Persistent Cost Efficiency at Public Community Colleges in the US: A Stochastic Frontier Analysis

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Abstract

This study utilizes an extensive panel data set spanning 15 years (2004–2018) and 752 public community colleges to investigate operating costs and persistent cost efficiency at public community colleges in the United States. We employ a generalized true random effects (GTRE) regression model that takes into account spatial correlation of costs among community colleges, to estimate cost efficiency via stochastic frontier analysis (SFA). The results reveal a positive relationship between operating costs and associate degrees and certificates as well both human (part- and full-time faculty) and financial resources (local, state and federal funding and tuition revenue), controlling for other variables. Furthermore, with an average persistent (long-term) efficiency of 87%, few institutions are relatively cost inefficient. Moving forward, campus leaders and policy makers alike may consider yearly data and efficiency calculations to develop strategic plans and funding alternatives. With 40 percent of first-time students transferring at least once within six years and over half of those students transfer from a community college, future research may study cost efficiency of community colleges while accounting for student transfers as an output.

Keywords Educational finance · Community colleges · Cost efficiency · Stochastic frontier analysis · Spatial analysis

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Introduction

In recent years, the economic climate of the United States has placed pressure on higher education policymakers and college campus leaders to become more cost efficient while increasing the production of baccalaureate degrees and certificates. At the same time, a similar effort has been made to focus on the community college sector as a point of access for students seeking post-secondary credentials. While community colleges were historically founded to help students complete their first two years of coursework, they have increasingly focused on vocational education, specifically on the completion of associate and certificate degrees (Cohen et al. 2014). The focus on increasing post-secondary credentials resulted in a significant increase in the number of associate degrees and certificates awarded (Sykes, 2012; Miller et al. 2016).

Unfortunately, unified data tracking of the production of these degrees is limited (Miller et al. 2016). However, recent research suggests there are private returns to earning associate degrees and certificates (Jepsen et al. 2014; Liu et al. 2015; Dadgar & Trimble, 2015; Bahr, 2019). For example, in a recent study, Bahr (2019) found positive returns for students completing certificates in California. Because of the private benefits of earning associate degrees/certificates, many states have begun to incentivize community colleges to increase their production via performance-based funding plans (McLendon & Hearn, 2013). While there is some research on the effects of performance-based policies on community college degree production (Li & Kennedy, 2018), not much is known about the institutional operating costs of degree and certificate production at public community colleges. Always a critical topic, this gap in the research has become even more concerning given the declining enrollment among community colleges due to COVID-19.

Purpose of This Study

The current work aims to shed light on four important questions in higher education. First, we identify and examine the factors explaining public community colleges' operating costs over the 15-year period. Second, we utilize recently developed statistical techniques to quantify cost efficiency at the institution level. We are defining cost efficiency as the extent to which institutions are operating at or below institutions with the lowest costs when producing a given number of outputs (e.g., degrees, certificates) with a given set of inputs (e.g., students, faculty, staff, physical capital) and input prices. Third, we statistically separate persistent/long-term efficiency from transient/short-term efficiency and highlight the factors that affect them. Fourth, this research asks: how do financial resources influence both operating cost and persistent cost efficiency at public community colleges in the U.S., while taking into account spatial interdependencies?

Contribution and Findings

The present research makes several contributions to the literature and knowledge set on community colleges financials and efficiency. In contrast to previous research (Sav, 2011 2012), the current work analyzes an extensive panel data set spanning 15 years (2004–2018) and 752 public community colleges with the following contributions to the literature. First, the few previous studies on costs at community colleges used either cross-sectional data (Toutkoushian & Lee, 2018) or panel data for a short period of time (Sav, 2012). Second, following Titus et al. (2017) and Vamosiu et al. (2018), we account for

geographic interdependence of operating costs and efficiency indices. By not accounting for the possibility of spatial correlation via a spatially weighted cost variable, previous studies implicitly assumed institutions across state borders or those located in rural versus metropolitan settings face similar operating costs.

Third, we introduce financial variables, in accordance with Bowen's (1980) cost theory. Bowen (1980) posits that the more revenue and financial resources an institution has available, the more it will spend in the pursuit of excellence and prestige. Fourth, we estimate how cost efficient each institution is both in the short-run (yearly basis) and over the long-run (the 14-year period). Separating efficiency by short- and long-term is essential for campus management and policy purposes. Specifically, it allows researchers to differentiate between singular management errors or incorrect responses to changes in market conditions and factor prices (e.g., faculty salaries) at one point in time (short run) and structural management problems and the misallocation of resources over the long-term. Therefore, this study provides campus leaders, researchers and policymakers with empirical analysis to inform discussions about the impact of funding on costs and cost efficiency at public community colleges.

Our results reveal a positive relationship between operating costs and both human (part/full-time faculty) and financial resources (local, state and federal funding and tuition revenue). The latter supports Bowen's theory of costs in the arena of public community colleges. Moreover, a higher percentage of students under age 25 as well as a higher percentage of minority students are associated with higher operating costs. Public community colleges located in urban areas face higher operating costs. Focusing on relative cost efficiency, the study uncovers that few institutions are cost inefficient, whether one considers short/residual/transitory or long/persistent term efficiency. The average short-term efficiency is high, 90%, with even the lowest 10th percentile institutions reaching 85% efficiency. The average long-term efficiency is also high, 87%, with the most inefficient public community college still achieving 82% cost efficiency. Furthermore, persistent efficiency, which most often evaluates long-term management practices or structural problems of the institution, has only a small statistical relationship to financial resources (state and local funding, Pell grants, and tuition revenue).

The rest of the paper is structured as follows: we continue with the literature review, followed by the theoretical framework, research design, results, conclusion and implications.

Literature Review

Community colleges, originally called junior colleges, began in the early half of the 20th century (Drury, 2003). While community colleges were originally envisioned as preparatory institutions for universities (Cohen et al. 2014), community colleges today serve several different functions. They offer certificate and associate degree programs in vocational areas for students who wish to go directly into the workforce. Community colleges also offer transfer programs and coursework to prepare students for transfer into a baccalaureate degree. Community colleges also serve the community by offering non-credit classes for community members seeking to take classes for enjoyment or to enhance skills without earning a credential. Despite their multiple missions, community colleges have one thing in common: they are open-access institutions, so any student can enroll no matter their personal or academic background.

Today, there are over 1050 community colleges across the country serving almost 45 percent of students in higher education (American Association of Community Colleges, 2020). Community college students are incredibly diverse—26 percent are Hispanic students, 13 percent are Black students, 6 percent are Asian American/Pacific Islander (American Association of Community Colleges, 2020). Almost 30 percent of community college students are first-generation students. The average community college student attends part-time (64 percent of community college students), maintains a job during school (72 percent of part-time students, 62 percent of full-time students), and is non-traditionally aged (average age: 28, median age: 24) (American Association of Community Colleges, 2020). The 6 year associate and certificate completion rate at public community colleges is 38.1% (National Student Clearinghouse Research Center, 2020). Almost 70% of first-time students enrolling in community college aim to eventually transfer and earn a bachelor's degree, but only 25% of students transfer and only 14% complete a bachelor's degree within six years (Horn & Skomsvold, 2011; Jenkins & Fink, 2016).

Community College Funding and Costs

Historically, community colleges rely on three sources of external funding: federal, state and local, with state funding being generally the most significant amount (McGuinness, 2014). With respect to state level funding, Mullin and Honeyman (2007) indicated that there are three ways in which states fund community colleges. First, some states have “no formula funding,” which means colleges are not funded based on a common calculation. Second, some states use “responsive funding” which is adjusted by the operating cost of education or funding based on prior year changes in enrollment. Because they are open access institutions and enrollments can vary widely due to economic conditions (Romano & Palmer, 2016), community colleges may be more susceptible to varying funding levels when employing enrollment funding formulas. Third, states using “functional component funding” justify their costs in terms of the components of operation within their institution.

A fourth, and more recently preferred, method of state funding has been performance-based funding. Performance-based funding (PBF) has been established as early as the 1980s where, in some states, a small proportion of funding was tied to performance measures (often called Performance-Based Funding 1.0). PBF became a much wider practice after 2009, when policies began to attach a larger proportion (or in some states, 100 percent) of funding to outcomes, or Performance-Based Funding 2.0 (Dougherty & Reddy, 2013; Li & Kennedy, 2018). In the wake of the College Completion agenda, state lawmakers began to increasingly focus on the performance of higher education institutions, particularly the low completion rates at community colleges. As a result, 30 states today have introduced or implemented laws to provide community college funding at least in part based on performance measures, such as degree completion (Snyder & Fox, 2016). PBF models at the community college focus on awarding funds based on a variety of metrics, including the completion of developmental coursework, passing college-level gateway courses, and completing a specific number of credit hours (Altstadt, 2012; McKinney & Hagedorn, 2017; Li & Kennedy, 2018). More specific metrics include the completion of certificates and associate degrees (McKinney & Hagedorn, 2017; Li & Kennedy, 2018). In fact, Li and Kennedy (2018) highlight that earned associate's degrees and certificates are the most frequently incentivized outcomes for PBF modes.

Another source of funding for public community colleges, *local funding* was present in twenty-seven states as of 2013 (McGuinness, 2014). The existence of local funding is

highly correlated with the type of governance of community colleges by state. This is in stark contrast with four-year public higher education institutions, which generally receive public funding in the form of state and local appropriations in all states. In fact, one of the important ways in which community colleges differ from other institutions of higher education can be seen through their reliance on local and state funding and tuition and fees (Wellman, 2011). State and local appropriations (if present) account for nearly 41% of community college funding, non-operating grants are 23% of revenue and tuition almost 16% (Dowd & Shieh, 2013). Decreases in state and local funding, which at times has come when enrollment was at its highest, such as during the Great Recession (Romano & Palmer, 2016), has often corresponded to increases in community college tuition. On average, tuition and fees at community colleges rose by nearly 40% from 2000 to 2015 (accounting for inflation) (National Center for Education Statistics, 2019). Despite this increase, public community college tuition is still far below tuition at public four-year institutions. In 2015–2016, the average cost for tuition, fees, and room/board was \$9,939 for public community colleges compared to \$19,189 at public four-year institutions and \$39,529 at private four-year institutions (National Center for Education Statistics, 2019). Increasing tuition prices across all sectors of higher education can often result in more students enrolling in community colleges instead of four-year institutions (Hemelt & Marcotte, 2016).

In terms of expenditures, community colleges spend approximately 42% of their total expenditures on instruction, compared to 29% at 4-year institutions (National Center for Education Statistics, 2018). Community colleges also spend more on student services (9% at community colleges compared to 5%), institutional support (17% at community colleges compared to 9%), and net grant aid to students (10% at community colleges compared to 4%).

Cost Efficiency

From an economic perspective, efficiency can be defined as a cost effectiveness ratio of operating costs divided by the effects or output (Levin et al. 2018). In the context of higher education, the question is whether the cost is a worthy investment for a given outcome. Dowd and Shieh (2013) further articulate that productive/technical efficiency is defined as the cost of goods or services produced, while economic efficiency is a measure of whether the cost of producing goods brings desirable outcomes. They further clarify that “economic efficiency cannot be obtained when socially undesirable outcomes are produced” (p. 45). For the purposes of this paper, we are defining cost efficiency in relative terms: the extent to which institutions are operating at or below institutions with the lowest costs when producing a given number of outputs (e.g., degrees, certificates) with a given set of inputs (e.g., students, faculty, staff, physical capital) and input prices (e.g., salaries, physical capital rental rates, etc.).

In order to operationalize cost efficiency for this study, it is important to define two key measures: inputs and outputs (Toutkoushian & Lee 2018). While enrollment or credit hours can be a useful output metric (Sav, 2011 2012) to analyze the educational reach, some argue that it is better to understand whether students are actually obtaining desirable outcomes, rather than merely enrolling. This may be particularly important when studying community colleges, which often have higher attrition rates compared to other public higher education institutions. Therefore, past studies on cost efficiency in higher education considered degree production/completion as one common output measure (Romano & Djajalaksana 2011).

Cost efficiency studies using Stochastic Frontier Analysis (SFA) to study higher education costs is a relatively recent area of study beginning in the 2000s (Gralka, 2018). These studies take slightly different approaches in terms of inputs and outputs, resulting in different conclusions. One study by Agasisti and Johnes (2015) explored both public and private universities using total expenses versus bachelor's degree production and found that these institutions tend to be relatively cost inefficient. Doyle (2015) studied public comprehensive universities and found that most institutions were cost efficient in terms of degree productivity. Some studies have investigated long-term (persistent) versus short-term (residual) efficiency, such as Titus et al. (2017), who found that colleges tend to be cost inefficient in the long-term rather than the short-term.

One critical point made by Agasisti and Johnes (2015) is that cost efficiency studies must be disaggregated by type of institution (e.g., community colleges, regional colleges, research universities), as different sectors of higher education have different sets of inputs and outputs to consider. Few studies aim to understand operational costs at community colleges and address the issue of cost efficiency. Toutkoushian and Lee (2018) analyzed whether community colleges achieved economies of scale. Using cross-sectional Delta Cost Project data (2013), enrollment as an instructional output measure and total cost and expenditures as the input measure, the authors found evidence that community colleges did exhibit economies of scale. There are even fewer studies employing Stochastic Frontier Analysis (SFA) to examine cost efficiency in the community college sector. Sav (2012) employed SFA to analyze whether cost and (in)efficiency differed between for-profit 2-year colleges and non-profit two-year colleges. Using IPEDS data from 2005 to 2009 fiscal years and teaching credit hours as output, Sav (2012) found that longer existing non-profit colleges (both public and private) were more cost efficient than newer for-profit colleges. Agasisti & Belfield (2017) also used IPEDS data examining a seven-year period and found little evidence of economics of scale—that cost appeared to be proportionate to output. They also found that colleges with higher proportions of minority students were less efficient and colleges with more traditionally-aged students were more efficient. The two studies analyzed a much shorter period of time than the current research and did not compute transient (short-term) cost efficiency versus persistent (long-term) cost efficiency, which are essential measures to consider in institutional and state level decision making (Filippini et al. 2018).

Romano and Djajalaksana (2011) analyzed spending at community colleges compared to other public colleges/universities to determine whether they were more cost efficient at educating students for the first two years compared to other public institutions. They used NCES and IPEDS data from 1987 to 2005 to look at trends in general expenditures, program costs and subsidies per student at two- versus four-year higher education institutions. They found a slight cost advantage to the public comprehensive institutions over the public community colleges but cautioned that it may be the result of vocational programs being more expensive to administer, compared to more introductory classes at four-year institutions.

Finally, one important consideration when analyzing the cost efficiency in higher education is geographic location (Baker & Levin, 2017; Toutkoushian & Lee, 2018). Baker and Levin (2017) argue that investigating cost efficiency in higher education requires consideration of geographic location. Toutkoushian and Lee (2018) similarly found cost differences among community colleges based on five geographic areas within the United States. The current study addresses geographic differences in costs by employing a spatial matrix containing the distance between an institution and its neighbors, with the relationship between costs at these institutions being less intense (inverse)

with distance. Intuitively, institutions within the same small region may be faced with similar costs, but as we move outside of that region, costs become less similar. Furthermore, urban and rural institutions are compared when separating persistent cost efficiency from transient cost efficiency at public community colleges.

Theoretical Frameworks

This study draws on the cost theory of the firm and Bowen's (1980) revenue theory of costs with respect to higher education institutions. The cost theory of the firm posits that the costs of production are related to outputs, inputs, input prices, and other exogenous factors. Graphically, the cost function is a boundary or an envelope that shows the lowest cost at which a given vector of outputs can be produced. Mathematically, a cost function describes a linear or non-linear relationship between the total costs of producing the desired level of output given the vector of inputs available.

Baumol et al. (1982) seminal work extended cost theory to analyze firms that produce multiple outputs. Cohn et al. (1989) applied the theory to higher education institutions, which can be viewed as firms with multiple outputs: colleges and universities produce both teaching and research. Community colleges educate students at the undergraduate level, but produce little to no research (Sav, 2011 2012; Agasisti & Belfield 2017). Although they engage almost exclusively in teaching, community colleges can also be viewed as "firms" that produce multiple outputs, particularly with respect to sub-baccalaureate degrees such as associate degrees and long, medium and short-term certificates.

Bowen's (1980) theory of revenue and costs postulates that, because of their peculiar nature, higher education institutions spend all the revenue they receive. This revenue includes: federal, state and local appropriations; tuition and fees; profits from auxiliary enterprises (e.g., dining hall, bookstores, etc.); donations and gifts from businesses and individuals; and grants and contracts from the government (federal, state, and local) and private entities. The extent to which costs vary may depend on the amount of funds received from each of those revenue streams. Compared to the public funding of other types of public higher education institutions, public funding of community colleges is rather complex, as detailed in the previous section. Depending on the state, some public community colleges receive either local or state appropriations only for operating expenses or only for capital expenses (Center for Community College Policy and Education Commission of the States, 2000). Within Bowen's framework, the degree to which these sources of revenue have an impact on expenditures, costs and cost efficiency at public community colleges has yet to be explored.

Research Design

Utilizing a method known as generalized true random effects (GTRE) regression to estimate a SFA model, drawing on IPEDS data, and using spatial weights, this research examines costs and cost efficiency at public community colleges. The approach is described in detail below, with mathematical steps and a working example in the online.

Method

The cost function takes a quadratic form, which permits fixed cost differences among outputs, is flexible in nature, and allows for zero values (Cohn et al. 1989; Koshal & Koshal, 1999; Lenton, 2008; Johnes & Johnes, 2009; Sav, 2011; Titus et al. 2017; Vamosiu et al. 2018). Allowing for zero values of outputs for some institutions and points in time is relevant since not all institutions produce all outputs (associate degrees, short, medium and long-term certificates) every year.

$$TC_{nt} = c_0 + \sum_{i=1}^k a_i Q_{int} + \frac{1}{2} \sum_{i=1}^k \sum_{j=1}^k b_{ij} Q_{int} Q_{jnt} + d_1 FTFaculty_{nt} + d_2 PTFaculty_{nt} + d_3 Fina_{nt} + d_4 Demo_{nt} + \rho \sum_{m=1}^n w_{nm}^2 TC_{mt} + u_{nt} + v_{nt} + r_n + h_n$$

TC_{nt} : cost for the n th institution at time t to produce k products; Q_{int} : output of the i th product (associate's degrees and certificates) $FTFaculty_{nt}$ and $PTFaculty_{nt}$: full/part-time faculty $Fina_{nt}$: vector of the five financial variables $Demo_{nt}$: vector of other explanatory variables: total enrollment, percentage of students under the age of 25, percent of students who are a minority, dummy variables indicating whether the institution is located in a large urban/suburban area;

$\sum_{m=1}^n w_{nm}^2 TC_{mt}$: spatial lag of the dependent variable

ρ (ρ): spatial parameter v_{nt} : idiosyncratic error term, u_{nt} : transient/residual/short-term inefficiency, r_n : random institution effects h_n : persistent/long-term/time-invariant inefficiency.

To take into account the possible correlation of operational costs among public community colleges in the same geographical area, this study employs spatial analysis to reveal differences in costs at a more disaggregate level. Intuitively, institutions within the same small region may be faced with similar costs, but outside of that region, costs become less similar. For example, community colleges employ faculty and staff within local market areas; therefore, it may stand to reason that labor costs for institutions on a small radius may be spatially dependent. Consequently, a spatially lagged cost variable can be calculated to account for differences in cost of living and market wages, where differences are more likely as the distance between community colleges increases. In other words, spatial analysis captures the reality that a change in an independent variable anywhere in the study domain affects costs not only in that domain, but in the surrounding areas as well, with decreasing intensity as the distance between institutions increases.

The spatial analysis creates the spatially lagged cost variable by employing a spatial matrix W and spatial weights (see Online Appendix), based on the nearest-neighbors of each public community college or binary contiguity weight matrices. In densely populated areas with many community colleges, nearest neighbor weights may only take into account the interdependency of costs among a few institutions in part of those geographical areas. Therefore, inverse distance squared (IDS) weights were created to consider the possible spatial correlation in entire geographic areas within distance bands around community colleges that are specified by the researcher. Compared to binary contiguity weight matrices, IDS weight matrices are more robust to misspecification. The presence of spatial dependence is tested for by Lagrange Multiplier test statistics (Anselin & Florax, 1995).

Following the recommendation of Filippini et al. (2018), this investigation employs generalized true random-effects (GTRE) regression techniques and utilizes panel data. Since their departure from cross-sectional data to estimate SFA (Aigner et al. 1977), researchers have built on the work of others to develop techniques that included the use of panel data.

These techniques include random-effects (Pitt & Lee, 1981; Kumbhakar, 1990; Battese & Coelli, 1992; Battese & Coelli 1995) and fixed-effects (Schmidt & Sickles, 1984; Cornwell et al. 1990) regression. Addressing the limitations of the random- and fixed-effects regression models of stochastic frontier analysis (SFA), Greene (2005) developed what he calls true fixed-effects and true random-effects regression models of SFA. Unlike other techniques, the true random-effects technique allows for estimates of time-variant inefficiency. Because of its complex log-likelihood function, SFA models employing true random-effects models are estimated using maximum simulated likelihood estimating (MSLE) techniques.

The GTRE model is an extension of the true random-effects model. Based on the work of Colombi et al. (2014) and further developed by Filippini and Greene (2016), the GTRE method enables analysts to decompose inefficiency into its transient (short-run) and persistent (long-run) components. Titus (2019) used GTRE regression to generate bachelor's degree production transient and persistent efficiency scores among public master's colleges and universities. Transient/short-run/residual inefficiency may reflect singular management errors or incorrect responses to changes in market conditions and factor prices (e.g., faculty salaries) at one point in time. Persistent/long-run inefficiency may reflect structural deficiencies in management and repeated misallocation of resources.

Unlike the multi-step method originated by Kumbhakar et al. (2014), the GTRE method allows for a faster and less cumbersome way to separate inefficiency into its component parts discussed above. Therefore, the SFA model is estimated in one step using GTRE regression via a MSLE technique.¹ Based on the estimated SFA (via GTRE regression), cost efficiency scores are derived by way of a method developed by Jondrow and colleagues (1982). This study extends the GTRE-generated SFA of public community colleges to take into account spatial interdependence of costs. Following Agasisti and Belfield's (2017) method in estimating technical efficiency, cost efficiency scores are estimated with and without financial-oriented predictors of cost inefficiency.

Data and Variables

The current research uses data from the U.S. Department of Education's Integrated Post-secondary Education Data System (IPEDS) covering 752 community colleges over a 15 fiscal year period, from 2004 to 2018. To identify such an institution in IPEDS, we used all seven IPEDS metrics delineating an institution's type and kept all the institutions who met all seven criteria and had no missing years of data. The dependent variable is operating costs, which are quantified as education and general expenditures (E&G) aggregated at the institution level, to include expenditures on instruction, research, public service, academic support, student services, institutional support, operations and maintenance (Fig. 1). While it is common to think of community colleges as only producing associate degrees, Horn et al. (2009) report that many of these institutions award almost as many certificates as associate degrees yearly. Therefore, applying microeconomic cost theory, the number of associate degrees and the number of short (1-year), medium (1- to 2- years) and long (2- to 4-years) term certificates are outputs in the quadratic cost function. As previously discussed, community colleges produce little to no research (Agasisti & Belfield, 2017). While Sav, (2012) includes research as an output measure in his 2005–2009 study

¹ For more detailed information on the GTRE and MSLE, see Filippini and Greene (2018).

Fig. 1 Costs by year in percentage terms (2004–2018)

indicating an average of 30 million dollars in research expenditures at public community colleges in Table 1), our data spanning 2004–2018 shows the average research expenditure is \$25,844, with 90% of the data points reporting zero expenditures on research. Because the presence of research expenditures is so rare (under 10% of the data), we do not consider research as a separate output.

The number of both full-time and part-time instructional faculty are considered inputs. Data on faculty salaries (a proxy for input prices) are incomplete, particularly for the part-time instructors, who constitute a significant percent (68.2%) of the teaching faculty (Online Appendix). Therefore, this variable is not included in the analysis.

The study includes other variables that are hypothesized to have an impact on operational costs, such as demographics, funding and revenue, and location. First, enrollment and demographics are discussed. Generally, enrollment is captured via the full-time equivalent (FTE) normalized measure. Specifically, twelve credits minimum of coursework is considered full-time, so two part-time students, one taking nine credits and one enrolled for three credits, are normalized to one full-time equivalent student. Reed (2016) and Staff (2017) emphasize the unique features of community colleges, who are open door institutions, and serve a disproportionately large number of part-time students (59.3% in our data) relative to their four-year higher education institution counterparts. With such a high fraction of part-time students, FTE is no longer an optimal measure. Intuitively, the FTE equivalency is not ideal given a few very common occurrences: each student is eligible for financial aid, which entails significant administrative work whether the student attends part- or full-time; each student must have individual registrar records kept, a labor cost that is the same whether the student is part- or full-time and; each student uses support services regardless of part- versus full-time attendance (Reed, 2016). Therefore, the current study

Table 1 Descriptive statistics

Variables	Mean (2004)	SD (2004)	Mean (2018)	SD (2018)	Mean	S.D.	Min	Max
Costs (in million \$)	39.01	34.52	55.79	56.37	49.74	47.97	2.672	564.0
Federal funds (in million \$)	8.303	7.593	11.70	11.47	12.03	12.50	0	271.2
State funds (in million \$)	17.50	14.78	20.84	22.51	19.27	19.16	0.004	310.8
Local funds (in million \$)	11.05	18.04	13.81	23.33	12.39	20.57	0	236.6
Tuition revenue (in million \$)	8.763	9.472	11.36	13.08	10.63	12.12	0.002	154.3
Pell grant revenue (in million \$)	5.561	5.091	9.060	9.859	8.996	10.48	0	257.0
Number of faculty	350.9	340.8	379.5	378.0	384.8	376.5	8	5817
Full-time	118.5	96.88	121.0	110.0	122.0	104.6	1	1311
Part-time	232.4	263.6	258.5	282.3	262.2	289.1	0	4506
Total enrollment	6362	6002	4796	5121	4726	4785	79	74,245
No. of associate degrees	484.5	407.2	814.0	850.9	648.3	644.9	0	9954
No. of certificates	271.8	381.7	509.2	774.5	385.3	557.0	0	15,506
Short-term certificates	162.0	316.4	299.7	455.2	226.0	384.5	0	4890
Medium-term certificates	103.2	132.5	204.6	474.7	153.6	277.9	0	10,616
Long-term certificates	6.577	32.34	4.866	18.27	6.276	26.52	0	653
Percent minorities	27.95	22.39	35.97	23.46	31.91	22.92	0	98.99
Percent enrolled < 25 yr old	57.76	9.999	68.96	10.51	58.55	17.76	0.208	100
Located in urban/suburban area	0.999	0.0365	0.519	0.500	0.525	0.499	0	1
Number of observations	748	748	748	748	11,220	11,220	11,220	11,220

uses total enrollment rather than FTE as a measure. Demographic variables include non-white students and the percent of enrolled students under the age of 25.

The financial variables (federal, state and local funding, tuition revenue and Pell grants) are of primary interest. Community colleges receive funding from federal, state and some local governments, as well as private grants and contracts, and Pell grants. Federal, state and local funding can each come from three sources: appropriations, non-operating and operating grants. Our exploratory data analysis revealed a significant number of instances where federal/state/local funding were listed under federal/state/local appropriations one year but listed under non-operating or operating federal/state/local funds and vice versa the following year. In order to account for this data issue, federal, state and local funds, respectively, were each aggregated across the three categories (i.e., appropriations, non-operating and operating funds). Lastly, tuition revenue is also included (Pell grant revenue is typically included as part of federal non-operating grants to avoid double counting). All financial variables are adjusted for inflation in 2018 dollars.

The study includes a dummy variable for whether the institution is located in a large urban area (i.e., large city or suburb). Furthermore, as discussed in the previous section, the possible correlation of costs among public community colleges in the same geographical area is captured by a spatially weighted cost variable. Time fixed effects are included in the model to account for unobserved variables that vary over time but not across institutions. State fixed effects are included in the model to allow for unobserved heterogeneity across states but not across time. Community colleges may also be under the governance of their respective county, district or city. However, there is no data depicting this potential structure for the institutions in our study. Consequently, unobserved heterogeneity across jurisdictions within a state is not taken into account in the analysis.

A list of all the variables used in this study and their descriptive statistics are shown in Table 1. All continuous variables were log transformed in the analysis to provide easier interpretation of the results.

Figure 2 shows the sharp increase in operating costs at community colleges, from an average of \$39.6 million in 2004 to \$56.7 million in 2018, a 42.7% change. Total federal funding and Pell grants at the institution level have increased during the economic recession (Fig. 2), but local and state level funding have remained relatively constant.

Figure 3 shows small increases in overall per student funding. Per student state level funding reductions during the economic recession are compensated by per student federal funding and Pell grants. Shifting to revenue, the in-district tuition and fees have increased by about 25% from an average of \$2289 in 2004 to an average of \$3082 in 2018 (Fig. 4).

The number of total degrees granted at community colleges during the 14-year period has almost doubled, from 585,770 in 2004 to 933,048 in 2018, with the Associate of Arts (A.A.) and Associate of Science (A.S.) still being the most popular degree (Fig. 5). In percentage terms, Fig. 6 reveals a somewhat constant split between Associate degrees and various length certificates awarded.

The current study faces the limitations associated with using secondary data. The number of students under the age of 25 was missing for certain institutions in certain years (at most, two years per institution). Missing data analysis revealed the information was missing at random (MAR) and was imputed using the Markov Chain Monte Carlo method. Faculty salaries are an important input cost, but because of IPEDS data limitations, we dedicated an online section to explain why this measure was excluded in this analysis. Furthermore, institutions that did not have data for all years have been dropped from the analysis.

Fig. 2 Costs and funding by year in thousands (2004–2018)

Fig. 3 Funding per fulltime equivalent student (2004–2018)

Fig. 4 Average tuition and fee by year (2004–2018)

Fig. 5 Number of degrees granted by year and type (2004–2018)

Fig. 6 Percentage of degrees granted by year and type (2004–2018)

Results

Cost Function

The number of degrees granted, both overall and by category follow an increasing trend between 2004 and 2017 (Fig. 5), but data for 2018 shows a significant decrease (9.7% drop in A.A./A.S. degrees, 12.9% drop in one-year or less certificates and 3.8% drop in one-to-two-year certificates between year 2017 and 2018). Complete data for 2019 and 2020 were not available at the time of this study, so the authors cannot statistically identify a change in trend with just a one-time occurrence. In order to avoid statistical bias from what may be an outlier year in the data, the analysis presented below uses the 2004–2017 data.

While the number of degrees and certificates are a proxy for output, enrollment is a proxy for size. It is reasonable to assume the size of an institution is linked to costs via the need for more instructors, physical space, academic and student support staff or even campus maintenance, and to have enrollment each year correlated with the number of associate degrees granted in that year at an institution (correlation coefficient of 0.79). To see if multicollinearity biases the GTRE model results, we repeat the analysis in five scenarios: (i) the first analysis includes total enrollment (shown below); (ii) the second one excludes total enrollment; (iii) the next three models each include various moving averages of total enrollment (3, 4 and 5 year) and; (iv) the last model includes a three-level categorical variable for size of institution based on the cutoffs for the 33rd percentile enrollment, 66th and over. (Due to space limitations, the last three models are not shown but are available from authors). Across all specifications, the significance and signs of the coefficients of key

Table 2 Cost function estimation results using the generalized true random effects model (GTREM)

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
No. of associate degrees	– 0.173*** 0.011	– 0.137*** 0.012	– 0.033*** 0.010	– 0.061*** – .010	– 0.016* 0.009
No. of certificates	0.047*** 0.004	0.060*** 0.006	0.025*** 0.004	– .033*** 0.005	0.021*** 0.004
No. of associate degrees squared	0.068*** 0.002	0.061*** 0.002	0.026*** 0.002	0.032*** 0.002	0.027*** 0.002
No. of certificates squared	0.008*** 0.001	0.008*** 0.001	0.004*** 0.001	0.003*** 0.001	0.003*** 0.001
No. of associate degrees *No. of certificates	– 0.020*** 0.002	– 0.025*** 0.002	– 0.012*** 0.002	– 0.013*** 0.002	– 0.009*** 0.002
Full-time faculty	0.160*** 0.003	0.160*** 0.003	0.239*** 0.003	0.256*** 0.003	0.318*** 0.003
Part-time faculty	0.006*** 0.001	0.006*** 0.001	0.001 0.001	0.001 0.001	0.002*** 0.000
Federal funds	0.067*** 0.001	0.077*** 0.001	0.038*** 0.001	0.038*** 0.001	
State funds	0.094*** 0.001	0.112*** 0.002	0.130*** 0.001	0.132*** 0.001	
Local funds	0.004*** 0.000	0.004*** 0.000	0.003*** 0.000	0.004*** 0.000	
Pell grant revenue	0.028*** 0.001	0.027*** 0.001	0.002** 0.000	– 0.000 0.001	
Tuition revenue	0.073*** 0.001	0.079*** 0.002	0.084*** 0.001	0.087*** 0.002	
Total undergraduate enrollment	0.198*** 0.003	0.224*** 0.004	0.257*** 0.003	0.250*** 0.003	0.365*** 0.003
Percentage students under 25	0.120*** 0.005	0.153*** 0.006	0.055** 0.005	0.057*** 0.003	0.088*** 0.005
Percent minorities	0.130*** 0.001	0.134*** 0.002	0.043*** 0.001	0.068*** 0.002	0.082*** 0.002
Located in urban/suburban area	– 0.018*** 0.002	– 0.018*** 0.002	0.028*** 0.002	0.018*** 0.002	0.025*** 0.002
Cost Spatial Lag	0.044*** 0.015	0.406*** 0.015	0.582*** 0.012	0.471*** 0.014	0.551*** 0.014
Constant	9.151*** 0.147	4.756*** 0.150	3.787*** 0.115	4.727*** 0.133	6.474*** 0.136
Sigma (r_i)	0.261*** 0.001	0.193*** 0.001	0.233*** 0.001	0.190*** 0.001	0.212*** 0.001
r_i	0.147*** 0.001	0.178*** 0.001	0.151*** 0.001	0.149*** 0.001	0.154*** 0.001
Sigma (u_{it})/Sigma (v_{it})	1.443*** 0.044	2.305*** 0.060	1.907*** 0.049	1.785*** 0.051	1.708*** 0.050
Sigma (h_i)	1.208*** 0.017	0.797*** 0.013	1.270*** 0.016	1.044*** 0.016	0.826*** 0.013

Table 2 (continued)

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
No of observations	10528	10528	10528	10528	10528
State fixed effects	No	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	Yes	Yes
Log likelihood	6721	6714	7489	7716	7104

+ $p < 0.1$

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

variables remain consistent, indicating little bias. Therefore, we present the results of the full model below.

The results of the econometric analysis are presented in Table 2. The first column shows the GTRE model estimates with neither state nor time fixed effects. Next, we introduce state and time fixed effects, one at a time (Model 2 and 3) and, together (Model 4). The benefit of state and time fixed effects is as follows: state fixed effects are meant to capture unobserved characteristics pertaining to each state individually that affect the community colleges within that state but may be different in other states; time fixed effects account for events that take place at a particular point in time and impact all institutions. It is important to note that the state is the unit of analysis for state fixed effects, which is different from the spatial analysis employed, which helps connect the costs of institutions (not states) in proximity to each other, which often means across state lines. The distance is calculated using latitude and longitude coordinates and it does not account for state lines, but simply for distance. It further allows us to capture the differences in costs between rural and urban institutions whether they are in the same or different states.

Model 5 includes the results without our key variables, the financial variables, to reveal the bias created by not considering financial resources. In other words, by not accounting for funds community colleges receive, we cannot fully understand their spending behavior. Due to the quadratic form of the function, the coefficients on the nonlinear variables do not allow for the usual linear interpretation. Focusing on the model that includes both state and time fixed effects (Model 4), there is a positive and statistically significant association between the number of full-time faculty ($\beta = 0.256$, $p < 0.001$) and total costs.

Proceeding to our key variables, total costs are positively associated with federal funds ($\beta = 0.038$, $p < 0.001$), state funds ($\beta = 0.132$, $p < 0.001$), local funds ($\beta = 0.004$, $p < 0.001$) and tuition revenue ($\beta = 0.087$, $p < 0.001$). These empirical findings are supportive of Bowen's theory of cost, with community colleges indeed spending more, the more funding they receive.

Total costs are positively related to total enrollment ($\beta = 0.250$, $p < 0.001$), the percent of students under the age of 25 ($\beta = 0.057$, $p < 0.001$) and percent of minorities enrolled ($\beta = 0.068$, $p < 0.001$). Institutions located in an urban area have higher costs ($\beta = 0.018$, $p < 0.001$). While we may suspect this correlates with higher wages and cost of living relative to non-urban areas, the current research is limited in its ability to establish such a relationship due to the lack of consistent data on faculty wages (Online Appendix) and no data on cost of living by areas within each state. The parameter estimates of the spatial lag of cost is statistically significant ($\beta = 0.471$, $p < 0.001$), revealing there

Table 3 Cost efficiency indices generated by the models presented in Table 2

	Mean	S.D.	Min	Max	P10	P25	P50	P75	P99
<i>Model 1</i>									
Residual cost efficiency index	0.911	0.039	0.524	0.981	0.862	0.893	0.919	0.937	0.966
Persistent cost efficiency index	0.824	0.002	0.807	0.845	0.822	0.823	0.824	0.825	0.829
<i>Model 2</i>									
Residual cost efficiency index	0.883	0.056	0.379	0.982	0.807	0.855	0.896	0.923	0.964
Persistent cost efficiency index	0.866	0.004	0.814	0.906	0.863	0.865	0.866	0.867	0.883
<i>Model 3</i>									
Residual cost efficiency index	0.900	0.047	0.594	0.982	0.839	0.880	0.912	0.932	0.965
Persistent cost efficiency index	0.840	0.004	0.807	0.859	0.838	0.839	0.841	0.842	0.851
<i>Model 4</i>									
Residual cost efficiency index	0.904	0.055	0.595	0.981	0.847	0.885	0.915	0.934	0.965
Persistent cost efficiency index	0.866	0.003	0.819	0.894	0.864	0.865	0.866	0.867	0.878
<i>Model 5</i>									
Residual cost efficiency index	0.902	0.045	0.522	0.984	0.843	0.883	0.912	0.933	0.964
Persistent cost efficiency index	0.854	0.002	0.835	0.902	0.852	0.853	0.854	0.855	0.862

is a positive correlation of costs among public community colleges in close geographical proximity.

Column 5 estimates the model without the key financial variables. Not including financial variables to explain cost at the institution level underestimates the relationship between the number of Associate degrees and certificates awarded and costs, while overvaluing the impact of hiring more full-time faculty and increasing enrollment on institution level operating cost. It further biases upward the true result of increasing the percentage of students under the age of 25 and overestimates the impact of an increase in the minority student enrollment. Model 5 further overvalues the impact of a public community college located in an urban area on operating costs. These differences, together with the lower log likelihood ratio, suggest that accounting for appropriations, grants and tuition revenue is essential to better understand costs. Simply put, money that is received is an important predictor of money that is spent.

Cost Efficiency

Residual efficiency is an index on a scale of 0 to 1 (or 0–100%) that captures how close to the cost frontier a public community college is operating in a certain year. It varies across time due to changes in the institution's behavior, as it captures singular management errors or incorrect responses to changes in market conditions and factor prices (salaries, rent, interest rates, etc.). Persistent/time invariant efficiency quantifies how close to optimal spending an institution is over the period studied. This measure tends to indicate recurring management errors and repeated misallocation of resources that is difficult to change over time. Our study finds virtually no correlation between residual and persistent efficiency (correlation coefficient of 0.0007).

Fig. 7 Kernel density of the residual/short-run cost efficiency indices

Residual/Short-Run Efficiency

Table 3 presents the residual and persistent cost efficiency indices across all five models. First to note, average persistent efficiency is lower than average residual efficiency across all models. Average residual efficiency varies little across models (91% in Model 1 is the highest, 88% in Model 2 is the lowest), while average persistent efficiency shows greater variation across models (82% in model 1 as the lowest value and 87% in Models 2 and 4 as the highest). Figure 7 reveals that short-run efficiency exhibits a non-linear time trend pattern, increasing to an all-time high in 2006 (90.8%), fluctuating afterwards to its lowest (89.1% on average).

Second, residual cost efficiency varies greatly across institutions. Focusing on Model 4, the lowest value is 59.5% and the highest 98.1%. Without including the financial variables, the bias would be downward to 52% (Model 5). If researchers were to consider neither state nor time fixed effects, that would cause a downward bias on the minimum residual cost efficiency computation to 52.4% (Model 1). In contrast, persistent cost efficiency in Model 4 shows only a 7.5% variation across institutions, with the lowest being 81.9% and the highest 89.4%. Excluding financial variables results in a persistent efficiency calculation of 83.5% at the minimum and 90.2% at the maximum. Furthermore, not accounting for state and time fixed effects (Model 1) would bias the minimum calculation downwards to 80.7% and the maximum to 84.5%. By not including state fixed effects (Model 3) shows a 6% downward bias on the lowest persistent cost efficiency community college and a 3.5% downward bias on the maximum.

Third, the public community colleges in the 25th percentile of the residual cost efficiency exhibit 88.5% cost efficiency. With Model 4 as the benchmark, the variation across models is small, with the highest downward bias (3%) observed when not accounting for

Table 4 Determinants of residual efficiency (efficiency in percentage terms)

Variables	Model 1	Model 2	Model 3	Model 4
Pct. students under 25	1.342* (0.630)		1.548* (0.634)	1.323* (0.608)
Pct. minority student	2.304*** (0.610)		2.445*** (0.624)	2.428*** (0.602)
Ratio of PT faculty	– 0.305 (0.636)	– 0.284 (0.627)	– 0.367 (0.622)	– 0.575 (0.599)
Tuition revenue		1.909*** (0.388)	1.961*** (0.381)	10.359*** (1.726)
Federal funding		0.958* (0.395)	0.958* (0.401)	3.910*** (0.627)
State funding		2.125*** (0.516)	2.140*** (0.513)	27.308*** (3.739)
Local funding		0.109* (0.054)	0.112* (0.054)	0.908*** (0.163)
Pell grants		– 0.154 (0.144)	– 0.173 (0.147)	– 0.638 (0.600)
Tuition revenue Sq.				– 0.281*** (0.062)
Federal funding Sq.				– 0.153*** (0.032)
State funding Sq.				– 0.817*** (0.122)
Local funding Sq.				– 0.062*** (0.012)
Pell grants Sq.				0.050 (0.038)
2005 (reference year–2004)	0.039 (0.181)	– 0.008 (0.174)	– 0.087 (0.174)	– 0.171 (0.169)
2006 (r.y.–2004)	0.063 (0.193)	– 0.051 (0.188)	– 0.196 (0.188)	– 0.155 (0.188)
2007 (r.y.–2004)	– 0.152 (0.209)	– 0.277 (0.207)	– 0.512* (0.208)	– 0.323 (0.217)
2008 (r.y.–2004)	– 0.392 (0.241)	– 0.694** (0.241)	– 1.039*** (0.241)	– 0.697** (0.242)
2009 (r.y.–2004)	– 0.604* (0.266)	– 1.200*** (0.292)	– 1.533*** (0.285)	– 0.955*** (0.271)
2010 (r.y.–2004)	– 0.494+ (0.265)	– 1.286*** (0.369)	– 1.696*** (0.356)	– 0.898* (0.384)
2011 (r.y.–2004)	– 0.504+ (0.268)	– 1.140** (0.355)	– 1.558*** (0.344)	– 0.854* (0.371)
2012 (r.y.–2004)	– 0.704* (0.304)	– 1.086** (0.371)	– 1.705*** (0.372)	– 1.077* (0.451)
2013 (r.y.–2004)	– 0.728* (0.311)	– 0.955** (0.362)	– 1.692*** (0.366)	– 1.134** (0.433)

Table 4 (continued)

Variables	Model 1	Model 2	Model 3	Model 4
2014 (r.y.–2004)	– 0.847** (0.311)	– 1.028** (0.345)	– 1.839*** (0.354)	– 1.238** (0.409)
2015 (r.y.–2004)	– 1.261*** (0.335)	– 1.460*** (0.354)	– 2.377*** (0.369)	– 1.644*** (0.407)
2016 (r.y.–2004)	– 1.413*** (0.338)	– 1.601*** (0.353)	– 2.518*** (0.369)	– 1.827*** (0.411)
2017 (r.y.–2004)	– 2.502*** (0.386)	– 2.431*** (0.346)	– 3.522*** (0.385)	– 2.702*** (0.393)
Constant	78.357*** (3.272)	12.433 (12.800)	– 2.033 (12.474)	– 266.951*** (30.355)
R^2	0.02	0.05	0.06	0.11
N	10,528	10,528	10,528	10,528

+ $p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

time fixed effects (Model 2). Half of the community colleges in our study have a residual cost efficiency below 91.5% (Model 4), results that exhibit about a 2% bias at most in the other models. Furthermore, the histogram and kernel density graph in Fig. 7 show little difference in the residual efficiency variation across community colleges located in an urban and those in rural communities.

The residual cost efficiency index is regressed on demographics and financial variables in an institution-level fixed-effects model with time fixed effects and adjustments for heteroskedasticity and serial correlation (Table 4). The percentage of students under 25 years of age and minorities is positively associated with residual efficiency. The same positive significant relationship exists between tuition revenue, funding from all three sources, and short-run efficiency. The ratio of part-time faculty is not statistically related to short-term efficiency. Time fixed effects show that, relative to the base year 2004, there are significant reductions in short-run inefficiency, on average, as early as year 2007 and consistently present across all specifications starting 2009. A follow up study should delve deeper into the specific market factors and their respective un-proportional impact on cost efficiency.

Persistent/Long-Run Efficiency

Long-run cost efficiency is one index for each institution capturing their efficiency over the fourteen years studied. The institutions in the lowest quartile (25th percentile) exhibit 86.5% cost efficiency (Model 4) and under, which is biased downwards in all other models not accounting for financial variables or state and/or time fixed effects (Model 1–4.2% bias, Model 3–2.6% bias and Model 5–1.2% bias). Persistent cost efficiency indices are essential in calculating the possible reduction in long-term costs without adjusting output/inputs. The results in Model 4 suggests that long-term costs at public community colleges in the lowest quartile could be reduced by at least 15.6% ($1/0.865-1$) without affecting current

Fig. 8 Kernel density of the persistent/long run cost efficiency indices

number of degrees and certificates granted, nor current number of full- and part-time faculty employed.

The lower half of the community colleges (50th percentile) have a persistent cost efficiency index of 86.6% or lower (Model 4), which is biased downwards in all other models (Model 1–82.4%, Model 3–84.1%, and Model 5–85.4%). At the highest level (99th percentile), the discrepancy between the models is as high as approximately 5%. The findings from Model 4 suggest that on average, public community colleges could reduce long-term operating costs by at least 15.5% ($1/0.866-1$) to get close to operating on the cost frontier over the long-run.

For persistent efficiency, there is little variation across states, with the most efficient state at 88% and, the least, only 0.4% lower. Furthermore, the histogram and kernel density graph in Fig. 8 show little difference in the persistent efficiency distribution between community colleges located in an urban versus rural community.

Next, we inquire what factors are linked to persistent efficiency. To account for differences across states, a binary variable reflecting whether the state has a governing board for community colleges, or some other coordinating entity is created (McGuinness, 2014). Because each institution has one persistent efficiency index, due to the time invariant nature of this metric, the index is regressed on the 14-year institution average of the demographic and financial variables. This cross-sectional data regression is estimated via the Ordinary Least Squares (OLS) method, with correction for heteroskedasticity (Table 5) All financial variables except state funding are statistically significant. From Table 5, a 1% increase in federal funding is associated with an approximate 0.3% (Model 2 and Model 3) decrease in long-term efficiency, on average, holding all else constant. The relationship between Pell grants and long-term efficiency is similar in magnitude, 0.3%, but positive. The decrease in cost efficiency following a 1% increase in local funding is a much smaller (less than

Table 5 Determinants of persistent efficiency (efficiency in percentage terms)

Variables	Model 1	Model 2	Model 3
Pct. students under 25	0.243** (0.093)		0.043 (0.052)
Pct. minority student	– 0.016** (0.005)		– 0.018** (0.006)
Urban	– 0.074*** (0.008)	– 0.041*** (0.007)	– 0.031*** (0.007)
Ratio of PT faculty	0.090+ (0.050)	– 0.061** (0.019)	– 0.050* (0.021)
Governing board present	0.028*** (0.007)	– 0.022*** (0.006)	– 0.024*** (0.006)
Tuition revenue		– 0.048*** (0.004)	– 0.056*** (0.004)
Federal funding		– 0.296*** (0.012)	– 0.287*** (0.012)
State funding		0.000 (0.005)	0.003 (0.005)
Local funding		– 0.008*** (0.001)	– 0.008*** (0.001)
Pell grants		0.301*** (0.015)	0.302*** (0.015)
Constant	85.611*** (0.419)	87.530*** (0.087)	87.342*** (0.256)
R^2	0.03	0.28	0.29
N	10,528	10,528	10,528

+ $p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

0.01%). Tuition revenue also has a negligible impact on long-run cost efficiency. Community colleges located in urban and suburban areas are less cost efficient than those in a rural setting. Persistent efficiency is positively related to the presence of a governing board in Model 1 (beta = 0.028, $p < 0.0001$), but negatively related in Model 2 and 3 (beta = –0.022 and, respectively, – 0.024, both $p < 0.001$). Similarly, the ratio of part-time faculty reveals a positive, but negligible impact on persistent efficiency in Model 1, but negative in Model 2 and 3. These results suggest more research is needed on the role these two variables have on long-run efficiency.

Long-term efficiency is also related to student demographics, with a negligible negative relationship between the percentage of minorities and long-term efficiency, and a small positive one when considering the percentage of students under age 25 in Model 1 only. Equity as it pertains to the mission and open acceptance policy of community colleges is an important issue for policy makers, campus management and researchers alike (Dowd & Shieh, 2013; Baker & Levin, 2017). Dowd and Shieh (2013) argue that whether community colleges are cost efficient does not detract from the fact that they offer access to higher education to many who could otherwise not likely pursue higher

Table 6 Top 20 most long-run cost efficient public community colleges in the U.S. 2004–2017 fiscal years

Rank	Institution Name	State
1	Illinois Eastern Community Colleges-Wabash Valley College	IL
2	University Of New Mexico-Los Alamos Campus	NM
3	New Mexico State University-Grants	NM
4	Cowley County Community College	KS
5	Ohio State University Agricultural Technical Institute	OH
6	Clovis Community College	NM
7	Bossier Parish Community College	LA
8	Richmond Community College	NC
9	Athens Technical College	GA
10	Allen County Community College	KS
11	Treasure Valley Community College	OR
12	Merced College	CA
13	Cisco Junior College	TX
14	Jefferson Community College	OH
15	Seminole State College	OK
16	Bladen Community College	NC
17	Fox Valley Technical College	WI
18	Sandhills Community College	NC
19	Montgomery Community College	NC
20	Warren County Community College	NJ

education. In this way, efficiency and equity can sometimes conflict with one another, although they are not always incompatible (Dowd & Shieh, 2013). Due to the negligible size of the estimated coefficients for the demographic variables, our findings suggest that equity and efficiency are not at odds for public community colleges.

Overall, the results indicate that long-term inefficiency is most likely the result of long-term management errors and repeated misallocation of resources that are difficult to change over time, rather than the factors investigated in this analysis. The top 20 most long-term cost-efficient institutions over the 2004–2017 fiscal year period are listed in Table 6. The top five include Illinois Eastern Community Colleges-Wabash Valley College (IL), University of New Mexico-Los Alamos Campus (NM), New Mexico State University-Grants (NM), Ohio State University Agricultural Technical Institute (OH), and Cowley County Community College (KS). Except for the last one, all these community colleges are either branch campuses of four-year institutions or located within multi-college districts. While we cannot draw conclusions based on the results of this study, these factors suggest that these community colleges may be engaged in cost sharing with their respective “parent” institution or “main” campus. Additional observations reveal that Seminole State College (OK) and University Of New Mexico-Los Alamos Campus (NM) have resident partners in the area that provide project-based work experience during for-credit internship courses, thus sharing the cost of the student education. Sandhills Community College (NC) established a partnership with the county school system, where, at the conclusion of a five-year plan of study, graduates will receive a high school diploma and an Associate of Arts degree, thus sharing the cost

of these students' higher education. These anecdotal observations suggest that future research is needed in order to better understand what institutional factors may or may not contribute to cost efficiency.

Discussion and Implications

Practice and Policy

Both short term and long-term efficiency are of great importance to campus leaders and policy makers on their own merit. The former reveals that institutions are very effective (90%) at responding to changes in market conditions. Long-term efficiency (87%) indicates room for improvement, potentially due to structural management problems and misallocation of resources over the long-term. This finding is consistent with past studies (e.g., Titus et al. 2017) examining the difference between short term and persistent efficiency but is a unique contribution to the study of efficiency of community colleges. One practical implication of this study is that community colleges should be nimble in responding to market changes to maximize cost efficiency. Like any other institutions of higher education, community colleges can be bureaucratic in nature and change can be slow. Higher education administrators and community college practitioners may find this task daunting and difficult. Such change, however, is not impossible and requires investment at the state and local level (Maliszewski et al. 2012). One suggestion that has not been empirically studied is to improve long term efficiency by creating cost sharing partnerships with important state level stakeholders. In the section above, we highlighted how cost-efficient community colleges partnered with state and regional workforce development agencies. Other partnerships may include the American Association of Community Colleges or specific-state organizational entities such as the Massachusetts-based Partnership to Advance Collaboration and Efficiencies (PACE).

Campus leaders and policy makers alike could develop strategic plans and funding alternatives based on inferences made from yearly data on short-run cost efficiency. Since short-run cost inefficiency captures the one-time management errors or incorrect responses to changes in market conditions and factor prices (e.g., faculty and staff salaries) at one point in time, assessing and encouraging learning from previous mistakes is essential. To see if such learning is happening, we compute the changes in short-run efficiency indices between all consecutive years and then average them. We find that 537 of the 752 institutions studied have a positive average, showing that they may indeed be learning from their mistakes. One way to ensure learning from past mistakes is from experience sharing among community colleges: institutions with increases in short-run efficiency over time may share their experiences and best management practices with their counterparts.

The results of this research point toward identifying public community colleges that are most cost efficient with respect to the production of associate degrees and certificates, given financial resources and other variables. In this study, we identify those institutions with the highest persistent cost efficiency scores. Future research should include case studies to examine the extent to which they engage in best management practices. State and local higher education policy makers can then promote and share those best practices with institutions that are relatively less cost efficient. A more detailed list of items to be considered in future research are shared in the next subsection.

Analysis of the equity of higher education can be drawn from two key questions: equity of what and equity for whom (Baker & Levin, 2017). Equity of what and whom could be considered through the lens of long-term efficiency. The analysis showed that the percentage of students under the age of 25 is positively associated with long-run cost efficiency, but the relationship is negative for minority students. In terms of size, there is a negligible negative relationship between the percentage of minorities and long-term cost efficiency, and a small positive one when considering the percentage of students under age 25. This finding, which is consistent with past research on the efficiency of community colleges (Agasisti & Belfield, 2017), may reflect minority students and non-traditional students completing degrees and certificates at lower rates. Consequently, additional support to improve completion rates may be needed (National Center for Education Statistics, 2019).

Community colleges stand out in the higher education landscape through their unique mission and open acceptance policy, characteristics that often raise equity concerns (Dowd & Shieh, 2013; Baker & Levin, 2017). As mentioned previously, our findings suggest that equity and efficiency are not at odds for public community colleges due to the negligible size of the estimated coefficients for the demographic variables. It is important for colleges to continue pursuing research-based practices for supporting non-traditional and marginalized students to support equitable outcomes, and those practices may require investment by colleges.

In seeking to understand community college cost efficiency, this paper focused on associate degree and certificate completions as a critical metric of output. However, not all community college students complete a sub-baccalaureate credential, as many students transfer prior to completion. Unfortunately, there is an absence of data tracking transfer students across various institutions (Jenkins & Fink, 2016) due to current federal regulations, which prevent scholars from tracking students across institutions. Furthermore, there is currently no unifying definition of transfer rates. Recent research on student mobility has indicated that the transfer function has diversified to become a multifaceted experience (Taylor & Jain, 2017), with eight different patterns of transfer: vertical; lateral; reverser; reverse credit; swirlers and alternating enrollees; concurrent enrollees, co-enrollment, double-dipping, simultaneous enrollees; dual credit, dual enrollment; and transient. Further, with over 70% of students transferring laterally from a two-year to a two-year or four-year to a four-year institution, vertical transfer is no longer the dominant pathway (Taylor & Jain, 2017). This makes tracking transfer students a challenge. When considering implications for community college efficiency, it is important to keep in mind the currently unmeasurable impact transfer students may have on an institution's output of associate degrees and certificates.

Future Research

After identifying best management practices at relatively “high” cost efficiency institutions, future research could pursue two issues. First, researchers should study cost efficiency of community colleges while accounting for student transfers as an output. Almost 40 percent of first-time students will transfer at least once within six years and over half of those students transfer from a community college (Shapiro et al. 2018). Despite the ubiquity of transfer, data including transfer rates is extremely limited, as it is not captured at the federal level and states have different methods of measuring transfer (Jenkins & Fink, 2016). Work

should be undertaken to improve the availability of data on transfer rates at community colleges across the country, so that future research can include transfers as an output.

Second, as a follow-up to the identification of the most cost-efficient public community colleges in this inquiry, qualitative methods, such as case studies, can then be employed to determine the specific “best practices” at those institutions.

Third, future research should include causal studies that involve the use of difference-in-differences regression and synthetic control methods. Those lines of investigation would seek to answer lingering underlying questions with respect to the effect of management practices on cost and cost efficiency at specific public community colleges that were identified in this study.

Finally, this study lays the foundation for building on this research going forward which would help to frame causal studies that would seek to uncover the actual effects of “best” management practices on operating costs, persistent cost efficiency, and other outcomes at previously identified institutions. Those other outcomes could also include persistent degree and certificate production efficiency at community colleges.

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