How Does Efficiency Targeting in School Aid Affect Efficiency and Equity in School Spending and Performance Scores?

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(AAbstract) Scholars have recently incorporated efficiency targeting into outcome-based school aid formulas. However, few studies have analyzed the impacts of efficiency targeting on school district efficiency, and fiscal and outcome equity. This paper analyzes the impacts by conducting simulations with FY 2014 Ohio school district data. Empirical findings reveal that efficiency targeting can improve both efficiency and equity, compared with the current Ohio school aid formula. In addition, the impact of efficiency targeting through power-equalizing aid is stronger than that of foundation aid.

Keywords: efficiency targeting in school aid, outcome-based school aid, fiscal and outcome equity

1. Introduction

Since the seminal Serrano case, school aid to local school districts attempted to enhance fiscal equalization. After the Kentucky Education Reform Act (KERA) of 1990, however, school aid formulas have now focused more on equalization of student performance in what has been known as outcome-based school aid (Baker and Green 2015; Flanagan and Murray 2004; Picus, Goertz, and Odden 2015; Reschovsky 1994; Oakland 1994; Rebell 2002).

Despite the call for enhanced equity in financial resources and student performance through state aid to local school districts, efficiency advocates have also joined series of lawsuits, demanding more efficient administration and education by the school districts. For instance, in the wake of budget cuts for the 2011-12 school year, a group of students, parents, and taxpayers in Texas joined a lawsuit to increase flexibility of school administrators and charter schools and to increase discretion in firing poorly performing teachers. In California's Vergara litigation, efficiency advocates contended that California's teacher tenure laws and seniority-based layoff rules ended up denying equal protection of the laws and called for more efficient school administration and education (Koski and Hahnel 2015). Has there been a comparable push for enhanced efficiency in school aid formulas?
In fact, scholars have incorporated efficiency targeting into outcome-based school aid formulas since even before the series of litigations for more efficient school administration and education (Ladd and Yinger 1994; Duncombe and Yinger 1997, 2000). Despite the significance of efficiency targeting in school aid, however, virtually no studies have yet analyzed how efficiency targeting can affect school district efficiency in a systematic way. In addition, no studies have investigated whether efficiency targeting can also improve equity. These two issues combined, the crucial question is whether and how efficiency targeting can improve both efficiency and equity simultaneously. This is because efficiency targeting interacts with local property valuation, as Section 3 of this paper indicates. By construction, most school aid is inversely related to local property valuation to enhance equity and as a result, efficiency targeting is necessarily linked to equity via local property valuation.

This paper conducts simulations with FY 2014 Ohio school district data to see whether efficiency targeting improves both efficiency and equity: from the simulated results, policy makers can select the range of efficiency targeting that can simultaneously enhance both. The major merit of this paper is in helping policy makers apply the well-designed and creative efficiency targeting in school aid to actual aid distributions. Thus, this paper fills a huge gap in the literature.

Section 2 provides a short literature review of equity and efficiency targeting in school aid. Section 3 presents mechanisms of efficiency targeting in school aid and provides expected impacts of efficiency targeting on efficiency and equity. Sections 4 through 6 introduce base models to run needed empirical estimations, and data sources and measurements. Sections 7 and 8 present overall empirical findings on the base models. Section 9 explains details of simulation strategies. Section 10 presents simulation results, followed by the conclusion.
2. Literature Review

Numerous studies have investigated whether and how much aforementioned outcome-based school aid formulas improve fiscal equity, outcome equity, or both. Most of the studies conducted at the national or state level indicate that the aid formulas significantly enhance equalization of fiscal resources across school districts (Hoxby 2001; Murray, Evans, and Schwab 1998; Evans, Murray, and Schwab 1997, 1999; Duncombe and Johnston 2004; Cullen and Loeb 2004; Imazeki and Reschovsky 2004). Other studies have revealed that outcome-based aid systems further improve outcome equity or at least permanently inject the values of adequacy of education into the debate of school financing (Koski and Hahnel 2015; Downs 2004; Duncombe and Yinger 1998).

However, few studies have systematically investigated how efficiency targeting in school aid formulas affects school district efficiency and equity. Only a couple of studies partially answer this question by analyzing the relationship between school aid and efficiency. Using data for 631 school districts in New York in 1991, Duncombe and Yinger (2000) showed how school aid programs to local school districts affect school district efficiency. In general, the more aid a school district receives, the less managerially efficient it becomes. For instance, increasing aid to New York City decreased school district efficiency significantly. As a result, if New York City wanted to reach New York State’s current median student performance level, one of a few options was to quadruple its local tax rate.

Duncombe and Yinger (1997) specifically applied efficiency targeting to New York's foundation aid to school districts. They ran multiple simulations, also using data for 631 school districts in New York in 1991. They provided clear reasons that policy makers should be
concerned about school districts' productive efficiency. Outcome-based school aid cannot enhance equity without accounting for local cost differentials (Downs and Stiefel 2015; Duncombe, Nguyen-Hoang, and Yinger 2015). However, Duncombe and Yinger (1997) assert that even if those outcome-based school aid formulas factor different local cost indices into their formulas, these formulas will eventually reward *inefficient* school districts if they do not control for efficiency. In short, the outcome-based aid formulas cannot enable school districts with low student performance scores to achieve state-set outcome or performance target unless they are as efficient as perfectly efficient districts. While Duncombe and Yinger's studies trail blaze the effort to identify the relationship between school aid and school district efficiency, they do not investigate whether efficiency targeting can systematically improve *both* efficiency and equity. As Duncombe and Yinger (1997) note, “The trick here is to find a balance between efforts to reward efficiency and efforts to achieve performance standards” (108). This paper is the first attempt to locate this tricky balance as such.

3. Efficiency Targeting in School Aid

Typical foundation aid looks like Equation (1):

\[
A_i = E^* - t^* V_i = E^* (1 - \frac{V_i}{V^*}) \tag{1}
\]

, where \( A_i \) is foundation aid to local school district \( i \), \( E^* \) is a state-set foundation spending level, \( t^* \) is a state-designated property tax rate required for school districts wishing to receive state aid, \( V_i \) is property valuation in local school district \( i \), and \( V^* \) is defined such that \( E^* = t^* \times V^* \) (Ladd and Yinger 1994; Duncombe and Yinger 1998, 2000). Outcome-based aid defines \( E^* \) in Equation (1) as \( S^* \times \bar{c} \) as in Equation (2), where \( S^* \) is a state-selected outcome or performance score target and \( \bar{c} \) is the marginal cost for performance score \( S \) in a school district with the state
average performance score. Outcome-based aid typically adjusts for local cost differentials by incorporating cost index, \(c_i\) (Ladd and Yinger 1994; Duncombe and Yinger 1998; Downs and Stiefel 2015). Finally, outcome-based foundation aid with efficiency targeting incorporates efficiency targeting index, \(ET\), as shown in Equation (2) (Duncombe and Yinger 1997).

\[
A_i = (S^* \cdot \bar{c} \cdot c_i) \cdot \left( \frac{1}{ET} - \left[ \frac{V_i}{(ET)^2} \right] \right) \quad (2)
\]

Feldstein (1975) suggested his well-known wealth neutralizing aid formula, but as Duncombe and Yinger (1998) clarify, it is difficult to apply to actual grant distribution. Instead, this paper employs an alternative version of wealth-neutralizing aid suggested by Duncombe and Yinger (1998), as shown in Equation (3):

\[
A_i = E_i \left[ 1 - \left( \frac{V_i}{V^*} \right)^\alpha \right] \quad (3)
\]

, where \(E_i\) is local school district \(i\)’s actual spending and \(t_i\) is its actual property tax rate, given \(E_i = t_i \cdot V^*\) if the state-set property valuation target still stays at \(V^*\). When \(\alpha = 1\), Equation (3) reduces to typical power-equalizing aid. Equation (3) exemplifies power-equalizing aid in this paper. Empirical studies have shown that power-equalizing aid tends to exert stronger impacts on recipient school districts’ spending due to the price effect associated with the aid, resulting in stronger fiscal equalization (Hoxby 2001; Munley and Harris 2010). However, the structure of Equation (3) in itself enhances the fiscal equalization effect. For instance, if \(V_i > V^*\), wealthier districts will be relatively more damaged because \(\left( \frac{V_i}{V^*} \right)^\alpha\) grows exponentially as \(\alpha\) increases. If \(V_i < V^*\), poorer districts will receive relatively larger aid as \(\alpha\) grows. We can also convert Equation (3) into outcome-based power-equalizing aid with efficiency targeting, such as Equation (4).\(^1\)

\[If \ c_i < \left( \frac{V_i}{V^*} \right), then \ \left[ \frac{V_i}{c_i} \right]^{\beta} \] gets even larger, which weights cost differentials even more strongly and vice versa. Of course, Equation (4) is one of various possible ways of specifying cost differentials.

\(^1\)
\[ A_i = (S_i \times MC \times c_i) \left( \frac{1}{ET} - \left[ \frac{\nu_i}{c_i} \right]^{\beta} \right) \quad (4) \]

where \( S_i \) is each school district's actual performance score and \( MC \) is each district's marginal cost per performance score.

In general, efficiency targeting or actual efficiency index ranges between 0 and 1, with 1 meaning the highest level of efficiency. In Equations (2) and (4), efficiency targeting rewards districts that are more efficient in school administration and education (Duncombe and Yinger 1997). For instance, assume that a certain district’s actual efficiency index is 1, which means that the district is the most efficient district. If efficiency targeting, \( ET \), is set at 0.5, then the state-set foundation expenditure levels in Equations (2) and (4) are doubled while the most efficient district needs only half the target expenditure amount to achieve what a district with an actual efficiency index of 0.5 can achieve. Therefore, efficiency targeting in school aid incentivizes less efficient school districts to improve their school administration and education. However, efficiency targeting also affects equity. As implied in Equations (2) and (4), varying \( ET \) changes the relative distance between state-set foundation expenditure levels and local property valuation, which necessarily influences the meaning of outcome targets in the foundation expenditure levels.\(^2\)

Then, another crucial question is how to construct school district efficiency index. Previous studies have applied Data Envelopment Analysis (DEA), adjusted for various factors (Duncombe and Yinger 1998), but Duncombe and Yinger (2009; 2011) and Eom et al. (2014) suggest a more convenient approach to developing efficiency index, as shown in Equation (5).

\[ e = kM^\theta Y + A \left( \frac{\nu}{P} \right)^{-1} \pi_p \left[ (MC) \left( \frac{\nu}{P} \right)^{-1} \pi_p \right] \quad (5) \]

\(^2\) Technical Appendix A provides details on how efficiency targeting might affect both efficiency and equity.
, where $e$ is a latent school district efficiency index ($0 < e < 1$), $M$ is a cluster of control factors that tap consumer-voters' monitoring of school district administration, $Y$ = before-tax income of a median voter, $A$ = per pupil state lump-sum (foundation) aid, $V$ = median market house value in a local school district * assessment ratio in Ohio (= 0.35), $\bar{V}$ = per pupil potential assessed property valuation, $X$ = per pupil assessed property tax exemption value, not reimbursed by the state government, $MC$ = marginal cost of educational cost per performance index score, and

\[
\pi_p = 1 - \frac{\text{Per Pupil Property Tax Rollback Credit}}{\text{Per Pupil Property Tax Rollback Credit} + \text{Per Pupil Property Tax}}.
\]

Later in this paper, all variables will be further detailed, but the latent efficiency index is a function of two primary factors. The variables in the first square brackets are rough income measures. As median voter income and per pupil aid increase, consumer-voters are less likely to monitor school administration tightly and as a result, efficiency tends to decrease (i.e. $\gamma < 0$). In contrast, the variables in the second square brackets measure consumer-voter tax prices. As tax prices for school district service increase, consumer-voters are more likely to monitor school district administration tightly (i.e. $\delta > 0$). The cluster of monitoring factors is also positively correlated with school district efficiency.


The mechanism of fiscal choice of a consumer-voter in an Ohio school district will be based on the recent literature (Duncombe and Yinger 1998, 2009; Munley and Harris 2010; Eom et al. 2014).

Where $Z$ = spending of a median voter on everything except local property and income taxes

\[
t = \text{effective (statutory) property tax rate}^3
\]

\[^3\text{The effective tax rate used in Ohio means property tax rate after being adjusted for property tax reduction factors} \]
\[ E = \text{per pupil local school district expenditure} \]

\[ C\{S\} = \text{per pupil total cost, } C, \text{ to achieve school performance, } S \text{ [see Equation (5) for other notations below]}, \text{ a median voter's budget constraint is defined as:} \]

\[ Y = Z + tV\pi_p \quad (6) \]

Since 1971, a 10 percent property rollback credit has been allowed to all real property not used in business, and another 2.5 percent rollback credit has been applied to owner-occupied homesteads (Ohio Revised Code 323.152). A homestead exemption allows "credits" to low-income senior citizens by shielding $25,000 of the market value of their homes. Beginning in 2014, this exemption has been means-tested, with the 2015 income threshold at $31,000.\(^5\) \(\pi_p\) measures how much the tax burden of property taxpayers diminishes with these three credits.

The budget constraint of an Ohio local school district is defined as:

\[ E = \frac{C\{S\}}{e} = t(\bar{V} - X) + A \quad (7) \]

In Equation (7), per pupil assessed property tax exemption value, \(X\), is subtracted from per pupil potential assessed property valuation because the exemption is not reimbursed by the state government. Per pupil local school district expenditure, \(E\), is defined in terms of cost function, \(C\{S\}\), adjusted for school district efficiency, \(e\): more efficient districts can achieve the same level of school performance with fewer resources (Ladd and Yinger 1994; Duncombe and Yinger 1998, 2011).

By arranging Equation (7) for \(t\) and substituting it into Equation (6), we have the equation for a median voter's fiscal choice in an Ohio school district:

\(^4\) Among 607 school districts in Ohio that were used for this paper, 189 levy school district income tax (SDIT). Regression results with and without the districts were almost the same. For the simplicity of model estimation, SDIT is not incorporated into Equation (6).

\[ Y + A \left( \frac{V}{V} \right) \left( 1 - \frac{X}{V} \right)^{-1} \pi_p = Z + \frac{C[S]}{\sigma} \left( \frac{V}{V} \right) \left( 1 - \frac{X}{V} \right)^{-1} \pi_p \] (8)

The left-hand side of Equation (8) equals the augmented income available for the median voter and the right-hand side lists his spending. His tax price is typically measured as how much he is willing to sacrifice his augmented income in order to pay for school service (i.e., the second part of the right-hand side). However, since this paper analyzes the impacts of school aid on school performance, the right-hand side of Equation (8) will be differentiated with respect to \( S \) to obtain:

\[ Tax \ Price = \frac{\dot{\sigma}}{\dot{S}} e^{-1} \left( \frac{V}{V} \right) \left( 1 - \frac{X}{V} \right)^{-1} \pi_p = (MC) e^{-1} \left( \frac{V}{V} \right) \left( 1 - \frac{X}{V} \right)^{-1} \pi_p \] (9)

5. Expenditure and Demand Models

Based on Eom et al. (2014) and Duncombe and Yinger (2009; 2011), \( C[S] \) in Equation (7) will be defined as:

\[ C[S] = \kappa S^\sigma W^\alpha N^\beta P^\lambda \] (10)

where, \( S \) is school performance index score, \( W \) is teacher salaries, \( N \) is student enrollment, and \( P \) is pupil characteristics. \( MC \) in Equations (5) and (9) can be designated as:

\[ MC = \frac{\dot{C[S]}}{\dot{S}} = \sigma \kappa S^{\sigma - 1} W^\alpha N^\beta P^\lambda \] (11)

By plugging Equations (5) and (10) into Equation (7), transforming the new equation into a double-log format, and by using the approximation that \( \ln\{1+a\} \approx a \) when \( a < 1 \), the expenditure equation is defined as:

\[ \ln E = \ln k^* + (\sigma - \delta(\sigma - 1)) \ln S + \alpha(1 - \delta) \ln W + \beta(1 - \delta) \ln N + \lambda(1 - \delta) \ln P - \rho \ln M - \gamma \ln Y - \gamma \left( \frac{\dot{A}}{\dot{V}} \right) \left( 1 - \frac{X}{V} \right)^{-1} \pi_p \] - \delta \ln \left( \frac{V}{V} \right) - \delta \ln \left( 1 - \frac{X}{V} \right)^{-1} - \delta \ln \pi_p \] (12)

There is one caveat in estimating Equation (12) for Ohio school districts. The coefficient of \( S \), \((\sigma - \delta(\sigma - 1))\), was consistently negative and \( \sigma \) was estimated at around -2. This
observation implies that Ohio’s school districts are operating under a kind of super-increasing returns to scale. Therefore, it would be convenient to treat the educational cost behavior of Ohio school districts as if it follows a constant return to scale: $\sigma = 1$. Equation (12) is now estimated without school performance index score, $S$, in the right-hand side. The dependent variable, $E$, is per pupil school district expenditure “per performance index score” in Equation (13).

$$\ln E = \ln k^* + \alpha (1 - \delta) \ln W + \beta (1 - \delta) \ln N + \lambda (1 - \delta) \ln P - \rho \ln M - \gamma \ln Y - \gamma \left( \frac{\bar{A}}{\bar{V}} \right) \left( 1 - \frac{x}{\bar{V}} \right)^{-1} \pi_p - \delta \ln \left( \frac{\bar{V}}{\bar{V}} \right) - \delta \ln \left( 1 - \frac{x}{\bar{V}} \right)^{-1} - \delta \ln \pi_p \quad (13)$$

To be consistent with Equation (13), Equation (10) will be redefined as:

$$\frac{C(S)}{S} = \kappa W^a N^b P^\lambda \quad (14)$$

, where $\frac{C(S)}{S}$ is the average cost of education per performance index score, which happens to equal the marginal cost of education per performance index score.

Coefficients in Equation (13) can be used to estimate $\frac{C(S)}{S}$ in Equation (14) and $e$ in Equation (5). The standard demand equation, which can also be estimated in a double-log form, is defined as (Eom et al. 2014; Duncombe and Yinger 2009, 2011):

$$S = K^* (D)^{\phi^*} \left[ Y + A \left( \frac{V}{\bar{V}} \right) \left( 1 - \frac{x}{\bar{V}} \right)^{-1} \pi_p \right]^{\theta^*} \left[ C^* (e^*)^{-1} \left( \frac{V}{\bar{V}} \right) \left( 1 - \frac{x}{\bar{V}} \right)^{-1} \pi_p \right]^{\mu^*} \quad (15)^6$$

, where $C^*$, which is derived from $\frac{C(S)}{S}$ in Equation (14), is the cost index with its average equal to 1 for the average school district. $D$ is demographic factors. Alternatively, $D$ will include copycat or yardstick competition variables (Case et al. 1993; Besley and Case 1995; Eom et al. 2014). The efficiency index, $e^*$, is derived from Equation (5) and equals 1 in the fully efficient school district. $C^*$ in this paper differs from Eom et al. (2014) and Duncombe and Yinger (2009, 2011).

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^6 $\theta^*$, $\mu^*$, and $\phi^*$ differ from $\theta$, $\mu$, and $\phi$. See, for more details, Eom et al. (2014), and Duncombe and Yinger (2009, 2011).
because $C^*$ is derived from per pupil educational expenditure per performance index score as noted in Equation (13).

6. Data and Measurement

Table 1 provides descriptive statistics for non-logged values of all variables used for estimating Equations (13) and (15). These variables are similar to those reported in the literature (Duncombe and Yinger 1998, 2000, 2009, 2011; Eom et al. 2014; Rockoff 2010). Table 1 also presents data sources. Performance Index (PI) Score is a weighted average of multiple measures of student performance in a full academic year. It ranges between about 72 and 113, with an average of 99.13. Student Enrollment is Formula Average Daily Membership (ADM) for FY 2014. All per pupil variables are constructed based on Student Enrollment. Per Pupil Expenditure Per PI Score ranges between $71.64 and $273.20. The average ratio of Students in Poverty is 0.43, much higher than that reported for New York school districts (Duncombe and Yinger 1998, 2009). As noted in Equation (5), $\bar{V}$ is the potential assessed property valuation per pupil, which is the sum of per pupil assessed property valuation and per pupil assessed exempt property valuation. The mean value of Tax Price, 0.31, is comparable to the values in earlier studies. The mean value of Inversed Tax Exemption Share is 1.12, denoting that the proportion of exempt property valuation is very small. As the amount of exempt property valuation increases, Inversed Tax Exemption Share also grows, which implies that the higher the property tax exemption, the higher the tax burden. In short, this is one of the composite tax price measures in Equation (9). Property Tax Rollback Credit is explained in Equations (5) and (6), which is another component of the composite tax price measures. Its mean value of 0.88 implies that the credit reduces taxpayers' tax price by about 12 percent.
Owner-occupied House Units, Population 5-19 Years Old, and Population 65 Years and Over are included as $M$ variables in Equations (5) and (13). Average Wage in Manufacturing is used as $D$ variables in Equation (14). Median Income (TY 2014) was used for the expenditure model, Equation (13), and Median Income (TY 2013) was included in the demand model, Equation (14), because Median Income (TY 2014) significantly deteriorated the estimation of the demand model.

7. Model Estimation and Empirical Findings

There are two methodological challenges in estimating Equations (13) and (15): heteroskedasticity and endogeneity. Heteroskedasticity tests based on multiple assumptions (Baum, Schaffer, and Stillman 2003) generally indicated the presence of heteroskedasticity in the two equations. Therefore, heteroskedasticity-consistent estimation was run based on Newey and West (1987).

Another challenge was the numerous venues for endogeneity in the two equations. In Equation (13), teacher salaries are usually set when school districts consider their budgets or expenditures. Therefore, teacher salaries are likely to be endogenous with per pupil per performance expenditure. Per pupil property valuation might affect school district expenditures because higher property valuation is likely to lead to higher school expenditures. Higher school expenditures in turn might affect local property valuation because the former is likely to be capitalized into the latter. As a result, all variables, which include per pupil property valuation, need to be treated as endogenous: Tax Price, Inversed Tax Exemption Share, and Foundation Aid Ratio. In a similar vein, Property Tax Rollback Credit needs to be treated as endogenous because property taxes might also be capitalized into property valuation. As property valuation affects
school expenditures that in turn might affect property valuation, property tax revenues are ultimately endogenous with school expenditures. Since Property Tax Rollback Credit includes property tax revenues, it should be treated as endogenous.

Endogeneity tests based on Baum, Schaffer, and Stillman (2007) indicate no strong evidence of endogeneity for the variables except for Teacher Salary and Property Tax Rollback Credit. Using all relevant data and the same method employed in Sections 4 and 5, Cost Index for FY 2012 for all school districts as well as other instrumental variables in this section were constructed. According to Equation (11), Teacher Salary is a factor that constructs marginal cost of education per performance index score. According to Equation (14), the marginal cost is used to compute Cost Index. As a result, Cost Index is a direct function of Teacher Salary. Since Teacher Salary for FY 2014 is related to Teacher Salary for FY 2012 under incremental budget decision processes, the former is also related to Cost Index for FY 2012. Since Teacher Salary for FY 2012 was not determined when school districts prepared school expenditures for FY 2014, it is unreasonable to expect that Cost Index for FY 2012 is related to the errors in Equation (13). Therefore, Cost Index for FY 2012 was used as the instrument for Teacher Salary. The null hypothesis of underidentification is rejected (Kleibergen-Paap rk LM statistics = 45.56: $\chi^2(1) \ p = 0.0000$) and Kleibergen-Paap Wald rk F statistic (= 79.51) is larger than 10, which means Cost Index for FY 2012 is not a weak instrument for Teacher Salary. The endogeneity test strongly rejects the null that Teacher Salary might be treated as exogenous ($\chi^2(1) \ p = 0.0003$). These tests were based on various tests in Baum, Schaffer, and Stillman (2007).

Given the incremental nature of governmental budget processes, property tax revenues for FY 2011 are likely to be related with property tax revenues for FY 2014, which are included

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7 In the presence of heteroscedasticity, Kleibergen-Paap Wald rk F statistic is preferred (Baum, Schaffer, and Stillman 2007).
in Property Tax Rollback Credit. However, it is unlikely that school expenditures for FY 2014 affect property values and property tax revenues for FY 2011. As a result, property tax revenues for FY 2011 are less likely to be related to errors in Equation (13). Similarly, property tax revenues for FY 2011 are likely to be related with Property Tax Rollback Credit but not with the errors in Equation (13). Logged property tax revenues for FY 2011 were used as the instrument for Property Tax Rollback Credit. The null hypothesis of underidentification is rejected (Kleibergen-Paap rk LM statistics = 45.56: $\chi^2(1) \ p = 0.0000$) and Kleibergen-Paap Wald rk F statistic ($= 79.51$) is larger than 10. Teacher Salary cannot be treated as exogenous ($\chi^2(1) \ p = 0.0003$). Technical Appendix B provides more details on the test results and three other variables: Tax Price, Inversed Tax Exemption Share, and Foundation Aid Ratio.

Fuller’s k-class Limited Information Maximum Likelihood (LIML) estimation, which is employed for both expenditure and demand equations, is less vulnerable to the potential bias from weak instruments and small sample bias (Baum, Schaffer, and Stillman 2007; Fuller 1977; Hahn, Hausman, and Kuersteiner 2004). Table 2 shows Fuller’s k-class LIML regression results for Equation (13), the expenditure model. The null hypothesis of underidentification is rejected. The weak identification test statistic is larger than the approximate threshold value of 10. In addition, two versions of Anderson-Rubin Wald Test strongly reject the null that the two endogenous regressors are jointly equal to zero. All independent variables are statistically significant, with expected signs. For instance, all tax price measures carry negative signs while all income and aid variables are positive. Squared values of Student Enrollment are further included in standard models, but their inclusion significantly deteriorated the overall model estimation. Since Student Enrollment is logged, the negative signs are also compatible with the
log-linear negative estimation in the literature. Technical Appendix B provides more details on the regression results.

In Equation (15), there are similar venues of endogeneity because higher school expenditures are likely to enhance Performance Index Score and as a result, the two variables are correlated. However, the same endogeneity tests show the presence of endogeneity only with Tax Price and Foundation Aid Ratio. In addition, efficiency index scores generated from Equation (5) are a function of per pupil property valuation, but they are linked to Performance Index (PI) Score via Equation (15). The latter in turn affects local property valuation because better school quality in terms of higher PI Score might be capitalized into property valuation. Since property valuation is related with efficiency index, Efficiency Index in Equation (15) needs to be treated as endogenous. Finally, higher PI Score necessarily requires more educational resources. As a result, PI Score is likely to affect Cost Index in Equation (15). Therefore, Cost Index is also treated as endogenous. However, the endogeneity tests indicate that only Efficiency Index is endogenous.

Property valuation for FY 2011 is likely to be related with property valuation for FY 2014 because property valuation does not change rapidly. Tax Price for FY 2014, which includes property valuation, is likely to be related with property valuation for FY 2011. However, it is unlikely that school expenditures for FY 2014 and PI Score might affect property valuation for FY 2011. As a result, the latter is less likely to correlate to errors in Equation (15). I used logged property valuation for FY 2011 as the instrument for Tax Price.

Property valuation for FY 2012 is likely to be related with property valuation for FY 2014 because property valuation does not change rapidly. Foundation Aid Ratio for FY 2014, which includes property valuation, is likely to be related with foundation aid ratio for FY 2012
that includes property valuation for FY 2012. However, it is unlikely that school expenditures for FY 2014 and PI Score affect foundation aid ratio for FY 2012. As a result, the latter is less likely to correlate with the errors in Equation (15). I used foundation aid ratio for FY 2012 as the instrument for Foundation Aid Ratio.

According to Equation (5), Efficiency Index includes median house value. Median house value for FY 2013 is likely to be related to that for FY 2014, given the stable housing price across years. Similarly, Efficiency Index is likely to be related to median house value for FY 2013. However, it is unlikely that school expenditures for FY 2014 and PI Score affect median house value for FY 2013. As a result, the latter is less likely to correlate to errors in Equation (15). Median house value for FY 2013 was used as the instrument for Efficiency Index. Endogeneity test results for the three variables above indicate the presence of endogeneity. Technical Appendix B provides all test details for the variables listed above.

Table 3 shows Fuller’s k-class LIML regression results for Equation (15), the demand model. The null hypothesis of underidentification is rejected. The weak identification test statistic is smaller than the approximate threshold value of 10, but as noted earlier, Fuller’s k-class LIML is powerful for weak instruments. In addition, two versions of Anderson-Rubin Wald Test strongly reject the null that the three endogenous regressors are jointly equal to zero. In Table 3, all independent variables are statistically significant, with expected signs. Average Wage in Manufacturing in counties surrounding school districts is negative, albeit insignificant, which implies that wage competition between teaching positions and manufacturing jobs is present. Technical Appendix B provides details of statistical results.

8. Impacts of Ohio's School Aid on Efficiency, Fiscal Equity, and Outcome Equity
Table 1 reports that the average efficiency index score of all Ohio school districts for FY 2014 is 0.616 under current school district systems and school aid formulas.

In the education finance literature, various equity measures have been used, such as the Gini coefficient, the Theil index, the McLoone index, the coefficient of variation, the Federal Range Ratio (Downs and Stiefel 2015; Duncombe and Johnston 2004). Various elasticity measures have also been used (Feldstein 1975; Duncombe and Yinger 1998). Since some simulations in this paper generate negative or extreme numbers, this paper applies the Gini coefficient, the coefficient of variation (COV), and various elasticity measures. With negative numbers of target variables, the Gini coefficient might create maximum values larger than one. Based on Chen, Tsaur, and Rhai (1982), the Gini coefficient is normalized between 0 and 1.

The Gini coefficient of per pupil expenditure in Ohio school districts is 0.101 for FY 2014. Coefficient of Variation (COV), which is similar in nature to the Gini coefficient, is 19.505. The elasticity between per pupil property valuation and the expenditure variable is 0.101, which is very close to the Gini value. Note that the expenditure largely derives from two major revenue sources, one from local property tax and the other from state aid. Local property tax revenue is a “direct” and positive function of per pupil property valuation. By formula, school aid is “indirectly” and inversely related to per pupil property valuation. The positive elasticity between per pupil property valuation and per pupil expenditure implies that the indirect and negative correlation between property valuation and school aid is not strong enough to reverse the positive relationship between property valuation and property tax revenue.

The Gini coefficient for Performance Index (PI) Score is 0.034. COV is 6.388. The elasticity between per pupil property valuation and PI Score is 0.074. The actual sample correlation between per pupil property revenue and PI Score is 0.343 (p < 0.0001). School aid is
inversely related to per pupil valuation, but it is positively related to PI Score “indirectly” through Equation (15). Here again, the positive elasticity between per pupil property valuation and PI Score indicates that the indirect and negative correlation between property valuation and school aid is not strong enough to reverse the inherent and direct positive correlation between per pupil property valuation and PI Score.

9. Simulations of Grants-in Aid

9.1. First-stage Simulations: Efficiency Targeting in Grants-in Aid

The first step in grants-in aid simulations is to vary Efficiency Targeting (ET) in Equation (2) while holding $S^*$ and $\bar{c}$ constant at their mean values of 99.13 and 105.93, respectively, and to vary ET in Equation (4). $V^*$ will also be fixed at its mean value of 159,685.5. To avoid complexity, ET will be varied from 0.05 (the lowest efficiency targeting) to 1 (the highest efficiency targeting), in increments of 0.05. In Equation (4), $\beta$ will be fixed at 0.2 because when $\beta$ is kept at lower values, equity measures like the Gini coefficient are similar to the measures from the actual sample. Of course, these values can be easily manipulated to see how the changes modify simulation results. If state policies opt for no-negative-aid restrictions, all negative values will be replaced with zero at this stage. Two further simulations are needed.

9.2. Second-stage Simulations: Mean Adjustment

The second step in aid simulations is to keep mean aid values of all simulated samples at the mean aid value of actual data sample, 4,180.641, to keep simulated aid amounts equal to actual budgets. We should add the mean difference ($= 4,180.641 – \text{mean of each sample obtained from the first-stage simulation}$) to all observations of each sample. However, for the no-negative-restriction simulations, if sample means are larger than 4,180.641, then the mean-difference...
adjustment might move some observations, for instance those slightly larger than zero, to negative domains. These observations should further be replaced by zero values, but this adjustment will cause the sample mean to deviate from 4,180.641. Thus, we need to multiply all sample observations by the ratio \( \frac{4,180.641}{\text{mean of each sample obtained after this mean-difference adjustment}} \), when no-negative-aid restrictions are imposed. The mean-difference adjustment compensates wealthy districts slightly more when no-negative-aid restrictions are imposed and the mean of a simulated sample is less than 4,180.641. In that case, wealthy districts, which might have received zero aid, now receive some aid equal to the mean-difference.\(^8\)

9.3. Third-stage Simulations: Range Adjustment by Standard Deviation

We should also keep the ranges of simulated aid amounts close to the range of the actual sample to avoid extreme and unrealistic values. A range-based scale factor can be developed as follows. If \( A_s > 4,180.641 \) where \( A_s \) is the amount of grants-in aid obtained from the second-stage simulations, \( A_s \) will be scaled down by using standard deviations of actual and simulated samples, as in Equation (16):

\[
A_{fs} = A_s - \left( A_s - 4,180.641 \right) \times \frac{\sigma}{\sigma_s}, \tag{16}
\]

where \( fs \) denotes the final-stage (e.g., third-stage) simulations, \( \sigma \) is the standard deviation of the original sample (1,791.736), and \( s \) denotes the second-stage simulations. Therefore, aid amounts obtained from the second-stage simulations will be proportionately adjusted by the amount that scales the simulated values down by the adjusted difference between them and 4,180.641.

If \( A_s < 4,180.641 \), aid amounts will be simulated according to Equation (17):

\[
\]

\(^8\) There is another viable option for mean adjustment. Refer to Technical Appendix C for more details.
\[ A_{fs} = A_s + \left[ (4,180.641 - A_s) \cdot \frac{\sigma}{\sigma_s} \right] \]  

(17)

Both Equations (16) and (17) will be rearranged into a single equation, Equation (18):

\[ A_{fs} = A_s \cdot (1 - \frac{\sigma}{\sigma_s}) + 4,180.641 \cdot \frac{\sigma}{\sigma_s} \]  

(18)

Finally, in case this operation changes sample means, an additional mean adjustment based on Section 9.2. is needed. Since \( \sigma_s \) remains the same per each simulated sample, the final aid samples generated from the third-stage simulations will be modified in systematic ways. Therefore, some equity measures used in this paper are highly comparable across the second-stage and third-stage samples. See Technical Appendix D for proof.

9.4. Imputing Impacts of Simulated Aid

To impute the impacts of simulated aid on per pupil per performance expenditure and Performance Index (PI) Score, Aid (A) in Equations (13) and (15) were replaced by aid amounts simulated at each value of Efficiency Targeting (ET) for “foundation” aid. The predicted value is multiplied by district PI Score to obtain simulated per pupil expenditure.

Ohio does not have matching aid, but the impact of matching aid can be duplicated by a tax credit as Bradford and Oates (1971) point out. For the case of power-equalizing aid for per pupil per performance expenditure, we can use the regression coefficient of Property Tax Rollback Credit, -3.058, to impute the price effect of power-equalizing aid as follows:

\[ \text{Per Pupil Expenditure Change} = \left( \frac{\text{Per Pupil Aid}}{\text{Per Pupil Property Tax} + \text{Per Pupil Aid}} \right) (3.058)(\text{Per Pupil Expenditure} - \text{Nonformula Aid}) \]  

(19)

In Equation (19), \( \frac{\text{Per Pupil Aid}}{\text{Per Pupil Property Tax} + \text{Per Pupil Aid}} \) indicates how much local tax price decreases by matching aid (Fisher 2016, 223-225). Non-formula aid amounts are excluded because this paper focuses on formula-based aid. Although the coefficient of Property Tax Rollback Credit is estimated for Equation (13) with per pupil expenditure per PI Score, we can apply it to
estimating per pupil expenditure change because it is an elasticity measure. A generally similar method is applied for PI Score change from Equation (15).

10. Simulation Results

10.1. Efficiency Targeting on Performance: Power-equalizing Aid (No Negative Aid)

10.1.1. No Negative Aid

Table 4 shows how Efficiency Targeting (ET) affects district efficiency measures and various equity measures for Performance Score (PS). It also shows the range of simulated aid amounts. Figure 1 succinctly summarizes Table 4. The horizontal axis denotes ET. efindex_14sim_70 (= Efficiency in Table 4) is simulated efficiency index scores that simulated aid amounts generate via Equation (5). As ET increases, simulated efficiency scores increase. When ET = 0.6, simulated efficiency score reaches the highest value of 0.754. The mean value of efficiency index obtained from the actual school district sample data is 0.616 as shown in Table 1. As long as ET is kept below 0.75 (with the simulated efficiency score of 0.691), overall school district efficiency should be improved through Efficiency Targeting in power-equalizing aid with the no-negative-aid restriction.

lpupvaltp_14_70 (=Outcome Elasticity in Table 4) measures the elasticity between per pupil property valuation and performance score, but this elasticity implicitly denotes how much the
inherent positive correlation between PV and PS, through local property tax revenues, might be suppressed by the negative correlation between PV and A as clarified in Section 8. Figure 1 shows that the overall elasticity between PV and PS, through both local property tax revenues and school aid, now turns negative throughout the entire range of ET. In addition, the negative correlation in absolute value is larger at the higher range of ET values, which is a signal for improved outcome equity.

$gini$ is the Gini coefficient for Performance Score (PS) that is predicted based on simulated Aid. Note that $gini$ is not necessarily a measure of equity in itself but an index of concentration for PS. Since the overall correlation between PV and PS is now negative, districts with lower property value have higher PS. If so, higher values of $gini$ generally denote that poorer districts are associated with higher PS values and as a result, the negative correlation between PV and PS in absolute value should be higher for higher $gini$ values. However, Figure 1 shows higher $gini$ values for relatively lower magnitudes of negative correlation between PV and PS, again in absolute value. We can explain this anomaly. When the correlation between PV and A is weaker in absolute value, the actual aid amounts can be larger especially for the higher property valuation. Therefore, wealthier districts might have received relatively larger aid amounts that led to higher PS values.$^9$ Then, lower values of $gini$ are more desirable from an equity-based perspective. In general, we should interpret the Gini coefficients along with various elasticity measures. Given the nature of coefficient of variation (COV in Table 4), scaledcov_70, which is the coefficient of variation divided by 100 for clearer visual presentation, carries results almost identical to $gini$.

$^9$ Table A. 2. in Technical Appendix A clearly shows that this scenario is possible. This scenario is a potential and tricky observation that efficiency targeting might generate.
We can also compare the above equity measures with those for the original sample. As reported in Section 8, the elasticity between per pupil property valuation and performance score for the original data sample is 0.074. In the first place, the positive value means that the negative correlation between property valuation and aid was not strong enough to reverse the inherent positive correlation between PV and PS, through local property tax revenues. In contrast, efficiency targeting in power-equalizing aid with no-negative-aid restriction returns negative correlations between PV and PS for the entire range of ET.

In sum, efficiency targeting through power-equalizing aid with no-negative-aid restriction places actual district efficiency higher than the average efficiency value, 0.616, of the original sample as long as ET is kept below 0.75. For the entire range of ET below 0.75, the elasticity between PV and PS is negative, which is also a clear sign of outcome equity improvement. As also noted above, lower gini values are better in terms of outcome equity in this specific case. Therefore, keeping ET close to 0.75 improves both district efficiency and outcome equity.

Finally, efficiency targeting is likely to generate abnormally larger aid amounts that are out of actual budget boundary. As reported earlier, the actual per pupil school aid ranges between $459.13 and $10,917.64. As shown in Table 4, maximum aid values are often far beyond the upper boundary. Equation (18) in Section 8.3 presents a quick fix to keep simulated aid values within the actual budget boundary. There are numerous ways to further shorten the range of simulated aid amounts. For instance, Equation (18) can be modified like Equation (19):

$$A_{fs} = A_s \left(1 - \frac{\sigma}{\sigma_s}\right) + 4,180.641 \cdot \frac{\sigma}{3 \sigma_s} \quad (19)$$
According to Equation D. 2 in Technical Appendix D, $4,180.641 \times \frac{\sigma}{3\sigma_s}$ will augment the absolute value of all elasticity measures, resulting in even stronger equity improvement.\(^{10}\)

10.1.2. Negative Aid

Figure 2 reports the results on how Efficiency Targeting (ET) in power-equalizing aid with negative aid affects efficiency and equity for Performance Score (PS). The patterns are almost identical to those in Figure 1, with some minor differences. Correlation measures replace elasticity measures to avoid missing negative values of A when it is transformed into logarithm. Up to the Efficiency Targeting (ET) value of about 0.5, corpupvaltpup_14 [correlation between PV and Performance Score (PS)] is slightly positive. Beyond that point, the correlation gradually turns negative. As Technical Appendix A shows, as ET changes aid amounts are likely to dramatically change, especially if negative aid is allowed.

Another difference is that gini has values closer to one up to the ET value of 0.45. These abnormally large gini values can be easily generated when there are as many negative values of PS as there are positive values, especially if their magnitudes are similar in absolute value. Another anomaly is the gini value of -2.48 when ET = 0.5. Even when we use the normalized Gini coefficient, this scenario can occur if per pupil aid amount and per pupil property tax amount are close to each other, as implied in Section 9.4. Here again, scaledcov_70 (scaled Coefficient of Variation) is similar to gini.

In sum, when ET ranges between 0.4 and 0.75, simulated efficiency (effindex_14sim_70) varies between 0.667 and 0.755. For the ET range beyond 0.5, the correlation between PV and PS, and that between PV and Efficiency, are negative. Power-equalizing aid with efficiency targeting and negative aid also significantly improves both efficiency and equity.

\(^{10}\) For foundation aid, this assumption might not obtain. See the last paragraph of Technical Appendix D for more detailed discussions of this issue.
10.2. Efficiency Targeting on Expenditure: Power-equalizing Aid

10.2.1. No Negative Aid

Figure 3 summarizes how Efficiency Targeting (ET) in power-equalizing aid with no-negative-aid restriction affects efficiency and equity for per pupil expenditure. Note that by definition efficiency in Figure 3 is the same as that in Figure 1. As clearly visualized, the impacts of ET on efficiency and equity for per pupil expenditure are almost identical to those for Figure 1.

10.2.2. Negative Aid

Figure 4 presents a mirror image to Figure 2, with almost the same implications on how Efficiency Targeting (ET) in power-equalizing aid with negative aid affects efficiency and equity for per pupil expenditure.

10.3. Efficiency Targeting on Performance: Foundation Aid

Based on the discussions introduced in Section 3, we can expect similar results from foundation aid with Efficiency Targeting (ET). However, there are a couple of differences. First, \((S^* \ast \bar{c} \ast c_i)\) in Equation (2) is mostly fixed as opposed to \((S_i \ast MC \ast c_i)\) in Equation (4), which is random. As a result, random curvatures in elasticity and correlation measures are less likely: most curves would be smoother. Second, \(\left[\frac{V_i}{c_i}\right]\) in Equation (2) is not exponentiated, so elasticity and correlation measures might be slightly different from those from power-equalizing aid.

10.3.1. No Negative Aid

Figure 5 shows how ET in outcome-based foundation aid with no-negative-aid restriction affects efficiency and equity for Performance Score (PS). Simulated efficiency (effindex_14sim_70) is now higher than the actual sample mean of 0.616 for the entire range of ET, with the simulated efficiency peaking at 0.765 when ET = 0.3. The elasticity between
Property Valuation (PV) and Efficiency (E) shows patterns slightly different from the values for power-equalizing aid, which might be attributable to different distributions of actual PV.

The elasticity between PV and PS (lpupvaltp_14_70) is positive for the entire range of ET. The elasticity for the actual data sample, as noted earlier, is 0.074, but all the elasticity values in Figure 5 are larger than 0.074. Once the elasticity is positive, smaller values of gini are more desirable in terms of equity, as indicated in Section 8. Although at higher values of ET gini values are lower, those values are still larger than the Gini coefficient of the actual data sample, 0.034. Coefficient of variation values are similar to those gini values. Despite the efficiency improvement in Figure 5, equity is somewhat damaged when ET is incorporated into outcome-based foundation aid with no-negative-aid restriction.

10.3.2. Negative Aid

Figure 6 shows how Efficiency Targeting (ET) in outcome-based foundation aid with negative aid allowed affects efficiency and equity for Performance Score (PS). Now the correlation between Property Valuation (PV) and Efficiency (E), corpupvaltpup_14, looks similar to the patterns for power-equalizing aid. In addition, the correlation between PV and PS, corpupvaltpup_14, is negative.

As long as ET is larger than 0.25, simulated efficiency scores range between 0.66 and 0.72, higher than the efficiency score of the actual data sample, 0.616. Given the negative correlation between PV and PS, larger gini values tend to imply stronger outcome equity. Coefficient of variation values also carry similar implications. In sum, keeping ET closer to 0.25 improves both efficiency and equity for PS in the case of outcome-based foundation aid with ET and negative aid allowed.

10.4. Efficiency Targeting on Expenditure: Foundation Aid
10.4.1. No Negative Aid

Figure 7 summarizes how Efficiency Targeting (ET) in outcome-based foundation aid with no-negative-aid restriction affects efficiency and equity for per pupil expenditure. Similar to Figure 5, efficiency is improved for the entire range of ET, but equity is damaged since the correlation between Property Valuation (PV) and Expenditure (Exp) is positive.

10.4.2. Negative Aid

Figure 8 summarizes how Efficiency Targeting (ET) in outcome-based foundation aid with negative aid allowed affects efficiency and equity for per pupil expenditure. The results are similar to Figure 6 but with one difference. Beginning from ET = 0.5, the correlation between PV and Exp turns positive. For the entire range of ET larger than 0.25, simulated efficiency scores are larger than 0.616, the efficiency score of the actual data sample. Therefore, maintaining ET larger than 0.25 but smaller than 0.5 improve both efficiency and equity.\footnote{The above two findings are based on the assumption that simulated efficiency indices do not affect school expenditures or Performance Index (PI) Score. Even when the simulated efficiency indices are allowed to affect school expenditures or PI Score, the two main findings remain almost unchanged. In addition, foundation aid with no-negative-aid restriction can now simultaneously improve both efficiency and equity if efficiency targeting values are kept very high. Refer to Technical Appendix E for more details.}

11. Conclusion

Scholars have recently incorporated Efficiency Targeting into outcome-based state aid to local school districts. While earlier school aid systems focused primarily on equity (fiscal equity and then outcome equity), outcome-based school aid with efficiency targeting can improve both efficiency and equity. Despite its important contribution to the practical management of school aid systems, virtually no studies have yet investigated whether and how it can systematically improve both efficiency and equity. This study is the first attempt to analyze the impacts of
outcome-based school aid with efficiency targeting on school district efficiency and fiscal and outcome equity. It conducts computer simulations to find more systematic patterns of the impacts. Empirical findings can be summarized as follows:

- Efficiency Targeting in outcome-based “power-equalizing” school aid can improve both school district efficiency and fiscal and outcome equity simultaneously for a wide range of efficiency targeting value.
- Efficiency Targeting in outcome-based “foundation” school aid can simultaneously improve both school district efficiency and fiscal and outcome equity for a limited range of efficiency target value. However, this impact is not present for foundation aid with no-negative-aid restriction.
- In most of these cases, Efficiency Targeting in outcome-based school aid tends to improve school district efficiency.

This paper also provides a method to adjust the range of simulated school aid while keeping total amounts of aid within the current state budget limit. The method also enables policy makers to estimate the change in equity measures, especially elasticity measures, when the range of simulated aid values changes. All these procedures are very convenient features for application of aid simulation in this paper to actual aid distributions.
References


Duncombe, William D., and John M. Yinger. 1999. Performance Standards and Educational Cost Indexes: You Can’t Have One Without the Other. Equity and Adequacy in Education Finance:


Sullivan, Meghan, and Mike Sobul. 2010. Property Taxation and School Funding. Columbus, OH: Ohio State Taxation Department. Tax Research Series Number One.


<table>
<thead>
<tr>
<th>Table 1. Descriptive Statistics</th>
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<tbody>
<tr>
<td><strong>Dependent Variables</strong></td>
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<tr>
<td>Per Pupil Expenditure Per Performance Index Score</td>
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<tr>
<td>Performance Index Score</td>
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**Cost Variables**

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<th>Mean</th>
<th>Standard Deviation</th>
<th>Min</th>
<th>Max</th>
<th>Data Source</th>
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<tbody>
<tr>
<td>Teacher Salary</td>
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<td>7,798.79</td>
<td>8,707.81</td>
<td>81,671.84</td>
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<tr>
<td>Student Enrollment</td>
<td>2,788.76</td>
<td>4,845.19</td>
<td>262</td>
<td>68,229.97</td>
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<td>Students in Poverty</td>
<td>0.43</td>
<td>0.21</td>
<td>0</td>
<td>1</td>
<td>A</td>
</tr>
<tr>
<td>Students with Disability</td>
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<td>0.03</td>
<td>0.06</td>
<td>0.27</td>
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<tr>
<td>Nonwhite Students</td>
<td>0.14</td>
<td>0.18</td>
<td>0.004</td>
<td>0.997</td>
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**Demand/Efficiency Variables**

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<th>Min</th>
<th>Max</th>
<th>Data Source</th>
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<tbody>
<tr>
<td>Tax Price $\left[\left(\frac{\nu}{\nu}\right)\right]$</td>
<td>0.31</td>
<td>0.08</td>
<td>0.07</td>
<td>0.69</td>
<td>A, D, E</td>
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<td>Inversed Tax Exemption Share $\left[\left(1 - \frac{x}{\nu}\right)^{-1}\right]$</td>
<td>1.12</td>
<td>0.10</td>
<td>1.02</td>
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<td>Property Tax Rollback Credit $[\pi_p]$</td>
<td>0.88</td>
<td>0.02</td>
<td>0.82</td>
<td>0.97</td>
<td>A, D</td>
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<tr>
<td>Foundation Aid Ratio $\left[\left(\frac{\delta}{\nu}\right)\left(\frac{\nu}{\nu}\right)\left(1 - \frac{x}{\nu}\right)^{-1}\pi_p\right]$</td>
<td>0.04</td>
<td>0.03</td>
<td>0.002</td>
<td>0.63</td>
<td>A, C, D, E, F</td>
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<td>Median Income (TY 2014)</td>
<td>34,633.5</td>
<td>8,131.38</td>
<td>18,540</td>
<td>74,911</td>
<td>F</td>
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<tr>
<td>Median Income (TY 2013)</td>
<td>34,322.5</td>
<td>8,113.89</td>
<td>19,627.5</td>
<td>75,346</td>
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<tr>
<td>Owner-occupied House Units</td>
<td>0.68</td>
<td>0.11</td>
<td>0.26</td>
<td>0.92</td>
<td>E</td>
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<tr>
<td>Population 5-19 Years Old</td>
<td>0.20</td>
<td>0.03</td>
<td>0.09</td>
<td>0.31</td>
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<tr>
<td>Population 65 Years and Over</td>
<td>0.16</td>
<td>0.03</td>
<td>0.07</td>
<td>0.34</td>
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<tr>
<td>Average Wage in Manufacturing</td>
<td>54,501.55</td>
<td>8,614.29</td>
<td>31,386</td>
<td>84,305</td>
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**Efficiency/Cost Indices, Marginal Cost**

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<th>Standard Deviation</th>
<th>Min</th>
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<th>Data Source</th>
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<tbody>
<tr>
<td>Efficiency Index</td>
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<td>0.114</td>
<td>0.00</td>
<td>0.999*</td>
<td>Estimated from the model</td>
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<tr>
<td>Cost Index</td>
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<td>0.28</td>
<td>0.00</td>
<td>2.43</td>
<td>Estimated from the model</td>
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</table>

Note: The number of observations is 607. When there were some missing observations, they were replaced by mean values.

Note *: The maximum value of efficiency index was set below one to avoid creating outliers when converted into natural logarithm.

Data Sources: A = Ohio State Education Department (2014 a); B = Ohio State Education Department (2014 b); C = Ohio State Education Department (2014 c); D = Ohio State Education Department (2013); E = U. S. Census Bureau a; F = Ohio State Taxation Department (2014); G = Ohio State Tax Department (2013); H = U. S. Census Bureau b; I = Ohio State Job and Family Services Department
| Variable | Coefficient | Pr > |z| |
|----------|-------------|------|-----|
| Constant | -8.260      | 0.000|
| **Cost Variables** | | | |
| Teacher Salary | 0.552 | 0.000|
| Student Enrollment | -0.028 | 0.045|
| Students in Poverty | 0.054 | 0.001|
| Students with Disability | 0.165 | 0.000|
| Nonwhite Students | 0.029 | 0.008|
| **Efficiency Variables** | | | |
| Tax Price $\left(\frac{\bar{x}}{\overline{p}}\right)$ | -0.663 | 0.000|
| Inversed Tax Exemption Share $\left(1 - \frac{x}{\bar{p}}\right)^{-1}$ | -0.638 | 0.000|
| Property Tax Rollback Credit $\pi_p$ | -3.058 | 0.000|
| Foundation Aid Ratio $\left(\frac{\bar{x}}{\overline{p}}\right)\left(\frac{\bar{x}}{\overline{p}}\right)^{-1} \pi_p$ | 4.586 | 0.000|
| Median Income (TY 2014) | 0.579 | 0.000|
| Owner-occupied House Units | -0.329 | 0.000|
| Population 5-19 Years Old | 0.108 | 0.055|
| Population 65 Years and Over | -0.143 | 0.001|
| Underidentification Test (Kleibergen-Paap rk LM Statistic) | 76.075 | Chi sq (1) P-val = 0.000|
| Weak-instrument-robust inference test (Anderson-Rubin Wald Test) | F(2, 592) = 39.58 | P-val = 0.0000|
| Weak-instrument-robust inference test (Anderson-Rubin Wald Test) | $\chi^2(2) = 81.04$ | P-val = 0.0000|
| Weak identification Test (Kleibergen-Paap rk F Statistic) | 65.208 |
| Uncentered R² (Centered R²) | 0.999 (0.399) |

**Note:** All values except for Foundation Aid Ratio are in natural logarithm. The endogeneity tests were run based on Baum, Schaffer, and Stillman (2007). The tests showed no evidence for endogeneity for Tax Price, Inversed Tax Exemption Share, and Foundation Aid Ratio.
| Variable                                  | Coefficient | Pr > |z| |
|-------------------------------------------|-------------|------|---|
| Constant                                  | -1.341      | 0.535|
| **Consumer-voter’s Income Variables**     |             |      |   |
| Median Income (TY 2013)                   | 0.563       | 0.002|
| Foundation Aid Ratio \( \left( \frac{\lambda}{\gamma} \left( \frac{\gamma}{\pi} \right)^{-1} \pi_P \right) \) | 2.611       | 0.080|
| **Tax Price Variables**                   |             |      |   |
| Tax Price \( \left( \frac{\gamma}{\pi} \right) \) | -0.452      | 0.022|
| Inversed Tax Exemption Share \( \left( 1 - \frac{x}{\gamma} \right)^{-1} \) | -0.360      | 0.050|
| Property Tax Rollback Credit \( [\pi_p] \) | -2.434      | 0.006|
| Cost Index                                | -0.571      | 0.007|
| Efficiency Index                          | 0.863       | 0.007|
| **Preference Variables**                  |             |      |   |
| Population 5-19 Years Old                | 0.183       | 0.002|
| Owner-occupied House Units                | -0.200      | 0.073|
| Student Enrollment                        | -0.012      | 0.001|
| Average Wage in Manufacturing             | -0.013      | 0.310|
| Underidentification Test (Kleibergen-Paap rk LM Statistic) | 12.772      | Chi-sq (1) P-val = 0.0004 |
| Weak-instrument-robust inference test (Anderson-Rubin Wald Test) | F(3, 595) = 19.95 | P-val = 0.0000 |
| Weak-instrument-robust inference test (Anderson-Rubin Wald Test) | \( \chi^2(3) = 61.05 \) | P-val = 0.0000 |
| Weak identification Test (Kleibergen-Paap rk F Statistic) | 5.507       |      |   |
| Uncentered R\(^2\) (Centered R\(^2\))    | 0.999 (0.563)|      |   |
| **Instrumental Variables**                |             |      |   |
| Logged Per Pupil 2011 Assessed Property Valuation, Efficiency Index for FY 2012, Median House Value for 2013 |

Note: All values except for Foundation Aid Ratio are in natural logarithm.
Table 4. Efficiency Targeting on Performance: Power-equalizing Aid (No Negative Aid)

<table>
<thead>
<tr>
<th>Efficiency Target</th>
<th>Gini</th>
<th>Efficiency</th>
<th>Efficiency Elasticity</th>
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Figure 1. Efficiency Targeting on Performance: Power-equalizing Aid (No Negative Aid)

Notes: gini (Gini coefficients); lpupvaltp_14_70 (elasticity between per pupil property valuation & performance score); lpupvaltp_14eff_70 (elasticity between per pupil property valuation & efficiency); effindex_14sim_70 (simulated efficiency index); scaledcov_70 (scaled coefficient of variation for performance score)
Figure 2. Efficiency Targeting on Performance: Power-equalizing Aid

Notes: gini (Gini coefficients); corpupvaltpuppup_14 (correlations between per pupil property valuation & performance score); corpupvaltp_14eff_70 (correlations between per pupil property valuation & efficiency); effindex_14sim_70 (simulated efficiency index); scaledcov_70 (scaled coefficient of variation for performance score)

Figure 3. Efficiency Targeting on Expenditure: Power-equalizing Aid (No Negative Aid)

Notes: gini (Gini coefficients); lpupvaltp_14_70 (elasticity between per pupil property valuation & per pupil expenditure); lpupvaltp_14eff_70 (elasticity between per pupil property valuation & efficiency); effindex_14sim_70 (simulated efficiency index); scaledcov_70 (scaled coefficient of variation for per pupil expenditure)
**Figure 4. Efficiency Targeting on Expenditure: Power-equalizing Aid**

Notes: gini (Gini coefficients); corpupvaltpopup_14 (correlations between per pupil property valuation & per pupil expenditure); corpupvaltp_14eff_70 (correlations between per pupil property valuation & efficiency); effindex_14sim_70 (simulated efficiency index); scaledcov_70 (scaled coefficient of variation for per pupil expenditure)

**Figure 5. Efficiency Targeting on Performance: Foundation Aid (No Negative Aid)**

Note: Refer to Figure 1 for the description of the variables in this figure.
Figure 6. Efficiency Targeting on Performance: Foundation Aid

Note: Refer to Figure 2 for the description of the variables in this figure.

Figure 7. Efficiency Targeting on Expenditure: Foundation Aid (No Negative Aid)

Note: Refer to Figure 3 for the description of the variables in this figure.
Figure 8. Efficiency Targeting on Expenditure: Foundation Aid

Note: Refer to Figure 4 for the description of the variables in this figure.
Technical Appendix A

Impacts of Efficiency Targeting on Revenue, Efficiency, and Equity

Efficiency Targeting Revenue Impact

Table A.1 shows how efficiency targeting affects perceived aid for a certain school district. Efficiency targeting or actual efficiency index ranges between 0 and 1, with 1 meaning the highest level of efficiency. The upper panel in Table A.1 shows how Efficiency Targeting (ET) affects perceived aid amount to a school district with an "actual" Efficiency (E) score of 0.2 (i.e. less efficient district). Assume that the default aid amount is $1 and all other aid parameters remain the same for this simple simulation. If ET increases from 0.2 to 1 in increments of 0.2, actual amounts of aid will decrease from $5 (=1/0.2) to $1 (=1/1) by way of Equations (2) and (4). Since this school district's actual E index is 0.2, the district needs $5 in aid to obtain the one-dollar spending effect of a fully efficient district (i.e. E = 1). The last column in Table A.1 measures Perceived Aid (= Aid - Needed Aid). If ET is 1 for this district, its perceived aid amount will be -$4 because it will actually receive one dollar of aid while it needs five dollars for the one-dollar spending effect of the fully efficient district. Overall, as ET increases, Perceived Aid decreases. This observation holds true for a fully efficient district with E = 1, as shown in the lower panel of Table A.1. This observation is defined as Efficiency Targeting Revenue Impact.

Targeting Incentive Efficiency Impact

To analyze how Efficiency Targeting Revenue Impact affects efficiency of school districts, we first need to formulate efficiency index. While previous studies have applied Data Envelopment Analysis (DEA) adjusted for various factors (Duncombe and Yinger 1998), Duncombe and Yinger (2009; 2011) and Eom et al. (2014) suggest a more convenient approach to developing efficiency index, as shown in Equation (A.1).

\[ e = kM^\rho Y + A \left( \frac{V}{\bar{V}} \right) \left( 1 - \frac{X}{\bar{V}} \right)^{-1} \pi_p \left[ (MC) \left( \frac{V}{\bar{V}} \right) \left( 1 - \frac{X}{\bar{V}} \right)^{-1} \pi_p \right]^\delta \]  

(A.1)

, where e is a latent school district efficiency index (0 < e < 1), M is a cluster of control factors that tap consumer-voters' monitoring of school district administration, Y = before-tax income of a median voter, A = per pupil state lump-sum (foundation) aid, V = median market house value in a local school district * assessment ratio in Ohio (= 0.35), \( \bar{V} \) = per pupil potential assessed property valuation, X = per pupil assessed property tax exemption value, not reimbursed by the state government, MC = marginal cost of educational cost per performance index score, and \( \pi_p = 1 - \frac{\text{Per Pupil Property Tax Rollback Credit}}{\text{Per Pupil Property Tax Rollback Credit} + \text{Per Pupil Property Tax}} \). The latent efficiency index is a function of two primary factors. The variables in the first square brackets are rough income measures. As a median voter's income and per pupil aid increase, consumer-voters are less likely to monitor school administration tightly and as a result, efficiency tends to decrease (i.e. \( \gamma < 0 \)). In contrast, the variables in the second square brackets measure a consumer-voter's tax prices. As tax prices for school district service increase, consumer-voters are more likely to monitor school district administration tightly (i.e. \( \delta > 0 \)). The cluster of monitoring factors is also positively correlated with school district efficiency. The first column in Table A.2, Efficiency, is the actual efficiency index obtained from the computer simulation for power-equalizing aid with no-negative-aid restriction, which will be introduced later in this paper.

The previous section showed that as Efficiency Targeting (ET) increases, the amount of Perceived Aid (PA) decreases. According to Equation (A.1), the decrease in A (i.e., perceived
aid

is negatively related to Efficiency (E) index. This observation is defined as Targeting Incentive Efficiency Impact: as ET increases, E tends to increase. Table A.2 generally confirms this expectation but with caveats, as indicated in the next section.

Property Valuation Efficiency Impact

Equations (2) and (4) show how local school districts' property valuation (\(V_i\)) can also affect Aid (A) and ultimately Efficiency (E). Property Valuation (PV) in Table A.2 is an index variable to proxy \(V_i\), with the highest PV equal to one, for ease of illustration. PV was assumed "fixed" in Table A.1. However, the distribution of actual property valuation measures of school districts is likely to be reshuffled and random as we conduct simulations, which we can identify only by empirical observation. In Equations (2) and (4), PV is negatively correlated with A. According to Equation (A.1), Aid is also negatively correlated with Efficiency. Therefore, there is a positive correlation between PV and E through Equations (2) and (4). Equation (A.1) shows that PV also affects E through different venues. \(\bar{V}\) in Equation (A.1) is the same as \(V_i\) in Equations (2) and (4), and it appears in multiple places in Equation (A.1). Since \(\gamma < 0\) in Equation (A.1), \(\bar{V}\), which "directly" interacts with Aid (A), is positively correlated with Efficiency (E). All these positive correlations between PV and E, which work through Aid, are defined as Direct Property Valuation Efficiency Impact.

Since \(\delta > 0\) in Equation (A.1), \(\bar{V}\), which is included in tax price measures, is negatively correlated with Efficiency (E). The negative correlation between PV and E via tax price measures is defined as Indirect Property Valuation Efficiency Impact. Note that Indirect Property Valuation Efficiency Impact does not work through Aid formula.

Now, Property Valuation (PV) in Table A.2 is not fixed but slightly adjusted, and as a result, the actual Aid (A) also changes. When ET = 0.50, Aid = 2.040 in the upper panel in Table A.2: 2.040 = \([(1 + (1 - 0.980))/0.50\]. The adjustment partially factors in PV of a certain school district. The adjustment is somewhat arbitrary but replicates, without significant distortion, what the negative sign does for \(V_i\) in Equations (2) and (4). As ET increases from 0.10 to 0.50 in the upper panel, predicted efficiency index based on Equation (A.1), Efficiency (E), increases from 0.62 to 0.74. In the lower panel, as ET increases from 0.60 to 1.00, E decreases from 0.75 to 0.59 and then increases to 0.65. In general, as ET increases, E increases as expected. However, it is impossible to explain the curvature at the higher end of ET without further accounting for Direct Property Valuation Efficiency Impact that implies a positive relationship between PV and E.

Table A.2 indicates that the positive correlation between Efficiency Targeting (ET) and Efficiency (E) (i.e., Targeting Incentive Efficiency Impact) is compromised by the positive Direct Property Valuation Efficiency Impact. Start from ET = 0.20 with PV = 1.000 in the upper panel in Table A.2. The decrease in PV is miniscule and as a result, the increasing pattern in E, which is driven primarily by Targeting Incentive Efficiency Impact, does not diminish. In the lower panel, however, PV significantly drops to around 0.961 and E rapidly decreases. As PV starts growing again, E starts increasing again, which confirms that Targeting Incentive Efficiency Impact is compromised by the positive "Direct" Property Valuation Efficiency Impact (i.e., decrease in PV now dampens E).

\[12\] It is theoretically more accurate to use Perceived Aid for Equation (A.1). In that case, however, model estimation and simulations might become too complex. Since the patterns of Aid and Perceived Aid are similar, the overall findings in this paper will remain almost the same even when we use Aid, instead of Perceived Aid, as done in this paper.
Impacts of Efficiency Targeting on Equity

Table A.2 confirms the inverse relationship between Property Valuation (PV) and Aid (A), which is typically deemed an equity measure. In the upper panel (relatively higher PV) in Table A.2, the correlation between PV and A is -0.0534, but that in the lower panel (relatively lower PV) is -0.797. Of course, more accurate estimation of correlations would be obtained from the correlations between simulated Aid amounts and PV values for each of the given ET values. However, the results in Table A.2 are sufficient to show possible correlations between certain variables that might generate their diverse combinations. Especially in Equation (4), \( S_i \times MC \times c_i \) might be random. Then, there will be numerous possible combinations of the variables, which we can only empirically observe.

Another useful observation is the correlation between A and Efficiency (E). Equation (A.1) indicates that A will negatively affect E but actual PV values will also affect E through "Direct" Property Valuation Efficiency Impact, as noted in the previous section. In the lower panel of Table A.2, the positive Direct Property Valuation Efficiency Impact seems to dominate the inherent negative correlation between A and E as the correlation between A and E is 0.772. This observation contrasts with -0.823 in the upper panel. From an equity-based perspective, this observation is desirable because districts with relatively lower PV now tend to receive relatively larger aid (i.e., stronger negative correlation between PV and A in absolute value) and their efficiency climbs higher.

The correlation between PV and E in Table A.2 is a "global" measure that is more comprehensive than the positive Direct Property Valuation Efficiency Impact. Now, it further covers negative Indirect Property Valuation Efficiency Impact. The global correlations between PV and E are all negative, which implies that the negative Indirect Property Valuation Efficiency Impact overwhelms the positive Direct Property Valuation Efficiency Impact.

Finally, models of school spending and outcome will predict how Aid affects school expenditure and outcome (e.g., student performance). Once we obtain the distributions of predicted school expenditure and outcome, we can estimate various equity indices such as the Gini coefficient. While the equity indices will be introduced later in this paper, one point is worth noting. Stronger negative correlations between PV and A generally mean that districts with lower property valuation tends to receive larger aid. However, there is still a possibility that districts with higher property valuation might get larger aid in absolute amount despite the relatively weaker negative correlation between PV and A. In the upper panel in Table A.2, the correlation is -0.0534, which is weaker than -0.797 in the lower panel, but the relatively wealthier districts receive much larger aid (A).
Table A.1. Efficiency Targeting Revenue Impact

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<th>Efficiency Targeting (ET)</th>
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<th>Needed Aid (NA)</th>
<th>Perceived Aid (PA = A-NA)</th>
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<td>5</td>
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Table A.2. Impacts of Efficiency Targeting on Efficiency and Equity

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<th>Needed Aid (NA)</th>
<th>Perceived Aid (PA = A-NA)</th>
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Correlation between PV & A = -0.0534
Correlation between A & E = -0.823
Correlation between PV & E = -0.430

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Technical Appendix B

### Variable Names Used In Appendix B

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<td>Students with Disability</td>
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<tr>
<td>Nonwhite Students</td>
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<td><strong>Demand/Efficiency Variables</strong></td>
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<td>Inversed Tax Exemption Share ([1 - \frac{X}{V'}]^{-1})</td>
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<tr>
<td>Property Tax Rollback Credit ([\pi_p])</td>
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</tr>
<tr>
<td>Foundation Aid Ratio ([\frac{A}{V'}] (\frac{V}{V'}) (1 - \frac{X}{V'})^{-1} \pi_p)</td>
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<td>Median Income (TY 2013)</td>
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<td>Population 65 Years and Over</td>
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### PART I: EXPENDITURE EQUATION PER TABLE 2

**Endogeneity Test Results for Teacher Salary (= lteacher\_sal)**

Using all relevant data and the same method employed in Sections 4 and 5, I constructed Cost Index for FY 2012 (= costindem) for all school districts.\(^{13}\) According to Equation (11), Teacher Salary is a factor that constructs marginal cost of education per performance index score. According to Equation (14), the marginal cost is used to compute Cost Index. As a result, Cost Index is a direct function of Teacher Salary. Since Teacher Salary for FY 2014 is related to Teacher Salary for FY 2012 under incremental budget decision processes, the former is also related to Cost Index for FY 2012. Since Teacher Salary for FY 2012 was not determined when school districts prepared school expenditures for FY 2014, it is unreasonable to expect that Cost Index for FY 2012 is related to the errors in Equation (13). Therefore, Cost Index for FY 2012 is

\(^{13}\) This holds true for all the tests in Technical Appendix B.
used as the instrument for Teacher Salary. Below is the endogeneity test results for Teacher Salary. All relevant test results are in blue fonts.

The null hypothesis of underidentification is rejected and Kleibergen-Paap Wald rk F statistic is larger than 10, which means Cost Index for FY 2012 is not a weak instrument for Teacher Salary. The endogeneity test strongly rejects the null that Teacher Salary might be treated as exogenous.

ivreg2 lpexpend_14 lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14 lpcpop519yr_14 lpcpop65yr_14 lmedohincty14 linverse_14 (lteachersal_14=costindem) ltaxprice_14 lminuspie_14 augpuptsf_14 lownhouse_14, endog(lteachersal_14) robust first

First-stage regressions
---------------------

First-stage regression of lteachersal_14:

OLS estimation
--------------

|              | Coef. | Robust Std. Err. | t    | P>|t| | [95% Conf. Interval] |
|--------------|-------|------------------|------|-----|----------------------|
| lteachersal_14 | .0023668 | .0117751 | 0.20 | 0.841 | -.0207593 - .0254929 |
| lformulaa_14   | .047547  | .0127003 | 3.74 | 0.000 | .0226038 - .0724901 |
| ldisability_14 | -.1631588 | .0269898 | -6.05 | 0.000 | -.2161663 - .1101513 |
| lnonwhite_14   | -.0529728 | .0269898 | -10.73 | 0.000 | -.6267044 - .0432752 |
| lpcpop519yr_14 | -.0082358 | .0215431 | -0.38 | 0.702 | -.0621663 - .0340743 |
| lpcpop65yr_14  | -.02079  | .0212728 | -0.98 | 0.329 | -.0625693 - .0209894 |
| lmedohinc_14   | -.1159791 | .0806003 | -1.44 | 0.151 | -.2742765 - .0423182 |
| linverse_14    | .0396122  | .0663223 | 0.60 | 0.551 | -.0906434 - .1698677 |
| ltaxprice_14   | .0307103  | .0394836 | 0.78 | 0.437 | -.0468345 - .1082552 |
| lminuspie_14   | .0384315  | .1959701 | 0.20 | 0.437 | -.3464497 - .4233128 |
| augpuptsf_14   | -.1811203 | .3499848 | -0.52 | 0.599 | -.8684833 - .5062427 |
| lownhouse_14   | .0310731  | .0368046 | 0.84 | 0.399 | -.0412104 - .1033566 |
| costindem      | .9964162  | .776968  | 13.74 | 0.000 | .7769473 - 1.215885 |
| _cons          | 10.67305  | .776968  | 13.74 | 0.000 | 9.147101  - 12.199 |

Included instruments: lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14 lpcpop519yr_14 lpcpop65yr_14 lmedohinc_14 linverse_14 ltaxprice_14 lminuspie_14 augpuptsf_14 lownhouse_14 costindem

F test of excluded instruments:
F( 1, 592) = 79.51
Prob > F = 0.0000

Angrist-Pischke multivariate F test of excluded instruments:
F( 1, 592) = 79.51
Prob > F = 0.0000
Summary results for first-stage regressions
---------------------------------------------

<table>
<thead>
<tr>
<th>Variable</th>
<th>F(1, 592)</th>
<th>P-val</th>
<th>AP Chi-sq(1)</th>
<th>P-val</th>
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NB: first-stage test statistics heteroskedasticity-robust

Stock-Yogo weak ID test critical values for single endogenous regressor:
- 10% maximal IV size: 16.38
- 15% maximal IV size: 8.96
- 20% maximal IV size: 6.66
- 25% maximal IV size: 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Underidentification test
Ho: matrix of reduced form coefficients has rank=K1-1 (underidentified)
Ha: matrix has rank=K1 (identified)
Kleibergen-Paap rk LM statistic = 45.56 P-val=0.0000

Weak identification test
Ho: equation is weakly identified
Cragg-Donald Wald F statistic = 687.10
Kleibergen-Paap Wald rk F statistic = 79.51

Stock-Yogo weak ID test critical values for K1=1 and L1=1:
- 10% maximal IV size: 16.38
- 15% maximal IV size: 8.96
- 20% maximal IV size: 6.66
- 25% maximal IV size: 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Weak-instrument-robust inference
Tests of joint significance of endogenous regressors B1 in main equation
Ho: B1=0 and orthogonality conditions are valid
Anderson-Rubin Wald test F(1,592)= 46.90 P-val=0.0000
Anderson-Rubin Wald test Chi-sq(1)= 48.01 P-val=0.0000
Stock-Wright LM S statistic Chi-sq(1)= 39.60 P-val=0.0000

NB: Underidentification, weak identification and weak-identification-robust test statistics heteroskedasticity-robust

Number of observations = 606
Number of regressors = 14
Number of endogenous regressors = 1
Number of instruments = 14
Number of excluded instruments = 1

IV (2SLS) estimation
---------------------

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity

Number of obs = 606
F(13, 592) = 41.78
Prob > F = 0.0000
Total (centered) SS = 20.73809124 Centered R2 = 0.5395
Total (uncentered) SS = 13253.29812 Uncentered R2 = 0.9993
Residual SS = 9.550423611 Root MSE = .1255

------------------------------------------------------------------------------
|               Robust               | Coef.   | Std. Err.  | z     | P>|z|    | [95% Conf. Interval] |
|-------------------------------|---------|------------|------|--------|----------------------|
| lpexpend_14                   | .4326161| .0799824   | 5.41 | 0.000  | .2758535 to .5893787 |
| lformulaa_14                  | -.0337956| .011676   | -2.89| 0.004  | -.0566801 to -.010911|
| lpoverty_14                   | .0395357| .0149317   | 2.65 | 0.008  | .0102701 to .0688013 |
| ldisability_14                | .1858277| .0276748   | 6.71 | 0.000  | .131586 to .2400694  |
| lnonwhite_14                  | .0389082| .011676   | -2.89| 0.004  | -.0196433 to .0581732|
| lpcpop519yr_14                | .0862099| .0149317   | 1.70 | 0.088  | -.0566801 to .1853558|
| lpcpop65yr_14                 | -.0482701| .0149317  | -1.49| 0.135  | -.1116275 to .105873 |
| lmedohincty14                 | .5018764| .0721078   | 6.96 | 0.000  | .3605478 to .643205  |
| linverse_14                   | -.4051051| .1014865  | -3.99| 0.000  | -.6040149 to -.2061953|
| ltaxprice_14                  | -.4892648| .0479841  | -10.20| 0.000  | -.5833119 to -.3952177|
| lminuspie_14                  | .453077 | .2899488   | 1.56 | 0.118  | -.1152123 to 1.021366 |
| augpuptsf_14                  | 4.926469| .4627737   | 10.65| 0.000  | 4.019449 to 5.833489 |
| lownhouse_14                  | -.2050635| .061079   | -3.36| 0.001  | -.3247761 to -.0853509|
| _cons                         | -.5241099| .9641649  | -5.44| 0.000  | -.7130827 to -3.35137 |

Underidentification test (Kleibergen-Paap rk LM statistic): 45.557
Chi-sq(1) P-val = 0.0000

Weak identification test (Cragg-Donald Wald F statistic): 687.099
(Kleibergen-Paap rk Wald F statistic): 79.508

Stock-Yogo weak ID test critical values: 10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Hansen J statistic (overidentification test of all instruments): 0.000
(equation exactly identified)

-endo- option:

Endogeneity test of endogenous regressors: 12.975
Chi-sq(1) P-val = 0.0003

Regressors tested: lteachersal_14

Instrumented: lteachersal_14
Included instruments: lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14 lpcpop519yr_14 lpcpop65yr_14 lmedohincty14 linverse_14 ltaxprice_14 lminuspie_14 augpuptsf_14 lownhouse_14
Excluded instruments: costindem

Endogeneity Test Results for Property Tax Rollback Credit (=lminuspie_14)

Given the incremental nature of governmental budget processes, property tax revenues for FY 2011 are likely to be related to property tax revenues for FY 2014, which are included in Property Tax Rollback Credit. However, it is unlikely that school expenditures for FY 2014 can affect property values and property tax revenues for FY 2011. As a result, property tax revenues for FY 2011 are less likely to be related to errors in Equation (13). Similarly, property tax revenues for FY 2011 are likely to be related to Property Tax Rollback Credit but not with the errors in Equation (13). Logged property tax revenues for FY 2011 are used as an instrument for Property Tax Rollback Credit.
The null hypothesis of underidentification is rejected and Kleibergen-Paap Wald rk F statistic is larger than 10, which means Cost Index for FY 2012 is not a weak instrument for Teacher Salary. The endogeneity test strongly rejects the null that Teacher Salary might be treated as exogenous.

```
ivreg2 lpexpend_14 lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14
lpcpop519yr_14 lpcpop65yr_14 lmedohincty14 linverse_14 lteachersal_14
ltaxprice_14 (lminuspie_14=lrollback11) augpuptsf_14 lownhouse_14, endog(lminuspie_14)
robust first
```

First-stage regressions
----------------------

First-stage regression of lminuspie_14:
OLS estimation
--------------

|         | Coef.  | Std. Err. | t     | P>|t|    | [95% Conf. Interval] |
|---------|--------|-----------|-------|--------|----------------------|
| lformulaadm_14 |  .0025665 |  .0014977 |  1.71 |  0.087 | -.000375 - .005508  |
| lpoverty_14     | - .0024762 |  .0016524 | -1.50 |  0.135 | -.0057216  .0007691 |
| ldisability_14  | - .0030542 |  .0016524 | -1.50 |  0.135 | -.006878   .000772  |
| lnonwhite_14    |  .0013623 |  .0010579 |  1.29 |  0.198 | -.0007153  .0034399 |
| lpcpop519yr_14  |  .0034575 |  .0060005 |  0.58 |  0.565 | -.0083275  .0152424 |
| lpcpop65yr_14   | - .0172287 |  .0047819 | -3.60 |  0.000 | -.0266202  .0087327 |
| lmedohincty14   |  .0369769 |  .00957   |  3.86 |  0.000 | .0181816   .0557722 |
| linverse_14     | - .0652769 |  .0153266 | -4.26 |  0.000 | -.095378  -.0351758 |
| lteachersal_14  |  .0333796 |  .0145262 |  2.30 |  0.022 | .0048504   .0619087 |
| ltaxprice_14    | - .0482354 |  .0060459 | -7.98 |  0.000 | -.0601095  -.0363613 |
| augpuptsf_14    | - .3373146 |  .0771532 | -4.37 |  0.000 | -.488842   -.1857873 |
| lownhouse_14    |  .0449337 |  .08488   | -5.29 |  0.000 | -.0061039  -.0282635 |
| lrollback11     |  .0359264 |  .003588  | -10.01|  0.000 | -.0429737  -.028879 |
| _cons           | - .7666421 | .1370814  | -5.59 |  0.000 | -1.035867  -.4974171 |

Included instruments: lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14
lpcpop519yr_14 lpcpop65yr_14 lmedohincty14 linverse_14
ltteachersal_14 ltaxprice_14 augpuptsf_14 lownhouse_14
lrollback11

F test of excluded instruments:
F(  1,   592) =  100.24
Prob > F =  0.0000

Angrist-Pischke multivariate F test of excluded instruments:
F(  1,   592) =  100.24
Prob > F =  0.0000

Summary results for first-stage regressions
-------------------------------------------

Variable | F( 1, 592) P-val | AP Chi-sq(1) P-val | AP F(1, 592) P-val
--- | --- | --- | ---
\( l\text{minuspie}_{14} \) | 100.24 0.0000 | 102.61 0.0000 | 100.24

NB: first-stage test statistics heteroskedasticity-robust

Stock-Yogo weak ID test critical values for single endogenous regressor:
- 10% maximal IV size: 16.38
- 15% maximal IV size: 8.96
- 20% maximal IV size: 6.66
- 25% maximal IV size: 5.53


NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

**Underidentification test**
- Ho: matrix of reduced form coefficients has rank=\( K\text{-}1 \) (underidentified)
- Ha: matrix has rank=\( K \) (identified)

Kleibergen-Paap rk LM statistic: \( \text{Chi-sq}(1)=63.98 \) \( P\)-val=0.0000

**Weak identification test**
- Ho: equation is weakly identified

Cragg-Donald Wald F statistic: 140.67
Kleibergen-Paap Wald rk F statistic: 100.24

Stock-Yogo weak ID test critical values for \( K\text{-}1 \) and \( L\text{-}1 \):
- 10% maximal IV size: 16.38
- 15% maximal IV size: 8.96
- 20% maximal IV size: 6.66
- 25% maximal IV size: 5.53


NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

**Weak-instrument-robust inference**
Tests of joint significance of endogenous regressors \( B_1 \) in main equation
- Ho: \( B_1=0 \) and orthogonality conditions are valid

Anderson-Rubin Wald test: \( F(1,592)=28.06 \) \( P\)-val=0.0000
Anderson-Rubin Wald test: \( \text{Chi-sq}(1)=28.72 \) \( P\)-val=0.0000
Stock-Wright LM S statistic: \( \text{Chi-sq}(1)=24.01 \) \( P\)-val=0.0000

NB: Underidentification, weak identification and weak-identification-robust test statistics heteroskedasticity-robust

Number of observations \( N \) = 606
Number of regressors \( K \) = 14
Number of endogenous regressors \( K\text{-}1 \) = 1
Number of instruments \( L \) = 14
Number of excluded instruments \( L\text{-}1 \) = 1

**IV (2SLS) estimation**

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity

| Number of obs | 606 |
| F(13, 592) | 28.68 |
| Prob > F | 0.0000 |
| Total (centered) SS | 20.73809124 |
| Centered R2 | 0.3563 |
| Total (uncentered) SS | 13253.29812 |
| Uncentered R2 | 0.9990 |
| Residual SS | 13.34958214 |
| Root MSE | 0.1484 |
|               Robust
|               lpexpend_14 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
<table>
<thead>
<tr>
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<tr>
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<tr>
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</table>

Underidentification test (Kleibergen-Paap rk LM statistic): 63.979
Chi-sq(1) P-val = 0.0000

Weak identification test (Cragg-Donald Wald F statistic): 140.673
(Kleibergen-Paap rk Wald F statistic): 100.241

Stock-Yogo weak ID test critical values: 10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Hansen J statistic (overidentification test of all instruments): 0.000
(equation exactly identified)

-endog option:
Endogeneity test of endogenous regressors: 37.739
Chi-sq(1) P-val = 0.0000

Regressors tested: lminuspie_14

Instrumented: lminuspie_14
Included instruments: lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14 lpcpop519yr_14 lpcpop65yr_14 lmedohincty14 linverse_14 lteachersal_14 ltaxprice_14 augpuptsf_14 lownhouse_14
Excluded instruments: lrollback11

Endogeneity Test Results for Tax Price (=ltaxprice_14)

Property valuation for FY 2012 is likely to be related to property valuation for FY 2014 because property valuation does not change rapidly. Tax Price for FY 2014, which includes property valuation, is likely to be related to tax price for FY 2012. However, it is unlikely that school expenditures for FY 2014 might affect tax price for FY 2012. As a result, the latter is less likely to correlate with the errors in Equation (13). Logged tax price for FY 2012 is used as the instrument for Tax Price. All relevant test results are highlighted in blue below.

ivreg2 lpexpend_14 lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14 lpcpop519yr_14 lpcpop65yr_14 lmedohincty14 linverse_14 lteachersal_14 (ltaxprice_14=ltaxprice12) lminuspie_14 augpuptsf_14 lownhouse_14, endog(ltaxprice_14) robust first

First-stage regressions
First-stage regression of ltaxprice_14:

OLS estimation

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Included instruments: lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14 lpcpop519yr_14 lpcpop65yr_14 lmedohincty14 linverse_14 lteachersal_14 lminuspie_14 augpuptsf_14 lownhouse_14 ltaxprice12

F test of excluded instruments:
F( 1, 592) = 405.16
Prob > F = 0.0000

Angrist-Pischke multivariate F test of excluded instruments:
F( 1, 592) = 405.16
Prob > F = 0.0000

Summary results for first-stage regressions

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<th>(Underid)</th>
<th>(Weak id)</th>
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<td>Variable</td>
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<td>ltaxprice_14</td>
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<td>0.0000</td>
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NB: first-stage test statistics heteroskedasticity-robust

Stock-Yogo weak ID test critical values for single endogenous regressor:
10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.
Underidentification test  
Ho: matrix of reduced form coefficients has rank=K1-1 (underidentified) 
Ha: matrix has rank=K1 (identified) 

Kleibergen-Paap rk LM statistic Chi-sq(1)=93.07 P-val=0.0000

Weak identification test  
Ho: equation is weakly identified 
Cragg-Donald Wald F statistic 755.85 
Kleibergen-Paap Wald rk F statistic 405.16

Stock-Yogo weak ID test critical values for K1=1 and L1=1: 
10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Weak-instrument-robust inference 
Tests of joint significance of endogenous regressors B1 in main equation  
Ho: B1=0 and orthogonality conditions are valid 
Anderson-Rubin Wald test F(1,592)= 53.51 P-val=0.0000
Anderson-Rubin Wald test Chi-sq(1)= 54.78 P-val=0.0000
Stock-Wright LM S statistic Chi-sq(1)= 37.53 P-val=0.0000

NB: Underidentification, weak identification and weak-identification-robust test statistics heteroskedasticity-robust

Number of observations N = 606 
Number of regressors K = 14 
Number of endogenous regressors K1 = 1 
Number of instruments L = 14 
Number of excluded instruments L1 = 1

IV (2SLS) estimation 
-----------------------------------------------
Estimates efficient for homoskedasticity only 
Statistics robust to heteroskedasticity

| lpxpend_14 | Coef. | Robust Std. Err. | z | P>|z| | [95% Conf. Interval] |
|------------|-------|------------------|---|-------|----------------------|
| ltaxprice_14 | -.4788245 | .0618874 | -7.74 | 0.000 | -.6001215 | -.3575274 |
| lformulaa_14 | -.0248963 | .0115644 | -2.15 | 0.031 | -.0475622 | -.0022304 |
| lpoverty_14 | .0266091 | .0157402 | 1.69 | 0.091 | .004241 | .0574593 |
| ldisabili_14 | .1772721 | .0281991 | 6.29 | 0.000 | .122003 | .2325413 |
| lnonwhite_14 | .0266091 | .0157402 | 1.69 | 0.091 | .004241 | .0574593 |
| lpcpop519_14 | .0858274 | .0504604 | 1.70 | 0.089 | -.0130731 | .184728 |
| lpcpop65y_14 | -.0395306 | .0337247 | -1.17 | 0.241 | -.056298 | .0265687 |
| lmedohinc_14 | .5373185 | .070995 | 7.57 | 0.000 | .3981708 | .6764662 |
| linverse_14 | -.3765129 | .1032798 | -3.65 | 0.000 | -.5789376 | -.1740882 |
| letachers_14 | .2202109 | .078907 | 2.79 | 0.005 | .065556 | .3748657 |
| lminuspie_14 | .6625039 | .3004597 | 2.20 | 0.027 | .0736137 | 1.251394 |
Underidentification test (Kleibergen-Paap rk LM statistic): 93.075
Chi-sq(1) P-val = 0.0000

Weak identification test (Cragg-Donald Wald F statistic): 755.854
(Kleibergen-Paap rk Wald F statistic): 405.163
Stock-Yogo weak ID test critical values: 10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Hansen J statistic (overidentification test of all instruments): 0.000
(equation exactly identified)

Endogeneity test of endogenous regressors: 0.207
Chi-sq(1) P-val = 0.6495

Regressors tested: ltaxprice_14

Endogeneity Test Results for Inversed Tax Exemption Share (=linverse_14)

Property valuation for FY 2012 is likely to be related to property valuation for FY 2014 because property valuation does not change rapidly. Inversed Tax Exemption Share for FY 2014, which includes property valuation, is likely to be related to inverted tax exemption share for FY 2012. However, it is unlikely that school expenditures for FY 2014 might affect inversed tax exemption share for FY 2012. As a result, the latter is less likely to correlate with the errors in Equation (13). Logged inversed tax exemption share for FY 2012 is used as the instrument for Inversed Tax Exemption Share. All relevant test results are highlighted in blue below.

```
ivreg2 lpexpend_14 lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14 lpcpop519yr_14 lpcpop65yr_14 lmedohincty14 linverse_14 lteachersal_14 lminuspie_14 augpuptsf_14 lownhouse_14, endog(linverse_14) robust first
```

First-stage regressions

First-stage regression of linverse_14:

OLS estimation

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity
Number of obs = 606
F( 13, 592) = 79.88
Prob > F = 0.0000

Total (centered) SS = 3.905538041
Centered R2 = 0.8230
Total (uncentered) SS = 11.69867429
Uncentered R2 = 0.9409
Residual SS = 0.6911353559
Root MSE = 0.03417

Number of obs = 606
F( 13, 592) = 79.88
Prob > F = 0.0000

Total (centered) SS = 3.905538041
Centered R2 = 0.8230
Total (uncentered) SS = 11.69867429
Uncentered R2 = 0.9409
Residual SS = 0.6911353559
Root MSE = 0.03417

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>linverse_14</td>
<td>Coef. Std. Err. t</td>
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<tr>
<td>lformulaadm_14</td>
<td>0.0072355 0.0031311 2.31 0.021 0.0010861 0.0133848</td>
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<td>lpoverty_14</td>
<td>-0.0113452 0.0050338 -2.25 0.025 -0.0212315 -0.0014588</td>
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<tr>
<td>ldisability_14</td>
<td>-0.0111715 0.0082676 -1.34 0.179 -0.0273550 0.0051201</td>
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<tr>
<td>lnonwhite_14</td>
<td>0.0038620 0.0021597 1.79 0.074 -0.0003796 0.0081036</td>
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<tr>
<td>lpcpop519yr_14</td>
<td>0.0035217 0.0153046 0.23 0.818 -0.0265362 0.0335796</td>
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<td>lpcpop65yr_14</td>
<td>-0.0109211 0.0095981 -1.14 0.256 -0.0297716 0.0079294</td>
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<td>ldisease_14</td>
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<td>lteachersal_14</td>
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<td>lpcpop65yr_14</td>
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<td>lteachersal_14</td>
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<td>lminuspie_14</td>
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<tr>
<td>augpuptsfl_14</td>
<td>0.6818840 0.1786253 3.82 0.000 0.3008719 1.032505</td>
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<tr>
<td>lownhouse_14</td>
<td>-0.0172813 0.0201425 -0.86 0.391 -0.0568407 0.022278</td>
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<tr>
<td>linvmatchexe12</td>
<td>0.6543462 0.0669975 9.63 0.000 0.5137645 0.7962797</td>
</tr>
<tr>
<td>cons</td>
<td>-0.2115612 0.2516596 -0.84 0.401 -0.7058154 0.2826931</td>
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</table>

Included instruments: lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14 lpcpop519yr_14 lpcpop65yr_14 lmedohincty14 lteachersal_14 ltaxprice_14 lminuspie_14 augpuptsfl_14 lownhouse_14 linvmatchexe12

F test of excluded instruments:
F( 1, 592) = 92.78
Prob > F = 0.0000

Angrist-Pischke multivariate F test of excluded instruments:
F( 1, 592) = 92.78
Prob > F = 0.0000

Summary results for first-stage regressions

<table>
<thead>
<tr>
<th></th>
<th>(Underid)</th>
<th>(Weak id)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>F( 1, 592) P-val</td>
<td>AP Chi-sq( 1) P-val</td>
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<tr>
<td>linverse_14</td>
<td>92.78 0.0000</td>
<td>94.98 0.0000</td>
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</table>

NB: first-stage test statistics heteroskedasticity-robust

Stock-Yogo weak ID test critical values for single endogenous regressor:
- 10% maximal IV size: 16.38
- 15% maximal IV size: 8.65
- 25% maximal IV size: 5.53


NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Underidentification test
Ho: matrix of reduced form coefficients has rank=K1-1 (underidentified)
Ha: matrix has rank=K1 (identified)

Kleibergen-Paap rk LM statistic Chi-sq(1)=38.63 P-val=0.0000

Weak identification test
Ho: equation is weakly identified
Cragg-Donald Wald F statistic 1026.68
Kleibergen-Paap Wald rk F statistic 92.78

Stock-Yogo weak ID test critical values for Kl=1 and L1=1:

- 10% maximal IV size: 16.38
- 15% maximal IV size: 8.96
- 20% maximal IV size: 6.66
- 25% maximal IV size: 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Weak-instrument-robust inference
Tests of joint significance of endogenous regressors B1 in main equation
Ho: B1=0 and orthogonality conditions are valid
Anderson-Rubin Wald test F(1,592)= 15.34 P-val=0.0001
Anderson-Rubin Wald test Chi-sq(1)= 15.70 P-val=0.0001
Stock-Wright LM S statistic Chi-sq(1)= 11.31 P-val=0.0008

NB: Underidentification, weak identification and weak-identification-robust test statistics heteroskedasticity-robust

Number of observations N = 606
Number of regressors K = 14
Number of endogenous regressors K1 = 1
Number of instruments L = 14
Number of excluded instruments L1 = 1

IV (2SLS) estimation
---------------------

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity
Number of obs = 606
F( 13, 592) = 40.35
Prob > F = 0.0000
Total (centered) SS = 20.73809124 Centered R2 = 0.5561
Total (uncentered) SS = 13253.29812 Uncentered R2 = 0.9993
Residual SS = 9.205652845 Root MSE = 0.1233

| linverse_14 | Coef. | Std. Err. | z | P>|z| | [95% Conf. Interval] |
|-------------|-------|-----------|---|------|----------------------|
| Robust      |       |           |   |      |                      |
| llinverse_14 | -.4881056 | .1173703 | -4.16 | 0.000 | -.7181471 | -.2580641 |
| lformulaadm_14 | -.0222724 | .0111699 | -1.99 | 0.046 | -.0441651 | -.0003797 |
| lpoverty_14 | .0244726 | .0158174 | 1.55 | 0.122 | -.0065289 | .0554742 |
| ldisability_14 | .1718246 | .0269737 | 6.37 | 0.000 | .1189858 | .2246906 |
| lnonwhite_14 | .0489606 | .009172 | 5.34 | 0.000 | .0309838 | .0669373 |
| lpcpop519yr_14 | .0873126 | .0499775 | 1.75 | 0.081 | -.0106414 | .1852667 |
| lpcpop65yr_14 | -.0505274 | .0326322 | -1.55 | 0.122 | -.1144853 | .0134306 |
| lmedohincty14 | .5537371 | .0681743 | 8.12 | 0.000 | .4201179 | .6873563 |
| lteacherasal_14 | .2207852 | .0774377 | 2.85 | 0.004 | .0690101 | .3725602 |
| ltaxprice_14 | -.5140588 | .0471437 | -10.90 | 0.000 | -.6064587 | -.4216588 |
| lminuspie_14 | .5626352 | .2962959 | 1.90 | 0.058 | -.018094 | 1.143364 |
| augpupstf_14 | 5.277583 | .4539162 | 11.63 | 0.000 | 4.387924 | 6.167243 |
| lownhouse_14 | -.2244755 | .0591296 | -3.80 | 0.000 | -.3403674 | -.1085836 |
| _cons | -3.612111 | .9939385 | -3.63 | 0.000 | -.5560195 | -.1664028 |

Underidentification test (Kleibergen-Paap rk LM statistic): 38.633
Chi-sq(1) P-val = 0.0000
Weak identification test (Cragg-Donald Wald F statistic): 1026.681
(Kleibergen-Paap rk Wald F statistic): 92.783

Stock-Yogo weak ID test critical values: 10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Hansen J statistic (overidentification test of all instruments): 0.000
(equation exactly identified)

Endogeneity test of endogenous regressors: 1.887
Chi-sq(1) P-val = 0.1696

Regressors tested: linverse_14

Instrumented: linverse_14
Included instruments: lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14
lpipop519yr_14 lpipop65yr_14 lmedohincty14 lteachersal_14
ltaxprice_14 lminuspie_14 augpuptsf_14 lownhouse_14
Excluded instruments: linvmatchexe12

Endogeneity Test Results for Foundation Aid Ratio (=augpuptsf_14)

Property valuation for FY 2012 is likely to be related to property valuation for FY 2014 because property valuation does not change rapidly. Foundation Aid Ratio for FY 2014, which includes property valuation, is likely to be related to foundation aid ratio for FY 2012. According to Equation (5), foundation aid ratio affects efficiency index. Therefore, foundation aid ratio for FY 2012 is related to efficiency index for FY 2012. However, it is unlikely that school expenditures for FY 2014 might affect efficiency index for FY 2012 via foundation aid ratio for FY 2012. As a result, the latter is less likely to correlate with the errors in Equation (13). Efficiency index for FY 2012 is used as the instrument for Foundation Aid Ratio. All relevant test results are highlighted in blue below.

ivreg2 lpexpend_14 lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14
lpipop519yr_14 lpipop65yr_14 lmedohincty14 linverse_14 lteachersal_14
ltaxprice_14 lminuspie_14 (augpuptsf_14=effindem) lownhouse_14, endog(augpuptsf_14)
robust

First-stage regressions

First-stage regression of augpuptsf_14:

OLS estimation

<p>| | |</p>
<table>
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<tbody>
<tr>
<td>Number of obs</td>
<td>606</td>
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<tr>
<td>F( 13, 592)</td>
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<tr>
<td>Prob &gt; F</td>
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<tr>
<td>Total (centered) SS</td>
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<td>Centered R2</td>
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<td>Total (uncentered) SS</td>
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<td>Uncentered R2</td>
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<td>Residual SS</td>
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<td>Root MSE</td>
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<td>lpcpop519_14</td>
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<tr>
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<tr>
<td>_cons</td>
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</tbody>
</table>

Included instruments: lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14 lpcpop519yr_14 lpcpop65yr_14 lmedohincty14 linverse_14 lteachersal_14 ltaxprice_14 lminuspie_14 lownhouse_14 effindem

F test of excluded instruments:
F( 1, 592) = 57.22
Prob > F = 0.0000
Angrist-Pischke multivariate F test of excluded instruments:
F( 1, 592) = 57.22
Prob > F = 0.0000

Summary results for first-stage regressions

<table>
<thead>
<tr>
<th>(Underid)</th>
<th>(Weak id)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>F( 1, 592)</td>
</tr>
<tr>
<td>augpuptsf_14</td>
<td>57.22</td>
</tr>
</tbody>
</table>

NB: first-stage test statistics heteroskedasticity-robust

Stock-Yogo weak ID test critical values for single endogenous regressor:
10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Underidentification test
Ho: matrix of reduced form coefficients has rank=K1-1 (underidentified)
Ha: matrix has rank=K1 (identified)
Kleibergen-Paap rk LM statistic Chi-sq(1)=43.44 P-val=0.0000

Weak identification test
Ho: equation is weakly identified
Cragg-Donald Wald F statistic 231.49
Kleibergen-Paap Wald rk F statistic 57.22

Stock-Yogo weak ID test critical values for K1=1 and L1=1:
10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53


NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Weak-instrument-robust inference
Tests of joint significance of endogenous regressors B1 in main equation
Ho: B1=0 and orthogonality conditions are valid

Anderson-Rubin Wald test \( F(1, 592) = 32.01 \) P-val=0.0000
Anderson-Rubin Wald test \( \text{Chi}-\text{sq}(1) = 32.77 \) P-val=0.0000
Stock-Wright LM S statistic \( \text{Chi}-\text{sq}(1) = 27.17 \) P-val=0.0000

NB: Underidentification, weak identification and weak-identification-robust test statistics heteroskedasticity-robust

| lpedexpend_14 | Coef. | Robust Std. Err. | z  | P>|z| | [95% Conf. Interval] |
|---------------|-------|------------------|----|-------|------------------------|
|               |       |                  |    |       |                        |
| augpuptsf_14  | 6.042069 | .8072313         | 7.48 | 0.000 | 4.459924 | 7.624213 |
| lformulaa_14  | -.0195776 | .0115417 | -1.70 | 0.090 | -.0421989 | .0030437 |
| lpoverty_14   | .019431 | .0166791 | 1.16 | 0.244 | -.0132595 | .0521216 |
| ldisabili_14  | .1627462 | .0277146 | 5.87 | 0.000 | .1084265 | .2170659 |
| lnonwhite_14  | .0514009 | .0115417 | 4.52 | 0.000 | .0328053 | .0699966 |
| lpcpop519_14  | .0768504 | .0519416 | 1.48 | 0.139 | -.0249532 | .178654 |
| lpcpop65y_14  | -.047695 | .032739 | -1.46 | 0.145 | -.1118622 | .0164722 |
| lmedohinc_14  | .603129 | .0759857 | 7.94 | 0.000 | .4541997 | .7520583 |
| lteachers_14  | .2121085 | .0735727 | 2.88 | 0.004 | .0679085 | .3563084 |
| ltaxprice_14  | -.5556448 | .0619752 | -8.97 | 0.000 | -.7771139 | -.4341757 |
| lminuspie_14  | .6557273 | .2862967 | 2.29 | 0.022 | .0945961 | 1.216859 |
| lownhouse_14  | -.2001077 | .0615846 | -3.25 | 0.001 | -.3208114 | -.0794041 |
| _cons         | -4.142312 | 1.136003 | -3.65 | 0.000 | -6.368838 | -1.915786 |

Underidentification test (Kleibergen-Paap rk LM statistic): 43.439
Chi-sq(1) P-val = 0.0000

Weak identification test (Cragg-Donald Wald F statistic): 231.486
(Kleibergen-Paap rk Wald F statistic): 57.217

Stock-Yogo weak ID test critical values: 10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Hansen J statistic (overidentification test of all instruments): 0.000 (equation exactly identified)

- endog- option:
Endogeneity test of endogenous regressors: 1.749
Chi-sq(1) P-val = 0.1860

Regressors tested: augpuptsf_14

Instrumented: augpuptsf_14
Included instruments: lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14 lpcpop519yr_14 lpcpop65yr_14 lmedohincty14 linverse_14 lteachersal_14 ltaxprice_14 lminuspie_14 lownhouse_14

Excluded instruments: effindem

Instrumental Variable Regression Results for Table 2

```
ivreg2 lpexpend_14  lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14
   lpcpop519yr_14 lpcpop65yr_14 lmedohincty14 augpuptsf_14 ltaxprice_14 linverse_14
(lteachersal_14 lminuspie_14 = costindem lrollback11 ) lownhouse14,fuller(4) robust
```

First-stage regressions

First-stage regression of lteachersal_14:

$$\text{OLS estimation}$$

| lteachersal_14 | Coef. | Robust Std. Err. | t | P>|t| | [95% Conf. Interval] |
|---------------|-------|------------------|---|-----|---------------------|
| lformulaa-14 | .0023433 | .0120573 | 0.19 | 0.846 | -.0213369 | .0260235 |
| lpoverty_14 | .0470344 | .0122989 | 3.82 | 0.000 | .0228796 | .0711891 |
| ldisability_14 | -.1635581 | .0254747 | -6.42 | 0.000 | -.2135898 | -.1135263 |
| lnonwhite_14 | -.0528018 | .0046594 | -11.33 | 0.000 | -.0619527 | -.0436508 |
| lpcpop519yr_14 | -.0086571 | .02216 | -0.39 | 0.696 | -.0521788 | .0348646 |
| lpcpop65yr_14 | -.0200075 | .0181463 | -1.10 | 0.271 | -.0556465 | .0156315 |
| lmedohincty14 | -.1141712 | .0820616 | -1.39 | 0.165 | -.2753386 | .0469961 |
| augpuptsf_14 | -.2382585 | .3761574 | -0.63 | 0.527 | -.9770238 | .5005068 |
| ltaxprice_14 | .0296235 | .0451966 | 0.66 | 0.512 | -.0591418 | .1183887 |
| linverse_14 | .0375404 | .0733612 | 0.51 | 0.609 | -.1065395 | .1816203 |
| lownhouse_14 | .0283304 | .0392036 | 0.72 | 0.470 | -.0486647 | .1053254 |
| costindem | 1.0003032 | .1097724 | 9.14 | 0.000 | .7874415 | 1.218623 |
| lrollback11 | -.0072384 | .0117946 | -0.61 | 0.540 | -.0304062 | .0159294 |
| _cons | 10.68637 | 7.830974 | 12.53 | 0.000 | 9.010506 | 12.36184 |

Included instruments: lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14 lpcpop519yr_14 lpcpop65yr_14 lmedohincty14 augpuptsf_14 ltaxprice_14 linverse_14 lownhouse_14 costindem lrollback11

```
F test of excluded instruments:
\[
F(2, 592) = 46.61 \\
\text{Prob} > F = 0.0000
\]
Angrist-Pischke multivariate F test of excluded instruments:
\[
F(1, 592) = 90.90 \\
\text{Prob} > F = 0.0000
\]

First-stage regression of \( l\text{minuspie}_14 \):

**OLS estimation**

- Number of obs = 606
- Total centered SS = .3339404718
  - Centered R2 = 0.5341
- Total uncentered SS = 10.03927704
  - Uncentered R2 = 0.9845
- Residual SS = .1555840602
  - Root MSE = .01621

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<tr>
<th></th>
<th>Coef.</th>
<th>Std. Err.</th>
<th>t</th>
<th>P&gt;</th>
<th>95% Conf. Interval</th>
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</thead>
<tbody>
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<td>.0011552</td>
<td>1.12</td>
<td>0.263</td>
<td>-.0009753 to .0035622</td>
</tr>
<tr>
<td>( l\text{poverty}_14 )</td>
<td>.0018559</td>
<td>.0016911</td>
<td>1.10</td>
<td>0.273</td>
<td>-.0018609 to .0042965</td>
</tr>
<tr>
<td>( l\text{disability}_14 )</td>
<td>-.0114527</td>
<td>.0036437</td>
<td>-3.14</td>
<td>0.002</td>
<td>-.0186089 to .0042965</td>
</tr>
<tr>
<td>( l\text{nonwhite}_14 )</td>
<td>-.0029156</td>
<td>.0011971</td>
<td>-2.44</td>
<td>0.015</td>
<td>-.0052666 to .0003944</td>
</tr>
<tr>
<td>( l\text{popp519yr}_14 )</td>
<td>.0023943</td>
<td>.0011971</td>
<td>2.02</td>
<td>0.044</td>
<td>.0000645 to .0047239</td>
</tr>
<tr>
<td>( l\text{popp65yr}_14 )</td>
<td>.0018559</td>
<td>.0016911</td>
<td>1.10</td>
<td>0.273</td>
<td>-.0018609 to .0042965</td>
</tr>
<tr>
<td>( l\text{medohinc}_14 )</td>
<td>.0018559</td>
<td>.0016911</td>
<td>1.10</td>
<td>0.273</td>
<td>-.0018609 to .0042965</td>
</tr>
<tr>
<td>( l\text{augpuptsf}_14 )</td>
<td>.0018559</td>
<td>.0016911</td>
<td>1.10</td>
<td>0.273</td>
<td>-.0018609 to .0042965</td>
</tr>
<tr>
<td>( l\text{ltaxprice}_14 )</td>
<td>.0018559</td>
<td>.0016911</td>
<td>1.10</td>
<td>0.273</td>
<td>-.0018609 to .0042965</td>
</tr>
<tr>
<td>( l\text{linverse}_14 )</td>
<td>.0018559</td>
<td>.0016911</td>
<td>1.10</td>
<td>0.273</td>
<td>-.0018609 to .0042965</td>
</tr>
<tr>
<td>( l\text{rollback11} )</td>
<td>.0018559</td>
<td>.0016911</td>
<td>1.10</td>
<td>0.273</td>
<td>-.0018609 to .0042965</td>
</tr>
<tr>
<td>( _\text{cons} )</td>
<td>-.3188326</td>
<td>.0912336</td>
<td>-3.49</td>
<td>0.001</td>
<td>-.4980134 to -.1396517</td>
</tr>
</tbody>
</table>

Included instruments: \( l\text{formulaadm}_14 \) \( l\text{poverty}_14 \) \( l\text{disability}_14 \) \( l\text{nonwhite}_14 \) \( l\text{popp519yr}_14 \) \( l\text{popp65yr}_14 \) \( l\text{medohinc}_14 \) \( l\text{augpuptsf}_14 \) \( l\text{ltaxprice}_14 \) \( l\text{linverse}_14 \) \( l\text{rollback11} \)

F test of excluded instruments:
\[
F(2, 592) = 83.94 \\
\text{Prob} > F = 0.0000
\]
Angrist-Pischke multivariate F test of excluded instruments:
\[
F(1, 592) = 132.54 \\
\text{Prob} > F = 0.0000
\]

Summary results for first-stage regressions

<table>
<thead>
<tr>
<th>Variable</th>
<th>( F(2, 592) )</th>
<th>( P )-val</th>
<th>AP Chi-sq(1)</th>
<th>( P )-val</th>
<th>AP F(1, 592)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( l\text{teachersal}_14 )</td>
<td>46.61</td>
<td>0.0000</td>
<td>93.05</td>
<td>0.0000</td>
<td>90.90</td>
</tr>
<tr>
<td>( l\text{minuspie}_14 )</td>
<td>83.94</td>
<td>0.0000</td>
<td>135.67</td>
<td>0.0000</td>
<td>132.54</td>
</tr>
</tbody>
</table>

NB: first-stage test statistics heteroskedasticity-robust

Stock-Yogo weak ID test critical values for single endogenous regressor:
5% maximal Fuller rel. bias 24.09
10% maximal Fuller rel. bias 19.36
20% maximal Fuller rel. bias 15.64
30% maximal Fuller rel. bias 12.71
5% Fuller maximum bias 23.81
10% Fuller maximum bias 19.40
20% Fuller maximum bias 15.39
30% Fuller maximum bias 12.76

NB: Critical values based on Fuller parameter=1
NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Underidentification test
Ho: matrix of reduced form coefficients has rank=K1-1 (underidentified)
Ha: matrix has rank=K1 (identified)
Kleibergen-Paap rk LM statistic Chi-sq(1)=76.08 P-val=0.0000

Weak identification test
Ho: equation is weakly identified
Cragg-Donald Wald F statistic 80.21
Kleibergen-Paap Wald rk F statistic 65.21

Stock-Yogo weak ID test critical values for K1=2 and L1=2:
5% maximal Fuller rel. bias 15.50
10% maximal Fuller rel. bias 12.55
20% maximal Fuller rel. bias 9.72
30% maximal Fuller rel. bias 8.03
5% Fuller maximum bias 14.19
10% Fuller maximum bias 11.92
20% Fuller maximum bias 9.41
30% Fuller maximum bias 8.01

NB: Critical values based on Fuller parameter=1
NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Weak-instrument-robust inference
Tests of joint significance of endogenous regressors B1 in main equation
Ho: B1=0 and orthogonality conditions are valid
Anderson-Rubin Wald test F(2,592)= 39.58 P-val=0.0000
Anderson-Rubin Wald test Chi-sq(2)= 81.04 P-val=0.0000
Stock-Wright LM S statistic Chi-sq(2)= 54.88 P-val=0.0000

NB: Underidentification, weak identification and weak-identification-robust test statistics heteroskedasticity-robust

Number of observations N = 606
Number of regressors K = 14
Number of endogenous regressors K1 = 2
Number of instruments L = 14
Number of excluded instruments L1 = 2

LIML estimation
---------------------
k = 0.99324
lambda = 1.00000
Fuller parameter=4

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity
Number of obs = 606
F (13, 592) = 33.26
Prob > F = 0.0000
| lpexpend_14 | Coef.  | Robust Std. Err. | z      | P>|z|    | [95% Conf. Interval] |
|------------|--------|------------------|--------|--------|----------------------|
| lteachers~14 | .5521908 | .097403          | 5.67   | 0.000  | .3612844 .7430972    |
| lminuspie_14 | -.3.058216 | .8194369        | -3.73  | 0.000  | -4.664228 -1.452149  |
| lformulaa~14 | -.0276208 | .013775          | -2.01  | 0.045  | -.0546194 -.0066223  |
| lpoverty_14 | .0540157 | .015898          | 3.40   | 0.000  | .0228562 .0851752    |
| ldisability~14 | .1645603 | .0304554        | 5.40   | 0.000  | .1048688 .2242518    |
| lnonwhite_14 | .0285432 | .010789          | 2.65   | 0.008  | .0073971 .0496893    |
| lpcpop519~14 | .1079922 | .0562433         | 1.92   | 0.055  | -.0022426 .2182271   |
| lpcpop65y~14 | -.1431728 | .0427794        | -3.35  | 0.001  | -.2270189 -.0593266  |
| lmedohinc~14 | .5794765 | .0884726         | 6.55   | 0.000  | .4060734 .7528796    |
| augpuptsf_14 | 4.586144 | .5315587         | 8.63   | 0.000  | 3.544308 5.62798   |
| ltaxprice_14 | -.662824 | .0721099         | -9.19  | 0.000  | -.8041567 -.5214913  |
| linverse_14 | -.6384516 | .134161         | -4.76  | 0.000  | -.9014023 -.375501   |
| lownhouse_14 | -.3286168 | .0865498        | -3.80  | 0.000  | -.4982512 -.1589823  |
| _cons | -8.25982 | 1.260423         | -6.55  | 0.000  | -.10.7302 -5.789436  |

Underidentification test (Kleibergen-Paap rk LM statistic): 76.075
Chi-sq(1) P-val = 0.0000

Weak identification test (Cragg-Donald Wald F statistic): 80.212
(Kleibergen-Paap rk Wald F statistic): 65.208

Stock-Yogo weak ID test critical values:
5% maximal Fuller rel. bias 15.50
10% maximal Fuller rel. bias 12.55
20% maximal Fuller rel. bias 9.72
30% maximal Fuller rel. bias 8.03
5% Fuller maximum bias 14.19
10% Fuller maximum bias 11.92
20% Fuller maximum bias 9.41
30% Fuller maximum bias 8.01

NB: Critical values based on Fuller parameter=1
NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Hansen J statistic (overidentification test of all instruments): 0.000
(equation exactly identified)

Instrumented: lteachersal_14 lminuspie_14
Included instruments: lformulaadm_14 lpoverty_14 ldisability_14 lnonwhite_14 lpcpop519yr_14 lpcpop65yr_14 lmedohincty14 augpuptsf_14 ltaxprice_14 linverse_14 lownhouse_14
Excluded instruments: costindem lrollback11

PART II: DEMAND EQUATION PER TABLE 3

Endogeneity Test Results for Tax Price (=ltaxprice_14)

Property valuation for FY 2011 is likely to be related to property valuation for FY 2014 because property valuation does not change rapidly. Tax Price for FY 2014, which includes property
valuation, is likely to be related to property valuation for FY 2011. However, it is unlikely that school expenditures for FY 2014 and PI Score might affect property valuation for FY 2011. As a result, the latter is less likely to correlate with the errors in Equation (15). Logged property valuation for FY 2011 is used as the instrument for Tax Price. All relevant test results are highlighted in blue below.

```
.ivreg2 lpi14 lmedohincty13 lcostindex_14 lformulaadm_14 lpcpop519yr_14 lownhouse_14 lminuspie_14 (ltaxprice_14=lvalue11) leffindex_14 augpuptsf_14 linverse_14 laveanwage_14 , endog(ltaxprice_14) robust first
First-stage regressions
------------------------
First-stage regression of ltaxprice_14:

OLS estimation
-------------

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity

Number of obs = 607
F( 11, 595) = 2577.75
Prob > F = 0.0000

Total (centered) SS = 41.91321906
Centered R2 = 0.9786
Total (uncentered) SS = 946.0146885
Uncentered R2 = 0.9991
Residual SS = .8967999522
Root MSE = .03882

+-------------------------------------------------------------+
|               Robust                                      |
|                Coef.  Std. Err.    t     P>|t|    [95% Conf. Interval] |
|-------------------------------------------------------------|
| lmedohincty13 |  .9464246   .0169388  55.87   0.000    .9131576    .9796917 |
| lcostindex_14 | -2.9872378   .0140886 -70.07   0.000   -3.014907   -2.959568 |
| lformulaadm_14 |  .0112803   .0029676   3.80   0.000     .005452    .0171086 |
| lpcpop519yr_14 | .2940524   .0151042  19.47   0.000     .2643857    .3237164 |
| lownhouse_14 | -2.515649   .0224891 -22.75   0.000   -2.555736   -2.473973 |
| lminuspie_14 |  4.169528   .0971512  42.92   0.000     4.036039    4.302787 |
| leffindex_14 |  1.491649   .0213152  69.98   0.000     1.449787    1.533511 |
| augpuptsf_14 |  6.892295   .1712205  40.25   0.000     6.556025    7.228565 |
| linverse_14 |  -.0904537   .0310408 -29.11   0.000    -.0964415    -.0844608 |
| laveanwage_14 |  .026771   .0111099   2.41   0.016     .0049516    .0485905 |
| lvalue11 |  -.0637409   .0119184 -5.35   0.000    -.0871482   -.0403336 |
| _cons |  -10.43763  .2186413 -47.74   0.000     -10.86703   -10.00822 |
+-------------------------------------------------------------+

Included instruments: lmedohincty13 lcostindex_14 lformulaadm_14 lpcpop519yr_14 lownhouse_14 lminuspie_14 leffindex_14 augpuptsf_14 linverse_14 laveanwage_14 lvalue11

F test of excluded instruments:
F(  1,   595) = 28.60
Prob > F = 0.0000

Angrist-Pischke multivariate F test of excluded instruments:
F(  1,   595) = 28.60
Prob > F = 0.0000

Summary results for first-stage regressions
----------------------------------------

<table>
<thead>
<tr>
<th>Variable</th>
<th>(Underid)</th>
<th>(Weak id)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ltaxprice_14</td>
<td>28.60</td>
<td>29.18</td>
</tr>
</tbody>
</table>

NB: first-stage test statistics heteroskedasticity-robust
Stock-Yogo weak ID test critical values for single endogenous regressor:

<table>
<thead>
<tr>
<th></th>
<th>10% maximal IV size</th>
<th>15% maximal IV size</th>
<th>20% maximal IV size</th>
<th>25% maximal IV size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16.38</td>
<td>8.96</td>
<td>6.66</td>
<td>5.53</td>
</tr>
</tbody>
</table>


NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Underidentification test
Ho: matrix of reduced form coefficients has rank=K1-1 (underidentified)
Ha: matrix has rank=K1 (identified)
Kleibergen-Paap rk LM statistic Chi-sq(1)=19.42 P-val=0.0000

Weak identification test
Ho: equation is weakly identified
Cragg-Donald Wald F statistic 40.52
Kleibergen-Paap Wald rk F statistic 28.60

Stock-Yogo weak ID test critical values for K_1=1 and L_1=1:

<table>
<thead>
<tr>
<th></th>
<th>10% maximal IV size</th>
<th>15% maximal IV size</th>
<th>20% maximal IV size</th>
<th>25% maximal IV size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16.38</td>
<td>8.96</td>
<td>6.66</td>
<td>5.53</td>
</tr>
</tbody>
</table>


NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Weak-instrument-robust inference
Tests of joint significance of endogenous regressors B_1 in main equation
Ho: B_1=0 and orthogonality conditions are valid
Anderson-Rubin Wald test F(1,595)= 7.56 P-val=0.0062
Anderson-Rubin Wald test Chi-sq(1)= 7.71 P-val=0.0055
Stock-Wright LM S statistic Chi-sq(1)= 6.26 P-val=0.0123

NB: Underidentification, weak identification and weak-identification-robust test statistics heteroskedasticity-robust

Number of observations N = 607
Number of regressors K = 12
Number of endogenous regressors K_1 = 1
Number of instruments L = 12
Number of excluded instruments L_1 = 1

IV (2SLS) estimation

-------------------

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity

Number of obs = 607
F( 11, 595) = 63.62
Prob > F = 0.0000

Total (centered) SS = 2.684862013
Centered R^2 = 0.9999
Total (uncentered) SS = 12814.77779
Uncentered R^2 = 0.9999
Residual SS = 1.198160901
Root MSE = 0.04443

| lpi14 | Robust | Coef. | Std. Err. | z     | P>|z| | [95% Conf. Interval] |
|-------|--------|-------|-----------|-------|------|----------------------|
| ltaxprice_14 | -.5154405 | .2101171 | -2.45 | 0.014 | -.9272624 | -.1036186 |
| lmedohincty13 | .6182155 | .1943132 | 3.18 | 0.001 | .2373686 | .9990625 |
| lcostindex_14 | -.5804733 | .2107589 | -2.75 | 0.006 | -.9935531 | -.1673935 |
| lformulaadm_14 | -.0084923 | .0035384 | -2.40 | 0.016 | -.0154275 | -.0015571 |
| lpcpop519yr_14 | .1958378 | .0641956 | 3.05 | 0.002 | .0700167 | .3216588 |
| lowhouse_14 | -.197107 | .1100139 | -1.79 | 0.073 | -.4127303 | .0185163 |
| lminuspie_14 | -2.562828 | .9263213 | -2.77 | 0.006 | -.4.378384 | -.7472713 |
| leffindex_14 | -.8770795 | .3184039 | 2.75 | 0.006 | .2530194 | 1.50114 |
| augpuptsf_14 | 3.206431 | 1.591094 | 2.02 | 0.044 | .0879443 | 6.324917 |
| linverse_14 | -.4266889 | .1997601 | -2.14 | 0.033 | -.8182119 | -.3516597 |
| laveanwage_14 | -.0084336 | .0134184 | -0.63 | 0.530 | -.0347332 | .0178661 |
Underidentification test (Kleibergen-Paap rk LM statistic): 19.417
Chi-sq(1) P-val = 0.0000

Weak identification test (Cragg-Donald Wald F statistic): 40.518
(Kleibergen-Paap rk Wald F statistic): 28.602

Stock-Yogo weak ID test critical values: 10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Hansen J statistic (overidentification test of all instruments): 0.000
(equation exactly identified)

Endogeneity test of endogenous regressors: 6.833
Chi-sq(1) P-val = 0.0090
Regressors tested: ltaxprice_14

Endogeneity Test Results for Foundation Aid Ratio (=augpuptsf_14)

Property valuation for FY 2012 is likely to be related to property valuation for FY 2014 because property valuation does not change rapidly. Foundation Aid Ratio for FY 2014, which includes property valuation, is likely to be related to foundation aid ratio for FY 2012 that includes property valuation for FY 2012. However, it is unlikely that school expenditures for FY 2014 and PI Score might affect foundation aid ratio for FY 2012. As a result, the latter is less likely to correlate with the errors in Equation (15). foundation aid ratio for FY 2012 is used as the instrument for Foundation Aid Ratio. All relevant test results are highlighted in blue below.

ivreg2 lpi14 lmedohincty13 lcostindex_14 lformulaadm_14 lpcpop519yr_14 lownhouse_14 lminuspie_14 leffindex_14 augpuptsf_14  
linverse_14 laveanwage_14, endog(augpuptsf_14) robust first

First-stage regressions

OLS estimation

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity

|            | Coef.  | Std. Err. | t     | P>|t| | [95% Conf. Interval] |
|------------|--------|-----------|-------|------|----------------------|
|augpuptsf_14| -.0881578 | .00469 | -18.80 | 0.000 | -.0973688 -.0789467 |
|lmedohincty13| .0822628 | .00597 | 13.78 | 0.000 | .0705379 .0939877 |
|lcostindex_14| .0209094 | .00563 | 3.71  | 0.000 | .0097472 .0320716 |

Number of obs = 607
F(11, 595) = 880.68
Prob > F = 0.0000
Centered R2 = 0.9916
Uncentered R2 = 0.9916
Root MSE = 0.00489
Included instruments: lmedohincty13 lcostindex_14 lformulaadm_14 lpcpop519yr_14 lownhouse_14 lminuspie_14 ltaxprice_14 leffindex_14 linverse_14 laveanwage_14 lumpaidratio12

F test of excluded instruments:
F(  1,   595) =    59.09
Prob > F      =   0.0000

Summary results for first-stage regressions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Underid: F(  1,   595)</th>
<th>Weak id: F(  1,   595)</th>
</tr>
</thead>
<tbody>
<tr>
<td>augpuptsf_14</td>
<td>59.09</td>
<td>59.09</td>
</tr>
</tbody>
</table>

NB: first-stage test statistics heteroskedasticity-robust

Stock-Yogo weak ID test critical values for single endogenous regressor:
10% maximal IV size             16.38
15% maximal IV size              8.96
20% maximal IV size              6.66
25% maximal IV size              5.53


NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Underidentification test
Ho: matrix of reduced form coefficients has rank=K+1 (underidentified)
Ha: matrix has rank=K (identified)
Kleibergen-Paap rk LM statistic Chi-sq(1)=51.08 P-val=0.0000

Weak identification test
Ho: equation is weakly identified
Cragg-Donald Wald F statistic 172.29
Kleibergen-Paap Wald rk F statistic 59.09

Stock-Yogo weak ID test critical values for K=1 and L=1:
10% maximal IV size             16.38
15% maximal IV size              8.96
20% maximal IV size              6.66
25% maximal IV size              5.53


NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Weak-instrument-robust inference
Tests of joint significance of endogenous regressors B1 in main equation
Ho: B1=0 and orthogonality conditions are valid
Anderson-Rubin Wald test F(1,595)= 7.56 P-val=0.0062
Anderson-Rubin Wald test Chi-sq(1)= 7.71 P-val=0.0055
Stock-Wright LM S statistic Chi-sq(1)= 7.59 P-val=0.0059

NB: Underidentification, weak identification and weak-instrument-robust test statistics heteroskedasticity-robust
Number of endogenous regressors \( K_1 = 1 \)
Number of instruments \( L = 12 \)
Number of excluded instruments \( L_1 = 1 \)

IV (2SLS) estimation

---

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity

Number of obs = 607
\( F(11, 595) = 70.24 \)
Prob > \( F \) = 0.0000

Total (centered) SS = 2.684862013
Centered R\(^2\) = 0.6046
Total (uncentered) SS = 12814.77779
Uncentered R\(^2\) = 0.9999
Residual SS = 1.061712074
Root MSE = 0.04182

| Coef. | Std. Err. | z    | P>|z| | [95% Conf. Interval] |
|-------|-----------|------|------|-----------------------|
| augpuptsf_14 | 2.110079 | 0.7939386 | 2.66 | 0.008 | 0.553988 - 3.66617 |
| lmedohincty13 | 0.4714225 | 0.0941623 | 5.01 | 0.000 | 0.2868678 - 0.6559772 |
| lcostindex14 | -3.997392 | 0.0983675 | -4.06 | 0.000 | -6.92536 - -2.069424 |
| lformulaadm14 | -0.0099819 | 0.030763 | -3.24 | 0.001 | -0.207322 - -0.0039524 |
| lpcpop519yr14 | 0.1315314 | 0.0289373 | 4.55 | 0.000 | 0.0748152 - 0.1882475 |
| lownhouse14 | -0.1058766 | 0.0517691 | -2.05 | 0.041 | -0.207322 - -0.004109 |
| lminuspie14 | -1.704656 | 0.390302 | -4.37 | 0.000 | -2.469634 - -0.936783 |
| ltaxprice14 | -3.43713 | 0.096058 | -3.49 | 0.000 | -5.265171 - -1.647929 |
| leffindex14 | 0.6043563 | 0.1485163 | 4.24 | 0.000 | 0.3132697 - 0.8954428 |
| linverse14 | -0.2764973 | 0.0994808 | -2.78 | 0.005 | -0.471476 - -0.0815186 |
| laveanwage14 | -0.0096991 | 0.0121693 | -0.80 | 0.425 | -0.0335505 - 0.014123 |
| _cons | -3.618803 | 1.102411 | -0.33 | 0.743 | -2.522566 - 1.798806 |

Underidentification test (Kleibergen-Paap rk LM statistic): 51.078
Chi-sq(1) P-val = 0.0000

Weak identification test (Cragg-Donald Wald F statistic): 172.288
(Kleibergen-Paap rk Wald F statistic): 59.089

Stock-Yogo weak ID test critical values: 10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Hansen J statistic (overidentification test of all instruments): 0.000
(equation exactly identified)

Endogeneity test of endogenous regressors:
\( \text{Chi-sq}(1) P\text{-val} = 14.866 \)

Regressors tested: augpuptsf_14

---

Endogeneity Test Results for Efficiency Index (=leffindex_14)

According to Equation (5), Efficiency Index includes median house value. Median house value for FY 2013 is likely to be related to that for FY 2014, given the stable housing price across years. Similarly, Efficiency Index is likely to be related to median house value for FY 2013. However, it is unlikely that school expenditures for FY 2014 and PI Score might affect median house value for FY 2013. As a result, the latter is less likely to correlate with the errors in
Equation (15). Median house value for FY 2013 is used as the instrument for Efficiency Index. All relevant test results are highlighted in blue below.

ivreg2 lpi14 lmedohincty13 lcostindex_14 lformulaadm_14 lpcpop519yr_14 lownhouse_14 lminuspie_14 ltaxprice_14 (leffindex_14=medhouse_13) augpuptsf_14 linverse_14 laveanwage_14, endog(leffindex_14) robust first

First-stage regressions

First-stage regression of leffindex_14:

OLS estimation

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity

|               | Coef.   | Std. Err. | t     | P>|t| | [95% Conf. Interval] |
|---------------|---------|-----------|-------|------|----------------------|
| lmedohincty13 | -.6046132 | .0152346  | -39.69 | 0.000 | (-.6345332, -.5746931) |
| lcostindex_14  | .6618359  | .0003011  | 2198.11 | 0.000 | (.6612446, .6624272)  |
| lformulaadm_14 | -.0028066 | .0019258  | -1.46  | 0.146 | (-.0065888, .0009755) |
| lpcpop519yr_14 | .6618359  | .0003011  | 2198.11 | 0.000 | (.6612446, .6624272)  |
| lownhouse_14   | -.0028066 | .0019258  | -1.46  | 0.146 | (-.0065888, .0009755) |
| lminuspie_14   | .5987819  | .0100578  | -18.61 | 0.000 | (-.2069506, .1674444) |
| lminuspie_14   | 2.696341  | .0576887  | 46.74  | 0.000 | (.5824475, .80964)    |
| ltaxprice_14   | .5987819  | .0100578  | -18.61 | 0.000 | (-.2069506, .1674444) |
| augpuptsf_14   | -.4477899 | .0974918  | -45.83 | 0.000 | (-4.659359, -4.276419) |
| linverse_14    | .5342972  | .0207309  | 25.77  | 0.000 | (.4935825, .5750118)  |
| laveanwage_14  | -.0083865 | .0068302  | -1.23  | 0.220 | (-.0218008, .0050277) |
| medhouse_13    | 2.15e-07  | .525e-08  | 4.09   | 0.000 | (1.12e-07, 3.18e-07)  |
| _cons          | 6.937554  | .173156   | 40.07  | 0.000 | (6.597483, 7.277626)  |

Included instruments: lmedohincty13 lcostindex_14 lformulaadm_14 lpcpop519yr_14 lownhouse_14 lminuspie_14 ltaxprice_14 augpuptsf_14 linverse_14 laveanwage_14 medhouse_13

F test of excluded instruments:
F(  1,   595) = 16.74
Prob > F = 0.0000

Angrist-Pischke multivariate F test of excluded instruments:
F(  1,   595) = 16.74
Prob > F = 0.0000

Summary results for first-stage regressions

(Underid) (Weak id)
Variable | F(  1,   595) P-val | AP Chi-sq(  1) P-val | AP F(  1,   595) F test of excluded instruments:
leffindex_14 |  16.74  0.0000 |  17.08  0.0000 |  16.74

NB: first-stage test statistics heteroskedasticity-robust

Stock-Yogo weak ID test critical values for single endogenous regressor:
10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53


NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Underidentification test
Ho: matrix of reduced form coefficients has rank=K1-1 (underidentified)
Ha: matrix has rank=K1 (identified)
Kleibergen-Paap rk LM statistic Chi-sq(1)=13.61 P-val=0.0002

Weak identification test
Ho: equation is weakly identified
Cragg-Donald Wald F statistic 20.02
Kleibergen-Paap Wald rk F statistic 16.74

Stock-Yogo weak ID test critical values for K1=1 and L1=1:
10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53


NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Weak-instrument-robust inference
Tests of joint significance of endogenous regressors B1 in main equation
Ho: B1=0 and orthogonality conditions are valid
Anderson-Rubin Wald test F(1,595)= 10.92 P-val=0.0010
Anderson-Rubin Wald test Chi-sq(1)= 11.14 P-val=0.0008
Stock-Wright LM S statistic Chi-sq(1)= 10.74 P-val=0.0010

NB: Underidentification, weak identification and weak-identification-robust

test statistics heteroskedasticity-robust

Number of observations N = 607
Number of regressors K = 12
Number of endogenous regressors K1 = 1
Number of instruments L = 12
Number of excluded instruments L1 = 1

IV (2SLS) estimation
----------------------------------------

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity

| lpi14 | Coef.  | Robust Std. Err. | z | P>|z|  | [95% Conf. Interval] |
|-------|--------|------------------|---|------|-----------------------|
| leffindex_14 | 1.116073 | .4292001 | 2.60 | 0.009 | .2748567 | 1.95729 |
| lmedohincty13 | .7220367 | .2450217 | 3.00 | 0.003 | .2418031 | 1.20227 |
| lcpiodindex_14 | -.7384596 | .2840346 | -2.62 | 0.009 | -1.295157 | -.181762 |
| lformulaadm_14 | -.0107281 | .0034521 | -3.11 | 0.002 | -.0174941 | -.0039261 |
| lpoppops519yr_14 | -.2274684 | .0786891 | 2.89 | 0.004 | .0732407 | .3816962 |
| lownhouse_14 | .2838537 | .1488304 | -1.90 | 0.058 | -.5740752 | .0093294 |
| lminuspie_14 | .1166681 | 1.176015 | -2.65 | 0.008 | -5.421632 | -.8117384 |
| ltaxprice_14 | -.603832 | .2598997 | -2.38 | 0.018 | -1.26777 | -1.18991 |
| augpupsf_14 | 3.959702 | 1.956736 | 2.02 | 0.043 | .12457 | 7.794835 |
| linverse_14 | -.516702 | .2395253 | -2.16 | 0.031 | -.986129 | -.0472411 |
| laveanwage_14 | -.090927 | .0136663 | -0.67 | 0.506 | -.0358781 | .0176928 |
| _cons | -3.215806 | 2.855013 | -1.13 | 0.260 | -8.611258 | 2.379916 |

Underidentification test (Kleibergen-Paap rk LM statistic): 13.608
Chi-sq(1) P-val = 0.0002
Weak identification test (Cragg-Donald Wald F statistic): 20.022
(Kleibergen-Paap rk Wald F statistic): 16.741
Stock-Yogo weak ID test critical values: 10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53
NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.
Hansen J statistic (overidentification test of all instruments): 0.000
(equation exactly identified)
-endog- option:
Endogeneity test of endogenous regressors: 9.468
Chi-sq(1) P-val = 0.0021
Regressors tested: leffindex_14
Instrumented: leffindex_14
Included instruments: lmedohincty13 lcostindex_14 lformulaadm_14 lpcpop519yr_14
lownhouse_14 lminuspie_14 ltaxprice_14 augpuptsf_14
linverse_14 laveanwage_14
Excluded instruments: medhouse_13

Endogeneity Test Results for Inversed Tax Exemption Share (=linverse_14)

Property valuation for FY 2012 is likely to be related to property valuation for FY 2014 because property valuation does not change rapidly. Foundation Aid Ratio for FY 2014, which includes property valuation, is likely to be related to inversed tax exemption share for FY 2012 that includes property valuation for FY 2012. However, it is unlikely that school expenditures for FY 2014 and PI Score might affect inversed tax exemption share for FY 2012. As a result, the former is less likely to affect the errors in Equation (15). Logged inversed tax exemption share for FY 2012 is used as the instrument for Inversed Tax Exemption Share. All relevant test results are highlighted in blue below.

ivreg2 lpi14 lmedohincty13 lcostindex_14 lformulaadm_14 lpcpop519yr_14 lownhouse_14
lminuspie_14 ltaxprice_14 leffindex_14 augpuptsf_14 (linverse_14=linvmatchexe12)
laveanwage_14 , endog(linverse_14) robust first

First-stage regressions
-----------------------
First-stage regression of linverse_14:
OLS estimation
-------------

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity

<p>| linverse_14 | Coef. | Std. Err. | t | P&gt;|t| | [95% Conf. Interval] |
|-------------|-------|-----------|---|-----|-------------------|
| lmedohincty13 | .3864377 | .0468578 | 8.25 | 0.000 | .2944109 | .4784645 |
| lcostindex_14 | -.4471298 | .0492503 | -9.08 | 0.000 | -.5438555 | -.3504042 |
| lformulaadm_14 | .0067849 | .0022944 | 2.96 | 0.003 | .0022788 | .011291 |
| lpcpop519yr_14 | .1328073 | .0188675 | 7.04 | 0.000 | .0957524 | .1698622 |</p>
<table>
<thead>
<tr>
<th>Variable</th>
<th>(Underid)</th>
<th>(Weak id)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F( 1, 595)</td>
<td>P-val</td>
</tr>
<tr>
<td>linverse_14</td>
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<td>0.0000</td>
</tr>
</tbody>
</table>

NB: first-stage test statistics heteroskedasticity-robust

Stock-Yogo weak ID test critical values for single endogenous regressor:
- 10% maximal IV size: 16.38
- 15% maximal IV size: 8.96
- 20% maximal IV size: 6.66
- 25% maximal IV size: 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Underidentification test
Ho: matrix of reduced form coefficients has rank=K1-1 (underidentified)
Kleibergen-Paap rk LM statistic Chi-sq(1)=71.19 P-val=0.0000

Weak identification test
Ho: equation is weakly identified
Cragg-Donald Wald F statistic: 503.39
Kleibergen-Paap Wald rk F statistic: 49.65

Stock-Yogo weak ID test critical values for K1=1 and L1=1:
- 10% maximal IV size: 16.38
- 15% maximal IV size: 8.96
- 20% maximal IV size: 6.66
- 25% maximal IV size: 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Weak-instrument-robust inference
Tests of joint significance of endogenous regressors B1 in main equation
Ho: B1=0 and orthogonality conditions are valid
Anderson-Rubin Wald test Chl-sq(1)= 1.38 P-val=0.2409
Anderson-Rubin Wald test Chl-sq(1)= 1.41 P-val=0.2357
Stock-Wright LM S statistic Chl-sq(1)= 1.39 P-val=0.2383

NB: Underidentification, weak identification and weak-identification-robust test statistics heteroskedasticity-robust

Number of observations: N = 607
Number of regressors: K = 12
Number of endogenous regressors: K1 = 1
Number of instruments: L = 12
### IV (2SLS) estimation

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity

|                        | Robust |                  | z  | P>|z| [95% Conf. Interval] |
|------------------------|--------|-----------------|----|------------------------|
| l1inverse_14           | .0910044 | .0766412         | 1.19 | 0.235 | -0.0592097 | .2412185 |
| lmedohincty13          | .1128777 | .057845         | 1.95 | 0.051 | -0.0004964 | .2262158 |
| lcostindex_14          | -.0242068 | .0604092         | -0.40 | 0.689 | -.1426066 | .0941933 |
| lformulaadm_14         | -.0142951 | .002999         | -4.77 | 0.000 | -.0201729 | -.0084173 |
| lpcpop519yr_14         | .0303151 | .0217241         | 1.40 | 0.163 | -.0122634 | .0728936 |
| lownhouse_14           | .0817479 | .0397953         | 2.05 | 0.040 | .0037506 | .1597453 |
| lminuspie_14           | -.169169 | .2828854         | -0.60 | 0.550 | -.7236142 | .3852762 |
| ltaxprice_14           | .0366616 | .0612006         | 0.60 | 0.549 | -.0832894 | .1566126 |
| leffindex_14           | -.0373582 | .091198         | -0.41 | 0.682 | -.1413865 | .2151029 |
| auwpustsf_14           | -.0856119 | .4080461        | -1.99 | 0.047 | -.1.88986 | -.0136779 |
| laveanwage_14          | -.0186861 | .01186         | -1.58 | 0.115 | -.0419311 | .004559 |
| _cons                  | 3.880384 | .7045839        | 5.51 | 0.000 | 2.499425 | 5.261343 |

Underidentification test (Kleibergen-Paap rk LM statistic): 71.191
Chi-sq(1) P-val = 0.0000

Weak identification test (Cragg-Donald Wald F statistic): 503.389
(Kleibergen-Paap rk Wald F statistic): 49.648

Stock-Yogo weak ID test critical values: 10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53


NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Hansen J statistic (overidentification test of all instruments): 0.000
(equation exactly identified)

Genreity test of endogenous regressors: 0.751
Chi-sq(1) P-val = 0.3860

Regressors tested: l1inverse_14

Instrumented: l1inverse_14
Included instruments: lmedohincty13 lcostindex_14 lformulaadm_14 lpcpop519yr_14 lownhouse_14 lminuspie_14 ltaxprice_14 leffindex_14 auwpustsf_14 laveanwage_14
Excluded instruments: linvmatchexe12

Endogeneity Test Results for Property Tax Rollback Credit (=lminuspie_14)

Given the incremental nature of governmental budget processes, property tax revenues for FY 2012 are likely to be related to property tax revenues for FY 2014. Since property tax revenues are included in Property Tax Rollback Credit, property tax rollback credit for FY 2012 is also related to Property Tax Rollback Credit for FY 2014. However, it is unlikely that school expenditures for FY 2014 and PI Score can affect property values and property tax revenues for FY 2012. As a result, property tax revenues for FY 2012 are less likely to be related to the errors.
in Equation (15). Similarly, property tax rollback credit for FY 2012 is likely to be Property Tax Rollback Credit but not with the errors in Equation (15). Logged property tax rollback credit for FY 2012 is used as an instrument for Property Tax Rollback Credit.

```plaintext
ivreg2 lpi14 lmedohincty13 lcostindex_14 lformulaadm_14 lpcpop519yr_14 lownhouse_14 (lminuspie_14=lpie12) ltaxprice_14 leffindex_14 augpuptsf_14 linverse_14 laveanwage_14, endog(lminuspie_14) robust first
```

First-stage regressions
-----------------------------------

First-stage regression of lminuspie_14:

OLS estimation
---------------------

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity

| lminuspie_14 | Coef. | Std. Err. | t     | P>|t| | [95% Conf. Interval] |
|--------------|-------|-----------|-------|------|-----------------------|
| lmedohincty13 | .0992167 | .0065824 | 15.07 | 0.000 | .0862892  .1121443  |
| lcostindex_14 | -1.099902 | .0046474 | -17.01 | 0.000 | -.1226918 -.0772866 |
| lformulaadm_14 | -.0000626 | .0004406 | -0.14 | 0.892 | -.0009672 .0008421  |
| lpcpop519yr_14 | .0360732 | .0029585 | 12.19 | 0.000 | .0302628 .0418835   |
| lownhouse_14 | -.0576235 | .0030975 | -13.37 | 0.000 | -.0630875 -.0521595 |
| ltaxprice_14 | -.1081797 | .0065287 | -16.57 | 0.000 | -.1290018 -.0873575 |
| leffindex_14 | .1663345 | .0097562 | 17.05 | 0.000 | .1471738 .1854953  |
| augpuptsf_14 | .7865255 | .0535121 | 14.70 | 0.000 | .68143 .8912611   |
| linverse_14 | -.0975532 | .0079035 | -12.34 | 0.000 | -.1130744 -.082032  |
| laveanwage_14 | .001135 | .0017357 | 0.65 | 0.513 | -.0022739 .0045439 |
| _cons | -1.158186 | .0784395 | -14.77 | 0.000 | -1.312238 -.104133  |

Included instruments: lmedohincty13 lcostindex_14 lformulaadm_14 lpcpop519yr_14 lownhouse_14 ltaxprice_14 leffindex_14 augpuptsf_14 linverse_14 laveanwage_14 lpie12

F test of excluded instruments:

F( 1, 595) = 207.36
Prob > F = 0.0000

Angrist-Pischke multivariate F test of excluded instruments:

F( 1, 595) = 207.36
Prob > F = 0.0000

Summary results for first-stage regressions
--------------------------------------------

(Overd) (Weak id)
<table>
<thead>
<tr>
<th>Variable</th>
<th>F( 1, 595)</th>
<th>P-val</th>
<th>AP Chi-sq( 1)</th>
<th>P-val</th>
<th>AP F( 1, 595)</th>
<th>P-val</th>
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<td>lminuspie_14</td>
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</tbody>
</table>

NB: first-stage test statistics heteroskedasticity-robust

Stock-Yogo weak ID test critical values for single endogenous regressor:

| 10% maximal IV size | 16.38 |
| 15% maximal IV size | 8.96 |
| 20% maximal IV size | 6.66 |
25% maximal IV size 5.53


NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Underidentification test
Ho: matrix of reduced form coefficients has rank=K1−1 (underidentified)
Ha: matrix has rank=K1 (identified)
Kleibergen-Paap rk LM statistic Chi-sq(1)=131.84 P-val=0.0000

Weak identification test
Ho: equation is weakly identified
Cragg-Donald Wald F statistic 454.51
Kleibergen-Paap Wald rk F statistic 207.36

Stock-Yogo weak ID test critical values for K1=1 and L1=1:

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Critical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>16.38</td>
</tr>
<tr>
<td>15%</td>
<td>8.96</td>
</tr>
<tr>
<td>20%</td>
<td>6.66</td>
</tr>
<tr>
<td>25%</td>
<td>5.53</td>
</tr>
</tbody>
</table>


NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Weak-instrument-robust inference

Tests of joint significance of endogenous regressors B1 in main equation
Ho: B1=0 and orthogonality conditions are valid

Anderson-Rubin Wald test F(1,595)= 2.81 P-val=0.0942
Anderson-Rubin Wald test Chi-sq(1)= 2.87 P-val=0.0904
Stock-Wright LM S statistic Chi-sq(1)= 2.85 P-val=0.0913

NB: Underidentification, weak identification and weak-identification-robust test statistics heteroskedasticity-robust

Number of observations N = 607
Number of regressors K = 12
Number of endogenous regressors K1 = 1
Number of instruments L = 12
Number of excluded instruments L1 = 1

IV (2SLS) estimation

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity

|              | Coef. | Std. Err. | z     | P>|z|     | [95% Conf. Interval] |
|--------------|-------|-----------|-------|---------|----------------------|
| lminuspie_14 | -.4742851 | .2771508 | -1.71 | 0.087   | -1.017491 .0689205  |
| lmedohincty13| .1703666  | .0549971 | 3.10  | 0.002  | .0625742 .278159  |
| lcostindex_14| -.0887587 | .0604598 | -1.47 | 0.142   | -2.072576 .0297403 |
| lformulaadm_14| -.0135771 | .0029291 | -4.64 | 0.000  | -.0139181 -.0130361 |
| lppcop519yr_14| .0497643  | .0212414 | 2.34  | 0.020  | .0105742 .0889554  |
| ltaxprice_14 | -.0263161 | .0588369 | -0.45 | 0.655   | -.1416342 .0989002 |
| leffindex_14 | .1348586  | .0912492 | 1.48  | 0.148   | -.0439865 .3137037 |
| augpuptsf_14 | -.4860818 | .4525954 | -1.07 | 0.283   | -.1373153 .4009888 |
| linverse_14  | .0192977  | .0662416 | 0.29  | 0.771   | -.1105534 .1491289 |
| laveanwage_14| -.0169797 | .011744  | -1.45 | 0.150   | -.0399974 .0060381 |
| _cons        | 3.194169  | .667626  | 4.79  | 0.000   | 1.887338 4.501   |

Underidentification test (Kleibergen-Paap rk LM statistic): 131.843
Chi-sq(1) P-val = 0.0000
Weak identification test (Cragg-Donald Wald F statistic): 454.512
(Kleibergen-Paap rk Wald F statistic): 207.364

Stock-Yogo weak ID test critical values: 10\% maximal IV size 16.38
15\% maximal IV size 8.96
20\% maximal IV size 6.66
25\% maximal IV size 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Hansen J statistic (overidentification test of all instruments): 0.000
(equation exactly identified)

-\texttt{endog}\- option:
\texttt{Endogeneity test of endogenous regressors:} 0.704
Chi-sq(1) P-val = 0.4014

Regressors tested: \texttt{lminuspie14}

Instrumented: \texttt{lminuspie14}

Included instruments: \texttt{lmedohincty13 lcostindex14 lformulaadm14 lpcpop519yr14 lownhouse14 lminuspie14 ltaxprice14 leffindex14 augpuptsf14 linverse14 laveanwage14}

Excluded instruments: \texttt{lpiel12}

Endogeneity Test Results for Cost Index (=\texttt{lcostindex14})

Cost index for FY 2012 is related to Cost Index for FY 2014 but it is unlikely that school expenditures for FY 2014 and PI Score might affect cost index for FY 2012. As a result, the latter is less likely to correlate with the errors in Equation (15). Logged cost index for FY 2012 is used as the instrument for Cost Index. All relevant test results are highlighted in blue below.

\texttt{ivreg2 lpi14 lmedohincty13 (lcostindex14=lcostindem) lformulaadm14 lpcpop519yr14 lownhouse14 lminuspie14 ltaxprice14 leffindex14 augpuptsf14 linverse14 laveanwage14, endog(lcostindex14) robust first}

First-stage regressions

First-stage regression of \texttt{lcostindex14}:

OLS estimation

\begin{verbatim}
            Robust
 lcostindex14 | Coef.  Std. Err.  t    P>|t|  [95\% Conf. Interval]        
----------------- +----------------- +-------- +-------- +----------------- 
  lmedohincty13  |  .8648748  .0193874  44.61  0.000  .8267987   .9029509
  lformulaadm14  |  .0072184  .0031551   2.29  0.022  .0010218   .0134150
  lpcpop519yr14  |  .2762735  .0151445  18.24  0.000  .2465303   .3060167
  lownhouse14    | -.5168715  .0205039 -25.21  0.000  -.5571404  -.4766027
  lminuspie14    | -4.108499  .0884406  -46.45  0.000  -4.282183  -3.934796
  ltaxprice14    | -.9130984  .0128081 -71.29  0.000  -.938253   -.8879438
  leffindex14    |  1.509751  .0007819 1930.94  0.000  1.508215   1.511286
  augpuptsf14    |  6.821159  .1503555  45.37  0.000   6.525867   7.116451
  linverse14     | -.8226588  .0309186 -26.61  0.000  -.8833719  -.7619458
  laveanwage14   |  .0208405  .0106187   1.96  0.050  -.0001422  .0416953

\end{verbatim}
Included instruments: lmedohincty13 lformulaadm_14 lpcpop519yr_14 lownhouse_14
lminuspie_14 ltaxprice_14 leffindex_14 augpuptsf_14
linverse_14 laveanwage_14 lcostindex_1

F test of excluded instruments:
F(  1,   595) =     5.21
Prob > F      =   0.0228

Angrist-Pischke multivariate F test of excluded instruments:
F(  1,   595) =     5.21
Prob > F      =   0.0228

Summary results for first-stage regressions

<table>
<thead>
<tr>
<th>Variable</th>
<th>(Underid) F( 1, 595) P-val</th>
<th>(Weak id) AP Chi-sq(1) P-val</th>
<th>(Underid) F( 1, 595) P-val</th>
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<tbody>
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<td>5.32 0.0211</td>
<td>5.21</td>
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</tbody>
</table>

NB: first-stage test statistics heteroskedasticity-robust

Stock-Yogo weak ID test critical values for single endogenous regressor:
10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Underidentification test
Ho: matrix of reduced form coefficients has rank=K-1 (underidentified)
Ha: matrix has rank=K (identified)
Kleibergen-Paap rk LM statistic Chi-sq(1)=5.31 P-val=0.0212

Weak identification test
Ho: equation is weakly identified
Cragg-Donald Wald F statistic 6.46
Kleibergen-Paap Wald rk F statistic 5.21

Stock-Yogo weak ID test critical values for K=1 and L=1:
10% maximal IV size 16.38
15% maximal IV size 8.96
20% maximal IV size 6.66
25% maximal IV size 5.53

NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.

Weak-instrument-robust inference
Tests of joint significance of endogenous regressors B1 in main equation
Ho: B1=0 and orthogonality conditions are valid
Anderson-Rubin Wald test F(1,595)= 0.65 P-val=0.4191
Anderson-Rubin Wald test Chi-sq(1)= 0.67 P-val=0.4142
Stock-Wright LM S statistic Chi-sq(1)= 0.65 P-val=0.4219

NB: Underidentification, weak identification and weak-identification-robust test statistics heteroskedasticity-robust

Number of observations N = 607
Number of regressors K = 12
Number of endogenous regressors K1 = 1
Number of instruments L = 12
Number of excluded instruments L1 = 1

IV (2SLS) estimation

Estimates efficient for homoskedasticity only
Instrumental Variable Regression Results for Table 3

```
ivreg2 lpi14 lmedohincty13 Icostindex_14 lformulaadm_14 lpcpop519yr_14 lownhouse_14
lminuspie_14 (ltaxprice_14 leffindex_14 augpuptsf_14)
linverse_14 laveanwage_14 ,fuller(4) robust first
```

Statistics robust to heteroskedasticity

Number of obs = 607
### F test of excluded instruments:

| Coef. | Std. Err. | t | P>|t| | [95% Conf. Interval] |
|-------|-----------|---|------|------------------|
| lvalue11 | -.7313248 | .0291662 | -25.07 | 0.000 | -.788606 | -.674037 |
| effindem | .8280258 | .1082296 | 7.65 | 0.000 | .6154672 | 1.040584 |
| medhouse13 | 4.53e-06 | 4.83e-07 | 9.38 | 0.000 | 3.58e-06 | 5.48e-06 |
| lmedohincty13 | -.1131972 | .0636462 | -1.78 | 0.076 | -.2381956 | .018013 |
| lcostindex14 | -.0019072 | .0013408 | -1.42 | 0.155 | -.0045405 | .000726 |
| lformulaadm14 | .0374418 | .0062773 | 5.96 | 0.000 | .0251134 | .0497703 |
| lpcpop519yr14 | .1038883 | .0349749 | 2.97 | 0.003 | .0351989 | .1725776 |
| lowhouse14 | -.0832073 | .0361807 | -2.30 | 0.022 | -.1542648 | -.0121499 |
| lminus14 | -.1544528 | .2709238 | -5.70 | 0.000 | -.2076611 | -.1012445 |
| linverse14 | -.1571595 | .085503 | -18.38 | 0.000 | -.1739519 | -.140367 |
| laveanwage14 | .0852196 | .0313812 | 2.72 | 0.007 | .0235883 | .1468509 |
| _cons | 6.442488 | 8.299785 | 7.76 | 0.000 | 4.812444 | 8.072532 |

#### F test of excluded instruments:

- F(3, 595) = 419.42
- Prob > F = 0.000

### Sanderson-Windmeijer multivariate F test of excluded instruments:

- F(1, 595) = 17.12
- Prob > F = 0.000

### First-stage regression of augpupts14:

#### Statistics robust to heteroskedasticity

- Number of obs = 607

| Coef. | Std. Err. | t | P>|t| | [95% Conf. Interval] |
|-------|-----------|---|------|------------------|
| lvalue11 | -.115289 | .0185365 | -6.22 | 0.000 | -.151694 | -.0788841 |
| effindem | .7950623 | .0761726 | 10.44 | 0.000 | .6454625 | .9446621 |
| medhouse13 | 1.28e-06 | 2.40e-07 | 5.35 | 0.000 | 8.13e-07 | 1.76e-06 |
| lmedohincty13 | -.481748 | .0371004 | -12.98 | 0.000 | -.5546117 | -.4088442 |
| lcostindex14 | .6572899 | .0022539 | 291.62 | 0.000 | .6528633 | .6617164 |
| lformulaadm14 | .0134589 | .0053793 | 2.50 | 0.013 | .0028942 | .0240236 |
| lpcpop519yr14 | -.1185229 | .0219725 | -5.39 | 0.000 | -.1616761 | -.0753697 |
| lowhouse14 | .3332151 | .0384491 | 8.67 | 0.000 | .2577026 | .4087275 |
| lminus14 | 1.773868 | .1636736 | 10.84 | 0.000 | 1.452411 | 2.095308 |
| linverse14 | -.6720733 | .0692601 | -9.70 | 0.000 | -.8080973 | -.5360493 |
| laveanwage14 | -.004288 | .0184205 | -0.23 | 0.816 | -.0404651 | .0318892 |
| _cons | 5.525839 | .4704388 | 11.75 | 0.000 | 4.601917 | 6.449762 |

#### F test of excluded instruments:

- F(3, 595) = 72.23
- Prob > F = 0.000

### Sanderson-Windmeijer multivariate F test of excluded instruments:

- F(1, 595) = 16.80
- Prob > F = 0.000

### First-stage regression of laveanwage14:

#### Statistics robust to heteroskedasticity

- Number of obs = 607

| Coef. | Std. Err. | t | P>|t| | [95% Conf. Interval] |
|-------|-----------|---|------|------------------|
| lvalue11 | -.0715328 | .0039724 | -18.01 | 0.000 | -.0993346 | -.0437311 |
| effindem | -.0670895 | .0122719 | -5.47 | 0.000 | -.0911909 | -.0429881 |
| medhouse13 | 3.64e-07 | 3.63e-08 | 10.02 | 0.000 | 2.93e-07 | 4.36e-07 |
| lmedohincty13 | -.0426181 | .0063191 | -6.95 | 0.000 | -.0546609 | -.0305753 |
| lcostindex14 | .000754 | .0003575 | 2.11 | 0.035 | .0000519 | .0014562 |
| lformulaadm14 | .0013778 | .0008536 | 1.51 | 0.107 | -.0002984 | .0030541 |
| lpcpop519yr14 | -.0009883 | .0031962 | -0.31 | 0.757 | -.0072656 | .0052889 |
| lowhouse14 | -.0088135 | .007808 | -1.13 | 0.259 | -.0241481 | .0065211 |
| lminus14 | -.0036961 | .027438 | -0.13 | 0.893 | -.0575831 | .050191 |
linverse_14 |   .0598384   .0119305     5.02   0.000     .0364074    .0832693  
laveanwage_14 |    .010383   .0033178     3.13   0.002     .0038669    .0168991  
   _cons |   1.173129   .0828052    14.17   0.000     1.010503    1.335755

F test of excluded instruments:
F(  3,   595) =   119.72
Prob > F = 0.0000
Sanderson-Windmeijer multivariate F test of excluded instruments:
F(  1,   595) =    17.16
Prob > F = 0.0000

Summary results for first-stage regressions

<table>
<thead>
<tr>
<th>Variable</th>
<th>F(  3,   595)</th>
<th>P-val</th>
<th>SW Chi-sq(  1)</th>
<th>P-val</th>
<th>SW F(  1,   595)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ltaxprice_14</td>
<td>419.42</td>
<td>0.0000</td>
<td>17.46</td>
<td>0.0000</td>
<td>17.12</td>
</tr>
<tr>
<td>leffindex_14</td>
<td>72.23</td>
<td>0.0000</td>
<td>17.14</td>
<td>0.0000</td>
<td>16.80</td>
</tr>
<tr>
<td>augpuptsf_14</td>
<td>119.72</td>
<td>0.0000</td>
<td>17.51</td>
<td>0.0000</td>
<td>17.16</td>
</tr>
</tbody>
</table>

NB: first-stage test statistics heteroskedasticity-robust

Stock-Yogo weak ID F test critical values for single endogenous regressor:
5% maximal Fuller rel. bias 9.61
10% maximal Fuller rel. bias 7.90
20% maximal Fuller rel. bias 6.61
30% maximal Fuller rel. bias 5.60
5% Fuller maximum bias 8.66
10% Fuller maximum bias 7.18
20% Fuller maximum bias 5.87
30% Fuller maximum bias 5.11

NB: Critical values based on Fuller parameter=1
NB: Critical values are for i.i.d. errors only.

Underidentification test
Ho: matrix of reduced form coefficients has rank=K1-1 (underidentified)
Ha: matrix has rank=K1 (identified)
Kleibergen-Paap rk LM statistic | Chi-sq(1)=12.77     P-val=0.0004

Weak identification test
Ho: equation is weakly identified
Cragg-Donald Wald F statistic | 6.30
Kleibergen-Paap Wald rk F statistic | 5.51

Stock-Yogo weak ID test critical values for K1=3 and L1=3:
NB: Critical values based on Fuller parameter=1
<nот available>

Weak-instrument-robust inference
Tests of joint significance of endogenous regressors B1 in main equation
Ho: B1=0 and orthogonality conditions are valid
Anderson-Rubin Wald test | F(3,595)= 19.95     P-val=0.0000
Stock-Wright LM S statistic | Chi-sq(3)= 45.79     P-val=0.0000

NB: Underidentification, weak identification and weak-identification-robust test statistics heteroskedasticity-robust

Number of observations | N  = 607
Number of regressors | K  = 12
Number of endogenous regressors | K1 = 3
Number of instruments | L  = 12
Number of excluded instruments | L1 = 3

LIML estimation
-------------
k = 0.99328
lambda = 1.00000
Fuller parameter=4

Estimates efficient for homoskedasticity only
Statistics robust to heteroskedasticity

Number of obs = 607
F( 11, 595) = 73.76
Prob > F = 0.0000

Total (centered) SS = 2.684862013
Centered R2 = 0.5634
Total (uncentered) SS = 12814.77779
Uncentered R2 = 0.9999
Residual SS = 1.172298464
Root MSE = 0.04395

-------------------------------------------------------------
|               Robust
lpi14 |      Coef.   Std. Err.      z      P>|z|     [95% Conf. Interval]
|-------------------------------------------------------------
ltaxprice_14 | -0.4519956   .1966172   -2.30   0.022   -.8373582   -.0666331
leffindex_14 |  .8627009   .3204471    2.69   0.007   .2346361   1.490766
augpuptsf_14 |   2.61062    1.492228   1.75   0.080   -.3140931   5.535333
lmedohincty13 |  .5632267   .1847496    3.05   0.002   .2011243   .9253292
lcostindex_14 |  -.5706549   .2121089   -2.69   0.007   -.9863807  -.1549292
lformulaadm_14 | -.0124739   .0037165   -3.36   0.001  -.0197581  -.0051896
lpcpop519yr_14 |  .1826348   .0594868    3.07   0.002   .0660428   .2992268
lownhouse_14 | -.1995118   .1111427   -1.80   0.073   -.4173476   .0183239
lminuspie_14 |   2.433941   .8879329    2.74   0.006   1.74258   3.124246
linverse_14 |  -.3604951   .1840026   -1.96   0.050   -.7211335  -.0001434
laveanwage_14 | -.0128496   .0126691    1.01   0.310  -.0376806   .0110013
    _cons |  -1.341146   2.159352   -0.62   0.535  -.5.573399   2.891107
-------------------------------------------------------------
Underidentification test (Kleibergen-Paap rk LM statistic): 12.772
Chi-sq(1) P-val = 0.0004
Weak identification test (Cragg-Donald Wald F statistic): 6.303
(Kleibergen-Paap rk Wald F statistic): 5.507
Stock-Yogo weak ID test critical values:NB: Critical values based on Fuller parameter=1
<not available>
Hansen J statistic (overidentification test of all instruments): 0.000
(equation exactly identified)
Instrumented: ltaxprice_14 leffindex_14 augpuptsf_14
Included instruments: lmedohincty13 lcostindex_14 lformulaadm_14 lpcpop519yr_14
lownhouse_14 lminuspie_14 linverse_14 laveanwage_14
Excluded instruments: lvalue11 effindem medhouse_13
Technical Appendix C

Another method, mean-ratio adjustment, to multiply all observations in each sample obtained from the first-stage simulation by the mean-ratio, (4,180.641/ mean of each sample obtained from the first-stage simulation), whether no-negative-aid restrictions are imposed or not. The key difference between the mean-difference adjustment and the mean-ratio adjustment is that the former compensates wealthy districts slightly more when no-negative-aid restrictions are imposed and the mean of a simulated sample is less than 4,180.641. In that case, wealthy districts, which might have received zero aid, now receive some aid equal to the mean-difference. Under the mean-ratio adjustment, however, these districts will still receive zero aid because zero times the mean-ratio is still zero. This fact alone implies stronger equity for the mean-ratio adjustment in school aid simulations. In this paper, however, the mean-difference adjustment was applied because Ohio’s actual foundation aid amounts range from $459.13 to $10,917.64 and aid simulations with no-negative-aid restrictions under the mean-difference adjustment often generate the lowest amounts that are non-zero.
Technical Appendix D

The range-based scale factor in Equation (18), which is applied during the third-stage simulations, does not fundamentally change the patterns of elasticity measures in this paper. To prove this expectation, let $$\ln E = \gamma_s \ln A_s$$ and $$\ln A_s = a \ln \bar{V}$$, where $$E$$ is efficiency index, per pupil school expenditure, or performance score, $$A$$ is grants-in-aid, $$\bar{V}$$ is per pupil property valuation, and $$s$$ denotes the second-stage simulations. By plugging the second equation into the first equation, we obtain $$\ln E = \gamma_s a \ln \bar{V}$$. Since $$E$$ is a function of $$\bar{V}$$, we can apply the derivative rule of log functions to the last equation and rearrange it to obtain Equation D.1:

$$\frac{\bar{V}}{E} \frac{dE}{d\bar{V}} = \frac{d(lnE)}{d(ln\bar{V})} = \gamma_s a$$ D.1.

Equation C.1. indicates that the property valuation elasticity of expenditure is $$\gamma_s a$$. The unknown question here is what happens to the elasticity if we change $$A_s$$ into $$A_{fs}$$. We can treat Equation (18) as if $$A_{fs} = b * A_s + c$$, where $$b$$ and $$c$$ are coefficients to be estimated. $$\ln E = \gamma_s \ln A_s$$ will be modified into $$\ln E = \gamma_s \ln (b * A_s + c)$$. We can rewrite $$\ln A_s = a \ln \bar{V}$$ as $$A_s = e^{a \ln \bar{V}}$$. The new property valuation elasticity of expenditure can be computed according to the following steps:

$$\ln E = \gamma_s \ln (b * e^{a \ln \bar{V}} + c) \quad \text{[by plugging } A_s = e^{a \ln \bar{V}} \text{ into } \ln E = \gamma_s \ln (b * A_s + c)]$$

$$\frac{1}{E} \frac{dE}{d\bar{V}} = \frac{b * (e^{a \ln \bar{V}})}{b * (e^{a \ln \bar{V}}) + c} = \frac{\gamma_s b * (e^{a \ln \bar{V}})}{b * (e^{a \ln \bar{V}}) + c} \quad \text{[derivative rules of log- and exponential-functions]}$$

D.2.

The difference between Equation D.1. and Equation D.2. is $$\frac{b * (e^{a \ln \bar{V}})}{b * (e^{a \ln \bar{V}}) + c}$$. However, since the numerator and the first part of the denominator are the same, the only difference is $$c$$ in the denominator. According to Equation (18), $$c = 4,180.641 + \frac{\sigma_s}{\sigma_s}$$. Therefore, the magnitude of the standard deviation of the first-stage simulation sample, $$\sigma_s$$, will decide the magnitude of changes in the new property valuation elasticity of expenditure. Intuitively, as $$\sigma_s$$ increases, the elasticity will increase as well. Since we have the values of $$\sigma_s$$, we can compare the second-stage samples and the third-stage samples in a systematic manner. If we make the final mean adjustment over Equation (18) as noted in Section 9.3., the additional adjustment factor will be $$\frac{4,180.641}{\bar{A}_{fs}}$$. We can treat the latter value as another constant, so Equation D.2. will not change. However, foundation aid affects target variables via Foundation Aid Ratio in Tables 4 and 5, which also include $$\bar{V}$$. Therefore, Equation D.2. might not obtain for foundation aid. Policy makers need to check simulation results to see how the elasticities are affected.
Technical Appendix E

Efficiency Adjustment on Simulations of Performance

The simulations in the above figures are all conducted under the assumption that efficiency indices of the original sample remain constant. According to Equation (15), however, simulated efficiency indices might independently affect Performance Index (PI) Score. This caveat should not be a significant issue for expenditure models. According to Equations (7) and (13), efficiency indices are already implicitly accounted for through the equation systems.

Figure 5.1. shows what happens to Figure 5 if we factor in the simulated efficiency indices in the "demand" equation for foundation aid with no negative aid. Note that Figure 5.1 reports some more measures that were introduced in Technical Appendix A. As we can easily expect from Equation (15), the only difference between Figure 5.1 and Figure 5 is the elasticity between per pupil property valuation and performance index score (lupvaltp_14_70). Despite the slightly different and still positive values of the elasticity, its actual values range between 0.013 and 0.083. This range is narrower than that in Figure 5, 0.086 to 0.210. The Gini coefficient in Figure 5.1 ranges between 0.031 and 0.050, which is also narrower than that in Figure 5, 0.037 and 0.082. As noted in Section 10.3.1., imposing Efficiency Targeting (ET) into outcome-based foundation aid with no-negative-aid restriction somewhat damages outcome equity compared with the current Ohio aid formula. However, Figure 5.1 indicates that there is some possibility of improving equity even for this case if we further account for simulated efficiency indices. The actual values associated with Figure 5.1. reveals that if we keep ET very high around 0.9, the elasticity is lower than the actual elasticity value of 0.034 and the actual Gini coefficient of 0.074, while simulated efficiency is higher than the actual efficiency value of 0.616. Note that whenever the elasticity is positive, smaller Gini values denote improved equity.

There is one observation worth noting in Figure 5.1. In Figure 5.1., the elasticity between per pupil property valuation and performance score (lupvaltp_14_70) is approximately mirroring the elasticity between property valuation and efficiency (lupvaltp_14eff_70). This is a plausible interpretation because the latter is the “global” elasticity between property valuation and efficiency. Since we could not impute the impact of power-equalizing aid on performance score directly through Equation (15), we imputed it from the price effect for Figure 1 as noted in Section 9.4. We can now apply the above observation to Figure 1. The elasticity between per pupil property valuation and performance score (lupvaltp_14_70) might look closer to the elasticity between property valuation and efficiency (lupvaltp_14eff_70) if we further account for the independent effect of efficiency on performance score. However, we can still expect that the former would stay negative. All in all, the conclusions made earlier are likely to remain almost unchanged.
Figure 5.1. Efficiency Targeting on Performance: Foundation Aid (No Negative Aid), Adjusting for Simulated Efficiency

Notes: For clear visual presentation, Coefficient of Variation is divided by 50 (rather than 100 for other figures), lpupvaltp_14aid_70 is divided by 5, and lpupvaltp_14_70 is multiplied by 2.