

⁶ As robustness check we show in the Online Appendix that results are similar including OPTs with duration above 3 or 6 months.

⁷ The percentage is calculated as follows. In 2017 159,980 foreign students started working on post completion OPTs (https://www.uscis.gov/sites/default/files/document/data/I-765_Application_for_Employment.FY03-19.pdf). At the same time 24,985 H-1B visas were given to international graduates who were previously under F-1 visas but which did not obtain a STEM OPT first (<https://www.ice.gov/doclib/foia/sevis/ApprovedforF-1toH1-Bvisa2012-2017.pdf>). Therefore, the share of foreign graduates who entered the US labor market with an OPT can be approximated as follows: $\frac{159,980}{(159,980+24,985)} = .8653$.

Fig. 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 ratio of OPT hires to international graduates was between one-fourth and one-third for master's graduates. This ratio already provides a naive estimate of the short-run transition rate for international graduates into initial employment in the US. The slope of a regression of international master's graduates by year and state on the corresponding number of post-completion OPTs for master's is equal to 0.25, showing that there is also a strong correlation between the two numbers across space.⁸

3. Estimating the transition rate from international students into local labor markets

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 Eq. (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 Eq. (1) a set of university-by-major fixed effects (α_{um}) and a set of year (α_t) fixed effects.⁹

The estimated β from Eq. (1) allows us to characterize the magnitude of the transition. A β close to zero means that after graduation, a small fraction of 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. We estimate Eq. (1) by changing the geographic definition underlying the construction of the variable FE_{umt} .

As emphasized before, the omitted variables in Eq. (1) can generate some bias in the estimation of β in either direction. To account for that, we use as instrumental variable the variations in the cost of attending a US public university for a foreign student, focusing on a part not correlated with local demand and university characteristics. 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 the quasi-random variation in the tuition fees paid by foreign students by estimating the following equation, controlling for the level of in-state tuition fees as well as other potential determinants of tuition fees:

$$\text{Out - of - statefees}_{umt} = \delta_{cs(u)} + \delta_t + \gamma_1 \ln - \text{stateFees}_{ut} + \gamma_2 X_{ut} + v_{umt} \tag{2}$$

where $\delta_{cs(u)}$ is a set of fixed effects interacting state with each category of the Carnegie classification and X_{ut} represents the vector of other potential determinants of out-of-state tuition fees. These include past levels of enrollment and graduation of native and for-

⁸ Figure A1 in the Online Appendix shows the scatterplot and regression line for this case.

⁹ Table A3 in the online Appendix shows the estimates using alternative structures of the fixed effects.

eign students, level of state appropriations as well as measures of resources devoted to college education such as expenditures per student or staff members per student. In a second step, we use \widehat{v}_{umt} , the residuals of Eq. (2), as a measure of what we call the "quasi-random" (part of the) fees and use this as an instrument to predict the number of international bachelor's (master's) graduates in a university, major and year, four (two) 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. Therefore, we estimate the following first-stage equation:

$$FG_{umt} = \delta_{um} + \delta_t + \gamma(\text{Quasi - Random Fees}_{u,t-x}) + \zeta_{umt} \tag{3}$$

where $\text{Quasi - Random Fees}_{u,t-x}$ is given by $v_{um,t-x}$ in Eq. (2) and where x is 2 for master's and 4 for bachelor's students. Since the instrument is a constructed variable, we make sure that the results hold when we bootstrap the standard errors in the estimation of Eq. (3)¹⁰. As a robustness check, we use the actual out-of-state fees as an instrument for the number of international graduates and get similar results, implying that the identifying variation from fee changes is mainly the quasi-random part.¹¹

4. Results

The first step of our estimation involves the estimation of the determinants of out-of-state tuition fees (Eq. 2). The results of this estimation are not reported here for the sake of brevity.¹² We find strong predictive power of in-state tuition fees on the number of international students. State appropriations are negatively, but not significantly, 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 disappears with two-year lags. Once we control for in-state tuition, the correlation of out-of-state tuition with measure of inputs per student is not significant. While we use our IV to predict number of foreign student graduating, we also check that they predict the number of foreign student enrolled 2–4 years before (see Table A2 of the Online Appendix.).

We then assess the validity of our IV estimates, beyond the above assessment of its strength. First, if the instrument is valid, the extracted residuals from Eq. (2) should predict the number of international graduates 2 to 4 years after, but should not predict the past number of international graduates or past international student enrollment. To that aim, [Table 1](#) shows the results of those validity checks. In Panel A we show that the predicted residuals (dependent variable) show very little correlation with past enrollment flows of international students for Bachelors (Specification 1 and 2) and Masters (specifications 3 and 4) using university-year (specifications 1 and 3) or university-major-year (specifications 2 and 4) as units of analysis. The coefficients on past international students, four or six years earlier (in row 1 and 3 of the Table) are not statistically significant in 7 out of 8 cases. Only one coefficient is significant at 10% which is roughly what to be expected in case of random error. In the case of past enrollment of native students, we see one coefficient significant at 5% in specification 1 (row 2). However, there is no systematic correlation of the pre-

¹⁰ See Table A9 in the online appendix.

¹¹ A possible alternative instrument at the university level is the quota that several public universities have for out-of-state students as percent of total. However, often the changes in quota follow the changes in inflow of out-of-state, raising issues of endogeneity, as hinted in [Bound et al. \(2020\)](#). Moreover quotas are only binding for the total enrolled students (and not newly admitted) and their level and evolution over time is hard to track across schools. Therefore we do not pursue this policy as instrument in this paper.

¹² Interested readers can find such results in Table A1 of the online Appendix

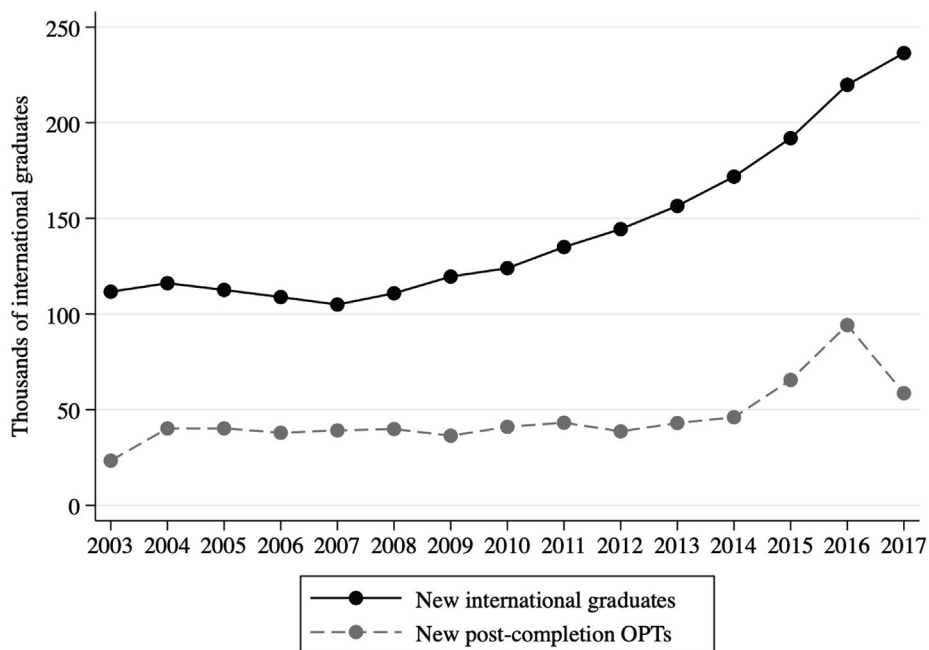


Fig. 1. Evolution of international master graduates and post-completion OPTs. **Notes:** This graph presents the evolution of the number of international bachelor and master graduated from US universities and the evolution of the number of new post-completion OPTs issued on each year between 2003 and 2017. Source: IPEDS and USCIS..

Table 1
Two tests of validity of the instrument.

Panel A: Relationship between IV and past number of enrollees and graduates.					
Dependent variable:	Predicted residuals from Eq. (1)				
	(1)	(2)	(3)	(4)	
	Bachelors'		Masters'		
	Enrollees per	Graduates per	Enrollees per	Graduates per	
International students	university	cell	university	cell	
4 years before	0.2841 (0.2967)	9.1438* (5.3012)	-0.2781 (0.5955)	2.2957 (2.0136)	
Native students	0.1130** (0.0533)	0.1742 (0.7656)	-0.0170 (0.1261)	0.2897 (0.6378)	
International students	0.5155 (0.3975)	3.0957 (2.9879)	0.3048 (0.5595)	0.7133 (1.8447)	
Native students	-0.0033 (0.0437)	0.7198 (0.7030)	0.2917* (0.1564)	-1.1157* (0.6032)	
University × Major FE	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Observations	295,266	295,302	138,334	138,375	
Panel B: Falsification test: IV and number of native students.					
Dependent variable:	graduates		enrollees		
	(1)	(2)	(3)	(4)	
	Bachelors'		Masters'		
Predicted residuals from Eq. (1)	0.0077 (0.0670)	0.0032 (0.0024)	0.0845 (0.0690)	0.0010 (0.0015)	
University x Major FE	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Observations	193,871	13,777	127,919	10,452	

Notes: Panel A: estimates the relationship between the predicted residuals of tuition fees (see Eq. 2) and past number of native and international graduates and enrollees. Std errors clustered at cell defined by state and category in the Carnegie Ranking. Panel B: falsification test. Relationship between instrument and the number of native graduates or native enrollees. ***, ** and * denote significance at 1, 5 and 10% levels. Source: IPEDS and USCIS.

dicted residual with 4-year lagged native enrollees in the other specifications. To provide further reassurance that the variation in the residual does not affect significantly native students (introducing spurious correlations), we then add, in Panel B of Table 1, another falsification exercise. There we show the coefficients of the predicted residuals on the number of native students graduates and enrollees. The values in all specifications are very small and

not statistically significant in any specification. Our instrument built from non-resident tuition fee is not significantly affecting enrollment and graduation of native students.

Reassured that our instrument passes validity and strength tests, Table 2 shows the 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 for the transition

within the state (in columns 1 and 5) and IV estimates for three alternative locations of the first job (state of graduation, US as a whole and within 60 kms from the university of graduation). We report the coefficients separately for international bachelor's (columns 1 to 4) and master's (columns 5 to 8) students. The coefficients of the first stage of IV estimation (Eq. 3) are displayed in the second row of the table. Results show that the residual variation in out-of-state tuition fees predicts negatively and very significantly (F-stats of first-stage regressions are 143 and 24 for bachelors and master) the number of international bachelor's or master's graduates 4 or 2 year later, respectively.

The IV estimates of Table 2 suggest that in-state transition rate is about 8 percentage points for international bachelor's students and about 23 percentage points for master's students.¹³ In other terms, about one out of 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 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 75 percent of locally educated foreign master's and more than 90 percent of bachelor's graduates do not translate into high skilled supply in the state. Studies that have estimated similar elasticities for natives, e.g. Bound et al. (2004) report OLS rates of (long-run) transition to working in the same state of about 0.3. Conzelmann et al. (2022) find transition rates of native and foreign college graduates within metropolitan areas and states of about 0.5 and 0.67 respectively. While not directly comparable to our estimates, this suggests that human capital leakages faced by US local economies are much higher for foreign students compared to native ones.

OLS estimates of the transition rate 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 if 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, 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 regress the change in the number of enrolled students in a given metropolitan area on the change in the average rents in the same city. Fig. 2 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 22 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.

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. The reasons for heterogeneous effects are basically twofold. First, due to an increase in the demand for STEM workers, induced by technological progress and the computerization of the US economy, the short-term transition rates for STEM graduates are likely to be larger than for non-STEM ones. Second, in 2008, the OPT program was extended to a maximum duration from 12 to 29 months for students graduating in STEM majors, with the purpose of improving access for international graduates to an initial job in the US. Table 3 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. 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 the coefficients are precisely estimated and they increase by more than 50% after the OPT reform. The transition rate for Bachelor STEM is imprecisely estimated before 2008. 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 results are in line with those of Demirci (2019).

We perform a set of robustness checks for the estimation of the transition rates. The results are only summarized here for sake of brevity.¹⁴ First, we show that the estimated coefficients are very similar when using out-of state tuition fees rather than the extracted quasi-random component from Eq. (2). Second, we evaluate the case for a 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 2007. We show that the share of the missing information in each cell is uncorrelated with the key variables of our analysis, namely tuition fees and past flows of native and international graduates. Third, we assess the robustness of the estimates to alternative structures of fixed effects (FE) in Eq. (1). In Table 2, we use year and university-major fixed effects. We find similar IV estimates with year, major and university FE, university and major-year FE as well as major and university-year FE. Fourth, we check whether our estimates are not driven by the activity in one major state of college education. Excluding once at a time those major states lead to transition rates similar to those obtained in Table 2.¹⁵ Fifth, we consider alternative restrictions on the length of the OPTs to capture the number of workers. We also include OPTs with lower duration in order to accommodate cases in which workers transit to another visa (such as H-1B) within the first year. Results turn out to be very similar. Finally, since our instrument is imputed, we also estimate standard errors using bootstrapping and we get similar significance levels of transition rates.

¹³ If we think we are undercounting foreign students entering labor market and only capturing about 86% of them, as stated in footnote 7, then the transition rates should be scaled up by a factor of 1.17 and the transition rates would be close to 9 and 26 percentage points. This assumes that the underestimation of access to first jobs by OPTs is homogeneous across universities and majors.

¹⁴ Tables A4 to A9 of the Online Appendix report these checks.

¹⁵ We nevertheless find some sensitivity to the exclusion of California for master's graduates.

Table 2
Impact of foreign graduates on short-term labor supply.

Dependent variable:	Number of OPTs in							
	same state OLS (1)	same state IV (2)	the US IV (3)	60 km radius IV (4)	same state OLS (5)	same state IV (6)	the US IV (7)	60 km radius IV (8)
Number of international graduates	0.0311*** (0.0003)	0.0784*** (0.0102)	0.1032*** (0.0132)	0.0745*** (0.0090)	0.1180*** (0.0006)	0.2253*** (0.0490)	0.1972** (0.0927)	0.1078*** (0.0281)
First stage: Predicted residuals from Eq. (1)		-0.0738*** (0.0062)	-0.0738*** (0.0062)	-0.0738*** (0.0062)		-0.0769*** (0.0158)	-0.0769*** (0.0158)	-0.0769*** (0.0158)
Univ × Major FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	192,889	192,889	192,889	192,889	127,235	127,235	127,235	127,235
First-stage F-statistic		142.7	142.7	142.7		23.63	23.63	23.63

Notes: OLS and IV estimates of transition rates of foreign graduates to the US labor markets defined at different geographic levels. Estimation period: 2007–2017.***, ** and * denote significance at 1, 5 and 10% levels. Sources: IPEDS and USCIS.

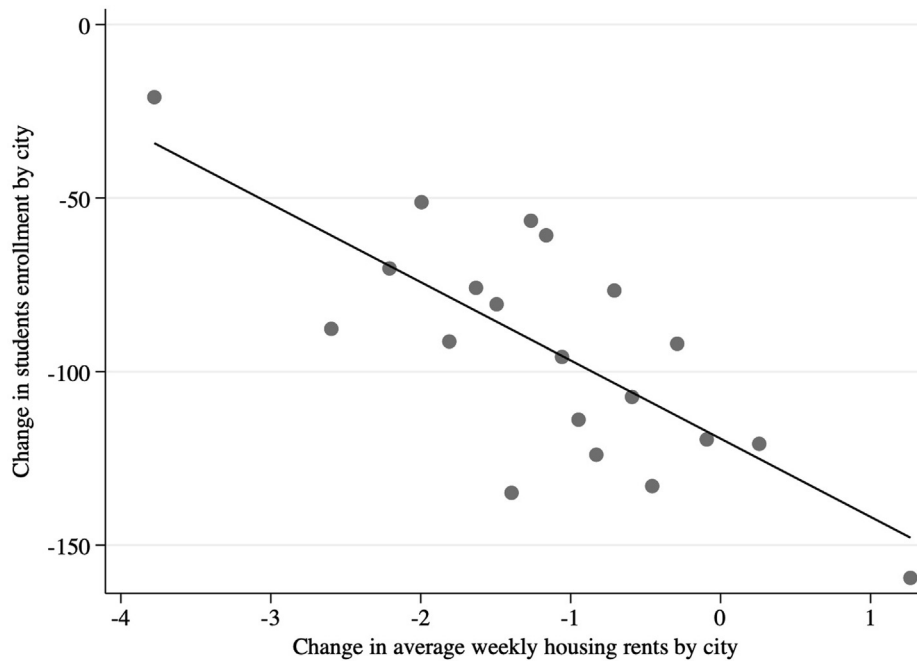


Fig. 2. Relationship between housing rents and international student enrollment. **Notes:** This binned scatterplot represents the relationship between the year-to-year change in the number of enrolled international students in city c and the year-to-year change in the average rents in this city. Observations are grouped into equal-sized bins where x and y values correspond to the average values computed within each bin. The line gives the regression line from the following estimated equation: $\Delta(\text{NberofNewFor.Students}_{c,t}) = \beta\Delta(\text{AverageHousingrents}_{c,t}) + \alpha_c + \alpha_t + \varrho_{c,t}$. The estimated β is -22.53 , with a standard error (clustered at the city level) equal to 6.03 .

Table 3
Impact of STEM and non-STEM foreign graduates on the labor supply.

Dependent variable:	Number of OPTs			
	before 2008 (1)	after 2008 (2)	before 2008 (3)	after 2008 (4)
		Bachelors'		Masters'
Number of international graduates in STEM majors	-0.3254 (0.3755)	0.1127*** (0.0080)	0.1192 (0.0787)	0.1847** (0.0909)
Number of international graduates in non-STEM majors	-0.0381 (0.0571)	0.0315 (0.0328)	-0.0770 (0.0687)	-0.0233 (0.3835)
University × Major FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	78,623	193,508	35,142	119,205
First-stage F-statistic	0.433	7.898	2.491	4.982

Notes: This table reports IV estimates of transition rates to labor market defined at the national level for STEM and non-STEM international graduates before and after the 2008 OPT reform. All specifications control for university \times major fixed effects. Sources: IPEDS and USCIS.

5. Conclusion

Foreign graduates 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. To estimate these transition rates, we use new university-level data on international graduates merged with individual data on Optional Practical Training (OPT) permits. 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 find that about 23% (8%) of international master's (bachelor's) graduates transition in the short run to a within-state job. In other terms, one more foreign master's (bachelor's) graduate increases the local supply of skilled workers by about 0.23 (0.8) workers. Furthermore, most of the foreign graduates who transition into US employment find their first job within the state of their university. Clearly, these estimates point out to significant human capital leakages and have important implications for labor markets and immigration policy. Our results also point out the existence of a significant heterogeneity in the transition rates into employment between STEM and non-STEM graduates and support that 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 their transition probability.

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at <https://doi.org/10.1016/j.jpube.2023.104917>.

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