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Eduardo Minuci
West Virginia University, egm0007@mix.wvu.edu

Amir B. Neto
West Virginia University, amneto@mix.wvu.edu

Joshua C. Hall
West Virginia University, jhall23@mail.wvu.edu

Department of Economics

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Eduardo Minuci

Amir Borges Ferreira Neto

Joshua Hall

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Efficiency, But At What Cost? Evidence from a DEA Analysis of WV School Districts

Eduardo Minuci*[1], Amir B. Ferreira Neto†[1], and Joshua Hall‡[1]

[1]College of Business and Economics, West Virginia University

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Abstract

West Virginia schools are consistently below the national average on the NAEP. Using Data Envelopment Analysis, we estimate the technical efficiency of West Virginia school districts. We find less variation in technical efficiency in West Virginia than in similar studies conducted in other states. This appears to be because of state policy imposing homogeneity of input usage. Due to the limited variation in technical efficiency across districts, we cannot analyze how non-school inputs such as socioeconomic factors affect technical efficiency across districts. Summary statistics organized by county economic status, however, suggest that socioeconomic status plays a role. Our results highlight an important limitation of DEA analysis on schools.

Keywords: Data Envelopment Analysis, Efficiency, Government, Public Schools
JEL Classification: H41, H76, I29

*E-mail: egm0007@mix.wvu.edu
†E-mail: amneto@mix.wvu.edu
‡E-mail: joshua.hall@mail.wvu.edu

1 Introduction

Public education focuses on the intellectual and cultural development of human beings. Attending school raises the cognitive skill level of an individual, which positively correlates with economic growth (Hanushek and Woessmann, 2012). Hanushek et al. (2016) estimate that if West Virginia could raise its academic achievement to match the state with the highest education achievement, the state would see an over 600% gain in state gross domestic product. Shifting out the education production function is no easy task, especially in a state like West Virginia (WV) that is dealing with persistent budgetary problems due to declining coal severance revenue (Eller, 2017). For any given level of spending, however, ensuring that school districts are operating as close to what is efficient is a way to improve the state's economic situation.

There is a long literature on education production (Hanushek, 1986). In this paper we use data envelopment analysis (DEA) to estimate the technical efficiency of West Virginia School Districts. DEA is a mathematical programming approach that identifies the production frontier of a firm (such as a school district) based on existing data and assumptions about the production process (Ruggiero, 2001). Doing so allows us to observe how much inefficiency there currently is in K-12 education in the state. The DEA approach has been used to analyze elementary and secondary schools in many states and countries (Cooper and Cohn, 1997; Kirjavainen and Loikkanen, 1998; Ruggiero and Vitaliano, 1999; Chakraborty et al., 2001) as well as institutions of higher education (Calhoun and Hall, 2014).

To preview our results, we find very little variation in technical efficiency across West Virginia school districts. Further investigation highlighted that West Virginia school districts are constrained in terms of input usage by state policy. While this reduces the amount of technical inefficiency, these rules likely constrain districts on the frontier from shifting the education production frontier outward. Due to the limited variation in technical efficiency across districts, we were unable to analyze how non-school input factors affect technical efficiency by district. Summary statistics organized by county economic status, however, suggest that socioeconomic status likely play a role in explaining county-level variation in technical inefficiency.

The remainder of the paper is as follows. Section 2 discusses the DEA approach to measuring technical efficiency. Section 3 discusses our data on West Virginia county school districts, while Section 4 presents our estimates of technical efficiency along with some summary statistics categorized by county economic status. Section 5 concludes with a discussion of our findings and their relevance for West Virginia education policy.

2 Measuring Technical Efficiency Using DEA

The technical efficiency numbers drawn from our data envelopment analysis are based on the work done by Bogetoft and Otto (2010). DEA studies the production process of each county every year and determines a measure that represents a 100% efficient system. It then compares the production process of each county with the determined standard measure. This allows the model to calculate a number between zero and one, which qualifies the efficiency of each production process. A county school district with a TE equal to one indicates that the county is producing at its maximum level given the choice of inputs it has.

In our research, we consider the Farrel's concept of technical efficiency, in which we assume that a more efficient production process is characterized by producing a certain level of output while utilizing the minimum resources required to do so. This research's model also assumes the idea of free disposal, determined returns of scale, and convexity of the production possibility frontier. Analyzing Bogetoft and Otto (2010), we can define our model letting x^k be the vector of m inputs used and y^k the n outputs produced by firm k. The technical efficiency can then be calculated by:

$$TE_k = \min_{E,\lambda^1,\ldots,\lambda^K} E$$
$$\text{subject to:}$$
$$Ex_i^* \geq \sum_{k=1}^{K} \lambda^k x_i^k, \qquad i = 1,\ldots,m \qquad (I)$$
$$y^* \leq \sum_{k=1}^{K} \lambda^k y_j^k, \qquad j = 1,\ldots,n \qquad (II)$$
$$\lambda \in \Lambda^K(\gamma) \qquad (III)$$

where $*$ refers to the standard firm, λ is the parameter set, and γ is an indicator of the return of scale. Bogetoft and Otto (2010) provide further information.

By changing the constraint (III), we can run a test to define whether the production process being analyzed operates at a decreasing or increasing returns to scale. We are able to run this test since the DEA is a non-parametric approach, which does not require us to define a specific production frontier. By solving the system above we are able to calculate a relative measure that represents the geometric distance of each district's production function from the production possibility frontier (PPF); this generates a measurement bounded between zero and one and represents the technical efficiency of each county of the state. Therefore, we have a relative measure of efficiency. To calculate the technical efficiency measure, we used the "Benchmarking" package in R described by Bogetoft and Otto (2010). In addition, we opted for a variable returns to scale set up.[1]

3 West Virginia School District Data

West Virginia has 55 county public school districts. Following from Hanushek (1986), education is produced with a mixture of school, family, and peer inputs. For the purposes of measuring technical efficiency, we are only concerned with school inputs as school districts have no direct control over families or peers. We obtained data on input usage by WV school districts from 2008 to 2015 from the West Virginia Department of Education (WVDOE). Our available inputs all are related to personnel and personnel usage. For example, we have the number of counselors per pupil at the district level or teachers per pupil at the district level. A full list of all of our inputs can be found in Panel A of Table 1. Panel B shows the outputs used in our analysis.

[1]We also calculate TE using a constant return to scale assumption and used it to identify districts operating under increasing returns to scale. No district operates under decreasing returns to scale.

Table 1: Descriptive Statistics for Inputs and Outputs on DEA

Panel A: Inputs				
Statistic	Mean	St. Dev.	Min	Max
Principal per pupil	0.003	0.001	0.002	0.006
Principal Salary per pupil	25.381	18.806	2.446	76.521
Assistant Principal per pupil	0.001	0.001	0.000	0.003
Assistant Principal Salary per pupil	20.447	15.792	0.000	69.438
Teachers per pupil	0.071	0.005	0.060	0.093
Teacher Salary per pupil	16.279	11.985	1.587	47.661
Counselor per pupil	0.003	0.001	0.001	0.004
Counselor Salary per pupil	17.590	13.671	1.775	59.636
Panel B: Outputs				
Statistic	Mean	St. Dev.	Min	Max
11th Grade Math Score	0.415	0.145	0.030	1.000
11th Grade English Score	0.432	0.102	0.130	1.000
Graduation Rate	0.820	0.066	0.660	0.970

N=385.

We follow the education production function literature and use annual state examinations in high school math and English, along with graduation rates, as our measures of output. While there are many important skills that students learn in school that are not captured on these examinations, the fact that the state examinations and graduation rates are part of the state's school accountability system are a sign that they should be considered primary outputs. During this time frame, West Virginia's state exams (WESTEST 2) ran from grade 3 through grade 11. Given the cumulative nature of education, we use the percentage of 11th graders proficient on WESTEST 2 scores.

4 Technical Efficiency Results for WV School Districts

To better understand school district efficiency in West Virginia we create three measures of technical efficiency by combining different inputs and different outputs. The variables selected as inputs are the number of staff members (principals, assistant principals, teachers, and counselor per pupil) and their respective average salaries. The variables selected as outputs are 11th grade test scores in Math and English and graduation rates. The combination of the inputs with each different output generates three technical efficiency measurements: TE-Math, TE-Eng, TE-Grad.[2]

[2] The average technical efficiency result for each West Virginia school district from 2008 to 2015 is presented in Table 4.

To get a good sense of the overall variation in our data, Table 2 provides summary statistics for our technical efficiency estimates. Note that this table included each county school district year measure. We see very high mean scores across all three output measures, suggesting that on average there is only about 7% technical inefficiency. This suggests that the average West Virginia school district could decrease inputs by 7%, on average, and still keep output (test scores or graduation rates) at the same level.

There are two things to note about the average technical efficiency numbers presented in Table 2. First, there is a consistency across the three output measures. This highlights to us that all of the three outputs are capturing roughly the same "production" by school district. Second, there is not a lot of variation in technical efficiency across school districts in West Virginia. The typical mean amount of inefficiency found in these types of studies is in the neighborhood of 20% (Primont and Domazlicky, 2004), with greater variation in technical efficiency across districts.

Table 2: Summary Statistics for Technical Efficiency

Statistic	N	Mean	St. Dev.	Min	Max
TE-Math	385	0.937	0.064	0.709	1.000
TE-Eng	385	0.939	0.063	0.736	1.000
TE-Grad	385	0.939	0.063	0.736	1.000

Salaries are the largest cost of any school district, comprising 80% or more of current expenditures (Myung et al., 2013). That fact, in and of itself, imposes restrictions on input usage by school districts. West Virginia, however, has a state basic salary schedule for teachers. While counties and the state can provide supplements to this base amount for each year in the salary schedule, in practice this has led to much less salary variation across districts than in nearby states. For example, in Ohio the minimum salary for a teacher with no experience and only a BA varies from a minimum of $25,671 in the Southern Local School district to $48,353 in Beachwood City School district (Education Policy Research and Member Advocacy, 2017). In West Virginia, the variation is between $32,675 (several districts) and $36,400 in Monongalia County Schools (West Virginia Department of Education, 2017). This is not surprising given that West Virginia Code states that "the salary potential of school employees employed by the various districts throughout the state does not differ by greater than ten percent between those offering the highest salaries and those offering the lowest salaries." (WV Code §18A-4-5)

Given that DEA analysis is a relative measure of efficiency, the homogeneity of salaries mandated by West Virginia state law would seem to be leading to the high degree of efficiency in the state. This cost efficiency, however, may come with a downside that cannot be observed in our framework. To the extent that constraints on input usage such as restrictions on compensation, prevent school districts from shifting out the production frontier, West Virginia school districts could be technically efficient but at a lower level of output than could otherwise be achieved. This highlights and important limitation of DEA analyses in education – the legal and institutional environment in which schools operate often determined by state-level policy that affects all observations equally and thus does not directly appear in the analysis.

Typically what is done in technical efficiency studies is to regress non-school inputs, such as county demographics, on the measure of technical efficiency. Given the limited degree of variation across districts, we decided not to pursue this approach. Instead, we provide in Table 3 summary statistics for our technical efficiency measure broken down by Appalachian Regional Commission (ARC) county economic status designation. West Virginia is the only state that lies entirely within the Appalachian region, thus we are able to employ this measure of the persistence of poverty. The ARC uses an index-based classification system to monitor the economic progress of Appalachian counties. The index is based on the comparison of national averages with a three-year average of the unemployment rate, market income per capita, and poverty rate. The ARC then places counties into one of five classifications based on this socioeconomic index: Distressed (bottom 10% ranked counties), At-Risk, Transitional (between 25% and 75% ranked), Competitive, and Attainment (top 10% ranked).

Table 3: Summary Statistics for Technical Efficiency based on Economic Status

Panel A: TE-Math					
Status	N	Mean	St. Dev.	Min	Max
Distressed	71	0.91	0.07	0.78	1.00
At risk	114	0.92	0.06	0.77	1.00
Transitional	185	0.95	0.06	0.71	1.00
Competitive	14	0.99	0.02	0.94	1.00
Attainment	1	1.00	NA	1.00	1.00
Panel B: TE-Eng					
Status	N	Mean	St. Dev.	Min	Max
Distressed	71	0.91	0.07	0.78	1.00
At risk	114	0.92	0.06	0.77	1.00
Transitional	185	0.96	0.06	0.74	1.00
Competitive	14	0.99	0.02	0.94	1.00
Attainment	1	1.00	NA	1.00	1.00
Panel B: TE-Grad					
Status	N	Mean	St. Dev.	Min	Max
Distressed	71	0.92	0.06	0.79	1.00
At risk	114	0.94	0.06	0.77	1.00
Transitional	185	0.97	0.05	0.77	1.00
Competitive	14	1.00	0.00	1.00	1.00
Attainment	1	1.00	NA	1.00	1.00

Looking at the mean and the min column in Table 3 suggests that counties with higher socioeconomic status seem to be more technically efficient. For example, Competitive counties have a mean technical efficiency of 0.99 and a minimum technical efficiency in any one year of 0.94. Contrast that with Distressed counties. While Distressed counties have a mean of 0.91, the minimum technical efficiency is 0.78. In addition to highlighting the importance of socioeconomic status to technical efficiency, these results are also suggestive of the fact that West Virginia school districts in counties that are Competitive or Attainment are constrained at their current level of technical efficiency. Unfortunately, DEA analysis is unable to answer that question.

5 Discussion and Implications

The primary objective of this paper was to estimate the technical efficiency of West Virginia school districts in order to see if there were cost efficiencies that could be achieved. Our results show that, that the average West Virginia school district is operating at 93% efficiency, well above the average for similar studies. In addition, we see little variation between the level of efficiency among the school districts.

Our findings have two implications for public policy in West Virginia. First, the high level of technical efficiency and the lack of variation reflects homogeneity across school districts. This uniformity is what appears to be desired policymakers in West Virginia given the requirement that salaries vary no more than 10% across school districts. Our results seem to support that the law is succeeding in leveling the playing field in West Virginia. Second, although the results suggest that education in West Virginia is doing well, this homogeneity might be resulting in a leveling down of education. This would be consistent with cross-state evidence from the National Assessment of Education Progress showing West Virginia schools as consistently being below average.

More generally, our findings highlight an important limitation of DEA analysis. As a relative measure of efficiency, it is only useful to the extent that school districts have the ability to freely use available inputs to shift out the production frontier. However, if school districts or schools are severely constrained, as West Virginia law seems to do by severely restricting teacher salaries, then DEA analysis is of limited use. At a minimum, our results suggest that those utilizing DEA analysis need to carefully consider the legal and institutional context of a locality before interpreting their results.

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Table 4: Descriptive Statistics for Average Technical Efficiency by County

County	TE-Math	TE-Eng	TE-Grad	County	TE-Math	TE-Eng	TE-Grad
Barbour	0.94	0.96	0.96	Mineral	0.92	0.93	0.99
Berkeley	1.00	1.00	1.00	Mingo	0.94	0.97	0.93
Boone	0.80	0.84	0.80	Monongalia	1.00	1.00	1.00
Braxton	0.87	0.92	0.88	Monroe	0.97	1.00	0.96
Brooke	0.90	0.97	0.99	Morgan	0.97	0.99	0.99
Cabell	1.00	1.00	1.00	Nicholas	0.92	0.94	0.95
Calhoun	0.83	0.89	0.89	Ohio	0.95	1.00	0.98
Clay	1.00	1.00	1.00	Pendleton	0.88	1.00	0.88
Doddridge	0.84	0.94	0.87	Pleasants	0.83	0.95	0.87
Fayette	0.91	0.94	0.91	Pocahontas	0.89	0.93	0.91
Gilmer	0.91	0.94	0.95	Preston	1.00	1.00	1.00
Grant	0.94	0.96	0.96	Putnam	0.99	1.00	1.00
Greenbrier	0.93	0.97	0.93	Raleigh	1.00	1.00	0.99
Hampshire	0.99	0.99	0.99	Randolph	0.88	0.91	0.88
Hancock	0.97	0.99	0.98	Ritchie	1.00	1.00	1.00
Hardy	1.00	1.00	1.00	Roane	0.96	0.99	0.96
Harrison	0.99	0.99	0.98	Summers	0.92	0.95	0.92
Jackson	0.91	0.96	0.92	Taylor	1.00	1.00	1.00
Jefferson	1.00	1.00	1.00	Tucker	0.92	0.98	0.94
Kanawha	1.00	1.00	1.00	Tyler	0.93	0.99	0.97
Lewis	0.96	0.97	0.96	Upshur	0.91	0.96	0.89
Lincoln	0.89	0.90	0.89	Wayne	1.00	1.00	1.00
Logan	0.98	1.00	0.98	Webster	0.92	0.98	0.92
Marion	0.94	0.96	0.95	Wetzel	0.85	0.90	0.92
Marshall	0.95	0.98	0.98	Wirt	0.86	0.90	0.93
Mason	0.90	0.93	0.90	Wood	1.00	1.00	1.00
Mcdowell	0.95	0.95	0.95	Wyoming	0.86	0.96	0.87
Mercer	0.97	0.97	0.96				