Higher Education (2023) 85:203–223
https://doi.org/10.1007/s10734-022-00829-5

Factors associated with the mobility of college students in Brazil: an analysis using a gravity model

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Accepted: 3 February 2022 / Published online: 12 March 2022

Abstract
The Brazilian government has adopted measures that aim to influence students' spatial mobility. The extent and success of such measures require detailed knowledge of the mobility determinants. Gravity models are the appropriate tool for analyzing the flows of college students from their place of origin to their destination. To analyze the determinants of student flows, we estimate a negative binomial regression model with Brazilian data. The results show the deterrence effect of distance on mobility, as the total costs of entering a university increase with the distance between the place of origin and the destination institution. Places with lower living costs and smaller university centers (campuses) are attraction factors to students, as are the possibility of having non-reimbursable financing and a larger number of study programs.

Keywords Gravity models · Student flows · Brazilian higher education

Introduction

Higher education is a highly institutionalized sector. There is, however, increasing evidence that higher education institutions engage in intense competitive and cooperative relationships. Unlike in research, relationships in education are mostly competitive. Students are an important source of funding, and often institutions are not willing to cooperate to offer joint programs. Several factors may affect competition for students, but distance is among the main determinants of student choices (Seeber et al., 2012). As student mobility has costs, institutions in the most densely populated and accessible regions are expected to attract more students. Hence, institutions have to increase their attractiveness

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to compensate for the costs of moving; this can be done by improving and promoting the institutional features that students value the most. Quality and reputation are examples of attributes that make institutions more attractive to prospective students, despite their distant location. Governments may also play an important role in incentivizing access and mobility through policies targeting students.

Additional policy measures require a good knowledge of the constraints faced by students. Two types of higher education candidates can be identified in Brazil: those who compete for places in public universities, which are more prestigious and free; and others that may apply to private universities, but whose access opportunities are influenced by the availability of funding or the possibility of reconciling work and family life with their studies (Lopes, 2017; Terribili Filho & Nery, 2009). Hence, equity in access to higher education requires special attention to student financial support.

For the last 20 years, the Brazilian government has been promoting the expansion of the higher education system, by means of a set of educational policies that target the promotion of the public segment and incentivize access to the private sector. As a result of these policies, there was a 325.9% increase in enrollment between 1997 and 2017 (INEP, 2019). Furthermore, between 2003 and 2014, the federal higher education system rose from 45 universities to 63, with 321 campuses distributed over 289 municipalities. This expansion has generated an educational market that is seeking to improve quality and to differentiate programs, institutions, and teaching modalities.

Programs such as the Student Financing Fund (Fies) and University for All (ProUni) are crucial in the current configuration of Brazilian higher education. The Fies, implemented in 2001, aims to facilitate access to higher education for low-income youngsters by offering them a loan that covers up to 70% of the costs of the program, with low interest rates and repayment starting only after graduation. ProUni, created in 2005, grants full and partial scholarships (50%) to private higher education institutions, and represents the main measure to democratize access to higher education. It follows that students receiving reimbursable loans coexist with students benefiting from non-reimbursable scholarships.

Students' spatial mobility has been stimulated. Since 2009, governmental measures have encouraged the use of the National Exam of Upper Secondary Education (Enem) to evaluate high schools, but also as a means of accessing higher education. In the following year, the Unified Selection System (Sisu) began to operate on a large scale in allocating candidates, to promote student mobility and incentivize the choice of higher education institutions in the whole country.

Since 2014, Brazilian higher education has experienced a stagnation with a constant number of enrollments, in large part due to the sharp drop in the governmental resources allocated to Fies and the change in the forms of concession. The volume of resources from Fies and ProUni was crucial for the increase in private sector enrollments (Chaves & Amaral, 2016; Miranda & Azevedo, 2020). Furthermore, in the Quota Law (Federal Law No. 12,711, approved in August 2012), determined that by 2016, 50% of enrollments in federal universities should be allocated to students coming from public high schools. Consequently, both the Quota Law and financing the private sector students have made it easier for socioeconomically disadvantaged students to access higher education in Brazil.

This research contributes to the existing literature on student mobility behavior, by paying special attention not only to distance and institution quality, but especially to the types of student financial support. Student mobility is reflected in the flows of individuals from each region of origin to each university, and student flows are appropriately modeled by means of a gravity model. Therefore, we estimate a negative binomial regression (NBR) model on student flows, at the mesoregional level, for 2017, because there is overdispersion of the dependent variable. To our knowledge, the differentiation of student financing types (i.e., reimbursable versus non-reimbursable support) and their impact on universities' attractiveness has not yet been analyzed in the literature on the Brazilian context.

The results show student mobility is also known to have a positive impact on the local labor markets, as regions attract highly skilled human capital who stay after graduation, with higher expected earnings (Parey & Waldinger, 2010; Montmarquette et al., 2002).

This paper is divided into four further sections. The "Determinants of student mobility" section presents and discusses the literature on the determinants of student mobility in the world and in Brazil. The "Methodology" section provides the data to be used in the analysis and the methodology used to obtain the results, which are then analyzed and discussed in the "Results and discussion" section. Finally, the "Concluding remarks" section draws the final conclusions of the research.

Determinants of student mobility

Investment and consumption motives for student mobility

From the 1970s onwards, a number of international studies sought to identify and quantify the determinants of student mobility, emphasizing aspects of attraction or repulsion. Student mobility, or student migration, as it is referred to in several studies, is part of the more general human migration process. Migration may be temporary or permanent, and it may be guided by several motivations and incentives. The neoclassical economic theory assumes that individuals are rational and make decisions to maximize their welfare (Massey, 1990; Todaro, 1969). It therefore understands migration as an optimal allocation of factors based on a rational decision (Haas, 2010; Fusco, 2005).

According to Tuckman (1970), human capital acquisition and consumption are the main motives for migratory movements. There are many forms of human capital investment. It is widely known that schooling provides people with resources, such as skills and knowledge, that will improve their future incomes and will have non-monetary benefits (Becker, 1962, 1993). Migration, in turn, is an example of a non-schooling investment in human capital; it is specific to the individual and is subject to both physical and economic depreciation and deterioration (Sjaastad, 1962). The human capital theory postulates that individuals migrate when the benefits, as higher expected income, greater employability, and better quality of life, outweigh the costs associated with the decision to migrate. These include material costs (e.g., the costs of a house change), but also immaterial costs of establishing new personal relationships and integrating into a different society. Schultz (1961) highlights the importance of internal migration for economic progress, which justifies the substantial investment it requires. It raises countries' productivity, and reduces wage differences and economic inequalities, which impact the overall economic system (Schultz, 1973).

On the other hand, the Theory of Consumption considers that mobility is a consumer decision, as demand reacts negatively to price and positively to income. Migration may be justified by non-pecuniary reasons related to the context in which students will study, such as local services, cultural and leisure supply, the university environment itself, and the pleasure of studying (Agasisti & dal Bianco, 2007; Beine et al., 2014). Students are often attracted by locally and regionally supplied amenities for leisure and socializing, which signals a consumption behavior of students in relation to higher education (e.g., Sá et al., 2004, for the Netherlands). Students may also consider natural amenities (such as weather and topography) at the institution location, in their decision to migrate to college (Dotzel, 2017).

These theories have been tested through various empirical works. A large number of studies rely on place-to-place data to estimate gravity models for student flows from an origin region to a destination, and their determinants: namely, pull/push factors and matched origin–destination information. Quality of education, reputation, internationalization, tuition, scholarships, student financing, and social assistance are among the most studied determinants of student mobility.

Tuckman's study (1970) was among the first to analyze student mobility, emphasizing that the higher the tuition costs and the per capita income of American states, the greater the migration to other locations.

Higher education institutions' characteristics and the features of their location are among the factors of attraction considered in the literature. Quality indicators have been identified as attraction factors. For instance, Sá et al. (2004) used the so-called student–teacher ratio, whereas Singleton et al. (2012) consolidated university rankings, such as *Times Good University Guide* rankings, employed as a proxy for quality. In addition, alternative indicators of the attractiveness of the universities have been analyzed. Bacci and Bertaccini (2020) examined the share of income movers, whereas Dotti et al. (2013) proposed a province attractiveness index and related it with the attractiveness of local labor markets.

Aspects of the environment also contribute to students' decision-making, according to the premises of the human capital theory, in which migration can be considered an investment related to the search for greater future gains through access to better study and work opportunities (Columbu et al., 2021). Consumption decisions also determine mobility, in relation to the influence of non-pecuniary reasons, such as the context in which students live and study (Sá et al., 2004; Agasisti & dal Bianco, 2007).

Despite the relevance of the quality of higher education institutions and their location in determining student mobility, distance as the spatial separation between students' place of origin and destination plays a key role in explaining student flows (Alm & Winters, 2009; Gibbons & Vignoles, 2012). Spatial separation can be measured in terms of distance, travel time, and travel cost. In general, a greater distance between students' residence and the destination university implies higher financial and social costs, as distance has been found highly correlated with both travel time and travel costs (Rietveld et al., 1999). Most studies have shown a negative association between distance and student mobility, including in countries where students typically demonstrate a great willingness to leave their parents' home early and relocate. Sá et al. (2004) corroborated this claim by analyzing the flows of regional students and universities to the Netherlands. The authors estimated gravity models and concluded that the behavior of future students is influenced by their distance from the university, which acts as a discouraging element.

Migration has also been analyzed by decomposing migratory flows in short-distance and long-distance flows, in which economic and non-economic factors are predominant, respectively, in the different movements (Biagi et al., 2011). In this sense, the disequilibrium models are defined, considering migration as an economic phenomenon and a "by-product" related to job search (Evans, 1999; Greenwood & Hunt, 1984), in areas with higher wages and more attractive opportunities.

Not necessarily opposed to this approach (Faggian & Royuela, 2010), equilibrium models address wage differences as factors that compensate only a portion of the spatial factors in non-economic factors, such as quality of life and climate (Graves, 1980). In general, distance incorporates variables that are difficult to measure and which are important for decision-making (Suhonen, 2014).

Table 1 lists some selected works on student mobility, and summarizes their results regarding the impact of several repulsion and attraction factors.

Student mobility in Brazil

Since the reformulation of the Enem in 2009, and the implementation of the Sisu Platform in 2010, the Brazilian public higher education selection system has shifted to a partially centralized model. In addition, the recent affirmative action policies, which focused on access to higher education and the expansion of the number of places in universities, sought to promote a structural change (Kerstenetzky, 2006; Mello Neto et al., 2014).

Enem is still a controversial topic in Brazil. Some people consider Enem a significant advance in the educational system, as it is a unified national examination, whereas others see it as an instrument for increasing regional, social, and racial inequalities (Meneghel, 2018). However, Silveira et al. (2015) emphasize the role of the exam and Sisu in creating equal opportunities. They facilitate student mobility to higher education institutions in widely disperse areas of the country, and allow them to travel to more developed regions.

Few studies in the Brazilian literature have investigated student mobility and the possible determinants of students' migratory behavior (e.g., Barufi, 2012; Li & Chagas, 2017). The pioneering study by Barufi (2012) aimed to analyze to what extent the increase in the number of places affected the migratory balance of higher education students. The results showed positive effects of the number of available places in higher education, the population size, and the quality-of-life measures (i.e., life expectancy and infant mortality rate), on net migration.

Machado and Szerman (2015) conducted the first study to measure the impact of Sisu on both student mobility and dropout. Results suggest that the implementation of Sisu led to a 2.6 percentage points increase in migration between municipalities and a 3.9 percentage points rise in interstate migration.

Similarly, Li and Chagas (2017), using data from 2006 to 2014, sought to investigate the impacts of this policy on inter- and intrastate migration and student dropout, through the estimation of a gravity model. According to the authors, students' enrollment in programs that have adopted Sisu increases their likelihood of interstate migration by 2.9 percentage points, and it reduces the likelihood of being an intrastate migrant by up to 3.95 percentage points.

Enem is generally correlated with the Brazilian national dimension and its socio-spatial differences; students from states with better basic conditions for the development of their studies obtain benefits in states with greater difficulties (Barbosa & Pôssas, 2017). In addition, according to Barbosa and Pôssas (2017), the competition loses its predominantly local or regional character and becomes national; this raises questions about fairness in the competition process, and the possibility of promoting remaining places in case of selected students' dropout.

Summing up, it is appropriate to investigate the mobility of higher education students further: more specifically, which factors determine their migration to a university in the Brazilian context. This research examines the most influential elements in the choices of Brazilian students when attending higher education; we believe these can provide tools for determining better public policies and conducting improvements in the university

Table 1 Annotated overview of studies on the student mobility

Research	Unit and year of analysis	Dependent variable	Results
Frenette (2004)	High school students, Canada; 1993–1998, 1996–1999	Choice between college and university	College nearby (-/+); no university/college nearby (·/-); top income tier (+/·); bottom income tier (-/·); highest educational level of either parent is a university degree (+/·); highest educational level of either parent is a college diploma (·), gender, female (+/·)
Faggian et al. (2007)	Seniors in college, Wales and Scotland; 1996–1997, 1999–2000	Choice of the location of the university attended	Gender, male (-/·), age (+/·), Medicine (-), Arts (-/+), Social Sciences (-/+), Science (+), ethnicity, white (+), number of higher education institutions in domicile area (+), number of higher education institutions in higher education area (-), population density in domicile area (±), population density in higher education area (±), quality of the university (+), economic activity rate in domicile area (·/-), average weekly earnings for professionals in domicile area (-)
Alm and Winters (2009)	College students from Georgia, USA; 2002	Student flows	Distance (-), government spending per freshman student (+), government spending per student (+), pct. of scholarships (+), mean SAT score (-), cost of living (-), centrality indicator (-), pct. Black graduates in higher education area (-), research university (+), regional university (+), state university (+)
Spiess and Wrohlich (2010)	Individuals who passed the final secondary school examination (Abitur), Germany; 1993–2006	Decision to enroll in a university	Distance to nearest university (-), distance to nearest university of applied sciences (-), gender, male (+), Abitur (+), father holds a university degree (+), mother holds a university degree (+), father does not have any vocational training (+), mother does not have any vocational training (-), parents live together (+), net income of parents per year (+), one sibling (-), more than one sibling (-), town size: medium (+), town size: large (-), population density in the university town (+)

Table 1 (continued)

Research	Unit and year of analysis	Dependent variable	Results
Dotti et al. (2013)	Seniors in college, Italy; 2007	Student flows	Mass of students—dest. (+), mass of students—orig. (+), distance (-), per capita income—dest. (·), per capita income—orig. (·), house prices—dest. (-), house prices—orig. (·), employment rate—dest. (+), employment rate—orig. (-), graduate job openings—destn. (+), graduate job openings—orig. (·), rectory (?), university attraction pole—dest. (+), small university—destn. (+/·), university fees—destn. (-), talents (+), research quality—destn. (-)
Ciriaci (2014)	College students and graduates, Italy; 2007	Decision to migrate	University rating—dest. (+), university rating—orig. (-), average number of professors per student—orig. (-), average number of professors (+), university with less than 10,000 students (+), 10,000–15,000 students (+), 15,000–40,000 students (+), more than 40,000 students (+), female gender (-), age (-), father's education (?), master's degree, wage differential (+), ratio between the value-added of the province where the individual studied and the national value-added (+), quality of live index—dest. (+), quality of life index—orig. (+)
Cullinan and Duggan (2016)	Graduates, Ireland; 2013	Student migration flows	Distance (-), centrality index (-), higher education institution in Dublin (-), total student flow (+), gender, female (+), gender, mixed (+), Catholic (+), economic disadvantage (-), deprivation index (-), HEI is an institute of technology (-), HEI is a college (·/-), total full-time undergraduate entrants (+), expenditure per student (+), non-academic to academic staff ratio (-)

Table 1 (continued)

Research	Unit and year of analysis	Dependent variable	Results
Liu et al. (2017)	University entrants and graduates, China; 2005	Location choice	Total population at the destination (-), potential destination is the origin province (+), railway distance between the capital of origin province and the capital of potential destination province is shorter than 800 km (+), railway distance between the capital of origin province and the capital of potential destination province is between 800 and 1600 km (+), average annual wage (-), urban unemployment rate (·), proportion of living expenses to income (·), average temperature (-), relative humidity (+), number of qualified doctors per 10,000 inhabitants (+), air quality (·), enrollments in HEI (+), number of national key universities (-), percentage of migrants in each region (+)
Türk (2019)	Graduates, Italy; 2007	Flows	Index of social capital (+), proportion of limited places offered by universities to the total places (·/-), distance (-), private institution (+), polytechnic institution (·/+), university located in the southern region (+/·), university located in the center region (·/+), university located on islands (·/-)

Statistically significant variables appear with the sign in parentheses. Non-significant variables are indicated by (·). Whenever the variable is operationalized via dummies that do not demonstrate a clear direction of the effect, the variable name is followed by (?). Multiple results are relative to similar variables.

Source: Prepared by the authors.

admission system, especially when considering the proportionality of repayable and non-repayable financing, by institution.

In this sense, we consider that all flows are long-distance, given the continentality of Brazil. Migration is well described by the so-called disequilibrium model, which states that individuals move to regions with higher wages and lower unemployment as a reaction to an initial disequilibrium in the origin labor market. As a result of those movements, at some point, the spatial equilibrium is restored (see Biagi et al., 2011). Furthermore, according to Miranda and Azevedo (2020), the funding available for access to private higher education is fundamental, but its influence on migration is still unexplored in the literature.

Methodology

The gravity approach

Spatial interaction models are derived from physics; they can predict the size of spatial flows between origin and destination in areas of interest. Their creation was initially focused on transport and trade logistics issues, but spatial interaction models have been applied in other analyses (Türk, 2019). Gravity models are among the most widely used types of interaction models and have been considered appropriate in a variety of contexts, such as health and education (Haynes & Fotheringham, 1985; Antonucci & Manzocchi, 2006).

According to Sen and Smith (2012), the multiplicity of gravity models' applications is due to the simplicity of their mathematical form and the intuitive nature of their fundamentals. Regarding their application to higher education, Faggian and Franklin (2014) state that future college students compare the utility of their current location with an alternative location, demonstrating that their level of utility maximization is consistent with a gravity model of migration.

In this sense, gravity models can help to identify influences of factors in student migration flows between regions, and patterns (Cattaneo et al., 2016; Van Bouwel & Veugelers, 2013). According to Bacci and Bertaccini (2020), this instrument enables the analysis of universities' reputation in recruiting students, in relation to student mobility and territorial characteristics: these are termed "attraction factors." Furthermore, the students' perspectives, decision-making, and subsidies relevant to the choices to move through space can be originated through gravitational models (Sá et al., 2004).

Thus, this study aims to explain the migratory flows of students aggregated by Brazilian mesoregions. In the empirical model, it is first assumed that individuals are rational and maximize their utility. Then, the decision on whether to migrate or not is made in relation to the consumption and investment decision, which considers the characteristics of the universities and the variables related to their socioeconomic conditions and location.

Student flows are described by the general gravity model expressed by Eq. (1):

$$F_{i,j} = O_{(Reg_i)} D_{(Univ_j)} f_{(d_{i,j})} \tag{1}$$

where $F_{i,j}$ represents the flow of students from region i to university j, $O_{(Reg_i)}$ are the socioeconomic characteristics of the region that influence students' departure from their place of origin, $D_{(Univ_j)}$ are the attributes of university j as a function of attractiveness to students, and $f_{(d_{i,j})}$ is a function of the straight line distance between the region and the resulting university for each "student flow"—a term that designates the mobility behavior of students.

The empirical model

The application of gravity models to the study of migration has been widespread. Traditionally, these models are estimated by ordinary least squares (OLS), but several flaws, inconsistencies, and biases have been pointed out (Wang et al., 1996). One of the most plausible alternatives is the use of Poisson models, as they allow for integer and non-negative dependent variables, such as student flows between regions, which occur randomly and independently over time (Dotti et al., 2013). However, Poisson models only provide correct estimates if the equidispersion theorem applies. As in the present analysis there is overdispersion of the dependent variable, a negative binomial regression (NBR) model has been estimated.

The NBR model generalizes the Poisson regression model (Cameron & Trivedi, 2010). Its main equation is Eq. (2), which represents the probability density function:

$$P(y_k) = \frac{\Gamma(y_k + \theta)}{\Gamma(\theta) y_k!} u_k^{\theta} (1 - u_k)^{y_k} \tag{2}$$

where y_k is the number of travelers; $\theta = 1/\alpha$, where α represents the dispersion parameter; $u_k = \theta/(\theta + \lambda_k)$, where λ_k represents the mean and $\Gamma(\cdot)$ is a gamma function. The NBR model accommodates overdispersion, $Var[y_k] = E[y_k]\{1 + \alpha E[y_k]\}$, converging to the Poisson model as $\alpha \rightarrow 0$.

In this work, the negative binomial regression gravity model is used. The results of the overdispersion tests (Table 4), Pearson/Hosmer–Lemeshow (Table 5), and likelihood ratio reveal that the data show a much larger dispersion than can be explained by the Poisson regression model (Appendix). Two specifications of the NBR model are presented: the simplest specification, in which distance is the only regressor, is compared with the most complete model, which examines the student flows aggregated by mesoregions, universities' features, characteristics of the places of origin and destination, and the decentralization of the universities. Finally, the adequacy of the estimates is verified by running the *countfit* user-written command on the Stata 14.0 software.

The data

The data were taken from the Higher Education Census (CES), conducted annually by the National Institute for Educational Studies and Research Anísio Teixeira (INEP); this is a declaratory and mandatory tool for research on higher education. It is carried out using decentralized data collection through online access to the electronic information system (Censup). The reference date is the year prior to the collection moment, and it gathers individualized information on higher education institutions, programs, students, and teaching staff. Several variables for characterizing the institutions and the student flows can be computed based on these data (see Table 2 for all the variables used in the current research).

Student flows, as the dependent variable of the empirical model, are measured at the mesoregion geographic level; they consider the municipalities where students were born (taken from the Census) as a proxy for the location of the high school attended. This

Table 2 Explanatory variables ($N=26{,}578$ flows)

Variable	Description	Mean	Standard deviation	Minimum	Maximum
Dependent variable					
Flows	Number of students from a region attending a given higher education institution	30	385.27	0	48,928
Destination (university) variables					
Teaching resources	Student–teacher ratio, i.e., number of teachers per student	33.54	199.22	3.29	2,765.63
Quality	Measured by the General Index for Programs (IGC), calculated by INEP	3.02	0.52	3	5
Concentration	Measured by the Herfindahl–Hirschman Index (HHI) calculated as the sum of the squares of each university's market share (in terms of number of students enrolled in each OECD* field of study in relation to the total number of enrolled students)	0.28	0.10	0.15	1
Scholarships	Proportion of students with scholarships/remuneration for participating in extra-curricular activities, non-mandatory internships, extension programs, tutoring, and research (on a scale from 0 to 1)	0.21	0.25	0	0.29
Social assistance	Proportion of students receiving some form of social support such as housing assistance, transportation, food and textbooks (on a scale from 0 to 1)	0.12	0.23	0	0.16
Reimbursable financing	Proportion of students who have any kind of reimbursable financing, the Student Financing Fund (Fies), the administration of state and local governments and HEIs, non-HEI entities, or other entities (on a scale of 0 to 1)	0.10	0.15	0	0.12
Non-reimbursable financing	Proportion of students with non-reimbursable student financing, full and partial scholarships from the University for All Program (ProUni), as well as municipal, state, and other funding (on a scale from 0 to 1)	0.16	0.24	0	0.34
Universal admission	Proportion of students who entered university via Enem (on a scale from 0 to 1)	0.34	0.31	0	0.98
Particular admission	Proportion of students who entered via a particular admission process and simplified and serial evaluation processes (on a scale from 0 to 1)	0.63	0.35	0	0.93
Private university	Dummy variable equal to 1 if the university is private, 0 otherwise	0.48	-	0	1
Decentralization	Dummy variable equal to 1 if the university has a campus in more than one mesoregion, 0 otherwise	0.55	-	0	1

Table 2 (continued)

Variable	Description	Mean	Standard deviation	Minimum	Maximum
Origin–destination variables					
Density ratio	Ratio of population density (inhabitants/km^2) of the region of origin to the region of destination, based on the Census estimates provided by DATASUS using IBGE sources	2.98	17.32	1	7,494.33
Distance	Straight line distance (Km) between each mesoregion of origin and destination institution	1,533.12	890.22	41.65	4,046.48

The OECD divides higher education programs into eight general areas: (i) Education; (ii) Humanities and arts; (iii) Social sciences, business and law; (iv) Sciences, mathematics, and computing; (v) Engineering, manufacturing and construction; (vi) Agriculture and veterinary medicine; (vii) Health and welfare; and (viii) Services.

Prepared by the authors using the research data.

generalization can be confirmed by the microdata provided by the Enem database, where, for 87.3% of the students, the city of birth coincides with where they attended high school.

According to data availability, 194 (destination) universities are considered, so the model calibration is based on 26,578 (= 194 × 137) flows, which correspond to all possible flows between the 137 mesoregions of origin and the 194 universities (of which, 63 are public and 131 are private institutions). The database comprises all students enrolled at the universities for the first time in 2017, except for distance-education students and those whose place was not available in CES.

The flows were aggregated by mesoregions of origin, following the Brazilian Institute of Geography and Statistics (IBGE).[1] The final database includes 822,934 individual movements attributed to 194 × 137 matrix cells. About 13,812 matrix cells (52%) corresponded to zero movements. The largest flow corresponded to 48,928, and the average flow size was 30 students.[2]

Higher education institutions are distributed throughout the national territory, with a concentration in the south and southeast regions. The onsite modality is present in 1,056 Brazilian cities, that is, in approximately 19% of the 5,564 cities. Soares and Lobo (2017) state that there was flexibility in the offer in two ways: by continuing the concentration of vacancies in metropolitan regions, south and southeast (traditional), as well as in new localities and regions.[3]

The Brazilian mesoregions, as the spatial unit used, group together municipalities with similar preservation and regional characteristics. According to the Brazilian Institute of Geography and Statistics (IBGE, 1990), this territorial division is derived from a social process, as a determinant of the natural framework; and from the communication network and places, as an element of spatial articulation—this is an intermediary element between the macro-regions (the highest and the most discriminated level) and microregions (levels in spatial objects). Furthermore, this territorial scale is equivalent to the European NUTS 2 level.

Regarding the explanatory variables (Table 2), several characteristics of the destination university are included. The first are the student–teacher ratio and a quality index to proxy the institutional quality. There are, on average, about 33 students per teacher. The General Index for Programs (IGC) is a measure of the quality of all programs offered by a given higher education institution. It is calculated by INEP as a weighted average of undergraduate and graduate student grades, and comprises information on infrastructures, teaching resources, and teaching staff. The IGC lies between 1 and 5; the average quality in the sample is about 3.2.

The Herfindahl–Hirschman Index (HHI) measures the field of study concentration of the programs offered by each institution, and ranges from 0 to 1. In 2017, it was, on average, 0.28, suggesting that universities show a low concentration of programs in a reduced number of fields.

Two binary variables are also included: an indicator of the type of institution (public versus private), and a decentralization indicator. It follows from Table 2 that about 48% of the flows have private institutions as the destination, whereas 55% of them go to universities that have a campus in more than one mesoregion (i.e., decentralized institutions).

[1] As of 2017, the IBGE (Brazilian Institute of Geography and Statistics) replaces the term mesoregion with an intermediate geographic region.

[2] Foreign students were excluded from the sample, as the Census does not provide the place of origin of non-Brazilian residents.

[3] For more details, see Barbosa (2020).

Different forms of admission are also accounted for by means of two variables: namely, the proportion of students admitted via both the Enem (a universal means of access), and the particular admission processes employed by each university.

In addition, the model also considers other elements that can act as attraction factors, such as scholarships and student assistance, as well as reimbursable and non-reimbursable financing (namely, the Student Funding Fund (Fies), and the University for All Program (ProUni), programs targeting students from private universities). About 10% of the students benefit from some kind of reimbursable financing such as Fies. About 21% of the students have some extracurricular activities, about 12% some type of social support, and 16% benefit from ProUni.

Finally, elements that have a connection between origin and destination mesoregions have been added. Population density ratios were used as a proxy for living costs (the more densely populated and urbanized the regions, the higher the living costs) and preferences for a more urban lifestyle (Widiputera et al., 2017; Agasisti & dal Bianco, 2007; Sá et al., 2004).

The spatial separation between the place of origin and the destination institution is measured by the distance, which, as already mentioned, is one of the determining factors of student mobility. All migration flows are long-distance, as shown by the high average of the distance variable, at about 1,533 km (Table 2).

Results and discussion

Estimation results for two different specifications using the negative binomial regression gravity model are shown in Table 3. The simplest model only includes the distance between the students' region of origin and the university region as destination; its estimation results are shown in the first column under specification I. The most complete model includes all relevant and available variables, as described in Table 2; the results are shown in the second column under specification II.

First, it appears that distance has a negative effect on student mobility, i.e., the greater the distance, the lower the probability of movement. Great distances act as a deterrent to student mobility, as evidenced by most studies (e.g., Sá et al., 2004). This result is also expected, considering the Brazilian territorial extension (the fifth-largest in the world), and the difficulty of mobility in the absence of low-cost airlines and rail systems. In general, the total costs of entering a university increase proportionally with the distance between the region of origin and the university of destination. According to Cattaneo et al. (2016), these costs include traveling for commuters, and housing costs in situations where the distance is too great and a change of residence is inevitable. Thus, an increase in student mobility may be related to an increase in benefits or cost savings.

The quality, as measured by the IGC, has a significant and positive impact on student flows. Brazilian students seem to expect that the future labor market benefits of a higher quality education will exceed the present mobility costs, suggesting that they are guided by investment motives.

Flows' response to increases in the proportion of students admitted via a particular form of access appears to be stronger than for those who enter the university via Enem. In a particular admission process, candidates choose the programs which they intend to study before taking the entrance exam and then before obtaining their grade, which does not occur with high uncertainty, unlike the Enem exam, which allows a choice to be made

Table 3 Estimation of results for two different specifications

Variables	Specification I	Specification II
Distance	−0.0009* (0.0000)	−0.0012*** (0.0000)
Density ratio		0.01902*** (0.0027)
Teaching resources		0.0003 (0.0002)
Quality		0.0435*** (0.0938)
Concentration		−2.8702*** (0.5922)
Scholarships		−1.6018*** (0.1915)
Social assistance		−0.1629 (0.2554)
Reimbursable financing		−0.1797 (0.4319)
Non-reimbursable financing		1.8206*** (0.2063)
Particular admission		2.3982*** (0.1829)
Universal admission		1.8970*** (0.2159)
Private university		0.6309*** (0.2290)
Decentralization		1.0629*** (0.0889)
Wald Chi 2	308***	1447.79***

Standard deviation in parentheses. ***, **, and * represent 1%, 5%, and 10% significance, respectively.

Prepared by the authors using the research data.

from the results (Li & Chagas, 2017). Access can be facilitated, as sometimes groups of private institutions located in the same state agree on the entrance exam students have to take (McCowan, 2005).

The positive impact of the share of students benefitting from non-reimbursable financing, mostly by partial and full scholarships from ProUni, reflects the importance of the financial constraints on student mobility decisions. Furthermore, partially or fully covered tuition is a stimulus to migration, given that ProUni can make the cost of migrating similar to that of admission to a public university, as there are no tuition costs in either case.

The proportion of scholarship holders has shown a negative effect on mobility. This result may express students' intention to seek sources of income not derived from the institutions, or of not attending higher education on an exclusive basis. Students often undertake internships during college, which are sometimes unpaid or underpaid.

Brazilian private universities seem to be more attractive and accessible to students than their public counterparts. The concentration of approximately 75% of the total supply of university places in private higher education is possibly linked to this result. According to Türk (2019), when students enroll in private universities, distance and other financial challenges become irrelevant, since they are already somehow linked to tuition costs.

As for the HHI indicator, universities with a more concentrated supply have less appeal to mobility, i.e., diversity of programs is a factor of attraction. According to Rossi (2010), this process is usually a by-product of the expansion and competition in access among universities, which seek to maximize enrollment by diversifying in terms of programs and teaching modalities.

The density ratio demonstrates that students tend to move to less densely populated regions, possibly related to the lower living costs and the safety afforded by these locations. Although positive, the magnitude of the effect is small. Density is related to a more urban lifestyle, with better leisure options and (more attractive) cultural activities; however, is also related to the higher costs of living in more urban areas. It may also be linked to a less intense competition for places, thus encouraging the deconcentration of large centers. According to Imeraj et al. (2018), higher housing prices in capital cities and large cities negatively contribute to the (perceived) attractiveness; however, there are job opportunities for highly skilled people in these locations. Ciriaci (2014) points out that migration to more urbanized locations occurs in the short and long term after graduation.

The presence of a university in other regions has a positive (and significant) impact on student flows, indicating a greater attractiveness; this is possibly due to the decentralization of universities, encouraged by the implementation of the Support Program for the Restructuring and Expansion of Federal Universities (ReUni). This result reaffirms what was verified by the density ratio: that the trend toward creating smaller campuses in smaller cities encourages student mobility due to lower living costs (Dotti et al., 2013).

Concluding remarks

Brazilian higher education has undergone significant changes in recent years, given the urgent need to increase the accessibility of the highest education level. The main interventions are government-backed, which has encouraged the move to a centralized admission system through Enem and Sisu, in addition to increasing the number of places in universities and encouraging the private sector. This paper has contributed to the search for the main determinants of the mobility of Brazilian university students. Some noteworthy findings emerge from the estimation results of a negative binomial regression model on student flows, for 2017.

Distance has a deterrence effect on student mobility. Students tend to choose institutions closer to the attended high school location; but also, they tend to move to locations with lower living costs and smaller campuses, possibly looking for more affordable accommodation. Costs are of major relevance when mobility decisions are being taken, but can be compensated by student funding. The higher the incidence of students with non-reimbursable financing, the more attractive the university. Student mobility is encouraged whenever anticipated benefits will exceed the present costs. High institutional quality, a proxy for high future returns, appeared to be an attractiveness factor, which suggests that Brazilian students are guided by investment motives.

The proportion of students admitted via a particular form of access has a stronger impact on student flows than those admitted via the universal form of access, but both positively affect student mobility. The Enem and Sisu have marked a dramatic change in the forms of access, from decentralized to centralized. Sisu represents an alternative to the entrance exam, and a way to reduce the inefficiencies generated by a local selection. This is because the search for the best matches between vacancies and candidates in the national territory increases the chances of admission, and allows greater geographic mobility among students; it also acts as a mechanism for the inclusion of students from underrepresented groups via the quota policy.

Private universities appear to be more attractive than their public counterparts. The influence of public policies on access to higher education through private expansion and programs such as ProUni may be one of the determining factors of this finding. There is a greater predominance of private universities in the national territory, which have a less disputed selection process than public ones. These characteristics make access to private institutions facilitated and program diversity emerges as a factor of attractiveness.

Despite the stimulus to higher education growth (expansion of places at institutions) and funding programs, the vast Brazilian territory and the low degree of regional mobility imply that students may need to travel great distances; this means that financial and, above all, costs will exceed the expected salary gains.

These results suggest that both policymakers and higher education managers should implement a number of policy measures and strategies in order to avoid inequalities in access to higher education in Brazil. One of the major policy issues that follow from this analysis relates to costs. The costs of travel and subsistence, in addition to being greater for migrants than for other students, may act in the opposite direction to Sisu's aim of promoting equal access. Further policies aiming at targeting the distance decay effect found in Brazilian higher education are needed. Furthermore, some policy interventions may try to influence the student decision-making process, the earlier the better. For example, organizational collaboration between secondary schools and higher education institutions can mitigate the negative impact of distance (Raab et al., 2018).

Higher education institutions may have also important work to do when it comes to student attraction. For private institutions, attracting students is essential for maintaining the institutions' activities and sources of financing. Fundraising via ProUni can help to attract students, as well as program differentiation. Since the proportion of scholarship holders has a negative effect on mobility, offering evening, distance, or weekend courses can be a strategy, as students can reconcile their academic activities with jobs and depend less on student financial support.

As living costs are relevant, decentralization of universities to areas of lower population concentration should be encouraged. The importance of program diversity as an attractiveness factor has implications for university strategies when aiming to capture students and enlarge their catchment areas. The expansion of higher education should encourage universities to further diversify their programs/fields of study.

This analysis nevertheless has some limitations that justify further studies on this issue. Consumption motives underlying the choice of a university cannot be fully captured here, especially those related to the higher education institution's location. Indicators of the unemployment rate, cost of living, and age breakdown of the population at the institution location should be explicitly added to the model; this requires additional data. In addition, the aggregate university quality measure used could be decomposed, in order to reflect variation across departments and programs of the same university (Abramo et al., 2011).

Notwithstanding these limitations, the main results of this research are relevant. The spatial distribution of higher education institutions and their accessibility have major implications for the demand for higher education, especially with the Brazilian government's recent internalization policies for federal universities, and the unified selection system. Therefore, political strategies can be adopted to attract people who are less likely to enter a university; furthermore, less accessible geographical locations can be identified, and their access increased by reducing geographic and economic barriers to access to higher education.

Appendix

Table 4 Overdispersion test

	Coefficient	Standard deviation	t	Confidence interval
Overdispersion test	6.31**	2.98	2.99	0.46–12.15

Prepared by the authors using the research data.

Represents 5% significance.

Table 5 Pearson and Hosmer–Lemeshow goodness-of-fit test

Deviance = 1,521,469*** Prob > chi2 (26,578) = 0.00
Pearson = 1.06e + 07*** Prob > chi2 (26,578) = 0.00

Prepared by the authors using the research data.

*** represents 1% significance.

Table 6 Goodness-of-fit test

PRM		BIC = 1.298e + 06				
		AIC = 59.88				
				Preferred	Over	Evidence
	vs NBR	BIC = − 1.518e + 05	dif = 1.450e + 06	NBR	PRM	Very strong
		AIC = 4.35	dif = 55.53	NBR	PRM	
		LRX2 = 1.45e + 06	prob = 0.00	NBR	PRM	$p = 0.00$
	vs ZIP	BIC = 990935.05	dif = 307290.43	ZIP	PRM	Very strong
		AIC = 48.11	dif = 11.77	ZIP	PRM	
		Vuong = 19.28	prob = 0.00	ZIP	PRM	$p = 0.00$
	vs ZINB	BIC = − 1.529e + 05	dif = 1.451e + 06	ZINB	PRM	Very strong
		AIC = 4.30	dif = 55.58	ZINB	PRM	
NBR		BIC = − 1.529e + 05				
		AIC = 4.35				
				Preferred	Over	Evidence
	vs ZIP	BIC = 990935.05	dif = − 1.143e + 06	NBR	ZIP	Very strong
		AIC = 48.11	dif = − 43.76	NBR	ZIP	
	vs ZINB	BIC = − 1.529e + 05	dif = 1193.82	ZINB	NBR	Very strong
		AIC = 4.30	dif = 0.05	ZINB	NBR	
		Vuong = 17.35	prob = 0.00	ZINB	NBR	$p = 0.00$
ZIP		BIC = 990935.05				
		AIC = 48.11				
				Preferred	Over	Evidence
	vs ZINB	BIC = − 1.529e + 05	Dif = 1.144e + 06	ZINB	ZIP	Very Strong
		AIC = 4.31	dif = 43.81	ZINB	ZIP	
		LRX2 = 1.14e + 06	prob = 0.00	ZINB	ZIP	$p = 0.00$

Prepared by the authors using the research data.

Robustness tests

According to Cameron and Trivedi (2010), the countfit command implemented in Stata 14.0 allows for a comparison of the estimates' adequacy obtained for Poisson (PRM), negative binomial (NBR), zero-inflated Poisson (ZIP), and zero-inflated negative binomial (ZINB) models. Furthermore, this command compares the four models using the BIC and AIC criteria and the Vuong test. The command guides the choice of the preferred model and provides evidence that supports the appropriate choice. Table 6 summarizes the implemented tests that support the use of the negative binomial model over the other models.

Acknowledgements This paper is financed by National Funds of the FCT – Portuguese Foundation for Science and Technology within the project «UIDB/03182/2020.

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