THE USE OF INSTRUMENTAL VARIABLES IN HIGHER EDUCATION RESEARCH

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ABSTRACT

Higher education researchers are often challenged by the difficulty of empirically validating causal links posited by theories or inferred from correlational observations. The instrumental variable (IV) estimation strategy is one approach that researchers can use to estimate the causal impact of various higher education–related interventions. In this chapter, we discuss how the body of quantitative research specifically devoted to higher education has made use of the IV estimation strategy: we describe how this estimation strategy was used to address causality concerns and provide examples of the types of IVs that were used in various subfields of higher education research. Our discussion is based on a systematic review of a corpus of econometric studies on higher education–related issues that spans the last 30 years. The chapter concludes with a critical discussion of the use of IVs in quantitative higher education research and a discussion of good practices when using an IV estimation strategy.

Keywords: Higher education; education research; quantitative methods; regression analysis; instrumental variables; endogeneity; econometrics

INTRODUCTION

A substantial body of research on higher education consists of studies using quantitative approaches: in the years 2000 and 2010, 42% of all journal articles published in 15 academic journals in this field had a predominantly quantitative methodology (Tight, 2013). Quantitative research in the social sciences is

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commonly challenged by the difficulty of empirically validating causal links posited by theories or inferred from correlational observations (Firebaugh, 2008). Higher education, which can be conceptualized as a complex set of educational interventions that are expected to bring about various individual and societal benefits, is no exception to this methodological challenge.

The difficulty of estimating the causal impact of various educational interventions is partly due to the fact that observational data are more readily available than experimental data, and researchers' inability to observe or measure theoretically important variables introduces a significant source of bias into impact estimates (Schneider, Carnoy, Kilpatrick, Schmidt, & Shavelson, 2007). The bias introduced by such omitted variables is also known as endogeneity bias (Xiqian & Borden, 2019) and can be described as a correlation between the independent variable and the error term in statistical models (Wooldridge, 2003). Several methodological approaches have been developed to address the problem of endogeneity, including fixed effects, instrumental variables (IVs), propensity score matching techniques, difference in differences designs, and regression discontinuity designs (Schneider et al., 2007).

In this chapter, we focus on the use of IVs in addressing the endogeneity problem in quantitative higher education research. The goal of the IV estimation strategy is to reduce bias in parameter estimates that might result from the presence of endogenous variable(s) in statistical models. Adopting an IV estimation strategy means including a variable in the model that can be used to estimate the extent to which the observed correlation between the independent variable(s) and the dependent variable is biased by endogeneity. Such a variable is called an instrument or IV. Including instrument(s) in a statistical model makes researchers' claims about causality stronger compared to correlational models.

In this chapter, we present a systematic review of how the IV estimation strategy was used in a body of econometric research on higher education–related issues. We provide an overview of the IV approach to estimating causal impact and an example from higher education research to illustrate this strategy. We systematically review a corpus of econometric studies published between 1990 and 2019. We report the endogenous dependent and independent variables used in the reviewed studies and provide a critical discussion of the IVs that were used to mitigate endogeneity in relation to these variables. Finally, a critical discussion of the use of IVs in higher education research is offered, highlighting good practices in using an IV estimation strategy.

INSTRUMENTAL VARIABLE ESTIMATION STRATEGY IN THE SOCIAL SCIENCES

A visual representation of the IV estimation strategy can be found in Fig. 1, adapted from Firebaugh (2008). In this path diagram, the problem of endogeneity is represented by the relationships between variables X, Y, and C. C stands for confounders: all individual characteristics and structural differences which are correlated with both the intervention of interest (represented on the diagram by X)

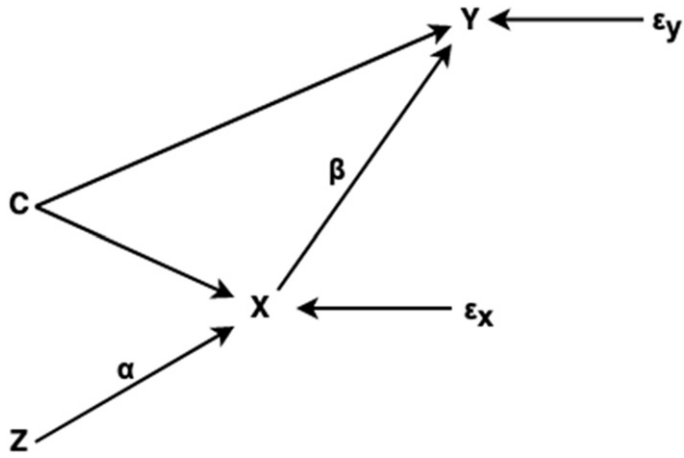

Fig. 1. Instrumental Variable Method for Estimating the Causal Impact of X on Y. *Source:* Adapted from Firebaugh (2008).

and the outcome of interest (represented by Y) and which cannot be measured directly within the current research design. In the presence of confounder(s), X and Y are endogenous. If there is a theoretical or empirical basis to suspect endogeneity, then the statistical correlation between X and Y (represented by β) cannot be interpreted as validation of the causal impact of the independent variable X on dependent variable Y. In such a situation, the presence of an instrument (represented on the diagram by Z) can help mitigate the endogeneity problem and strengthen causal claims (Firebaugh, 2008).

Two assumptions must be true for a variable to function as an instrument. The first assumption is that Z causes X. An IV estimation strategy should only be adopted if Z, X, and Y constitute a causal chain in which Z causes X and X in turn causes Y. The second assumption is that Z is randomly distributed in relation to Y. This means that there can be no *direct* causal relationship between Z and Y. There can only be an *indirect* relationship between Y and Z through Z's impact on X. As per the first assumption, α in Fig. 1 represents the causal impact of Z on X. Using an IV estimator means that we divide the correlation of Z and Y ($\alpha\beta$) with the direct impact of Z on X (α), which gives us β. If both assumptions regarding the instrument Z are met, we can interpret β as the causal impact of X on Y (Firebaugh, 2008).

An IV estimation strategy in practice involves fitting a two-stage least squares regression model (Angrist & Pischke, 2009). In the first-stage equation, the endogenous independent variable X is the outcome, and the IV Z is the predictor. Estimating α gives us the predicted values of X. In the second-stage equation, we estimate β by regressing the endogenous dependent variable (Y) not on the observed values of X, but on the predicted values of X that were calculated with the help of instrument Z in the first-stage equation.

IV Estimation Strategy in Higher Education Research: An Example

Parey and Waldinger (2011) set out to estimate the causal impact of study abroad participation on cross-border employment. They studied the population of German university graduates. The intervention was defined as having been enrolled at a university outside of Germany during the student's bachelor studies. The outcome of interest was whether the university graduate worked in a country other than Germany 12 months after completing their bachelor's degree program. Descriptive statistics of the analyzed sample indicated that the university graduates who studied abroad were employed outside of Germany at substantially higher rates (10.2%) than the university graduates who did not study abroad (2.7%).

Parey and Waldinger were concerned that there might be unobserved differences between university graduates who participated in study abroad and those who did not, which might partially explain the differences in the postgraduation mobility of these individuals. In other words, the authors feared that nonrandom assignment (i.e., selection or self-selection) into study abroad participation biased their results. An IV estimation strategy can be used when participation in an intervention is nonrandom, but the *incentive* to participate in the intervention is randomly assigned (Firebaugh, 2008). In such a scenario, a measure of the incentive can be used as an instrument.

The introduction of dedicated scholarships for international student mobility (such as the Erasmus scholarships in Germany and other European countries) provided an incentive for university students to study abroad by decreasing the direct costs associated with studying in another country. Therefore, Parey and Waldinger argued, students who attended universities where Erasmus scholarships were offered (or where more Erasmus scholarships were offered) might have been more likely to study abroad than comparable students at comparable universities that did not offer Erasmus scholarships (or offered fewer scholarships).

Is variation in the availability of Erasmus scholarships across German universities a good instrument (Z) for addressing the endogeneity problem that biases the estimate of correlation between study abroad (X) and work abroad (Y)? Parey and Waldinger regressed the number of German university students who studied abroad on the availability of Erasmus scholarships at German universities and found evidence of a statistically significant positive relationship between scholarship availability and study abroad participation. The authors interpreted this as evidence of the causal impact of scholarship availability (Z) on study abroad (X), thereby meeting the first assumption for the instrument. The second assumption is that there is no direct impact of the instrument on the outcome of interest. The second assumption for instruments (i.e., that Z is randomly assigned in relation to Y) cannot be tested empirically with observational data; authors must defend it on conceptual grounds. Parey and Waldinger argued that, after controlling for time-invariant differences in university characteristics, there are no channels through which the availability of Erasmus scholarships might influence university graduates' employment outcomes.

ENDOGENOUS VARIABLES AND INSTRUMENTS IN HIGHER EDUCATION RESEARCH

In this section, we first provide information about our literature search strategy and the corpus of econometric studies we reviewed. After this, we describe results from our systematic review, organized by the thematic domain of studies. For each domain, we describe the endogenous dependent and independent variables and the instruments that researchers used in econometric studies in that domain.

The Corpus of Econometric Studies Reviewed

To identify relevant econometric studies, we searched EconLit, a database of electronic resources – journal articles, working papers, and dissertations – compiled by the American Economic Association in August 2019. We decided to focus our review efforts on EconLit because we expected to identify studies using IVs at the intersection of econometrics (where the interest is primarily the research method) and higher education (where the interest is mainly thematic). This delimitation is not meant to imply that the IV estimation strategy is only relevant for higher education researchers whose conceptual understanding of higher education is informed by economics.

We delimited our literature search thematically and methodologically. We used keywords describing higher education (higher education, college, university, postsecondary education) in combination with keywords referring to statistical terms commonly used to describe an IV approach (IV, exogenous, two-step, selection, Heckman correction) to identify relevant studies. Delimiting the search to English language studies published in or after 1990, we identified 371 publications that had abstracts with relevant keywords.

After retrieving the publications, we initially reviewed them for relevance, defined as (1) addressing research questions that are related to higher education and (2) featuring an empirical approach that includes the use of IVs. The review left us with 103 journal articles or working papers (we also identified 25 dissertations that met our criteria for relevance, but, due to time and capacity limitations, we decided not to conduct a detailed review of them). We conducted a detailed review of these 103 studies. We excluded 31 papers for not being thematically or methodologically relevant. We further excluded one article due to lack of transparency in reporting results. We could not obtain a copy of two papers and excluded one more paper that was written in German.

The discussion in the subsequent sections is based on our review of a total of 68 journal articles or working papers. Table 1 shows the number of studies within each thematic domain. We assigned papers to domains based on the outcome(s) that the authors sought to explain using an IV estimation strategy. Six studies were included in more than one domain; this is the reason why the sum of counts per domain does not equal the total number of studies.

Table 1. Reviewed Studies by Domain of Research.

Empirical Domain of Research	Number of Studies
Economic impact of higher education	31
Student achievement	17
Performance of faculty members and institutions	10
Student access, choice, and participation in higher education	9
Noneconomic benefits of higher education attainment	5
Student behavior in higher education	2
Total	68

Economic Impact of Higher Education

The largest number of studies ($n = 31$) sought evidence of a causal impact of higher education attainment on employment, earnings, and economic growth. Several reviewed studies tested whether higher education attainment caused better employment outcomes. Table 2 summarizes information from this body of research. Table 2, like all following tables in this chapter, is structured as follows. The first column lists the outcome variables; the studies sought to explain variation in these variables in response to some intervention or treatment. The middle column lists the relevant interventions or treatments; these are the independent variables suspected to be endogenous in relation to the dependent variable listed in the same row. Finally, the right-end column lists the variables used as instruments to mitigate the endogeneity bias in estimating the causal impact of the intervention on the outcome.

For example, authors of the study listed in the first row in Table 2 (Velez, Cominole, & Bentz, 2019) wanted to estimate the causal impact of student loan debt (independent variable) on employment (dependent variable). Recognizing that unobserved individual and structural differences might influence both student loan borrowing and employment outcomes, they instrumented the amount of debt with average tuition levels in the students' home state. The authors empirically validated that differences in average public tuition levels were linked to differences in student loan borrowing: students attending university in states with higher average public tuition borrowed more. Moreover, Velez et al. argued that differences in average tuition did not influence the employment outcomes of university graduates directly, only indirectly, through their impact on student loan debt. These empirical and conceptual reasons led them to use differences in average tuition as an instrument to mitigate the endogeneity between student loan debt and employment in their econometric models.

Some of the studies listed in Table 2 looked at the incidence of (un)employment in the analyzed samples, while other studies used higher education to predict various attributes of employment: self-employment, employment abroad, (mis)match between field of university education and field of employment, occupational category, job satisfaction, and participation in job-related training. All studies in this group employed micro level analyses. The endogenous

Table 2. Impact of Higher Education on Employment – Overview of Key Variables.

Endogenous Dependent Variable	Endogenous Independent Variable(s)	Instrumental Variable(s)
Employment	Debt from undergraduate student loans	Enrollment-adjusted average tuition level at public universities in the student's home state (Velez et al., 2019)
	Participation in study abroad	Proportion of students in a given discipline/university who studied abroad (di Pietro, 2015)
	Study field (STEM/non-STEM)	• Mother's education • Proportion of women among STEM faculty members in the region of residence (Mourifie, Henry, & Meango, 2018)
Wage employment/self-employment	University education	Parental education (Habibov, Afandi, & Cheung, 2017)
Employment at home/abroad	Study abroad participation	• Availability of Erasmus scholarships at the student's university (Parey & Waldinger, 2011; di Pietro, 2012) • Award of *Talentenprogramma* study abroad scholarship (Oosterbeek & Webbink, 2011)
(Mis)match between field of university education and field of employment	Debt from undergraduate student loans	Enrollment-adjusted average tuition level at public universities in the student's home state (Velez et al., 2019)
	Study field (STEM/non-STEM)	• Mother's education • Women among STEM faculty members in the region of residence (Mourifie et al., 2018)
White-collar occupation	College attendance	Birth cohort, corresponding to a change in the state-mandated college admissions policy (Jung, Pirog, & Lee, 2016)
Job satisfaction	Field of study	• Parental education • Age of entry to university • Type of secondary education (academic vs vocational) • University admissions score (Vila, Garcia-Aracil, & Mora, 2007)
Participation in work-related training	Years of schooling	Presence of a university in the county of birth (Kramer & Tamm, 2018)

independent variable – some form of higher education intervention – was operationalized not only as years of schooling or completion of higher education but also in terms of attributes of the higher education experience, for example, field of study or participation in international student mobility.

Table 3 summarizes information from studies on the causal impact of higher education on earnings. Earnings were mostly measured at the individual level, but some meso and macro level studies looked at average salaries of university degree holders across firms or cities. Micro level studies measured the treatment as years

Table 3. Impact of Higher Education on Salaries – Overview of Key Variables.

Endogenous Dependent Variable	Endogenous Independent Variable(s)	Instrumental Variable(s)
• Earnings • Income	• Years of schooling • Educational attainment • University degree	• Year in which the individual was born (Heckman & Li, 2004; Jung et al., 2016; Kyui, 2016; Lemieux & Card, 2001; Pons & Gonzalo, 2002) • Parental education (Bunel & Guironnet, 2017; Heckman & Li, 2004; Lemieux & Card, 2001; Pons & Gonzalo, 2002; Salas-Velasco, 2006) • Parental income (Heckman & Li, 2004) • Receipt of assistance from college during job search (Kong, 2017) • Marital status, number of children in the household, health status (Akhmedjonov, 2011) • Residence, e.g., region within a country (Kyui, 2016) • Proximity to college (Bunel & Guironnet, 2017; Card, 1993; Nybom, 2017; Pons & Gonzalo, 2002) • Living with the parents during university studies (Pons & Gonzalo, 2002) • Availability of higher education in a particular city (Muravyev, 2008) • Higher education attainment level in a particular city (Muravyev, 2008) • Average earnings in the municipality of residence (Nybom, 2017) • Heteroskedasticity in returns to college education (Heckman & Li, 2004; Wang, 2012)
	College quality	Availability of "quality" 4-year institutions near the student's residence (Long, 2008)
	Field of study	• Mother's education • Proportion of women among STEM faculty members (Mourifie et al., 2018)
	International student mobility	Student resides in the same canton as the university they attend (Messer & Wolter, 2007)
Salaries within a city	City-level average educational attainment	Historical relocation of university departments (Glaeser & Lu, 2018)
	Proportion of employees with higher education	• Historical presence of higher education institutions (land-grant colleges) in the city • Historical age structure of the city (Moretti, 2004)
Salaries within firms	Proportion of employees with higher education	• Changes in the supply of higher education degrees in local institutions • Density of supply of manufacturing degrees, interacted with the size of the youth cohort in the same province (Bratti & Leombruni, 2014)

Table 4. Impact of Higher Education on Economic Growth – Overview of Key Variables.

Endogenous Dependent Variable	Endogenous Independent Variable(s)	Instrumental Variable(s)
Light density at night (proxy for economic prosperity)	Proportion of population with higher education	Historical presence of Catholic missionaries in the district (Castelló-Climent, Chaudhary, & Mukhopadhyay, 2018)
Salaries per capita	Proportion and change in employees with a bachelor's degree or higher	Historical trends of higher education attainment (Fan, Goetz, & Liang, 2016)
Growth in total factor productivity	Proportion of employees with higher education	Historical demographic structure of the state population (Panda, 2017)
Firm's performance: • Patent applications • New products • New business lines • New process improvements	Relationship with: • Other firms • Universities • Research institutions	Average level of cooperation with other firms, universities, and research institutions in the firm's industry and region (Yasar & Paul, 2012)

of schooling or completion of higher education and type of postsecondary education (disaggregated by field of study, student mobility, and quality of the institution). Meso level studies used stock of (higher) education in a location as the endogenous independent variable which is to be instrumented.

A third subset of studies was concerned with the impact of higher education attainment on economic growth. In these studies (summarized in Table 4), the outcome variable was an aggregate measure of economic performance: per capita salary, growth in total productivity, light density at night, and the innovative performance of firms. One of the endogenous predictors of economic growth in these studies was the stock of human capital, typically operationalized as proportion of the population with a college or university degree. In one study, it was not higher education per se, but interactions between local firms, higher education institutions, and research institutes that constituted the intervention (Yasar & Paul, 2012).

Studies that sought to address the endogeneity problem to estimate the economic impact of higher education relied on a diverse set of IVs. At the micro level, measures of the socioeconomic status (SES) of university students – parental education, parental income, marital status, number of children in the household – were often used as instruments. Other instruments used in this subset of studies were geospatial or historical variables. Geospatial instruments (e.g., the presence of a higher education institution in a city or region or the proximity of the student's residence to the nearest higher education institution) capitalize on differences in the incentive to participate in higher education. The reasoning that students who live closer to universities or live in cities where there are more universities are more likely to attain higher education because they have lower costs (and thus higher incentives to participate) has an intuitive appeal. Macro

level studies that investigated the economic impact of higher education almost exclusively relied on panel data, which allow for the construction of time-lagged instruments.

The last class of IVs in this group of studies rested on variation in the availability of university-based interventions, such as variation in the availability of Erasmus scholarships (Parey & Waldinger, 2011; di Pietro, 2012, 2015) or variation in students' exposure to career counseling (Kong, 2017).

Student Achievement

Table 5 summarizes information about studies that sought to explain college and university students' achievement in response to various interventions; the unit of analysis in these studies was the individual student. Some studies operationalized students' academic performance as grades and examination results, while others measured achievement as college/university completion or dropout. Other measures of academic performance included the number of courses taken and choice of major (Bettinger & Long, 2010).

The endogenous independent variables included not only measures of academic engagement (e.g., hours of study) but also aspects of university life (e.g., living in a dormitory, binge drinking, and participation in varsity athletics) that were hypothesized to influence student achievement. Characteristics of the teaching and learning context constituted another type of endogenous independent variable. These included class size, college/university quality, proportion of courses taken from nontenured staff (Bettinger & Long, 2010), courses taken online, and exposure to particular teaching interventions (Paloyo, Rogan, & Siminski, 2016).

Measures based on geographical location of colleges and individuals were used to mitigate concerns regarding the selection and self-selection of university students into dormitories (de Araujo & Murray, 2010) and online courses (Krieg & Henson, 2016; Xu & Jaggars, 2013). Other instruments were based on students' attitudes and family background; for example, religious attitudes and parental use of alcohol were used as instruments for binge drinking (Wolaver, 2007). Another set of instruments capitalized on variation in exposure to peer influence, such as through membership in classes or study groups (Paloyo et al., 2016; de Paola & Scoppa, 2011) or through the presence of dormitory roommates (Insler & Karam, 2019; Stinebrickner & Stinebrickner, 2007).

Occasionally, university policies were also used as instruments to mitigate selection and self-selection into higher education experiences. For example, differences in institutional dormitory policies were used to instrument student accommodation (de Araujo & Murray, 2010), differences in institutional policies pertaining to allowing alcohol on campus were used to instrument binge drinking among underage students (Wolaver, 2007), while differences in tenure policies were used to instrument the proportion of courses in which students were taught by nontenured faculty members (Bettinger & Long, 2010).

Several studies used variation in supply–demand dynamics to create instruments. For example, the price of alcohol was used as an instrument for binge

Table 5. Student Achievement – Overview of Key Variables.

Endogenous Dependent Variable	Endogenous Independent Variable(s)	Instrumental Variable(s)
Academic performance: Student's grades and exam results	Living in a dormitory	• Distance of hometown from campus • Being denied housing (de Araujo & Murray, 2010).
	Online delivery of teaching	Distance of hometown from campus (Xu & Jaggars, 2013)
	Online delivery of prerequisite courses	Distance of hometown from campus (Krieg & Henson, 2016)
	Academic ability of peers	Ability of peers at the previous level of education (de Paola & Scoppa, 2011)
	Hours of study	• A roommate with a video game • Roommate's hours of study in high school • Roommate's expected hours of study (Stinebrickner & Stinebrickner, 2007)
	Student demand for a particular academic program	Number of universities offering degree course in the particular field (de Paola, 2011)
	Binge drinking	• Dollar price of alcohol • Religious attitudes • Parental use of alcohol • Availability of alcohol for underage students (Wolaver, 2007)
	Participation in varsity athletics	Number of peers from the same military academy recruited for a varsity sport prior to college enrollment (Insler & Karam, 2019)
	Participation in Peer Assisted Study Sessions (PASS)	Financial incentive to participate in the PASS intervention (Paloyo et al., 2016)
Degree completion or dropout	College quality	Availability of "quality" 4-year institutions near the student's residence (Long, 2008)
	Class size	Average class size in the student's intended major (Bettinger & Long, 2018)
	Labor market demand for specific occupations	Projected evolution of retirement ratios in the population (Bardhan, Hicks, & Jaffee, 2013)
	Housing booms	Historical trends in housing prices (Charles, Hurst, & Notowidigdo, 2018)
	Student demand for a particular academic program	Number of universities offering degree course in the particular field (de Paola, 2011)
Degree completion among nontraditional age university students	Tax benefit for higher education	• Eligibility for educational tax benefits • Individual earnings (LaLumia, 2012)
PhD completion among female students	Proportion of female faculty members in the department	• Male faculty members leaving the department • Simulated number of male faculty members in the department (Hale & Regev, 2014)
Academic trajectory (course-taking and major choice)	Courses taken from nontenured staff	Proportion of courses in a department taught by each rank of instructor, relative to the average number of tenure-track faculty who taught in that term (Bettinger & Long, 2010)

drinking (Wolaver, 2007), changes in the projected size of retirement-age cohorts were used to instrument labor market demand for particular occupations (Bardhan et al., 2013), while the evolution of housing prices was used to instrument housing booms (Charles et al., 2018). By the same logic, the supply of university places relative to demand for higher education in those particular study fields was used as an instrument in studies looking to identify the causal impact of study fields on course and degree completion (Long, 2008; de Paola, 2011).

Performance of Faculty Members and Institutions

In the body of econometric studies that we reviewed, performance of faculty members was typically measured at meso (institutional) and macro (state) levels. There are only a few studies that sought causal explanations of differences in faculty performance at the individual level (Cainelli, Maggioni, Uberti, & de Felice, 2012; Waldinger, 2012). The dependent variables included some form of performance indicator in research, development, or innovation, such as research output counted via bibliometric techniques (e.g., number of publications, citations, patents). Occasionally, research performance was measured by the input allocated to research activities, such as the amount of funds allocated to teaching–learning and research–development, respectively. Endogenous independent variables at the individual level included the propensity for faculty members to collaborate with other faculty members (e.g., coauthorship). Meso level predictors of faculty performance included not only different measures of institutional quality, size, and funding but also the degree of internationalization (Carillo, Papagni, & Sapio, 2013) (Table 6).

The attempts to address endogeneity in this subset of studies drew on three types of relationships to create instruments. The first type of instrument relied on the importance of politics and policies for institutional performance: politicians and policies determine budgets, which in turn are expected to affect institutional performance (Aghion et al., 2010; Blume-Kohout et al., 2009; Ejermo & Källström, 2016; Fowles, 2014; Kholmuminov et al., 2019). In extreme political situations (e.g., Nazi cleansing), politics influenced the composition of departments, which in turn impacted individual performance within the affected departments (Waldinger, 2012).

The second set of instruments utilized differences in academics' access to, and position in, professional networks. Scholars who live closer to other scholars in their field of study or who are more visible internationally have lower costs (and thus higher incentives) to collaborate. Differences in incentives to collaborate with local or international colleagues are expected to translate to differences in academic performance (Cainelli et al., 2012; Carillo et al., 2013). The third set of instruments included macro level economic changes that were considered exogenous to higher education: evolution of the stock market (Fowles, 2014) or macroeconomic and policy shocks in countries which represented sources of academic migration (Stuen et al., 2012). Such exogenous economic and policy shocks were expected to curb individual and institutional preferences.

Table 6. Performance of Faculty Members and Institutions – Overview of Key Variables.

Endogenous Dependent Variable	Endogenous Independent Variable(s)	Instrumental Variable(s)
Research outputs: • Publications • Citations • Patents	Propensity for coauthorship	Authored chapters in edited books (Cainelli et al., 2012)
	Department quality	Changes in departmental composition due to the politically motivated dismissals of academics in 1933 (Waldinger, 2012)
	Department size	Number of dismissals in 1933 (Waldinger, 2012).
	Institutional R&D expenditures	• Amount of governmental block grants for R&D in the previous year • Amount of nonblock grants for R&D that the university received (Ejermo & Källström, 2016)
	Expenditure for research universities	Political vacancies in the federal legislative bodies with control over the allocation of federal funds to research universities through ear-marked projects (Aghion, Dewatripont, Hoxby, Mas-Colell, & Sapir, 2010)
	Educational expenditure per type of college	College enrollments in the constituency of the chairperson of the state legislative body with control over the allocation of state funds to colleges (Aghion et al., 2010)
	• Number of coauthors not affiliated to the department • Number of visiting scholars to the department	• Internationally mobile students at the department • Availability of funds for students' international mobility • University location • Number of researchers within 100 kilometers who work in the same field as the faculty member (Carillo et al., 2013)
	Number of international (doctoral) students	Macroeconomic and policy shocks in source countries (Stuen, Mobarak, & Maskus, 2012)
Funding: • Non-federal R&D funding	Historical federal funds for R&D	Predicted federal funding, based on historical trends (Blume-Kohout, Kumar, & Sood, 2009)
• Expenditures on education and related expenses	Institutional revenues from tuition & mandatory fees	• Political context • Historical trends in the stock market (Fowles, 2014)
• Private R&D funding	Number of international (doctoral) students	• Geographic proximity of home country to host country of international (doctoral) students • Linguistic closeness of home and host countries (Haussen & Übelmesser, 2016)
• Expenditure on teaching	Institutional revenues from tuition fees	• Institutional revenues from the state ("development fund") • Income from enrollments in excess of the original enrollment quota (Kholmuminov, Kholmuminov, & Wright, 2019)

Student Access, Choice, and Participation in Higher Education

Higher education access and participation was analyzed at micro level, generally to identify what caused students to go to university. Access and participation were operationalized in these studies as enrollment in a graduate program, enrollment in higher education in one's 30s and 40s, enrollment of domestic students, or attendance at an elite university. The endogenous independent variables included some measure of prior educational experience, such as the type of secondary school attended (academic or vocational), preexisting student loan debt, or the ability and college choice of students' secondary school peers. Macro level independent variables included structural changes, such as the evolution of the housing market or change in the proportion of international students at domestic universities (Table 7).

Table 7. Student Access, Choice, and Participation in Higher Education – Overview of Key Variables.

Endogenous Dependent Variable	Endogenous Independent Variable(s)	Instrumental Variable(s)
University enrollment	Changes in the housing market	Historical trends in housing prices (Charles et al., 2018)
	Peer ability	Peers-of-peers' ability during the previous cycle of education (Mendolia, Paloyo, & Walker, 2018)
	Graduation from a vocational secondary school	Frequency at which vocational secondary schools versus high schools are mentioned by parents in the local community (Chen, 2009)
College enrollment	Peer college choice	• Number of siblings • Average number of siblings at the student's school • Average number of siblings at the student's school, interacted with parental education (Fletcher, 2013)
Graduate school attendance	Debt from undergraduate student loans	• College financial aid policies (Zhang, 2013) • Enrollment-adjusted average tuition level at public universities in the student's home state (Velez et al., 2019)
30s/40s students' attendance	Tax benefit for higher education	• Eligibility for educational tax benefits • Individual earnings (LaLumia, 2012)
Elite university attendance	Peer ability	• Peers-of-peers' ability during the previous cycle of education (Mendolia et al., 2018)
Student demand for higher education	Tuition fee increases	Political party in power (Neill, 2009)
Proportion of domestic students at universities	Number of international students at the university	• Historical enrollment patterns of students from origin countries • Change in visa regulations, interacted with subject preferences and price (i.e., tuition fee) sensitivity (Machin & Murphy, 2017)

The structural factors were instrumented via other structural factors, with the chain of causality being historically determined (Charles et al., 2018; Machin & Murphy, 2017). The ability of students' high school peers, which arguably influenced whether students enrolled in a university, was instrumented via the ability of the peers of those high school peers from the previous educational cycle (Mendolia et al., 2018). A different study (Fletcher, 2013) hypothesized that peer ability influenced college choice and instrumented peer ability with the social environment from the previous educational cycle. Graduation from a vocational secondary school, which was found to be an endogenous, negative predictor of university enrollment, was instrumented by the perceived prominence of vocational secondary schools in the community (Chen, 2009). In these cases, the causal link between the instrument and the endogenous independent variable was based on previous socialization.

Student loan debt, an endogenous predictor of higher education enrollment beyond the first cycle, was instrumented via financial aid policies (Zhang, 2013) or via saturation in student demand induced by state funding of higher education (Velez et al., 2019). Tuition fee increases were instrumented via the political party in power (Neill, 2009). The policy of offering tax benefits for college enrollment, another endogenous predictor of higher education enrollment beyond the traditional undergraduate age, was instrumented via a combination of eligibility for benefits and individual earnings (LaLumia, 2012). These instruments were created based on the same logic, i.e., state policies determine variation in incentives to undergo treatment (borrowing for graduate school, claiming tax benefits, paying tuition).

Noneconomic Benefits of Higher Education Attainment

The noneconomic benefits of higher education include a variety of behaviors and attitudes that might be attributed to college attendance. The quantitative studies that we reviewed tested the causal link between higher education attainment and such outcomes as smoking, mortality, political preferences for the far right, within-country migration, and a complex set of attributes of personal life that could be associated with quality of life. The endogenous independent variables included different measures of educational attainment and debt from undergraduate student loans. The instruments accounted for policy interventions and the geography of the higher education sector, both of which were assumed to provide an exogenous source of variation in individuals' decision to enroll in college, and were assumed not to directly influence the various noneconomic outcomes of interest (Table 8).

Student Behavior in Higher Education

We found two studies that used an IV estimation strategy to seek causal explanations of college student behavior. Averett, Terrizzi, and Wang (2017) sought to explain variation in measurable weight and the incidence of disordered eating behaviors (anorexia and bulimia) among women attending college, using sorority membership as the endogenous independent variable. The authors instrumented

Table 8. Noneconomic Benefits of Higher Education – Overview of Key Variables.

Endogenous Dependent Variable	Endogenous Independent Variable(s)	Instrumental Variable(s)
Health: • Smoking • Mortality	Higher education attainment (years)	• Risk of being drafted into military service during the Vietnam War (Buckles, Hagemann, Malamud, Morrill, & Wozniak, 2016) • Risk of being drafted into military service during the Vietnam War, interacted with the risk of being killed in war (de Walque, 2007)
Far-right political preferences	Proportion of college-educated population in the region	Presence of higher education institutions in the region (Chan, 2019)
Within-country migration	Higher education attainment	Supply of higher education over time and across regions (Haapanen & Böckerman, 2017)
• Family life (married, children) • Ownership of residence • Work–life balance	Debt from undergraduate student loans	Enrollment-adjusted average tuition level at public universities in the student's home state (Velez et al., 2019)

sorority membership with membership in fraternities in the same college. Chastain, Gohmann, and Stephenson (2017) tested whether attendance at American football games was causally impacted by whether alcohol was sold at the stadium. They instrumented the policy of selling alcohol in the stadium with local propensity for alcohol consumption, measured as the population in each institution's home county that was either Baptist or Mormon.

DISCUSSION AND RECOMMENDATIONS FOR RESEARCHERS

We conclude this chapter by a brief reflection on the problems and good practices that we identified in the corpus of empirical research we reviewed. Our reflections and subsequent recommendations for higher education researchers concern two areas: (1) the strength and validity of IVs used in higher education research and (2) the differences between parameters estimated with the help of an IV estimation strategy versus other strategies.

In statistical analyses that incorporate an IV estimation strategy, it is important to empirically test the "strength" of the proposed instrument, i.e., the statistical significance and magnitude of correlation between the IV and the endogenous independent variable. "Weak" instruments can bias the IV estimates and therefore their use should be avoided (Bound, Jaeger, & Baker, 1995). Statistical tests of the strength of the instrument were reported in most studies that we reviewed; we consider this a good practice that should be followed by all

researchers who use IV estimation strategy. Step-by-step guidance on how to test the strength of the IV can be found in Angrist and Pischke (2009).

Demonstrating the strength of correlation between the proposed instrument and the endogenous independent variable is necessary, but it is not sufficient for establishing the validity of an instrument. It is equally important that the second assumption regarding instruments is met: there should be no direct causation between the instrument and the outcome. We believe that this assumption was violated in some of the studies we reviewed. A substantial subset of econometric studies that used an IV estimation strategy to estimate the causal impact of higher education attainment used various measures of students' SES as instruments. Student SES is strongly correlated with higher education attainment in many contexts, which makes various measures of SES (such as parental education and family income) attractive candidates for instruments. Nevertheless, researchers must carefully consider whether using SES as an instrument is appropriate in the context of their study. The socioeconomic background of university students may be considered a suitable instrument only if it is theoretically and empirically justified to assume that SES affects postgraduation outcomes *only* through its effect on educational attainment. In contexts where social and cultural capital play an important role in finding employment and accessing prestigious, well-paid jobs, such an assumption is not defensible and the use of SES variables as instruments should be avoided.

A strong theoretical argument combined with evidence from relevant empirical research can be an effective way of strengthening the conceptual validity of the instruments. In addition, whenever possible, researchers should draw on additional data and perform additional analyses to support their theoretical argument regarding the validity of their proposed instrument; a good example of how this can be done is found in Glaeser and Lu (2018).

When adopting an IV estimation strategy, we consider it a good practice to report both the IV estimates and other estimates of the parameters of interest. This practice was followed by most studies in the corpus we reviewed: out of the 68 studies, 58 studies reported both IV and ordinary least squares (OLS) estimates of the parameters. Reporting both OLS and IV estimates is important because differences between the parameter estimates provide important insights about factors that may confound the relationship between higher education–related interventions and their impact and about the direction and magnitude of the bias that such confounders might introduce. The papers by Akhmedjonov (2011), Heckman and Li (2004), and Wang (2012) provide further discussion of the mechanisms that can explain differences between OLS and IV estimates and how such differences can be interpreted.

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