Chapter 3: Measurement of Cost Differentials*

William Duncombe
John Yinger
The Maxwell School, Syracuse University

Introduction

The evaluation of education cost differentials across school districts has been an important topic in education finance research for decades (Fowler and Monk, 2001). Interest in this topic has grown in recent years with the emergence of adequacy as the primary standard in school finance litigation and the growth of state accountability systems that focus on student performance. Each of these developments calls attention to the fact that some districts must spend more than others to obtain the same performance, that is, to education cost differentials. The link between research and policy on this topic is not well developed, however, and existing state aid formulas usually contain ad hoc cost adjustments that fall far short of the across-district cost differences estimated by scholars. The objective of this chapter is to synthesize the research literature on education cost differences across school districts and to discuss the implications of this literature for state education aid formulas. The material in this chapter complements the discussions of equity and adequacy in Chapters 1 and 2 of Section 3.

The term "cost" in economics refers to the minimum spending required to produce a given level of output. Applied to education, cost represents the minimum spending required to bring students in a district up to a given average performance level. Education costs can be affected by three categories of factors, each of which is outside of school district control: (1) geographic differences in resource prices; (2) district size; and (3) the special needs of some students. In this chapter, we address the principal methods for estimating the cost impacts of each of these factors. These impacts need not be the same, of course, for every measure of student performance.

While states commonly adjust their basic operating aid programs for differences in the capacity of school districts to raise revenue, typically measured by property wealth or income, few states systematically adjust these programs for cost differences across districts. Instead, cost adjustments tend to be confined to ancillary aid programs or to be non-existent. This is a critical limitation because the success of a basic operating aid formula in providing the funds needed for an adequate education in each district, however defined, is linked to the accuracy of the cost adjustment. If the adequacy standard is defined as access to a minimum set of resources, then the basic aid formula—not a separate categorical aid program—needs to account for geographic variation in resource prices. If the adequacy standard is defined as a minimum level of student performance, then the basic aid formula also requires cost adjustments for district size and student needs.

Because cost adjustments may vary with the measure(s) of student performance or with conditions in a state, standard cost adjustments are not available. Instead, each state needs to estimate its own cost adjustments or else settle for approximate adjustments based on studies in similar states. Estimating cost adjustments is a challenging enterprise that requires clear judgments about state educational objectives, good data, and technical expertise. These challenges are the subject of this chapter.

The focus here is on cost differentials across school districts, not across individual schools. School districts are the primary budget decision making units, and taxing power and budget authority lie with district officials. Accordingly, state school finance systems are focused on distributing education aid to school districts, not schools, in most cases. Recent research has highlighted inequity in the distribution of resources across schools within large urban school districts (Rosa and Hill, 2004; Stiefel, Rubenstein and Berne, 1998;) and some districts have introduced formula-based distribution formulas (weighted student formulas) to improve the equity of intra-district resource allocation (Odden, 1999). The measures of cost differentials due to student needs discussed in this chapter would also be appropriate for intra-district funding formulas.

The chapter is organized roughly in line with the major cost factors. We begin by discussing briefly the one method that can produce estimates for all three types of cost factors—education cost functions. We then turn to looking at other methods for estimating geographic resource price differences, the cost effects of enrollment size, and the cost impacts of various student characteristics. Each section describes the most frequently used methods, discusses their strengths and weaknesses, and provides key references for more detailed information.

Education Cost Functions

To estimate the relationship between spending, student performance, and other important characteristics of school districts, many education researchers employ one of the key tools of production theory in microeconomics, namely, a cost function. Cost is defined as the spending required to reach a given level of student performance using current best practices. Cost cannot be directly observed, however, so cost functions are estimated using district spending (usually operating spending per pupil) as the dependent variable. Spending may deviate from cost because some school districts are inefficient, that is, they deviate from current best practices. As a result, cost functions need to be estimated with controls for school district efficiency, if possible.

More formally, education costs, C, depend on (1) student performance (S); (2) resource prices (W), such as teacher salaries; (3) enrollment size (N); and (4) student need measures (P), which are discussed in detail below; that is, $C = f(S, W, N, P)$. Now let e stand for school district efficiency in delivering S. Without loss of generality, we can set the value of e at 1.0 in an efficient district, so that it has a value between zero and one in a district that does not use current best practices. With this scaling, we can write the cost/efficiency equation that scholars estimate as:

$$E = \frac{C}{e} = \frac{f(S, W, N, P)}{e} \tag{1}$$

This formulation makes it clear that a district that does not use best practices ($e < 1$) must spend more than an efficient district ($e = 1$) to achieve the same level of performance (S), all else equal.

Equation (1) has been widely used in various forms because it addresses many fundamental questions of interest to scholar and policy makers. For example, a cost function measures how much a given change in teacher salaries, district enrollment, or student needs affects the cost of achieving a particular level of student performance at a given level of efficiency. The cost function methodology has been refined over the last few decades, and cost function studies have been undertaken for several states.[1]

In order to estimate equation (1) using multiple regression analysis, researchers must address several methodological challenges. The first challenge is to identify a performance objective and find data to measure it (S). One common approach, for example, is to select the performance measure or measures that are most central to a state's school accountability system, which typically include student performance on state-administered tests and perhaps graduation rates. Other studies select available test-score information, usually on math and English scores in a variety of grades. In addition, these measures of student performance are determined simultaneously with district spending, so they need to be treated as endogenous when equation (1) is estimated.[2]

Many production function studies (and a few state accountability systems) focus not on levels of student performance, as measured, say, by the share of students passing a state test, but instead on the change in student performance over time, often referred to as a value-added measure. This approach is difficult to implement in a cost study, however, because a value-added approach requires test score information on the same cohort in different grades—information that is not generally available.

Moreover, value-added measures provide noisy signals about student performance, particularly in small school districts (Kane and Staiger, 2002).[3]

A second methodological challenge is to control for school district efficiency (*e*). The problem is that efficiency cannot be directly observed, so a researcher must select a method to control for efficiency indirectly. Three approaches to this challenge, each with limitations, have appeared in the literature. The first approach is to estimate the cost function with district fixed effects, which control for all district characteristics, including efficiency, which do not vary over time (Downes and Pogue, 1994). The limitations of this approach are that it cannot control for district efficiency that varies over time and that, by removing all cross-section variation it undermines a researcher's ability to estimate the impact of *S*, *W*, *N*, and *P* on costs.

The second approach is to estimate a cost frontier based on the lowest observed spending for obtaining any given student performance, to calculate each district's deviation from this spending as an index of inefficiency, and then to control for this measure in an estimated cost function (Duncombe, Ruggiero, and Yinger, 1996; Duncombe and Yinger, 2000; Reschovsky and Imazeki, 2001). [4] A limitation of this approach is that this index of "inefficiency" reflects both cost and efficiency differences across districts. As a result, this approach may lead to underestimated coefficients of cost variables, such as student poverty, because a portion of the impact of these variables on costs may be captured by the estimated coefficient of the "inefficiency" index.

The third approach is to identify factors that have a conceptual link to efficiency and then to control for them in a cost function regression. A limitation of this approach is these conceptual links cannot be directly tested. Nevertheless, a strong case can be made for the inclusion of two types of efficiency controls. First, some district characteristics might influence the incentives for voters to monitor school officials or for school officials to adopt best practices. For example, Reschovsky and

Imazeki (2004b) control for efficiency using a measure of competition from other public schools, which might influence the behavior of school officials. Second, some district characteristics, such as median household income or tax price, might influence voters' demand for measures of school-district performance other than *S*. Because efficiency can only be defined relative to specific measures of school-district performance, in this case *S*, any spending to obtain other measures of performance is, by definition, inefficient.[5] Income and tax price are examples of variables that help control for this type of inefficiency (Duncombe and Yinger (2000, 2005a, 2005b).

A third challenge is to select a functional form for the cost model. This form reflects underlying assumptions about the technology of production, such as the degree of substitution between inputs, economies of scale, and the interaction between school and non-school factors. Most education cost studies have used a simple multiplicative cost function, which works well in practice but which imposes limits on both factor substitution and economies of scale.[6] By contrast, Gronberg et al. (2004) use a flexible cost function that does not impose significant restrictions on production technology. This approach adds many variables to the cost model, however, which makes it more difficult to identify cost effects with precision.[7]

Despite the empirical challenges involved in estimating cost functions, they have some clear advantages over other methods of estimating cost differentials. First, they use actual historical data and statistical methodology to separate the impact of factors outside and within district control on the cost of reaching student performance levels. Second, they can provide measures of overall cost differentials across districts as well measures of individual cost factors (resource prices, enrollment, and student needs) that can be used in state aid formulas. Some scholars have criticized cost functions on the grounds that their technical complexity makes them difficult for state policy makers to understand (Guthrie and Rothstein, 1999).[8] One of the objectives of this chapter is to explain the intuition behind cost functions to help make them more accessible to policy makers. After all, complex statistical procedures are accepted in some policy arenas, such as revenue forecasting and program evaluation, and we see no reason why they could not become accepted in the design of state education aid formulas.

In the following sections we describe the use of cost functions and other methods to estimate cost differentials for resource prices, economies of size, and student needs.

Geographic Variation in Resource Prices

The impact of geographic variation in the prices of goods and services on the purchasing power of school districts has been recognized for decades (Brazer and Anderson, 1974; Chambers, 1978). Eleven states incorporate geographic cost of education indices (GCEI) into their school funding formulas (Huang, 2004) and the National Center for Education Statistics (NCES) has sponsored the development of GCEI for all school districts in the country using two different methods (Chambers, 1997; Taylor and Fowler, 2006).

Controlling for the compensation a district must offer to attract personnel of a given quality is particularly important for accurate cost estimation, because personnel compensation makes up a large share, well over half, of a district's budget.[9] In this section, we discussing the reasons for variation in resource prices and review the four most common approaches for estimating GCEI. Each of these approaches attempts to measure the extent to which the cost of personnel varies across districts based on factors outside of districts' control—not on variation in districts' generosity.

Variation in the price of inputs other than personnel has been largely ignored in the literature. This remains an important topic for future research.

Reasons for Geographic Variation in Resource Prices: The prices school districts must pay for resources can differ across school districts for several reasons: (1) cost-of-living; (2) labor market conditions; (3) local amenities; and (4) working conditions for employees. The higher the cost-of-living in an area, defined as the resources required to purchase a standard bundle of goods and services, the more school districts in the area must pay to attract employees of a given quality. Local labor market conditions can also affect the salaries districts are required to pay. If an area's unemployment rate for professionals is relatively high, for example, then teachers and school administrators may have relatively limited choices of alternative jobs. Under these circumstances new teachers and administrators will be more apt to accept school district offers with lower salaries and benefits.

School employees, like other employees, may also be willing to sacrifice some compensation to have ready access to amenities such as access to cultural events and business services; proximity to coastline, lakes, mountains, and parks; access to good highways, airports, and rail transportation; and access to good state or local public services.

Finally, the salary required to attract instructional and administrative personnel may depend on the working conditions in the school district, which depend both on school policies and on student characteristics. Working conditions that teachers care about may include factors under district control, such as school size, class size, professional development spending, availability of instructional materials, school leadership and culture, and districts may be trade off spending on factors related to working conditions against increased teacher compensation. Working conditions for teachers also may be influenced by factors outside district control, such as the socio-economic backgrounds of their students. Research on the teacher mobility indicates that teacher employment decisions can be influenced by characteristics of the students they are teaching (Hanushek, Kain, and Rivkin, 2001, 2004; Scafidi, Sjoquist, and Stinebrickner, forthcoming; Falch and Strom, 2005; Ondrich, Pas, and Yinger, forthcoming).

Cost-of-Living (COL) Index: The cost-of-living approach estimates price differences for a "market-basket" of goods and services across geographic areas (Duncombe and Goldhaber, 2003). For each factor in the market basket, price data is collected by geographic area and a market basket is identified using data on consumer expenditure patterns. The final COL index is the spending required to purchase the market basket in each location relative to the state or national average. The use of a COL index as an education cost adjustment is based on the assumption that teachers compare real wages across districts, not nominal wages. This assumption implies that a high-COL district cannot attract the same quality teachers as a low-COL district without paying higher nominal wages.

The principal strengths of the cost-of-living approach are its conceptual simplicity and the fact that COL indices are based on private sector prices outside of district control (McMahon, 1996). This simplicity comes at a price, however. Even if a COL index accurately captures variation across locations in consumer prices and in the wages required to attract teachers, school personnel do not necessarily shop or live where they work.[10] In addition, COL indexes do not capture variation across districts in working conditions and local amenities, which can affect the compensation required to attract equal quality teachers. Moreover, COL data at the school district level are surprisingly difficult to obtain; existing national and state-level COL indexes provide no insight into within-state COL variation (Nelson, 1991; McMahon, 1996). Colorado, Florida, and Wyoming have developed COL indices for their school aid calculations (Rothstein and Smith, 1997; Florida Department of Education, 2002; Wyoming Division of Economic Analysis, 1999; Colorado Legislative Council Staff, 2002).[11]

Competitive Wage Index (CWI): Another approach for estimating a GCEI is to use information on variation in private sector salaries (or full compensation), particularly for occupations similar to teaching. The NCES recently published CWI estimates for all school districts in the U.S. (Taylor and Fowler, 2006) and some states, including Ohio, Massachusetts, New York, and Tennessee, have used measures of average private wages as cost adjustments in their education aid formulas (Rothstein and

Smith, 1997; Massachusetts Department of Education, 1999; New York State Education Department, 2003; Eff and Eff, 2000; Ohio Department of Education, 2003).

One approach to developing a CWI is to use information on average salaries by occupation to construct a weighted average of salaries in occupations comparable to teaching, typically professional, managerial, or technical occupations (Rothstein and Smith, 1997). The major source for this data is the *Occupational Employment Survey* (OES) published by the U.S. Bureau of Labor Statistics, which is available for labor market areas. One disadvantage of this approach is that it assumes that private employees in these occupations are comparable on experience, education, and demographic factors across geographic areas.

A more appealing approach is to use detailed individual-level data on private employees to construct a private wage index that controls for employee characteristics. Taylor (2004) has applied this approach to Texas school districts and recently developed a CWI for all school districts in the country (Taylor and Fowler, 2006). Using data from the Census, Taylor and Fowler (2006) regress salaries of college graduates on demographic characteristics (age, gender, ethnicity, education, and hours worked), occupational categories, and indicator variables for labor market areas. The regression results are used to "predict the wages that a nationally representative person would earn in each labor market area" (Taylor and Fowler, 2006, p. 9). The CWI is obtained by dividing the predicted wage by the state or national average wage. This CWI can be updated for other years by using the OES to estimate changes in wages across years by occupation and labor market area.

The comparable wage methodology is straightforward, and a carefully constructed CWI should capture the impact of cost-of-living, local amenities, and labor market conditions on the salary a district must pay to attract teachers of a given quality. The principle drawback to this methodology is that average private sector salaries are not likely to reflect differences in working conditions for teachers across districts. For example, private sector salaries in professional occupations are not likely to reflect the demographics of the student body in a district, the age and condition of school buildings, the extent of overcrowding in classrooms, and so on, which could be very important to the job choices of teachers.

Hedonic Teacher Cost Index (TCI): Another approach to estimating GCEI is to separate the impact on teacher (or other employee) compensation of factors in and out of district control using statistical methods—and then to determine costs based only on external factors. What sets this approach apart from the others is that, to the extent possible with available data, it directly accounts for the effects of school working conditions on the salaries required to attract teachers to a district. Hedonic salary studies have been conducted for several states, including Alaska, Maryland, and New York (Chambers et al., 2004b; Chambers, Taylor, and Robinson, 2003; Duncombe and Goldhaber, 2003; Duncombe, Lukemeyer and Yinger, 2003); however, only Texas, presently uses a hedonic-based cost adjustment in its aid formula (Alexander et all, 2000; Taylor, 2004). In addition, Chambers (1997) uses a hedonic regression to developed a teacher cost index for all school districts in the country; unfortunately, however, his data include only two variables related to a district's education environment, namely, district enrollment and the share of students from a minority group.

The hedonic salary approach involves estimating a multiple regression model in which employee salary (or salary plus fringe benefits) is regressed on teacher characteristics, working conditions under district control (such as school or class sizes), and factors outside district control that are related to cost-of-living, labor market conditions, local amenities, and school working conditions. Characteristics of teachers typically include education, experience, gender, race, type of assignment, and certification status. Some studies include other measures associated with teacher quality, such as certification test score performance and ranking of the college a teacher attended (Chambers, 1997; Duncombe, Lukemeyer and Yinger, 2003; and Duncombe and Goldhaber, 2003). Amenity variables typically include distance to a central city, climate and crime rates, and working-conditions variables include district enrollment and student characteristics (e.g., race, language proficiency, and poverty).

Hedonic models are typically estimated with individual teacher-level data using standard multiple regression methods. To construct a personnel cost index, the coefficients for discretionary factors are multiplied by the state average value for that factor, while coefficients for external (i.e., non-discretionary) factors are multiplied by actual values for that district. The sum of these terms is the predicted salary required to attract an employee with average characteristics to a particular district, and the salary index compares this predicted salary to the state average.

Because they have the most complete controls, hedonic salary models are likely to produce the most accurate TCI, that is, the most accurate estimate of the salary required to attract teachers with given characteristics to work in a district. Even hedonic estimates face several difficult challenges, however.

Perhaps the most difficult challenge is to fully control for teacher quality. Teacher characteristics included in existing studies capture several important dimensions of teacher quality, but these characteristics predict only a small share of variation in teacher quality as directly measured from teachers' impacts on the test scores of their students (Hanushek, Kain, and Rivkin, 2005). Moreover, teacher quality is likely to be negatively correlated with concentrated student disadvantage, so imperfect controls for teacher quality will bias the coefficients of the student disadvantage variables toward zero. As a result, hedonic studies may systematically understate the impact of concentrated student disadvantage on the compensation a district must pay to attract teachers of a given quality.

In addition, actual teacher salaries may not correspond in all districts to the minimum salaries required to attract teachers with certain characteristics into the district. Some districts could be overly generous or particularly inept in bargaining, for example. Differences between actual salaries and minimum required salaries are signs of district inefficiency, and they could lead to biased results in hedonic salary models if the (unobserved) factors that lead to inefficiency are correlated with the explanatory variables in the model.

Another challenge is that readily available COL measures may reflect discretionary district decisions. For example, housing prices often account for most of the variation in private prices across geographic areas but they may partially reflect differences in perceived education quality across districts. Using MSA level housing prices reduce this endogeneity (Duncombe and Goldhaber, 2003). Some hedonic studies have used unimproved agricultural land as a COL measure to avoid the potential endogeneity of housing prices; however, agricultural land in central cities or inner ring suburbs often does not exist, and has to be imputed (Chambers et al., 2004b). Private sector salaries can serve as a proxy for cost-of-living, labor market conditions, and some amenities, but are likely to be influenced by housing prices (and education quality) as well.

Several studies have attempted to address potential biases in hedonic salary models. Teacher fixed effects models have been estimated to control for unobserved teacher quality differences (Taylor, 2004; Chambers, Taylor, and Robinson, 2003). To account for the possibility of omitted compensation or working condition variables, some studies have included an estimate of the turnover rate in the model (Chambers et al., 2004b; Duncombe and Goldhaber, 2003). Finally, a few hedonic studies have included variables to control for school district efficiency (Duncombe, Lukemeyer and Yinger, 2003; Duncombe and Goldhaber, 2003).

The TCI calculated from hedonic salary models tend to display relatively little variation, because most of the variation in teacher salaries is explained by key features of teacher salary schedules, usually education and experience, and because information on other determinants of teacher quality and on working conditions is incomplete.[12] The limited impact of working conditions on hedonic TCI runs counter to recent research on teacher labor markets, which finds that teacher mobility is influenced by the characteristics of the students they teach (Hanushek, Kain, and Rivkin, 2001; Scafidi, Sjoquist, and Stinebrickner, forthcoming; Falch and Strom, 2005; Ondrich, Pas, and Yinger, forthcoming). More research is needed to resolve this apparent contradiction.

Teacher Cost Indices from Cost Functions: Resource prices, particularly teacher salaries, are key variables in education cost functions. The coefficient on the teacher salary variable indicates the increase in costs required to maintain student performance levels when teacher salaries increase (holding other variables in the model constant). Using this coefficient and measures of teacher salaries by district it is possible to construct a teacher cost index (relative to the state average), which reflects variation in teacher salaries weighted by the impact of teacher salaries on spending.

Two different types of salary measures have been used in education cost functions: (1) private sector wage indices, such as a CWI (Reschovsky and Imazeki, 1998, 2001; Imazeki and Reschovsky, 2004a, 2004b); and (2) actual teacher salaries for teachers with similar education and experience levels. Recognizing that teacher salaries can be set simultaneously with spending levels in the annual budget process, studies using actual teacher salaries often treat them as endogenous variables in estimating the cost function (Duncombe and Yinger, 2000, 2005a, 2005b).[13] In these studies, the teacher salary index is based not on actual salary but instead on salary predicted on the basis of factors outside a district's control.

A teacher cost index derived from a cost function is similar in some respects to a CWI and should capture variation in employee compensation due to differences in cost-of-living, labor market conditions, and amenities across school districts. Because student characteristics are also included in the cost model, the teacher cost index is not likely to reflect the impact of working condition differences across school districts on the wages required to attract teachers.[14] This impact may appear, however, in the estimated coefficients of these student characteristics; if so, it will appear when teacher cost indexes and pupil weights (discussed below) are combined.

The strength of this approach is that it produces a teacher cost index that both reflects variation in key factors affecting teacher salaries and is weighted by the impact of teacher salaries on spending. The accuracy of this approach depends, however, on the quality of the cost-model controls for student disadvantage and school-district efficiency.

Enrollment Size and Education Costs

The 90-percent drop in the number of school districts in the United States since 1938 represents one of the most dramatic changes in education governance and management in the twentieth century. While the pace of school district consolidation has slowed considerably since the early 1970s, some states still provide financial incentives to encourage school district consolidation (Gold et al., 1995; NCES, 2001). At the same time; however, operating aid formulas in a number of states compensate districts for small size or sparsity, thereby discouraging consolidation (Baker and Duncombe, 2004; Huang, 2004). In this section we briefly review the reasons for and the evidence on the relationship between costs and district size before discussing methods to estimate the cost effects of size.

Reasons Costs May Vary with Enrollment: Economies of scale are said to exist when the cost per unit declines as the number of units goes up. In the case of education, the focus has been on economies of size, which refer to a decline in per-pupil expenditure with an increase in district enrollment, controlling for other cost factors. Several explanations have been offered for economies of size in education (Haller and Monk, 1988). First, some district services, such as central administration, are relatively fixed in the sense that the same central administrative staff may be able to serve a significant range of enrollment without a degradation of service. Economies of size might exist if larger school districts are able to employ more specialized labor, such as science or math teachers, which could improve the quality of instruction at no additional cost. Furthermore, teachers may be more productive in a large school district because they can draw on the experience of many colleagues. In addition, large districts may be able to negotiate bulk purchases of supplies and equipment at a relatively low cost or use their monopsony power to impose lower wages on their employees .

The existence of economies of size in education has been challenged for several reasons. First, some studies claim that the potential cost savings from consolidation are seldom realized because districts seldom lay off staff, salaries are often leveled-up across the merging districts, and transportation costs actually increase (Guthrie, 1979; Lee and Smith, 1997). Second, large school districts tend to have large schools, which, according to some studies, lead to lower student performance (Fowler and Walberg, 1991; Friedkin and Necochea, 1988; Haller, 1992; Lee and Smith, 1997) by hurting staff morale, student motivation and involvement in school, and parental involvement (Howley 1996;Cotton 1996).

Evidence on Economies of Size in Education: A large literature on economies of size in education has emerged over the last four decades. Since this literature has been covered in depth in existing literature reviews (Fox, 1981; Andrews, Duncombe, and Yinger, 2001), we only summarize the main findings. The vast majority of evidence on economies of size has come from the estimation of education cost functions. The early evidence on economies of size found sizeable economies with the cost-minimizing size for an urban district as high as 30,000 students (Fox, 1981). Recent cost function research, which have addressed a number of methodological limitations with early studies (Andrews, Duncombe, and Yinger, 2001), has also found that there may be sizeable economies of size in education, but that most of the cost savings from an increase in district enrollment are exhausted once enrollment levels of 2,000 to 4,000 pupils are reached. Surprisingly, few formal evaluations of the effects of school district consolidation on costs have been conducted (Howley, 1996). One exception is an evaluation of school district consolidations in New York from 1985 to 1997 (Duncombe and Yinger, 2005c). They found sizeable savings in operating costs from consolidation of two very small districts (combined enrollment under 100 students), but that operating cost savings became relative small (6% or less) when the consolidating districts have a combined enrollment over 3,000.[15]

Methods for Estimating Cost Effects of Enrollment Size: A common method used by states to construct scale adjustments is to estimate average district costs by enrollment class and then compare the average cost in a class to average costs in relatively large districts. Kansas used this strategy, for example, to develop "low enrollment weights," which are used in calculating operating aid (Duncombe and Johnston, 2004). The problem with this approach is that it does not consider factors other than enrollment size or sparsity, such as student performance, resource prices, topography, and student needs, that might affect spending differences across districts.

The cost function method provides the most direct way to determine the relationship between enrollment and costs. By controlling for student performance, resource prices, student needs, and efficiency, cost functions have the potential for isolating the effects of enrollment size on cost differences. The key decisions in estimating economies of size in a cost function is selecting measures of student counts, and the functional form of the relationship between cost and enrollment.

Student counts used in aid formulas generally are of three types: 1) enrollment, which is the count of all students at one point in time (usually the fall); 2) average daily membership (ADM), which is an estimate of the average enrollment over the course of the year; and 3) average daily attendance, which measures the average number of students actually attending school. In general, the difference between these student counts is quite small except in the large cities where attendance rates are often lower.

The existence of economies of size implies a negative relationship between per pupil spending and enrollment at least over some range of enrollment. However, it is likely that the rate of decline in per pupil spending occurs more quickly at low enrollment levels, than at higher enrollment levels because of relatively fixed costs, such as central administration. Several different functions have been used to account for the possible non-linear relationship between enrollment and per pupil cost. The most common approach is to use a quadratic function (the natural log of enrollment and its square) to model the relationship. Quadratic functions allow for the relationship between enrollment and per pupil costs to go from negative to positive, and cost function studies have found diseconomies of scale as well as economies of scale (Reshovsky and Imazeki, 1998, 2001; Imazeki and Reschovsky, 2004a, 2004b). In states with a few high enrollment school districts (e.g., New York) the quadratic function can lead to estimates of large diseconomies of scale; some studies have used cubic functions to reduce the effects of these large districts (Duncombe and Yinger, 2000; Duncombe, Ruggiero, and Yinger, 1996). To allow for a more flexible relationship between enrollment and per pupil costs, several cost function studies have used enrollment classes instead of a quadratic functions (Duncombe, Lukemeyer, and Yinger, 2003; Duncombe and Yinger, 2005a, 2005b). Flexible cost functions, such as translog functions, provide another alternative for specifying the enrollment-spending relationship by including both a quadratic term and a number of interaction terms between enrollment and other variables in the cost model (Gronberg et al., 2004).

Professional judgment studies can also be used to estimate the effects of size on costs. (See Chapter 2 for a more detailed discussion of this approach.) In professional judgment studies, panels of education professionals are asked to estimate the resources required to produce a particular set of student performance results. Panels are typically asked to do estimates for prototypical schools or districts with different characteristics, such as enrollment size or poverty rates (Baker, 2005). The estimates for the prototypical districts can then be extrapolated to districts of different sizes to develop an economies-of-size estimate for all districts in a state. Using the results of professional judgment studies in several states, Baker (2005) found that the shape of the per-pupil cost curve relative to enrollment was very similar to that found in cost function studies.

Student Disadvantage and Education Costs

Extensive research on the determinants of student success in school indicates that peer characteristics, family composition, parental education and employment status, and neighborhood characteristics can significantly affect student success (Coleman et al., 1966; Haveman and Wolf, 1994; Pollack and Ginther, 2003; Ferguson and Ladd, 1996; Jensen and Seltzer, 2000). In addition, student characteristics can affect the mobility decisions of teachers—and hence both the quality of teachers and the costs of teacher recruitment and training. Moreover, districts with a high concentration of students living in poverty or with limited English proficiency face much greater challenges than other districts in helping their students reach academic proficiency. In this section, we discuss the types of student characteristics considered in the literature, the methods available for estimating the additional costs required to bring disadvantaged students to a given performance level, and how states have accounted for student disadvantage in their aid formulas.

Measures of At-Risk Students: The term "at-risk" implies that a student is at a higher risk of failing to meet educational objectives than are other students because of characteristics of the student or of his or her family or peers. The most widely used measure of "risk" or disadvantage is poverty. One key measure of poverty for education cost studies is the child poverty rate, defined as the share of school-age population (5 to 17 years old) living in a poor household. The Census Bureau also provides intercensal estimates of child poverty.[16] An alternative poverty measure more commonly used in education research is the share of students that qualify for a free or reduced-price school lunch as part of

National School Lunch Program administered by the U.S. Department of Agriculture.[17] This measure has the advantage over the census poverty measure in that it is updated annually, but it is based in part on decisions by families to apply for participation in the program and on decisions by school districts to offer and promote this service.[18] Particularly for elementary students, the percent of students eligible for a free lunch is highly correlated with the child poverty rate.[19]

Other measures of student "risk" available in the decennial census include the share of children living with a single mother and the share of children living with a single mother who has an income below the poverty line and is not a high school graduate. States may also collect information on "Title 1" students (those eligible for Title 1 services) and student mobility rates.

Students with limited English proficiency (LEP) may also face significant challenges succeeding in school. Many states collect information on students who qualify for bilingual education programs or students that have been identified as needing language assistance. Unfortunately, however, there is no standard definition of LEP across states, and the LEP data in some states are of questionable accuracy. An alternative measure is available from the Census, which collects information on the number of children ages 5 to 17 who live in households where English is spoken "not well" or "not at all" or of children that are living in households that are "linguistically isolated."[20]

Students with disabilities or special needs generally require more resources than other students to reach the same student performance standards. To account for these extra costs, many states incorporate pupil weights or other adjustments for special needs students in their school aid formulas. In Chapter ??, Chambers and Parish provide a detailed discussion of state policies, including aid formulas, to account for students with special needs.

Methods for Estimating Additional Costs to Educate Disadvantaged Students: In this section, we briefly explore some of the methods for estimating the extra costs required to educate disadvantaged students. These costs are often called pupil weights.

Cost functions provide a direct way to estimate the impact of student disadvantage on the cost of education, holding student performance constant. To be specific, the coefficients on the variables measuring student disadvantages can be used to calculate pupil weights for each type of disadvantage (Duncombe and Yinger, 2005a). A weight of 1.0 indicates for a given type of student disadvantage that it costs 100 percent more to bring a student in that category up to given performance standards than the cost for a student without disadvantage. Poverty weights estimated from cost functions fall between 1.0 and 1.5 for states with large urban areas, such as Texas, New York, and Wisconsin, and between 0.6 and 1.0 for rural states (Duncombe and Yinger, 2005b; Duncombe, Lukemeyer, and Yinger, 2006).[21] One exception comes from the cost function study for Texas by Gronberg et al.(2004), which leads to weights for students in poverty between 0.23 and 0.31.[22]

Another approach for estimating the higher costs required to support at-risk students is to use professional judgment panels. These panels can be asked to estimate the required resources needed to reach student performance standards for schools with different levels of poverty (or LEP shares). The differential in costs across these prototype schools can be used to develop rough estimates of pupil weights by student type. Pupil weights from professional judgment panels are based on the judgments of professional educators, and may be sensitive to the instructions given to the panels and to the ability of panel participants to identify the extra programs that would be required to bring at-risk students up to the specified performance standard (Rose, Sonstelie, and Richardson, 2004).

Baker (2006) compared several professional judgment studies and cost function studies for the same state and found that pupil weights produced from professional judgment studies are generally lower than weights produced from cost function studies. In Kansas and New York, for example, poverty weights calculated using the results from professional judgment studies (Augenblick et al., 2001; Chambers et al., 2004a) are half those calculated in cost function studies (Duncombe and Yinger, 2005b; Duncombe and Yinger, 2005a).[23] One exception is the professional judgment study in Maryland done by Augenblick and Myers (2001), which estimated pupil weights of 1.0 or higher for poverty and LEP.

How States Adjust for Student Disadvantage: Almost all state governments have some type of aid program that provides additional funds to districts with a relatively high concentration of at-risk students. Some states include cost adjustments for poverty or LEP in the basic operating aid formula, some provide categorical aid programs for at-risk students, and a few use both of these strategies (Carey, 2002; Baker and Duncombe, 2004; Huang, 2004). As pointed out earlier, the categorical aid route alone cannot provide the cost adjustments needed to meet an adequacy standard.

The costs of at-risk students are usually incorporated into operating aid programs through the use of pupil weights. The weighted-pupil approach is used to adjust the basic operating aid formula for poverty in 15 states, for students with limited English proficiency in 9 states, and for students with handicaps in 14 states (Duncombe and Yinger, 2005a). Most states use eligibility for the National School Lunch Program as their measure of poverty, but some states use Census poverty estimates or federal welfare eligibility. Carey (2002) found that the pupil weights used by states for students living in poverty range from 0.15 to 0.30.

With the except of Maryland, which recently implemented an aid formula with a poverty weight from a study that used the professional-judgment method, no state uses statistically estimated pupil weights in its formula. Nevertheless, pupil weights have been estimated for many states and have been considered in many policy debates.

Conclusions and Directions for Future Research

We find a broad consensus among scholars that the cost of achieving any given level of student performance is higher in some districts than in others because of (1) differences in the compensation needed to attract school personnel, (2) differences in enrollment size, and (3) differences in the concentration of disadvantaged students or those with special educational needs. We do not find a consensus, however, on the magnitude of these cost differences or on the best methods for estimating them. Instead, we observe an active literature with many different approaches to estimating costs and a lively debate about the strengths and weakness of each approach.

From our perspective, the core of this topic is the estimation of education cost models. Although scholars disagree about the details, these models are now widely used and have influenced the debate about state aid formulas in many states. The most difficult issue that arises in estimating these models is how to control for school-district efficiency. No consensus on the best approach has yet emerged and far more work on this topic is needed. Questions of variable selection and functional form also deserve more attention. Because they play such a critical role in state education aid formulas, pupil weights should continue to be a focus of this research.

A second focus of the literature has been on estimating teacher cost indexes. This topic also has important links to policy because a state aid formula cannot provide the resources needed to reach any student performance target without accounting for teacher costs. As we have shown, scholars have addressed this topic using a wide range of approaches with different strengths and weaknesses. The hedonic wage approach is the most appealing conceptually, but it also requires data that are often not available, and more research developing and comparing all the approaches would be valuable.

Finally, we are struck by both the clear link between cost estimation and the objectives of most state education aid formulas and the need for more work to make cost studies accessible to policy makers. Complex statistical procedures are accepted in some policy arenas, such as the revenue forecasts used in budgeting, but are only beginning to be accepted in the design of state education aid formulas. Because careful estimates of cost differentials can help policy makers achieve their educational objectives, we believe that further efforts to make these estimates accessible would be valuable.

References

Alexander, C. D., Gronberg, T. J., Jansen, D. W., Keller, H., Taylor, L. L., and Treisman, P. U. (2000). *A Study of uncontrollable variations in the costs of Texas public education*. A summary report prepared for The 77th Texas Legislature. Austin, TX: Charles A. Dana Center, The University of Texas at Austin.

Andrews, M., Duncombe W., and Yinger, J. (2002). Revisiting economies of size in education: Are we any closer to a consensus? Economics of Education Review, 21, 245-262.

Augenblick and Myers, Inc. (2001). Calculation of the cost of an adequate education in Maryland in 1999-2000 using two different analytic approaches. Prepared for the Maryland Commission on Education Finance, Equity, and Excellence (Thornton Commission).

Augenblick, J., Myers, J., Silverstein, J., and Barkis, A. (2001). Calculation of the cost of an adequate education in Kansas in 2000-2001 using two different analytic approaches. Submitted to the Legislative Coordinating Council, State of Kansas.

Baker, B. D. (2005). The emerging shape of educational adequacy: From theoretical assumptions to empirical evidence. Journal of Education Finance, 30, 259-287.

Baker, B. D. (forthcoming). Evaluating the reliability, validity and usefulness of education cost studies. Journal of Education Finance.

Baker, B. and Duncombe, W. (2004). Balancing district needs and student needs: The role of economies of scale adjustments and pupil need weights in school finance formulas. Journal of Education Finance 29, 195-221.

Bifulco, R. and Duncombe, W. (2002). Evaluating student performance: Are we ready for prime time? In J. W. Fowler (Ed.), Developments in school finance: 2001-02 (pp. 127-153). Washington, DC: National Center for Education Statistics.

Brazer, H. E., and Anderson, A. (1974). A cost adjustment index for Michigan school districts. In E. Tron (Ed.) Selected papers in school finance, 1975 (pp. 23-81). Washington, DC: U.S. Department of Education.

Carey, K. (2002). State poverty based education funding: A survey of current programs and options for improvement. Washington, DC, Center on Budget and Policy Priorities.

Chambers, J. G. (1978). Educational cost differentials and the allocation of state aid for elementary/secondary education." Journal of Human Resources 13, 459-481.

Chambers, J. G. (1997). A technical report on the measurement of geographic and inflationary differences in public school cost*s*, Volume III. Washington, DC: National Center for Education Statistics.

Chambers, J., Taylor, L., and Robinson, J. (2003). Alaska school district cost study: Volume I and II. Report submitted to Legislative Budget and Audit Committee by American Institutes for Research [AIR].

Chamber, J. G., Parrish, T., Levin, J., Smith, J, Guthrie, J., and Seder, R. (2004a). The New York adequacy study: Determining the cost of providing all children in New York an adequate education: Volume 1—Final report. Report submitted to the Campaign for Fiscal Equity by AIR/MAP.

Chamber, J. G., Parrish, T., Levin, J., Smith, J, Guthrie, J., Seder, R., and Taylor, L. (2004b). The New York adequacy study: Determining the cost of providing all children in New York an adequate education: Technical appendices. Appendix J. Report submitted to the Campaign for Fiscal Equity by AIR/MAP.

Coleman, J., et al. (1966). Equality of educational opportunity. Washington DC: U.S. Government Printing Office.

Colorado Legislative Council Staff (CLCS). (2002). 2001 school district cost-of-living study." Memoradum from Deb Godshall, Assistant Director of CLCS to members of Colorado General Assembly, Feburary 25.

Cotton, K. (1996). Affective and social benefits of small-scale schooling." Eric Digest. EDO-RC-96-5.

Downes, T. and Pogue, T. (1994). Adjusting school aid formulas for the higher cost of educating disadvantaged students. National Tax Journal, 67, 89-110.

Duncombe, W., and Goldhaber, D. (2003). Adjusting for geographic differences in the cost of educational provision in Maryland. Report submitted to the Maryland State Department of Education.

Duncombe, W. and Johnston, J. (2004). The impacts of school finance reform in Kansas: Equity is in the eye of the beholder. In: J. Yinger (Ed.), Helping children left behind: State aid and the pursuit of educational equity (pp. 147-193). Cambridge, MA: MIT Press

Duncombe, W., Lukemeyer, A., and Yinger, J. (2003). Financing an adequate education: A case study of New York. In J. W. Fowler (Ed.), Developments in school finance: 2001-02 (pp. 127-153). Washington, DC: National Center for Education Statistics.

Duncombe, W., Lukemeyer, A., and Yinger, J. (2006). The No Child Left Behind Act: Have federal funds been left behind? Unpublished paper.

Duncombe, W., J. Ruggiero, and J. Yinger. (1996). Alternative approaches to measuring the cost of education." In: H.F. Ladd (Ed.), Holding schools accountable: Performance-based reform in education. (pp. 327-356).Washington, DC: The Brookings Institution.

Duncombe, W. and Yinger, J.. (2000). Financing higher student performance standards: The case of New York State." Economics of Education Review, 19, 363-386.

Duncombe, W. and Yinger, J. (2004). Amicus Curiae Brief of William Duncombe and John Yinger, submitted to Supreme Court of the State of New York, County of New York, September 17.

Duncombe, W. and Yinger, J.. (2005a). How much does a disadvantaged student cost?" Economics of Education Review, 24, 513-532.

Duncombe, W. and Yinger, J. (2005b). Estimating the cost of meeting student performance outcomes adopted by the Kansas State Board of Education. A study prepared for the Kansas Division of Legislative Post Audit.

Duncombe, W. and Yinger, J. (2005c). Does school consolidation cut costs? Center for Policy Research Working Paper, Syracuse University,November.

Eff, E., and Eff, A. (2000). How much should a teacher cost?: Comparing Tenessee school districts using hedonic housing price indices. Unpublished paper.

Falch, T. and Strom, B. 2005. Teacher turnover and non-pecuniary factors. Economics of Education Review, 24, 611-631.

Ferguson, R. F., and Ladd, H. F. (1996). How and why money matters: An analysis of Alabama schools." In H. F. Ladd (Ed.), Holding schools accountable: Performance-based reform in education. (pp. 265-298). Washington, DC: The Brookings Institution.

Florida Department of Education. (2002). 2002 Florida level index. Tallahassee, Fl: author, http://www.firn.edu/doe/fefp/pdf/fpli2001.pdf.

Fowler, W. J. and Monk, D. H. (2001). A primer for making cost adjustments in education. NCES 2001-323. Washington, DC: U. S. Department of Education, Office of Educational Research and Improvement.

Fowler, W. and Walberg, H.J. (1991). School size, characteristics, and outcomes. Educational Evaluation and Policy Analysis, 13, 189-202.

Fox, W. F. (1981). Reviewing economies of size in education. Journal of Educational Finance, 6, 273-296.

Friedkin, N. E. and Necochea, J. (1988). School system size and performance: A contingency perspective. Educational Evaluation and Policy Analysis, 10, 237-249.

Gold, S. D., Smith, D.M., and Lawton, S. B. (1995). Public school finance programs of the United States and Canada, 1993-94. Volume 1. Albany, NY: Center for the Study of the States.

Gronberg, T, Jansen, W., Taylor, L., and Booker, K. 2004. School outcomes and school costs: The cost function approach. Available at: http://www.schoolfunding.info/states/tx/march4%20cost%20study.pdf

Guthrie, J. W. (1979). Organization scale and school success. Educational Evaluation and Policy Analysis, 1, 17-27.

Haller, E. J. (1992). High school size and student indiscipline: Another aspect of the school consolidation issue?" Educational Evaluation and Policy Analysis, 4,145-156.

Haller, E. J. and Monk, D. H. (1988). New reforms, old reforms, and the consolidation of small rural schools. Educational Administration Quarterly, 24, 470-483.

Hanushek, E. A., Kain, J. F., and Rivkin, S. G. (2005). Teachers, schools, and academic achievement. Econometrica, 73, 417-458.

Hanushek, E. A., Kain, J. F., and Rivkin, S. G. 2004. The revolving door. Education Next, 4, 76 - 82.

Hanushek, E. A, Kain, J. F., and Rivkin, S. G. (2001). Why public schools lose teachers. National Bureau of Economic Research, Working Paper no. 8599, November.

Haveman, R. and Wolfe, B. (1994). Succeeding generations: On the effects of investments in children. New York: Russell Sage Foundation Jensen and Seltzer.

Howley, C. (1996). The academic effectiveness of small-scale schooling (An update). Eric Digest, Report No. EDO-RC-94-1.

Huang, Y. (2004). Appendix B: A guide to state operating aid programs for elementary and secondary education," In J. Yinger (Ed.) Helping children left behind: State aid and the pursuit of educational equity, (pp. 331-351). Cambridge, MA: MIT Press.

Imazeki, J. (2001). Grade-dependent costs of education: Evidence from Illinois. Draft paper, San Diego State University.

Imazeki, J. and Reschovsky, A. (2004a). School finance reform in Texas: A never ending story. In: J. Yinger (Ed.) Helping children left behind: State aid and the pursuit of educational equity (pp. 251-281). Cambridge, MA: MIT Press.

Imazeki, J. and Rechovsky, A. (2004b).Estimating the costs of meeting the Texas educational accountability standards. Available at: http://www.investintexasschools.org/schoolfinancelibrary/studies/files/2005/january/reschovsky_coststudy.doc

Jensen, B. and Seltzer, A. (2000). Neighborhood and family effects in education progress. The Australian Economic Review, 33, 17-31.

Kane, T.J. and Staiger, D.O. (2002). The promise and pitfalls of using imprecise school accountability measures. Journal of Economic Perspectives, 16, 91-114.

Kansas Legislative Division of Post Audit. (2006). K-12 education: Reviewing free-lunch student counts as the basis for at-risk funding, part 1. Topeka, KS: author.

Lee, V. E. and Smith, J. B. (1997). High school size: Which works best and for whom?" Educational Evaluation and Policy Analysis. 19, 205-227.

Massachusetts Department of Education. (1999). An analysis of geographic differences in school operating and construction cost. Boston, MA: author, September 15.

McCarty, T. A. and Yaisawarng. (1993). Technical efficiency in New Jersey school districts. In H. O. Fried, C.A. Knox Lovell, and S. S. Schmidt (Eds.) The measurement of productive efficiency: Techniques and applications. New York: Oxford University Press.

McMahon, W. W. (1996). Interstate cost adjustments. In J. W. Fowler (Ed.), Selected papers in school finance 1994 (pp. 89-114). Washington, DC: National Center for Education Statistics.

National Center for Education Statistics (NCES). (2001). Public school finance programs of the United States and Canada: 1998-99. NCES 2001-309. Washington DC: author.

NCES. (2003). Common core of data (CCD), National public education financial survey, 2002-03. Washington DC: author.

Nelson, F. H. (1991). An interstate cost-of-living index. Educational Evaluation and Policy Analysis, 13,,103-111.

New York State Education Department. (2003). Recognizing high cost factors in the financing of public education: The calculation of a regional cost index. Albany, NY: author.

Odden, A. (1999). School-based financing in North America. In M.E. Goertz and A. Odden (Ed.), School-Based Financing. Thousand Oaks, CA: Corwin Press, Inc.

Ohio Department of Education. (2003). Ohio's school foundation funding program. Colombus, OH: author.

Ondrich, J., Pas, E., and Yinger, J. (Forthcoming). The determinants of teacher attrition in upstate New York. Public Finance Review.

Ondrich, J. and Ruggiero, J. (2001). Efficiency measurement in the stochastic frontier model. European Journal of Operational Research, 129, 432-442.

Pollack, R. A. and Ginther, D. K. (2003). Does family structure affect children's educational outcomes? National Bureau of Economic Research, Working Paper no. 9628, April.

Ray, S. C. (1991). Resource use in public schools: A study of Connecticut. Management Science, 37, 1520-1628.

Reschovsky, A. and Imazeki, J. (1998). The development of school finance formulas to guarantee the provision of adequate education to low-income students." In J. W. Fowler (Ed.), Developments In school finance: 1997 (pp. 123-147). Washington, DC: National Center for Education Statistics.

Reschovsky, A., and Imazeki, J. (2001). Achieving educational adequacy through school finance reform. Journal of Education Finance, 26, 373-396.

Roza, M. and Hill, P. (2004). How within-district spending inequalities help some schools to fail. In D. Ravitch (Ed.), Brookings Papers on Education Policy (pp. 201-227). Washington, DC: The Brookings Institution).

Rose, H., Sonstelie, J. and Richardson, P. (2004). School budgetins and student achievement in California: The principal's perspective. San Francisco, CA: Public Policy Institute of California.

Rothstein, R. and Smith, J. (1997). Adjusting Oregon education expenditures for regional cost differences: A feasibility study. Submitted to Confederation of Oregon School Administrators. Management Analysis and Planning Associates, L.L.C.

Ruggiero, J. (1998). Non-discretionary inputs in data envelopment analysis. European Journal of Operational Research, 111, 461-468.

Ruggiero, J. (2001). Determining the base cost of education: An analysis of Ohio school districts. Contemporary Economic Policy, 19, 268-279.

Scafidi, B., Sjoquist, B., and Stinebrickner, T. (Forthcoming). Race, poverty, and teacher mobility. Economics of Education Review.

Stiefel, L., Rubenstein, R., and Berne, R. (1998). Intra-district equity in four large cities: Data, methods and results. Journal of Education Finance, 23, 447-467.

Taylor, L. (2004). Adjusting for geographic variations in teacher compensation: Updating the Texas cost-of education index. Austin, TX: Joint Select Committee on Public School Finance.

Taylor, L. L. and Fowler, W. J. (2006). A comparative wage approach to geographic cost adjustment. Washington, DC: U.S. Department of Education.

Wyoming Division of Economic Analysis. 1999. The Wyoming cost of living index: policies and procedures. http://eadiv.state.wy.us/wcli/policies.pdf. Cheyenne, WY: Division of Economic Analysis, Department of Administration and Information, August.

Endnotes

*Acknowledgements: We would like to thank Leanna Stiefel, Helen Ladd, and Ted Fiske for their excellent comments and suggestions on an earlier version of this chapter. We are fully responsible for any errors and omissions.

[1] Cost functions have been conducted for New York (Duncombe and Yinger, 2000, 2005a; Duncombe, Lukemeyer, and Yinger, 2003), Arizona (Downes and Pogue, 1994), Illinois (Imazeki, 2001), Texas (Alexander et al., 2000; Imazeki and Reschovsky, 2004a, 2004b; Gronberg et al. 2004), Wisconsin (Reschovsky and Imazeki, 1998, 2001), Kansas (Duncombe and Yinger, 2005b), and Missouri (Duncombe, Lukemeyer, and Yinger, 2006).

[2] More formally, equation (1) needs to be estimated with two-stage least squares regression, which requires additional "instruments." These instruments are variables that influence *S* but do not influence *E* directly. Recent studies use instruments that measure the determinants of the demand for *S*, such as socio-economic characteristics, in comparable school districts, which form a point of comparison for voters and school officials (Duncombe, Lukemeyer, and Yinger, 2006; Duncombe and Yinger, 2005a, 2005b). Many studies use a district's own income and tax-price as instruments. These instruments are not legitimate, however, because, as shown below, they are determinants of efficiency and therefore influence *E* directly. The choice of instruments is an important topic for future research.

[3] In their studies of Texas, Imazeki and Reschovsky (2004a, 2004b) and Gronberg et al. (2004) use measures of value-added across 1 or 2 years

[4] The main method used with this approach is Data Envelopment Analysis (DEA). Ruggiero (1998) shows how to separate cost and efficiency factors in DEA, but his approach requires far more observations than are available for any state because each district must be compared with other districts that have the same performance <u>and</u> the same cost factors. A multi-stage DEA-based approach has been used by McCarty and Yaisawarng (1993), Ray (1991), and Ruggiero (2001). Another approach is a

stochastic frontier regression (Alexander et al., 2000; Gronberg et al., 2004). Ondrich and Ruggiero (2001) show, however, that stochastic frontier regression produces the same results as an OLS regression except that the intercept has been shifted up to the frontier. As a result, this approach does not remove biases caused by omitting controls for efficiency.

[5] In a cost-function context, it is not possible to separate inefficiency associated with "wasteful" spending from inefficiency associated with spending on performance measures other than those included in *S*. It follows that a given school district could be deemed inefficient in providing one measure of student performance, say math and English scores, and efficient in providing another, say art and music.

[6] Most studies use a variant of the Cobb-Douglas function, which is multiplicative in form. The Cobb-Douglas function assumes that the elasticity of substitution between all inputs is equal to one, and that the elasticity for economies of scale is constant at all levels of output.

[7] One of the most popular flexible cost functions used in empirical research is the translog cost function. A translog cost model includes squared terms for each input price and outcome, and adds interaction terms between all factor prices, and outcomes. Gronberg, et al. (2004) also include a number of interaction terms between outcomes, teacher salaries, and non-school factors. In all, they have over 100 variables in their cost function for Texas compared to 18 variables in the Texas cost model estimated by Imazeki and Reschovsky (2004b).

[8] Downes (2003) argues that rejecting the cost function method because it not easy to understand "means that other methodologies should be used in place of the cost function methodology, even if the cost function methodology is theoretically sound and is most likely to generate valid estimates of the spending levels needed to meet the standard. Taken to the extreme, this argument implies that, in choosing a method to determine adequate spending levels, one is better off choosing a method that is

easy to understand but wrong rather than a method that is difficult to explain but produces the right answers." (p. 8)

[9] Based on spending in the 2002-03 school year for all school districts in the United States, compensation (salaries and fringe benefits) represents 90% of current expenditures and 50% of total expenditures (NCES, 2003).

[10] Colorado has recognized this possibility by calculating cost of living for "labor pool areas." Labor pool areas are designed to reflect where teachers in the district live, rather than where they work.

[11] The geographic unit for construction of the index is counties for Florida and Wyoming, and counties and their neighboring counties for Colorado. For a detailed description of geographic cost adjustments used in other states see Appendix A in Duncombe and Goldhaber (2003).

[12] Some hedonic salary studies have not included any measures of student characteristics (Chambers et al., 2004b), and a number of studies do not include measures of student poverty (Chambers, 1997; Chambers, Taylor, and Robinson, 2003; Taylor, 2004).

[13] Specifically, the cost models are estimated with two-stage least squares regression, and "instruments" are identified for teacher salaries. Instruments have included private sector salaries, county population density, and teacher wages in surrounding or similar districts. The last of these instruments may not be appropriate if salaries in one district are influenced by salaries in nearby districts.

[14] These conditions might be included if the index is based on predicted salaries and student characteristics are among the variables used to predict salaries. No study has investigated the magnitude of this effect, however.

[15]They also found large, significant economies of size in capital spending (doubling district size cuts capital spending by 24 percent). However, the existence of generous building aid in New York to support consolidation may have lead to significant short-run increases in capital spending as well. The

time-frame of the study was not long enough to determine whether consolidation causes a long-run decline in capital spending.

[16] One comparison of intercensal estimates of child poverty and the decennial census in 1989 found that these measures at the county level varied by 17 percent on average. Information on estimation methodology, and predictive accuracy for the intercensal estimates of poverty are available from the Census Bureau at http://www.census.gov/hhes/www/saipe/schooltoc.html.

[17] Children with incomes at or below 130 percent of the federal poverty line are eligible for a free lunch, and students between 130 and 185 percent of the poverty line are eligible for a reduced price lunch. In addition, households receiving Food Stamps, Aid to Dependent Children (ADC), Temporary Assistance to Needy Families (TANF), or the Food Distribution Program on Indian Reservations (FDPIR) are also eligible for a free lunch. A description of the program and eligibility requirements is available at http://www.fns.usda.gov/cnd/Lunch/AboutLunch/faqs.htm.

[18] In a recent audit of free-lunch student counts, the Kansas Legislative Division of Post Audit (2006) found, based on a random sample of 500 free-lunch students, that 17% of free-lunch students were ineligible, and 3% of eligible students didn't apply.

[19] Census child poverty in 2000 had a correlation equal to 0.8 with the K-6 free-lunch shares in New York (Duncombe, Lukemeyer and Yinger, 2003), 0.7 with the K-12 free lunch shares in Kansas (Duncombe and Yinger, 2005b), and 0.93 with the K-12 subsidized lunch rates in Maryland (Duncombe and Goldhaber, 2003).

[20] Language ability is estimated from the long form of the Census, in which individuals are asked if they speak a language other than English and are asked their ability to speak English. A household in which all members of the household 14 years or older do not speak English well and speak at least one other

language than English are classified as linguistically isolated. See http://eddev01.pcci.com/sdds/ref00.asp.

[21] The higher student poverty weights in urban states compared to rural states may reflect the possibility that student performance is significantly worse in high-poverty inner city schools than in high-poverty rural schools (Olson and Jerald, 1998). To account for the possible effects of concentrated urban poverty, Duncombe and Yinger (2005b) included in their cost model for Kansas an additional poverty variable, which is the percent free lunch students multiplied by pupil density (pupils per square mile). The found a statistically significant urban poverty effect.

[22] These weights are our estimates based on the estimated range in marginal effects for free lunch students in Table 3 in Gronberg et al. (2004) divided by average spending per pupil. They should not be attributed directly to the authors of that study. These relatively low weights may be due in part to the fact that this study interacts the child poverty rate with several other variables. Several of these interaction terms are not statistically significant. An alternative way to separate cost and efficiency is developed by Ruggiero (1998, 2001) based on the two-step methods developed by McCarty and Yaisawarng (1993) and Ray (1991). In the first stage Ruggiero compares the spending per pupil of each district to a cost frontier (districts with equivalent outcomes and lower spending) using data envelopment analysis (DEA). The index produced from the first-stage DEA captures both inefficiency and cost differences across districts. Ruggiero then regresses this index on a set of cost factors, and the predicted value from this regression is his estimate of cost of education index. The first-stage of this method uses a non-parametric method, data-envelopment analysis, which can be sensitive to measurement error (Bifulco and Duncombe, 2002).

[23] In New York, we developed poverty weights using information in the professional judgment study (Chambers et al., 2004a); these estimates should not be attributed to the authors of the study. Our

estimates of poverty weights in this study range from 0.37 in middle school to 0.81 in elementary school (Duncombe and Yinger, 2004).