Re(de)fining College Access and its Association with Divergent Forms of Financial Aid: A Proposed Conceptual and Analytic Framework

Introduction

Education beyond high school is a policy topic of great public concern as decisions made on this area significantly affect millions of families every year. Even though access to college is not the solution to all problems young people may face, failing to positively impact access to postsecondary education may not only serve to exacerbate the widening socioeconomic gaps but would also reinforce the potential negative implications associated with no college enrollment, particularly in regard to unemployment, poverty and crime (Baum, Ma, & Payea, 2010; Matthews, 2010). Given that "absent some degree of postsecondary education, thriving in our competitive, global economy becomes much more difficult" (White House Task Force, 2008, p. 2), under a positive externality perspective (McMahon, 2009), providing access to college to as many youth as possible is an investment that benefits individuals, communities, states, and the entire United States in general.

A significant body of literature indicates that reducing the cost of college attendance through financial aid encourages college enrollment (*e.g.*, Abraham & Clark, 2006). The rationale behind this relationship is that, despite the foregone earnings that postponing immediate employment represents, financial aid reduces concerns about education investment affordability (DesJardins, McCall, Ott, & Kim, 2010). While the previous statements and rationale hold true, most of college access research considers almost exclusively enrollment in a four-year college as the primary sector of interest (Nora, 1990[1]) and focuses on traditional students (*e.g.*, students graduating in spring and enrolling in college in the fall of the same year) as the target population of interest. Considering that the American higher education system is configured by nine sectors[2] and also accommodates non-traditional students, this

[1] Nora's 1990 study is a cornerstone research article as it not only explored the community college sector but also focused on Hispanic students. However, different from the access perspective discussed in this study, Nora's piece focused on retention. Notably, Nora concluded that both campus and non-campus (Pell grants) based resources proved significant in improving Hispanic students' retention prospects.

[2] According to IPEDS, these sectors are: public four-year, private non-profit four-year, private for-profit four-year, public two-year, private non-profit two-year, private for-profit two-year, public less than two-year, private non-

traditional depiction of the relationship between financial aid may underestimate the true effect of such aid in access and affordability among students attending sectors and levels other than the four-year sector and who are not classified as traditional. From this perspective, one can then argue that our current conceptualization of college access is limited by two important exclusions, as depicted below.

First, researchers have *traditionally* excluded non-recent high school graduates from college access models. Second, models have *traditionally* excluded high school graduates enrolling outside the four-year sector from measures of state-level college access. To be clear, note that these two exclusions noted, do not imply that there is no research on the effect of factors affecting student persistence and financial aid in the two-year sector. For example, Luna-Torres, McKinney, Horn, & Jones (2018) have recently published an article exploring debt burden accumulation and academic outcomes among community college students in a large urban community college system in Texas. Similarly, Gonzalez Canche (2014, 2019a) have tested whether the two-year path toward a four-year degree resulted in lower debt accumulation compared to the four-year path to a four-year degree. Note, however, that these studies do not focus on access and financial aid, but in financial aid and student outcomes. From this perspective, rather than claiming that there is *there is as large a gap in the literature* on aid and persistence that has expended over and above the four-year sector, this study argues that there is a gap in the literature on access and financial aid at the state level that has accounted for non-recent high school graduates enrolling at institutions other than the four- (and as shown by Nora (1990) and Luna-Torres, McKinney, Horn, & Jones (2018)) and two-year sectors.

The relevance of addressing these exclusions is that they may not only mask the real measure of *college access* in a given state but also the ways in which different forms of aid (need-based, merit-based, loan-based) may impact *college access* across *different sectors* and *levels*. Accordingly, this study offers a conceptual model to comprehensively measure college

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profit less than two-year, private for-profit less than two-year.

access indicators using census level data provided by the Integrated Postsecondary Education Data System (IPEDS) from the National Center for Education Statistics (NCES). This model enables one to account for mobility patterns of first-time degree-seeking students classified as recent high school graduates (RHGs) and non-recent high school graduates (NRHGs). Furthermore, the mobility *or enrollment* patterns included in this conceptualization enable assessment of retention, in-migration and out-migration in a given academic year *t* and in a given state *i*. In sum, this proposed framework highlights the complex ways in which access to higher education at the state-level can be measured and posits empirical research questions that researchers and students can begin addressing to enhance their understanding of college access, financial aid and their association. The following section discusses the relevant literature on *student access and financial aid* while the subsequent elaborates on the conceptual framework discussed in this manuscript.

Relevance for the Study of Hispanic College Access and Choice

According to the U.S. Department of Education (2017, 2018), the current state of Hispanic high school graduates in terms of college participation shows a 17 percentage points increase in 2015 compared to the college access rates observed in 2000 (22% compared to 39%). Nonetheless, Hispanic students are as likely to enroll in the two- or four-year for-profit sectors as they are to enroll in the public two- or four-year sectors. These college choices among Hispanic students are worrisome when considering that the for-profit sector has been consistently associated with the lowest completion rates within 150% of the expected graduation time. These 150% graduation time vary according to the level of the institution. For students enrolling in a two-year institution, this completion time is three years, whereas for students attending the four-year sector, it is six years after initial college enrollment. These college choices may explain why while “More Hispanics are going to college. The bad news? They’re still behind” (Field, 2018). Another concerning aspect of this enrollment choice is that for-profit colleges have been conceptualized as employing predatory practices that result in more debt accumulation and default rates (Deming, Goldin,

& Katz, 2011). Although the present study proposes a conceptual framework to analyze the relationship between financial aid disbursements and sector of enrollment regardless of specific ethnicity, such a proposed framework can be adapted to analyze the ways in which the proposed relationships affect college enrollment rates of Hispanic students in general, with the prospects to separate this overall category into more specific origins (*e.g.*, Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin, regardless of race). The following section depicts relevant literature informing the proposed framework.

Relevant Literature on Access and Financial Aid

The effect of state-based financial aid on undergraduate student access to college and mobility patterns has puzzled researchers for many years. While merit-based aid was originally designed to improve access to the private sector (Dynarski, 2004), increases in the reliance upon tuition as a means of financing public higher education that started to be prompted by governmental policies in decade of the 1970s (Rusk & Leslie, 1978, p. 531), fueled the appearance of Georgia's Helping Outstanding Pupils Educationally (HOPE) scholarship in 1993. HOPE set precedent on merit-based aid initiatives that impacted the public sector and aimed at retaining bright students within state borders. Evidence shows that this program affected students' decisions to remain in-state as opposed to move out of state to enroll in public or private colleges (Cornwell, Mustard, & Sridhar, 2006; Doyle, 2010). Based on these claims, other states decided to make similar investments and since then the emergence of state merit-based programs became common ground in the U.S. higher education system. As of 2015-2016, according to NASSGAP (2018, Table 3), 43 states and D.C. disbursed $2.58 billion in non-need grant-aid or merit-based aid. This means that only seven states refrained from offering this form of aid.

Researchers, however, have argued that merit-based initiatives do not expand access, but rather just influence where these students, who are likely to afford college even without the financial help, will end up attending (Cornwell et al., 2006; Doyle, 2010). Despite these notable concerns, the relevant point is that merit-based aid does appear to have an effect on

students' college-choice decisions. Another form of aid, that is more prevalent by being present in all but two states and D.C., and represents 65% of the total state grant aid disbursement (or $8.16 billion) in 2015-2016, is need-based aid. Notably, however, this form of aid has been relegated to a secondary place. The reason being that research has not found evidence of its impact on improving students' likelihood to access college. For example, Toutkoushian and Hillman (2012) found that need-based aid had no effect on expanding access nor on retaining students in-state. These authors, however, only estimated aggregated models including two- and four-year college attendance of recent high school graduates (RHG) at the state level. While they also included another model that accounted for RHG four-year entrants only, it may be possible that need-based aid may have a stronger effect in the public two-year sector. However, a standalone model that included only two-year students was not offered by the authors. This omission is considered remarkable as students eligible to need-based help are far more likely to be concentrated on two-year colleges (Doyle, 2009; González Canché, 2014a, 2017a, 2017b, 2018d; Leigh & Gill, 2003; Long & Kurlaender, 2009; Melguizo & Dowd, 2009; Sandy, Gonzalez, & Hilmer, 2006; Stephan, Rosenbaum, & Person, 2009) than in the four-year sector. In addition, the lack of effect of need-based financial aid disbursement on reducing outmigration may be explained by the fact that it is unlikely that students eligible for need-based aid would be thinking of attending college out-of-state as this decision requires monetary resources that are unlikely to be met by need-based aid (Cooke & Boyle, 2011; González Canché, 2014b, 2017c, 2018b, 2018c; Zhang & Ness, 2010). Consequently, need-based aid is assumed to mostly influence access to less selective institutions in-state, while not affecting students' decisions to move out-of-state.

The state non-grant-based aid is a third type of financial aid that has traditionally been left out of models measuring the impact of monetary aid on access and student mobility patterns. Indeed, none of the studies reviewed for the preparation of this manuscript included this measure of financial aid. Nonetheless, the potential influence of non-grant aid should not

be overlooked. As of 2016, 44 states in the contiguous U.S. offered some form of non-grant aid reaching $1.76 billion in aid disbursed (National Association of State Student Grant & Aid Programs, 2018, p. 8). Non-grant aid differs from grant aid (merit and need-based) in that it requires some form of repayment or comes in a form of a payment. Specifically, according to NASSGAP reports non-grant aid accounts for loans, conditional grants and work study (leading to tuition waivers). As in the case of need-based aid, non-grant aid may be influencing access to less selective postsecondary education institutions, yet to date there is no evidence to corroborate or discard this statement using state non-grant aid data, as delineated by NASSGAP.

State appropriations constitute a peculiar form of financial aid, as they can be conceptualized as a mechanism to reduce tuition prices for resident students—*e.g.*, students who enroll in colleges within the states where their parents have been paying state taxes. Based on this notion, Toutkoushian and Hillman (2012) tested its effects on access to public two- and four-year institutions. The exclusion of private institutions from models that use state appropriations is justified because few private institutions receive funds from this source (González Canché, 2014b). Nonetheless, with the proposed framework to be discussed below, it may be worth testing whether these amounts disbursed in a state *i* influence shifts in college access to different levels within the public college sector and time since high school graduation. For example, Toutkoushian and Hillman found that state appropriations have a significant effect in increasing the percentage of RHG enrolling in two- and four-year public institutions while holding constant state-level characteristics and need- and merit-based aid. However, when the analyses only accounted for enrollment in public four-year institutions, this association disappeared, meaning that the significant variation was being driven by the two-year sector yet, the authors did not obtain a magnitude of this effect. Another important source of variation would consist of testing whether state appropriations impact enrollment variation of nonrecent high school graduates across different levels of the public sector.

From the discussion presented thus far, this proposed framework may serve to test

whether state appropriations, need-based, merit-based, and non-grant-based aid disbursed at a given state are associated to increases in postsecondary education access for first-time college students at a given state and at different sectors of the postsecondary education system of such a state. Moreover, the proposed conceptual model will enable testing not only if financial aid amounts per full-time student are associated with increases in in-state student enrollment at institutions located in state *i*, but also, what postsecondary sectors of that state are more likely to be affected by the amounts of aid disbursed. In addition, this proposed model discussed below will enable testing for spatial dependence by modeling the influence on college access of state *i* conditional on its neighboring states' average financial aid amounts disbursed, their enrollment patterns and tuition reduction agreements neighboring states may have. The working hypothesis is that neighboring states' emphasis on financial aid, state characteristics and tuition reduction agreements play a role in student mobility patters in state's *i* above and beyond this state's merit based aid disbursed.

Proposed Conceptual Framework

Every year millions of high school graduates aspire to enroll in (any/some form of) college. One measure of college access consists in dividing state's *i* number of recent high school graduates (RHG) enrolling in college by the total number of high school graduates that state produced in a given academic year. For example, in the academic year 2009-2010 California produced 439,802 high school graduates from public and private institutions (Digest of Education Statistics, 2011, 2012), of whom 249,894 or 57% enrolled in any form of Title IV eligible institutions in-state in the academic year 2010-2011 (U.S. Department of Education, Integrated Postsecondary Education Data System, 2012a, 2012b).[3] At the national level, the

[3]California's unique first-year college access dynamics change when just looking at the estimates provided by IPEDS, which indicates that the total number of students produced by California, which include non-recent high school graduates is the highest across the nation with 436k. Moreover, California also hosts the highest number: of students, also about 436k. Additionally, California retains 92% of these students produced, exports 36k, the second highest number and attracts 36k, the third highest across the contiguous United States. This results in California having a net export/import difference of 0. These statistics are depicted in Figure 4.

percentage of the 3.41 million high school graduates enrolling in any form of Title IV eligible institutions in-state was 52.9% (1.8 million). These new enrollees are also referred to as recent high school graduates (RHG) as they enroll in college within 12 months of graduation.

This access measure $\left(\frac{Total\ college\ entrants}{Total\ High\ school\ graduates}\right)$, although straightforward, could be misleading in terms of real access to higher education provided by a given state. That is, in that same academic year a total of 953 thousand non-recent high school graduates (NRHG), who also were first-time in-state degree-seeking students. The only difference between these NRHG and RHG is that the former enrolled in college over 12 months of having graduated from high school. Notably, by the metric used before, NRHG would not be accounted for in the computation of college access, a characteristic typical of studies on college access and financial aid (Toutkoushian & Hillman, 2012).

The proposed conceptual framework argues that the inclusion of NRHG in the computation of access should not be overlooked. Not only do NRHG students occupy seats, pay in-state (or out-of-state) tuition, and absorb monetary and non-monetary resources, but also and perhaps more importantly, have the right to receive an education for the betterment of themselves, their families and their communities. Accordingly, ignoring them from the conceptualization of college access may hinder understandings of the impact of resources disbursed by states to provide college education in different sectors, levels, and forms. This concern is more relevant when considering that NHRG represent 29% of the total in-state student population, and one third of the total student freshmen produced by a given state.[4]

[4]This latter computation is based on dividing the total number of NRHG students who enroll in any form of college (in-state, out-of-state) in 2010-2011 by the total number of students enrolling in college (in-state and out-of-state) in 2010-2011 (1.08million /3.27million).

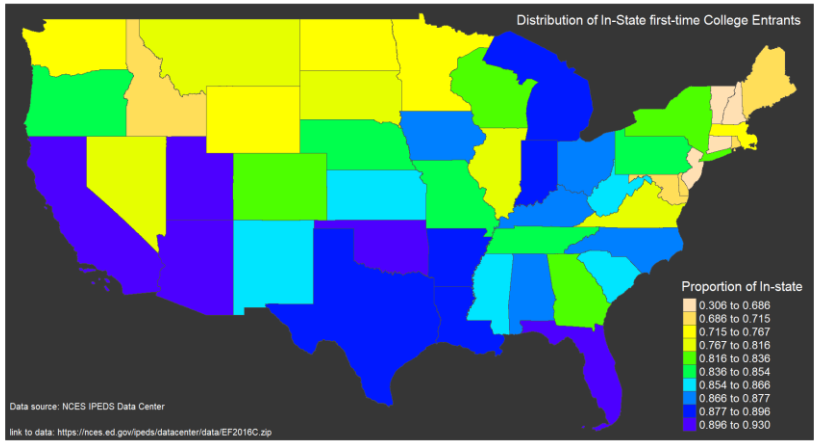

Figure 4(a). Distribution College entrants

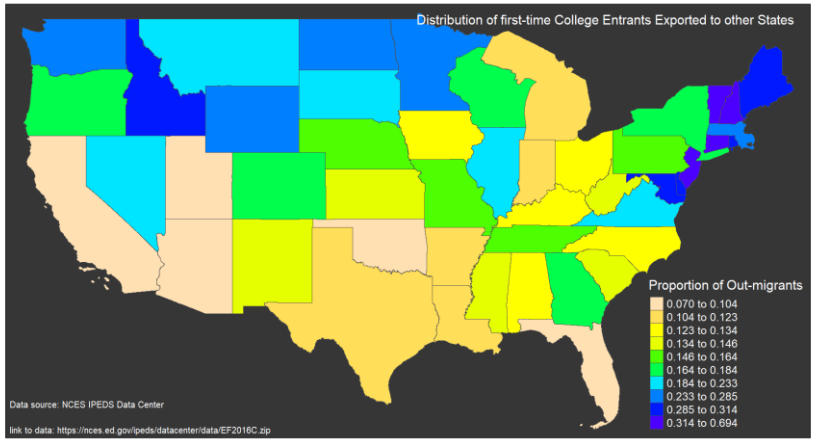

Figure 4(b). Distribution of Students Exported

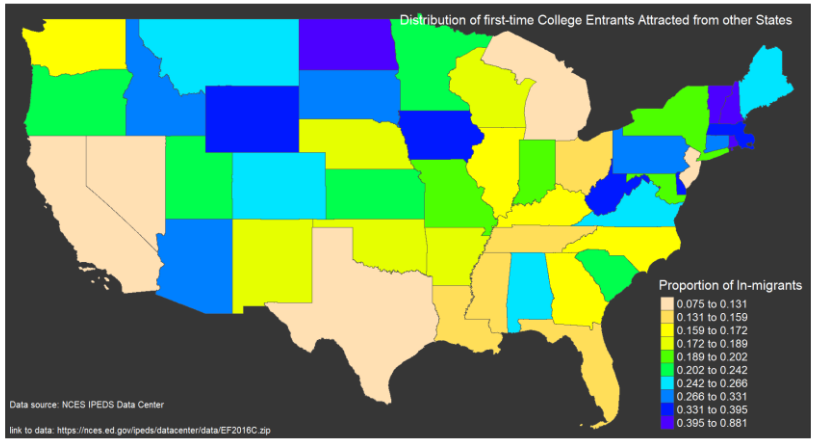

Figure 4(c). Distribution of Students Imported

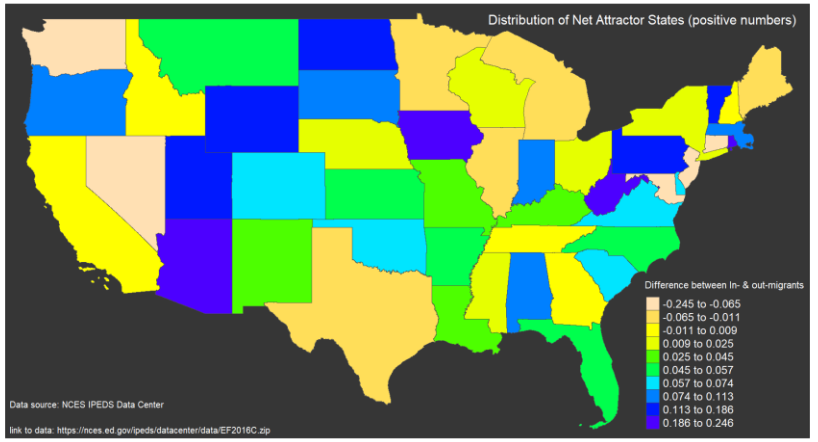

Figure 4(d). Distribution of Students Imported and Exported

Figure 4. Example of California's College Access Dynamics

This proposed framework aims at re(de)fining the ways access may be measured and affected by different forms of financial aid with special emphasis on time since high school graduation and sectors of initial enrollment. The interplay between time since graduation and sector of enrollment is considered important based on the following reasons. If college access is defined as the proportion of recent high school graduates (RHG) enrolling in public in-state four-year institutions, this measure would only account for 817 thousand of the 3.41 million high school graduates of 2009-2010 (which represents 23.9%). Under this view, the 34.4% of the total RHG freshman students who, on average, found access to college in the public two-year sector in the contiguous U.S. postsecondary education system in 2010-2011 would be discarded (IPEDS, 2012a; 2012b). This measure would also fail to account for 55% of the total number of in-state and out-of-state non-RHG (952,820) who were welcomed by the public two-year sector that academic year. Moreover, our definition of access to postsecondary education could be further improved by accounting for enrollment beyond the public sectors. As in the case of NRHG, ignoring the role private two- and four-year colleges have in college access, equates to assuming that these sectors have no role in providing access and that state financial aid disbursements have no effect whatsoever in variations of access to those sectors. Even though financial aid disbursements may indeed have no effect on access to these unexplored sectors, empirical evidence, practically absent, is needed to improve our understanding on the matter.

The relationship between college access and financial aid is arguably straightforward. The amount of financial aid that a given state disburses to support college attendance, in its different forms such as merit, need, and loans, is assumed to affect the variation of college access of that state (Cornwell et al., 2006; Doyle, 2010; Toutkoushian & Hillman, 2012). While our knowledge of their relationship has been greatly improved by previous research, this relationship has mainly been measured by, either considering only one form of aid, namely merit-based aid (see Cornwell et al., 2006; Doyle, 2006, 2010; Dynarski, 2000, 2008; Zhang, Hu, & Sensenig, 2013; Zhang & Ness, 2010) or by restricting the analyses to RHG

enrolling in the public two- and four-year sectors. The latter case is true in the very few cases when aid was expanded to also account for need-based (in addition to merit-based) and state appropriations in the models (see Toutkoushian & Hillman, 2012). This framework is based on the notion that our current understanding of the relationship between aid and access could be improved by including the following analytic strategies in the models: (a) accounting for more than one form of aid, (b) considering other postsecondary sectors that also provide access to college within a given state, and (c) modeling the potential impact of aid on access of NRHGs. In summary, the proposed framework calls attention to the complex ways in which access to higher education in a given state can be measured and the heterogeneous impact that different forms of financial aid disbursements may have on those definitions of college access.

Re(de)fining notions of college access, by considering different post-secondary sectors, levels, and time since high school graduation, is important as the inferences made from the effect of financial aid on college access may be a function of the ways the authors define the latter. For example, if access is defined as the proportion of RHG high school graduates at state *i* enrolling in in-state public four-year institutions, then the effect of need-based financial aid may not be important in influencing access to this sector (as concluded by Toutkoushian & Hillman, 2012). This important conclusion may be in part based on the definition of access these authors employed given the type of students typically attending public four-year institutions. That is, RHG enrolling in public four-year may rely more on merit- (Toutkoushian & Hillman, 2012) or on institutional-based aid (Doyle, 2010) rather than on need-based aid. On the other hand, and related to this point, if the definition of college access allows to model the effect of financial aid on enrollment patterns in the public two-year sector for both RHGs and NRHGs, this approach may better capture the influence of need-based aid on access to this sector. This claim is based upon the notion that the effect of need-based aid on access may be more accurately observed in sectors attracting higher concentrations of students from lower income backgrounds who do not necessarily qualify

for merit-based aid and who are likely to be in actual need of financial support. Consequently, given that students eligible to need-based help are more likely to be found in the public two-year sector (Doyle, 2009; Leigh & Gill, 2003; Long & Kurlaender, 2009; Melguizo & Dowd, 2009; Nora, 1990; Sandy et al., 2006; Stephan et al., 2009), need-based aid may be influential in providing college access to students enrolling at these institutions.

The proposed framework operationalizes (a) access, (b) aid disbursements, and (c) the ways they interact. With regard to (a) access to higher education, the author advocates for expanding our current operationalizations of access in order to include different sectors, levels and subpopulations of students. Researchers have traditionally excluded non-recent high school graduates from college access models (see Toutkoushian & Hillman, 2012, for an excellent summary on the topic), which may potentially mask the real measure of college access in a given state. In addition, conceptualization of access to college would benefit from accounting for mobility patterns of first time degree-seeking students. These patterns include in-state retention (students who graduated in state *i* and enrolled in state *i*), in-migration (students who graduated in state *i'* and moved in to state *i*), and out-migration (students who graduated in state *i* and moved out-of-state to state *i'*) of first-time degree-seeking student in a given academic year *t* and in a given state *i*.

In terms of re(de)fining (b) state financial aid disbursements, authors may call attention to the different types and amounts of aid that states disburse every year to ease college attendance (need-, merit-, non-grant-based aid, and state appropriations). After accounting for these types of aid, authors may emphasize two different ways they can operationalize "student per capita aid disbursements" and how the level of precision used in this process may impact the inferences made from the models. In the first approach used to create these per full-time equivalent student (FTE), researchers have relied on the total state population who is "college-age eligible" (18-24 years of age). By accounting for many more people eligible than the actual number of students enrolled (making them actually eligible), this approach may potentially bias the effect of aid on access by making it look less important

than in reality. For example, based on 2010 Census data the population 18-24 years in Alabama is 479,175, but, based on actual 2010-2011 IPEDS enrollment data (2012a; 2012b), the total number of resident students enrolled full-time in any form of undergraduate education is 193,123, or 40% of the college-age eligible pool in Alabama, the corresponding ratio in the contiguous U.S. is 38.11%. The rationale behind this claim is that by dividing the total amount of aid by a number that is larger than the actual number of potential aid recipients, each student who is a potential recipient in actuality would receive a lower amount, on average, than what was actually disbursed. A different, and arguably a more precise, approach is based on the inclusion of actual resident students enrolled in undergraduate education in a given state conditional on full-time equivalent status. It is hypothesized that these two operationalizations will render different inferences when measuring the effect of per capita aid disbursement on college access.

Regarding the rather complex (c) interplay between access and financial aid disbursements, the authors may argue that the effect of diverse forms of financial aid per FTE on access may be heterogeneous depending on what sector, level and subpopulation of first-time degree-seeking students the author is observing. The working hypothesis is that, *ceteris paribus*, students who actually need the aid should be affected the most by need-based aid disbursements. For example, non-recent high school graduates enrolling in public two-year institutions may be affected the most by need-based aid, compared to any of the other subpopulations analyzed, namely recent high school graduates enrolling in private four-year institutions. Finally, given that students move into and out of state to attend college, the spatial location of the state, along with regional and state agreements should be accounted for before making inferences from the models. Consequently, this proposed framework claims that spatial dependence is an issue that should not be overlooked. The models fitted using this proposed framework should test whether outcome variables present evidence of spatial dependence. While the notions discussed so far seem plausible, empirical evidence is required to corroborate or discard them. This proposed framework aims at

providing researchers with the means to obtain such evidence.

Thus far, the discussion has been centered on the relationship between increasing in-state enrollment and state financial aid disbursements. However, state financial aid disbursements (other than merit-based) may also have an effect on student mobility patterns in the forms of in-migration (attracting students from other states) and out-migration (sending students out of state). This relationship is an important topic due to the benefits associated with attracting non-resident students and retaining students instate. At the state and local levels, the immediate benefits associated with retaining RHG and attracting non-resident students come from expenditures associated with the cost of living while attending college. In addition, states may also benefit in the long run if a significant proportion of college graduates decides to remain in the state's workforce after graduation (Cooke & Boyle, 2011). The authors' current understanding of relationships between mobility patterns and financial aid has emphasized state and regional college tuition discounts that may be appealing to RHG and NRHG to cross their states borders to enroll in college (Zhang & Ness, 2010). Consequently, variables capturing this potential influence should be included in the models.

Cooke and Boyle's paper constituted a remarkable step forward in explaining student mobility patterns. It was the first to simultaneously model the influence of origins and destinations on mobility patterns. Motivated by these authors' contribution, along with Zhang and Ness's study, the proposed framework should account for state and regional agreements (Zhang & Ness, 2010) and state characteristics of states of origin and possible destinations (Cooke & Boyle, 2011). These destinations are defined as neighboring states in the models testing for the variation of college access, in-migration, and out-migration patterns as a function of financial aid. The assumption behind the analyses is that states' enrollment patterns (proportion of access, in-migration and out-migration) is affected not only by each state's characteristics (such as financial aid disbursements per FTE, state and regional tuition reduction agreements, unemployment rates, college-age population, disposable income after taxes, proportion of the population 25 and older with college degree), but also by the

characteristics of their neighboring states. In other words, states' location is assumed to play a role in the relationship between diverse forms of college access and financial aid, that until now has been difficult to be modeled.

College Access Framework

Every year, a given state *i* "produces" *x* number of high school graduates who enrolled at any form of post-secondary education. The total number of first-year students can be classified in in-state or out-of-state students depending on the state where they decided to attend college. In addition to the number of students produced by a given state, such state also hosts *y* number of students who came from other states *i'*. Thus, the total number of first-time, full-time students hosted by a given state *i* in a given academic year *t* is comprised by high school graduates from that state *i*, and high school graduates from other states *i'*. In short, students related to state *i* can be separated in three types: students who attended high school at state *i* and (a) enrolled in college at state *i*, (b) enrolled in college in a difference state *i'*, and (c) students who graduated from high school at state *i'* but enrolled at state *i*.

Figure 1 exhaustively partitions the population of first-time degree-seeking college students hosted by a given state *i* in a given academic year *t*. This figure also emphasizes the complex ways in which college access can be conceptualized and constitutes the college access framework of total college freshman in state *i* that is proposed and that could be analyzed in future studies. The partitions A, E and F of Figure 1 represent the *x* number of high school graduates a given state *i* produced in year *t*. From these recent high school graduates (RHG) only partitions A and F enroll in college within 12 months of graduation; students in partition A do so in state *i* (in-state students), while students in partition F enroll in college out-of-state, which is also known as out-migration of RHG. The portion of RHG of state *i* who did not enroll in college within 12 months of college graduation is captured by partition E. The sizes of these partitions vary from state to state and the actual estimates of

each one can be obtained from survey data provided by IPEDS (2012a; 2012b; 2012c; 2012d) as shown in Table 1.

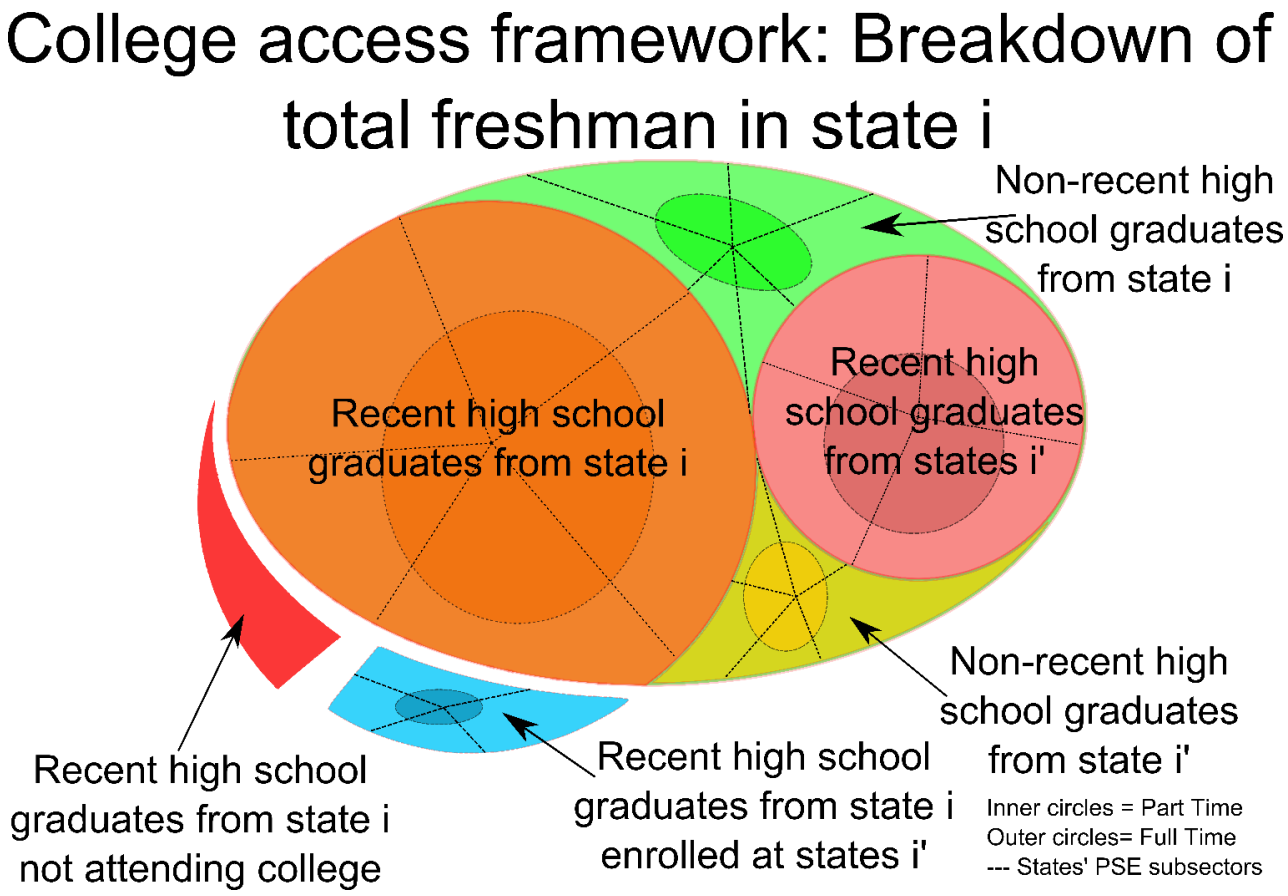

Figure 1. College access framework: Breakdown of total freshman in state *i*

Table 1
Total state's first-time, degree/certificate seeking undergraduate students (IPEDS, 2010)

St.	Hosted	Prod.	In-St.	In-mig	Out-mig	%In-St.	%Out-mig	%In-mig	%Prod
AL	53.68	46.67	40.53	13.15	6.15	86.83	13.17	24.50	86.95
AZ	82.94	62.90	57.33	25.61	5.58	91.14	8.86	30.88	75.84
AR	31.02	29.07	25.67	5.35	3.41	88.29	11.71	17.25	93.73
CA	436.19	435.76	400.04	36.15	35.72	91.80	8.20	8.29	99.90
CO	58.33	53.64	44.15	14.17	9.48	82.32	17.68	24.30	91.96
CT	38.05	43.20	27.10	10.95	16.10	62.74	37.26	28.77	113.54
DE	9.69	8.71	6.00	3.69	2.71	68.86	31.14	38.11	89.88
DC	11.53	4.47	1.37	10.16	3.11	30.55	69.45	88.14	38.82
FL	205.85	192.91	174.37	31.48	18.55	90.39	9.61	15.29	93.72
GA	103.69	104.31	86.69	17.00	17.62	83.11	16.89	16.40	100.60
ID	13.30	13.13	9.26	4.05	3.88	70.48	29.52	30.41	98.73
IL	124.51	134.62	103.55	20.96	31.07	76.92	23.08	16.84	108.12
IN	84.21	76.41	67.62	16.59	8.79	88.50	11.50	19.70	90.74
IA	47.98	34.45	30.09	17.89	4.35	87.36	12.64	37.28	71.79
KS	34.90	32.56	27.84	7.05	4.71	85.52	14.48	20.21	93.29
KY	44.76	42.76	37.04	7.71	5.72	86.63	13.37	17.23	95.54
LA	45.41	43.77	38.74	6.67	5.03	88.51	11.49	14.69	96.38
ME	12.54	13.27	9.30	3.24	3.97	70.07	29.93	25.86	105.81
MD	56.14	64.79	45.02	11.11	19.76	69.49	30.51	19.79	115.41
MA	83.90	74.83	54.01	29.89	20.83	72.17	27.83	35.63	89.20
MI	107.48	109.93	97.99	9.49	11.94	89.14	10.86	8.83	102.28
MN	56.98	59.81	45.34	11.64	14.47	75.81	24.19	20.42	104.97
MS	37.70	37.01	32.02	5.68	4.99	86.52	13.48	15.06	98.17
MO	66.99	63.82	54.19	12.80	9.63	84.91	15.09	19.11	95.27
MT	10.19	9.49	7.54	2.66	1.95	79.43	20.57	26.08	93.06
NE	19.54	19.00	15.91	3.64	3.10	83.71	16.29	18.60	97.24
NV	20.01	22.69	18.35	1.66	4.34	80.88	19.12	8.29	113.39
NH	14.18	14.07	8.04	6.14	6.03	57.13	42.87	43.31	99.23
NJ	81.97	111.68	75.43	6.54	36.25	67.54	32.46	7.98	136.25
NM	23.31	22.11	18.93	4.38	3.19	85.59	14.41	18.80	94.86
NY	214.55	208.52	173.19	41.36	35.33	83.06	16.94	19.28	97.19
NC	97.27	92.26	80.52	16.75	11.74	87.28	12.72	17.22	94.85
ND	9.36	7.01	5.20	4.16	1.82	74.07	25.93	44.49	74.94
OH	135.13	133.54	116.03	19.11	17.51	86.89	13.11	14.14	98.82
OK	46.94	43.09	38.73	8.21	4.36	89.88	10.12	17.49	91.80
OR	36.99	33.70	28.19	8.79	5.51	83.65	16.35	23.77	91.13
PA	154.10	133.39	112.56	41.54	20.83	84.38	15.62	26.96	86.56
RI	16.74	11.11	7.66	9.08	3.45	68.96	31.04	54.23	66.38
SC	49.21	45.01	38.96	10.25	6.05	86.55	13.45	20.82	91.48

Continued on next page

Table 1 – continued from previous page

St.	Hosted	Prod.	In-St.	In-mig	Out-mig	%In-St.	%Out-mig	%In-mig	%Prod
SD	10.37	8.99	7.11	3.26	1.88	79.09	20.91	31.45	86.68
TN	65.98	65.80	56.02	9.96	9.78	85.13	14.87	15.10	99.72
TX	249.32	257.36	230.50	18.81	26.85	89.57	10.43	7.55	103.22
UT	37.45	31.04	28.86	8.59	2.18	92.98	7.02	22.94	82.87
VT	8.32	5.81	3.06	5.26	2.75	52.66	47.34	63.21	69.86
VA	84.56	78.61	64.02	20.54	14.59	81.45	18.55	24.29	92.96
WA	43.08	47.42	36.08	7.01	11.34	76.08	23.92	16.26	110.06
WV	24.92	17.82	15.32	9.61	2.50	85.95	14.05	38.55	71.49
WI	62.37	61.45	50.82	11.54	10.63	82.71	17.29	18.51	98.53
WY	6.09	5.03	3.85	2.23	1.18	76.64	23.36	36.66	82.65

%Instate=Instate/Produced, %In-mig=In-migration/Hosted, %out-migration=Out-mig/Produced
%Produced=Produced/Hosted. All the estimations include only title IV institutions as of 2010-2011

The corresponding condensed distributions for the academic year 2010-2011 are presented in Table 2.[5] Each partition of Figure 1 contains an inner-darker circle along with internal divisions. The inner circle represents part-time freshman and the outer circle represents full-time freshman. The divisions represent the post-secondary sectors and levels that configure each state's higher education system within each partition. As mentioned above, the current state of the literature on college access and different forms of financial aid is founded upon traditional measures of college access which have considered only one or two triangles formed in the partition A. That is, college access is currently defined as the proportion of all RHG produced by state *i* who enrolled full-time in public two- (sub-partition A4) and/or four-year institutions in state *i* (sub-partition A1). Scholars who included outmigration of RHG has also limited their analyses to either enrollment in public two- and four-year colleges out-of-state (subpartitions F4 and F1, respectively) or on only merit-based aid (see Cornwell et al., 2006; Dynarski, 2000, 2008; Toutkoushian & Hillman, 2012; Zhang et al., 2013; Zhang & Ness, 2010).

[5]All coding schemes required to replicate the proportions along with the survey data available on-line is available upon request. These computations include only students enrolling in Title IV eligible institutions in the contiguous U.S.

Table 2

*Distribution of students in-migrating to, remaining in, or out-migrating from state **i** in 2010-2011 (source IPEDS)*

	In-migrated			In-state			Out-migrated		
	μπ	Min	Max	*μπ*	Min	Max	*μπ*	Min	Max
μ Total Recent HS Grad.	8873	1103	34000	36802	628	249894	7901	783	31666
μπ RHG	0.266[1]	0.062	0.93	0.781[4]	0.235	0.922	0.218[2]	0.077	0.764
4-year public RHG	0.447*	0.011	0.865	0.482†	0.102	0.803	0.359†	0.208	0.626
4-year priv. nonprofit RHG	0.428*	0	0.967	0.125†	0	0.377	0.484†	0.222	0.732
4-year priv. profit RHG	0.018*	0	0.11	0.013†	0	0.04	0.029†	0.009	0.069
2-year public RHG	0.073*	0	0.357	0.344†	0	0.691	0.075†	0.008	0.301
2-year or less public/priv. RHG	0.031*	0.001	0.275	0.034†	0.011	0.176	0.051†	0.01	0.118
μ Total Non-Recent HS Grad.	3649	345	16833	19445	739	150148	2562	392	7256
μπ NRHG	0.266[3]	0.065	0.697	0.832	0.409	0.955	0.167[4]	0.59	0.044
4-year public NRHG	0.231**	0.03	0.864	0.157††	0.009	0.642	0.107††	0.032	0.275
4-year priv. nonprofit NRHG	0.191**	0	0.567	0.037††	0	0.135	0.13††	0.046	0.324
4-year priv. profit NRHG	0.188**	0	0.774	0.071††	0	0.274	0.388††	0.152	0.658
2-year public NRHG	0.219**	0	0.668	0.546††	0	0.871	0.168††	0.061	0.558
2-year or less public/priv. NRHG	0.168**	0.005	0.563	0.186††	0.028	0.485	0.204††	0.059	0.469

[1]with respect to (wrt) hosted RHG, [2]wrt produced RHG, [3]wrt hosted NRHG, [4]wrt produced NRHG

*wrt in-migrated RHG †wrt in-state RHG, **wrt in-migrated NRHG ††wrt in-state NRHG

Figure 1 further shows that while the current conceptualization used to study the effect of financial aid on college access has greatly improved our understanding on the matter, it could be expanded in hopes to continue improving our understandings of the association of access and financial aid. In addition to highlighting that the total number of first-time freshman in a state *i* is not only composed by *y* number of RHGs (partitions A, B) and *z* number of NRHGs (partitions C, G), these *y* and *z* number of freshman in a state *i* are also comprised of resident (partitions A, C) and nonresident students (partitions B, G). It is under this frame that state and regional agreements may play an important role in attracting students to these partitions (B and G), or in sending students out-of-state (partitions D and F). The main assumption behind the influence of state and regional tuition discount agreements, is that neighboring states that share agreements are far more likely to exchange students than neighboring states with no agreements being shared.

Figure 1 also shows that all of these subgroups of first-time degree-seeking students (in-state, in-migrated, and out-migrated students) are distributed in different sectors and levels of that state's postsecondary education system. These sectors and levels are represented with numbers ranging from 1 to 5, where 1 is public four-year sector, 2 is private not-profit four-year sector, 3 is private for-profit four-year sector, 4 is public two-year sector, and 5 includes two-year or less for profit and not-profit sectors. Once again, the potential limitation of current research consists in assuming that different forms of financial aid only affect the variation of one or two of the sub-partitions of partition A. The hypothesis of this proposed framework is that different forms of aid shift the distribution of freshman enrollments to different sectors conditional on time span since high school graduation (*i.e.*, RHG and NRHG). For example, need-based aid may shift to a greater extent the enrollment patterns of NRHG in the public two-year sector, and this effect may be even more pronounced than the effect of this form of aid on RHG also enrolling in this sector.

Incorporating NRHG Into the Measures of College Access

While important, the inclusion of NRHG in the measures of college access is

challenging. Going back to the first example, if recent high school graduates enrolling in college (RHGC) in year *x* is used as the dividend and total RHG (TRHG) of that year is the divisor ($RHGC_t/TRHG_t$), the resulting proportion (0.53 in 2010-2011) comes from dividing a fraction of the whole by its whole at time *t*. Simply adding NRHG enrolling in college at time *t* ($NRHGC_t$) to the previous division would be inaccurate because $RHGC_t$ and $NRHGC_t$ are not part of the same whole $TRHG_t$ even though both of them enroll in college for the first time at time *t*. $NRHGC_t$ were part of the TRHG at time $t - n$ ($TRHG_{t-n}$) and the real issue is that this total would be a function of going back *n* number of years to add the fraction of $TRHG_{t-n}$ who never enrolled in college until time *t*, which is virtually impossible given that IPDES surveys do not capture high school graduation year of new entrants. The problem associated with pretending that $RHGC_t$ and $NRHGC_t$ are the part of the same whole (because they enroll in college the same academic year) is that dividing their sum by their assumed whole ($RHGC_t + NRHGC_t)/TRHG_t$, will result in an inflation of the real access to higher education in the contiguous United States. Thus, omitting them deflates access estimates to higher education, but naively including them inflates access to higher education.

Solving the Issue. A reasonable solution to the problem just depicted consists of measuring shifts in proportions of enrollments among different sectors for $RHGC_t$ and $NRHGC_t$ as a function of financial aid disbursements. For instance, looking at Figure 1 one could measure if different forms of aid shift proportions of enrollments within $RHGC_t$ and $NRHGC_t$. That is, looking only at partition *A* at time *t*, which represents $RHGC_t$ who enrolled in-state at time *t*, one could start asking if specific forms of aid (merit, need, loans) impact the variation of the proportion of enrollments in the public four-year sector. Under this perspective, note that the total of partition A in a state *i* at time *t* (TA_{it}) could be the divisor of the subpartition A_{it} who enrolled in sector 1 ($A1_{it}$), which represents public, four-year colleges in-state *i* at time *t*. Similarly, the previous rationale could be extrapolated to the $NRHGC_t$, were its total C in state *i* at time *t* (TC_{it}) would be the divisor of specific sectors researchers or analysts may aim to examine.

In addition to looking at shifts in proportions within states, researchers could also

analyze out-migration and in-migration patterns of $RHGC_t$ and $NRHG_t$. For example, it is possible to analyze if aid disbursements have any effect on reduction of out-migration for $RHGC_t$ enrolling in private four-year institutions out-of-state, which is the result of dividing the total sub-partition $F2_{i't}$ by its total $TF_{i't}$, where the *i'* subscript corresponds to any state *i'* other than the students' home state *i*. Finally, analysts could test if aid disbursements affect the in-migration of RHGC to specific sectors of state *i*. It could be the case that merit-based aid disbursements affect enrollment in the public four-year sector of out-of-state students ($B1_{i't}$ /TB_{it}) while it has no effect on enrollments in the public two-year sector. All these data sources are available from the IPEDS and the author can share them upon request, including all coding schemes to replicate all the tables presented here.

Re(de)fining Access and Financial Aid Association

With the purpose of building upon previous research to expand the ways current research is addressed, this manuscript shows a model of financial aid impact on college enrollment in Figure 2. This figure builds upon the information presented in Figure 1 and adds measures of financial aid disbursed by state *i* during an academic year. As Figure 2 shows the total student state financial aid per full-time equivalent student (FTE) of that state in a given year consists of three main forms of financial aid as presented by the National Association of State Student Grant and Aid Programs (NASSGAP, 2018): need-based, merit-based and non-grant aid (loans or amounts that are to be repaid or worked for in order to obtain them, this point was depicted in the literature review section). In addition to these three forms of aid, a given state disburses *x* amount in state appropriations to institutions located in different sub-sectors of its post-secondary education system.[6] Following Toutkoushian and Hillman (2012), while state appropriations are also

[6]In the 2010-2011 even some institutions in the private for-profit and not-for-profit sectors reported having received state appropriations. Following Figure 2 these amounts aggregated at the state level are presented in Table 1.

assumed to influence access to college little attention has been given to measuring its impact on access; it is then important to comprehensively analyze its impact on moderating enrollment across different sectors and across different student sub-populations, such as RHG and NRHG.

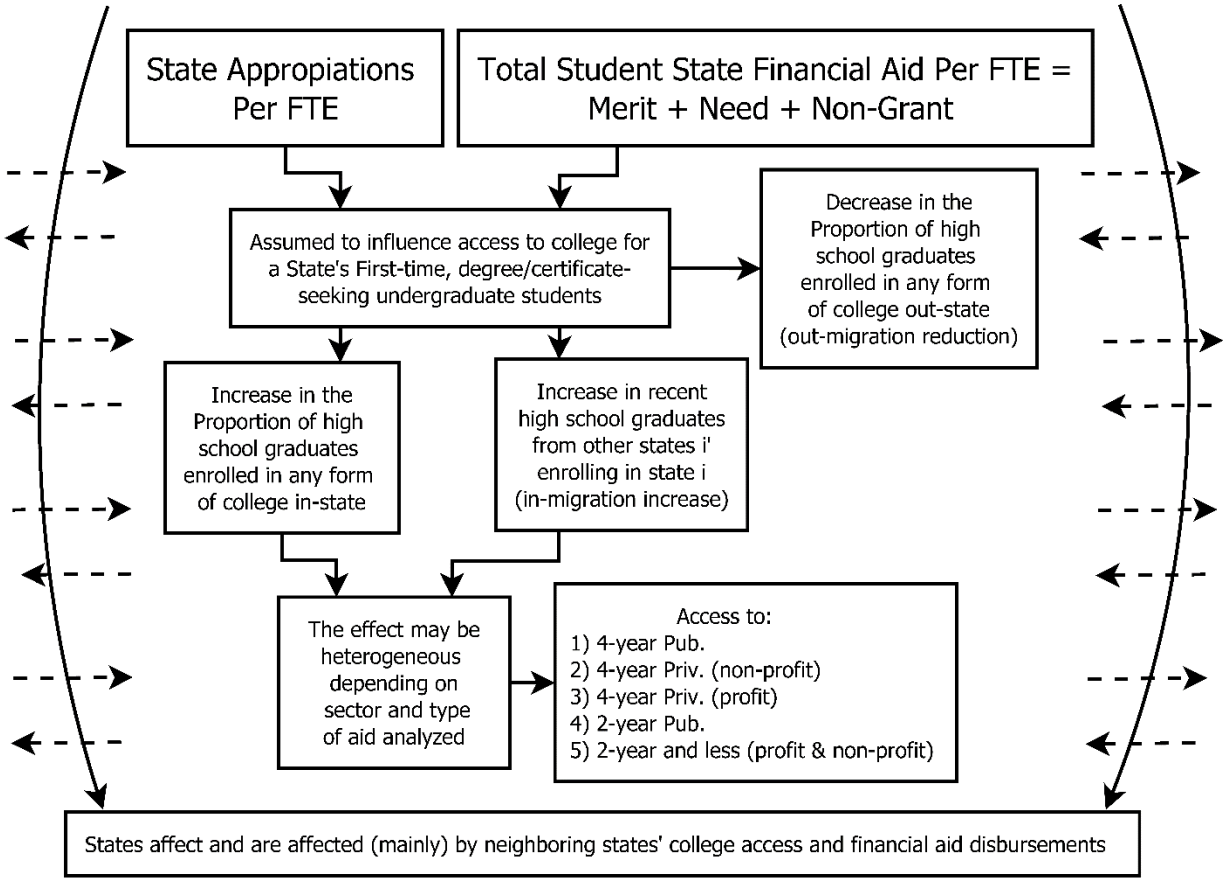

Figure 2. Conceptual and operational models fitted in this study

The effect of these forms of aid on college access could be measured in at least three categories: (a) decrease in student outmigration (partitions D and F of Figure 1), (b) increase in the proportion of RHG and non-RHG enrolled in any form of college in-state (partitions A and C of Figure 1), and (c) possible increase in the in-migration of students from other states i^t to state *i* (partitions B and G of Figure 1). With respect to student mobility (in-migration and out-migration) of freshman students, building upon important work on the matter (see

Cooke & Boyle, 2011; Zhang & Ness, 2010) this proposed framework posits the need to model the influence of spatial location of a state on access and financial aid disbursements. The rationale behind this notion is that states affect and are affected (mainly) by neighboring states' college access patterns, financial aid disbursements and other state characteristics (Cooke & Boyle, 2011; Zhang & Ness, 2010). Consequently, the incoming and outgoing arrows shown in Figure 2 represent the simultaneous effect of each states on its neighboring states as well as the incoming effects of the latter on the former on college access and mobility patterns.

Some of the relevant research questions that can be addressed using the proposed framework are:

1. Is there evidence of spatial dependence in the measures of college access, financial aid disbursements and state-level characteristics that may bias the inferences made from the models if these dependences are not modeled?
2. Do different forms of aid shift the distribution of freshman enrollments to different sectors in-state conditional on time span since high school graduation after controlling for state-level characteristics, and potential spatial dependence in the models?
3. Do different forms of aid affect the distribution of in-migration and out-migration students to different sectors conditional on time span since high school graduation after controlling for state-level characteristics, and potential spatial dependence in the models?

The first question can be addressed relying on Moran's I, a technique to test for spatial dependence as described in the Appendix section. In case the outcome variables (shifts in the distribution of enrollment in-state, in-migration, and out-migration) present evidence of spatial dependence, the second and third questions may be addressed using Simultaneous Autoregressive Models, which will correct for the spatial dependence of the error terms

potentially captured by the use of the Moran's I approach —also discussed in the Appendix section.

Some Initial Implications

Aggregated measures of financial aid (e.g., lumping together need-, merit- and loan-aid), may seem to fail short in affecting variation in access to higher education. This is particularly true when ignoring specific sectors and levels configuring each state's higher education system. Similarly, ignoring that RHG and NRHG have divergent monetary needs, on the one hand, and that financial aid policies may differentiate them, on the other hand, constitutes another important source of bias regarding the effect of divergent forms of financial aid on divergent types of students and sectors of enrollment. For example, in Tennessee the College Promise program targets RHG who met certain academic requirements and fill up the Free Application for Federal Student Aid (FAFSA) form. NRHG, however, are not eligible for this free college program. Notably, NRHG may be eligible for a non-traditional HOPE financial aid, but this aid does not target college access but rather may influence continuation. In non-traditional HOPE, eligible NRHG may apply after having completed 12 consecutive semester hours (around four classes) earning a minimum of 2.75 GPA.[7] This brief discussion highlights the importance of accounting for diversity of the student population, types of aid, and institutions for the real effect of financial aid may be found in shifting enrollments to different sectors (*i.e.* two-year as a function of state appropriations and need-based aid) and different time since high school graduation [RHG vs NRHG]).

Although important, the distinction between types of students hosted by a given state

[7] For more information about this program, including recent changes such as change of eligibility given sector of attendance, please see https://www.tn.gov/collegepays/money-for-college/tn-education-lottery-programs/tennessee-hope-scholarship---nontraditional.html

may not have been adequately operationalized when building indicators that measure average amount of dollars spent per FTE student offered at a given state. For example, NASSGAP reports consider the total grant dollars per student as the average amount received by all 18-24 years of age residents of a given state. And this measure does not differentiate between need-based and non-need (merit) based grant dollar amounts disbursed.

The proposed framework argues that using state population ages 18-24 to build indicators aimed to capture states financial aid effects on college access may be biasing the effect of financial aid downwardly. Only a fraction of that 18-24 years population is actually "eligible" to receive that aid. For example, in the academic year 2010-2011, the California's population ages 18-24 was 3,922,951 whereas the population of high school graduates who enrolled at any form of post-secondary education was 439,420 students, representing a difference of 3.5 million. Consequently, an indicator of average aid disbursed per student, built using the 18-24 years' population the *per capita* amount, is $324.48 (1.27E+09/3.92E+06). Conversely, when only accounting for state residents who may be eligible to some portion of that aid (since they actually enrolled in college), the *per capita* aid is $2,896.90 (1.27E+09/4.39E+05). This difference may completely change the inferences made about its impact on college access and migration decisions. In sum, assuming that all the population ages 18-24 in a given state should be considered as potential recipients of financial support may mask the effect of the aid amounts disbursed by the states on college access.

In addition to the conservative indicators of financial aid typically employed, it is likely that those indicators have heterogeneous effects across different sectors configuring a given state's postsecondary education system. State appropriations per student are supposed to only impact public institutions, thus students enrolled at private colleges may add noise to model estimates. Furthermore, it is likely that need-based aid had a stronger impact on access in two-year institutions, as the two-year sector is known for being an access point for underrepresented, low income students. With this in mind, models that disaggregate

conditional on postsecondary education sector should be fitted before making strong claims such as lack of association between changes in the level of need-based grants and access to higher education. It is known that merit-based aid impacts where, not whether, students will attend college (Cornwell et al., 2006; Doyle, 2010), thus before concluding that need-based financial aid does not expand access, more evidence is required. This proposed framework aims at providing researchers with the means to conduct more comprehensive and less biased analyses.

Although some may argue that the inclusion of Federal appropriations should also be included, the distribution of this financial disbursement is practically absent in most states. That is, in comparative terms, Federal appropriations represent a minimal contribution. Across the contiguous United States, 95% of the total state and federal appropriations combined come from states appropriations. Figure 3 shows the distribution of these state and federal amounts [Figures 4(a) and 4(b)], along with their combined amount [Figure 3(c)] and the proportion of the total that comes from state appropriations [Figure 3(d)]. In general note that in States like California, Texas, and New York both state and federal appropriations are in the top distribution decile for Figures 4(a), 4(b), and 4(c), but this is not the case for 4(d), or the proportion of state appropriations from the total. This is explained by their robustness in both measures, whereas for other states (e.g., Nevada, Utah, South Dakota), 100% of these amounts come merely from the state.

In synthesis, considering that different sectors attend different subpopulations of students (e.g., two-year institutions tend to attract low-income, first-generation in college students), failing to disaggregate the models may mask heterogeneous effects of financial aid disbursed by a given state as the effect of financial aid is assumed to vary conditional on the type of aid disbursed. For example, merit based-aid should have no effect on enrollment patterns in the two-year sector, as these institutions traditionally have open-door admission policies, thus do not require high academic standards associated with merit-based aid disbursements. Consequently, while merit-based aid is assumed to influence enrollment

patterns at more selective institutions, need-based aid should influence enrollment patterns at less selective institutions such as two-year colleges.

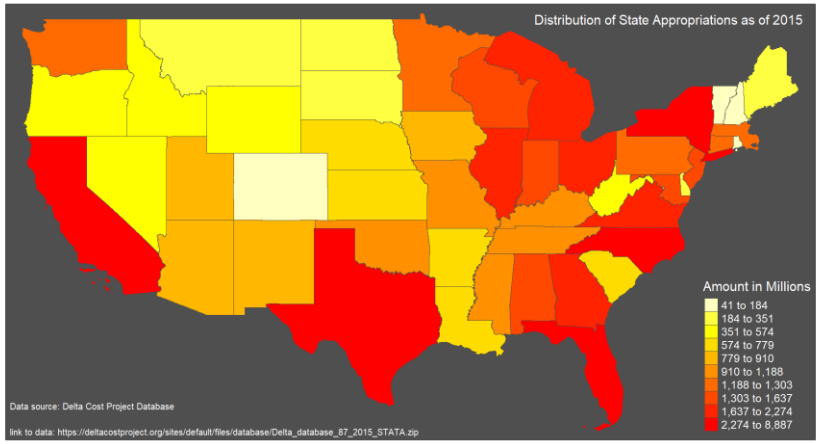

Figure 3(a). Distribution of State Appropriations as of 2015

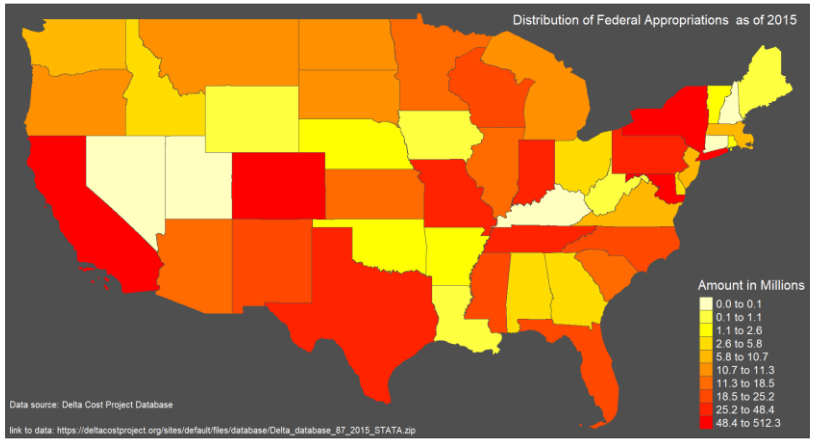

Figure 3(b). Distribution of Federal Appropriations as of 2015

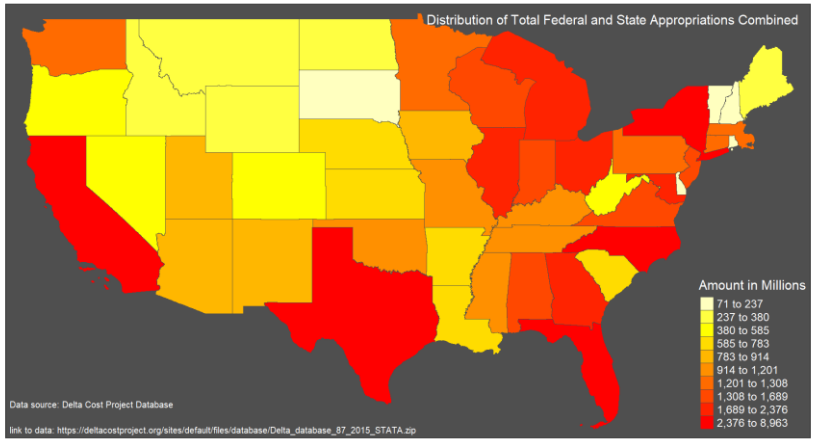

Figure 3(c). Distribution of State and Federal Appropriations as of 2015

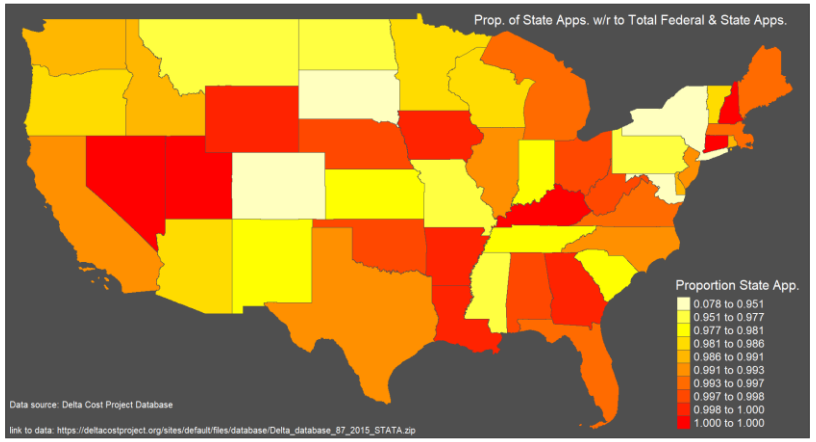

Figure 3(d). Distribution of Proportion of State Appropriations from the total shown in Figure 3(c) as of 2015

Figure 3. State and Federal Appropriations in 2015 (Delta cost Project data)

Closing Remarks

The purpose of presenting these myriad of possibilities in measuring and defining college access rates is not to over-complicate our conceptualization of this important issue, but to offer an innovative perspective that may enable more precise operationalizations using sources of big data critically. The data sources and free and powerful analytic software required to conduct rigorous analyses are both available; it is the authors' obligation as education researchers to use them critically in hopes to move the field forward.

This closing section offers some closing remarks with regard to training and critical thinking on challenges and opportunities related to the use of big and geocoded data in education research (see González Canché, 2018a, for an expanded version).

1. It is usually recommended to revisit cornerstone research incorporating big and geocoded data. This revisiting process involves addressing old important issues using new approaches and expanding on the scope that previous research was able to cover.
2. When possible, researchers should incorporate more than one analytic sample as validity and robustness checks. This holds true even when analyzing survey and sample data, such as the one provided by the National Center for Education Statistics.
3. Researchers should aim to test for effect heterogeneity as it is not realistic to assume that a given predictor variable of interest may impact participants with the same or very similar magnitude. Also, the disaggregation of analytic samples based on participants' attributes such as gender, ethnicity, and RHG and NRHG statuses pushes us to use critical lenses in education research.
4. Always prioritize relevance of research question over use of sophisticated methods and big data.
5. The use of theory is crucial when using big data and sophisticated methods.
6. Invest in the development/strengthening of big and geocoded data management skills.

Big and geocoded data offers the possibility of improving our understanding of higher

education issues. One of the most important recommendations this manuscript offers is regarding the need to train researchers in the use of big and geocoded data. Overall, the message is clear: given the availability of large amounts of data, graduate programs in education should continue investment in the development of researchers' visual-display, data management, and statistical modeling skills. This training will not only make them more marketable but will also benefit the field in general. Finally, this training should not be conceived as a substitute to the development of theoretical understandings and investment in qualitative skills, the false quant versus qual dichotomy is archaic and just creates division that weakens our understandings and knowledge building prospects.

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Appendix: Spatial Econometric or Geostatistical Analyses: Moran's *I* and SAR Models

Moran's *I*.

The spatial dependence of the outcome variables may be tested relying on Moran's I, which is perhaps the most frequently used and flexible technique to test for spatial dependence. Equation (1) shows that Moran's *I* is calculated as a ratio of the product of the variable of interest and its spatial lag, with the cross-product of the variable of interest, which is then adjusted for the spatial weights used

$$I = \frac{n}{\Sigma_{i=1}^{n}\Sigma_{j=1}^{n} w_{ij}} \frac{\Sigma_{i=1}^{n}\Sigma_{j=1}^{n} w_{ij}(y_i-\bar{y})(y_j-\bar{y})}{\Sigma_{i=1}^{n}(y_i-\bar{y})^2}, \quad (1)$$

where y_i is the *ith* outcome of interest at state$_i$, $\bar{y}$ is the mean of the outcome variable, and w_{ij} is the spatial weight resulting from the link between state$_i$ and states$_j$ that constitute the neighboring states of state$_i$. The states' neighboring structures are shown in Figure 4. In the case of spatial independence between states' outcomes and the mean outcome, the estimated value of Moran's *I* would be zero. As the differences from the global mean depart from zero, the product of this difference times w_{ij} would become more pronounced, thus rendering evidence of spatial dependence.[4] The values of Moran's *I* range from −1 (perfect dispersion) to +1 (perfect correlation). A value of zero indicates a random spatial pattern (see Bivand, Pebesma, & Gómez-Rubio, 2008, 2013). To provide more insight behind the rationale of Moran's I, note that the estimate of *I* can also be obtained through an iterative version of an OLS model as follows

$$\bar{y}_j = \alpha + y_i\beta + U_i \quad (2)$$

where $\bar{y}_j$ or the average outcome of the neighbor(s) of y_i is regressed on y_i to obtain β, which iteratively will yield the value of I in equation (1).

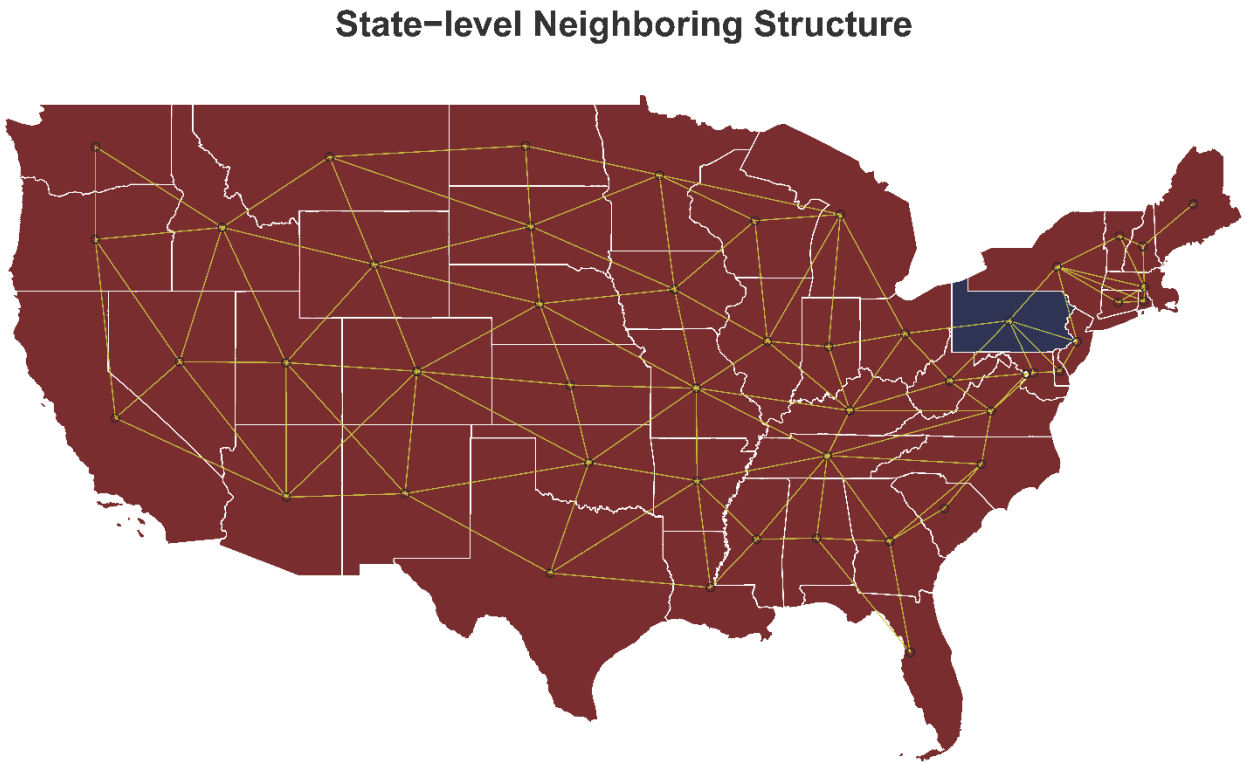

Figure 4. Neighbors at the state level

Simultaneous Auto-Regressive (SAR) Model. The simultaneity resulting from the mutual influence of two neighbors i and j can be represented as

$$y_i = \alpha_j y_j + X_i\beta + \epsilon_i \quad (3a)$$

$$y_j = \alpha_i y_i + X_j\beta + \epsilon_i, \quad (3b)$$

where α is a coefficient associated with the spatially lagged version of the outcome of interest and represents that the observed values of y at location i depend on those at location j, and *vice versa*. X_i represents other sets of covariates and predictors in the model, and ϵ_i represents the error terms that the SAR model rendered, as described subsequently in equation (5). In the case of n observations with two or more neighbors (Gonzalez Canche, 2019b), equations (3a) and (3b) can be generalized as

$$y_i = \lambda \sum_{j=1}^{n} w_{ij} y_j + X_i\beta + \epsilon_i, \quad (4)$$

where λ is a spatial autocorrelation parameter and w_{ij} is a matrix that represents spatial dependence conditional on the neighboring structure used. In this study, w_{ij} was built from

neighboring states sharing one border or a corner (*e.g.* California's neighbors are Arizona, Nevada, and Oregon), as shown in Figure 5. Each SAR output presents a coefficient λ that, if statistically significant, indicates there is a problem of spatial dependence that needs to be addressed.

In SAR, the error terms ϵ_i are the result of the following modeling procedure:

$$e_i = \sum_{i=1}^{m} w_{ij} e_j + \epsilon_i, \quad (5)$$

here ϵ_i represents the residual errors that are assumed to be independently distributed following a normal distribution with zero mean and diagonal covariance matrix Σ_ϵ with elements $\sigma_{\epsilon i}^2, i = 1, \dots, m$, and constant variance σ_ϵ^2. The w_{ij} values represent spatial dependence between the e_i of state$_i$ and the e_i of state$_i$'s neighboring institutions. All w_{ii} are automatically set to zero so that each state is not regressed on itself (Bivand et al., 2008).[8] After fitting the SAR models, the residual errors ϵ_i were tested for spatial dependence using a Moran's I. If the test yields statistically significant results, then either the neighboring structure was not well specified or there were other structural constrains, and the spatial (or social) dependence issues were not successfully addressed (see Gonzalez Canche, 2019).