Private Demands for Public Capital: Evidence from School Bond Referenda

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Abstract

This paper develops a framework for estimating demand for school infrastructure investment that is financed through local bond referenda. Our framework takes explicit account of the irregular and discrete nature of local capital investment and the objective functions of local school boards. Our empirical model consists of a three-equation system composed of a proposed spending equation, a vote equation, and a selection equation. Estimated income and price elasticities of demand for school infrastructure are similar to those found in studies of current school spending. We also find that school boards act like risk-averse, budget-maximizing agenda-setters.

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I. Introduction

For almost three decades, researchers have been using referenda outcomes to estimate demand for local school spending. As Rubinfeld and Shapiro (1989) note, the continued interest in the subject stems mainly from the policy relevance of estimates of the income and price elasticities of demand for schooling. For example, estimates of those elasticities are critical to the design of intergovernmental grant programs. Yet, while numerous studies have examined the role that income and tax price play in determining local demand for current school spending, we know of no study that examines the role these important variables play in determining local demand for school infrastructure spending. As a result, the existing literature provides only a partial picture of the financing of elementary and secondary education. In this paper we take a first step towards completing that picture by developing a framework for estimating local demand for school infrastructure spending.

In most states, school infrastructure is financed primarily with funds raised through local general obligation bond referenda. If local voters approve a bond issue, the bonds are then repaid with property tax overrides that remain in effect until the bonds are fully repaid. The institutional environment of bond referenda presents several challenges to the estimation of demand for local school infrastructure. First, the power to propose a bond issue lies exclusively with local school boards and voters are faced with a take-it-or-leave-it proposition on a specific quantity of revenue and its use. As a result, spending proposals are likely to reflect not only the preferences of voters but also the preferences and objectives of school boards. Second, local investment in school infrastructure is lumpy: districts tend to hold bond referenda infrequently and request large sums when they do. Thus, unlike current school spending, school capital spending tends to be irregular and discrete.

In section II, we develop a framework to estimate demand for school infrastructure that takes explicit account of these institutional features of bond referenda. Our framework extends the traditional decisive-voter and agenda-setting models used to examine local demand for current school spending by taking explicit account of the irregular and discrete nature of local school infrastructure investment. Specifically, unlike the models used to examine demand for current school spending, our model incorporates a selection condition that determines whether or not a school board will place a spending proposal on the ballot. We demonstrate that this selection condition is unlikely to be random. As a result, consistent estimation of demand for local school capital spending requires one to model the nonrandom nature of observed spending proposals.

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1 See for example, Borcherding and Deacon (1972), Inman (1978), Bergstrom, Rubinfeld and Shapiro (1982), and Rubinfeld and Shapiro (1989) to name just a few.

2 Our research also complements the work of Holtz-Eakin and Rosen (1989, 1993) and Temple (1994) on the determinants of state and local capital investment. However, those studies focus on aggregate capital investment by state and/or local governments and therefore abstract from the institutional environment of local bond referenda.
Our framework also allows us to examine the objective function of local school boards. The majority of studies that examine demand for local school spending assume a competitive agenda-setting process, in which the setter targets the desired level of spending of the decisive voter. However, there are several reasons to believe local school infrastructure investment might be better characterized by a budget-maximizing agenda-setting process, in which the setter targets the maximum amount the decisive voter will accept. First, school boards almost certainly consist of individuals with strong preferences for school quality, providing the motive for them to maximize their budgets. Second, school boards typically have better information than the electorate about the actual costs associated with any construction project. This asymmetric information is likely to provide school boards with considerable market power and hence the opportunity to maximize their budgets. Following Romer, Rosenthal and Munley (1992) and Rothstein (1994), we test the predictions of these two competing agenda-setting models. Our test is based on vote outcomes of local school bond elections. With budget-maximizing agenda setting, the fraction of voters supporting a bond issue should be independent of the characteristics of the decisive voter. In contrast, with competitive agenda setting the fraction of voters supporting a bond issue should depend on the characteristics of the decisive voter.

Section III presents the empirical model of demand for school infrastructure investment. Our model consists of a three-equation system composed of a proposed spending equation, a vote equation, and a selection equation. We use maximum likelihood estimation techniques to obtain consistent estimates of the parameters of our model. We estimate our model using data from California’s unified school districts. Our data set, which is described in section IV, consists of census data on community characteristics, a measure of the existing capital stock in each district, and data on proposed bond issues and corresponding vote outcomes from 1996 to 2000. Our findings, presented in section V, indicate that local demand for school infrastructure spending is price and income inelastic. Furthermore, our estimates of the price and income elasticities of demand for school infrastructure are similar to those found in studies of current school spending. Our results also provide strong support for the hypothesis that observed spending proposals and vote outcomes suffer from nonrandom sample selection. Indeed, we find that ignoring sample selection leads to substantial bias in the estimated parameters of the proposed spending and vote equations. Finally, our results suggest that school boards behave neither like budget-maximizing agenda-setters who target the maximum amount the decisive voter will accept, nor like competitive agenda-setters who target the desired level of spending of the decisive voter. Rather, their behavior is consistent with a budget-maximizing model in which setters are risk-averse. That is, due to the political and monetary costs associated with holding an election and uncertainty about voter preferences, school boards propose spending levels that are smaller than the maximum amount the decisive voter is willing to accept.
II. Theory

We begin by examining demand for capital investment in public schools from the perspective of an individual resident of a local community. The individual derives utility from two goods: the quality of education at the local public schools, $Q$, and a composite good, $X$. It is assumed that decisions made in time period $t$ maximize intertemporal expected utility

$$E[V_t] = \sum_{i=t}^{\infty} \beta^{t-i} E[U(X_t, Q_t)],$$

(1)

where $\beta \equiv 1/(1+r)$ is a time discount factor. For simplicity we assume that $r$, the discount rate for this individual, is also the market interest rate on public debt in the community.

Local school quality is produced by labor and capital services, $L_t$ and $K_t$. Following a number of studies of demand for current school spending, (e.g. Borcherding and Deacon, 1972; Bergstrom and Goodman, 1973), we allow for economies of scale in producing school quality through a function specifying that quality, $Q_t$, depends also on enrollment, $N_t$:

$$Q_t = N_t^{-\gamma} \cdot f(L_t, K_t).$$

(2)

The parameter $\gamma \in (0,1)$ captures economies of scale in providing school quality to greater student enrollment. If $\gamma = 0$, $Q$ is a pure public good and the marginal cost of providing $Q$ to an additional student is zero. If $\gamma = 1$, $Q$ is a pure private good.

For simplicity $L_t$ is exogenously fixed, an assumption corresponding in our empirical work to the fact that current spending per pupil (as well as input costs) is outside of district control. The endowed capital stock, $K_t$, is determined by earlier investment decisions and also cannot be contemporaneously adjusted. However, bond-financed investment in period $t$ increases capital services in the future according to the difference equation

$$K_{t+1} = K_t \cdot (1 - \delta) + (I_t + R_t) / p_t,$$

(3)

Current spending per pupil was equalized in California in response to the State Supreme Court ruling in Serrano v. Priest. Endogenous current spending would substantially complicate the model, but the same basic structure of the capital decision remains.
where $\delta$ is the rate of physical depreciation, $I_t$ is bond revenue raised through a local referendum in period $t$, $R_t$ is revenue from state and other local sources of capital funding, and $p_t$ is the price of capital goods in the community.

The individual’s period $t$ budget constraint details the tradeoff between current private consumption, $X_t$, and investment in the public capital stock, part of which can be financed through additions to community bond debt, $D_t$:

$$X_t + p_t \cdot \left( K_{t+1} - K_t \cdot (1 - \delta) \right) = Y_t + \tau_t \cdot (D_{t+1} - D_t).$$

(4)

In this expression, $Y_t \equiv M_t + \tau_t \cdot (R_t - r \cdot D_t)$, represents “full income” where $M_t$ is permanent income in period $t$ net of all taxes except those paid on property to service the public debt, and $\tau_t$ is the individual’s tax share. On the left-hand side of (4) are current expenditures on consumption and the individual’s share of capital improvement costs. The right-hand side represents financing available for these expenditures, including the issue of new bond debt. Note that debt financing in period $t$ increases the individual’s share of debt service, $\tau_t \cdot r \cdot D_t$, and therefore decreases full income in subsequent periods.

A single voter does not choose the paths of $K$ and $D$ directly; in fact, the greater part of this section will focus on the political process that determines investment. The foundation of this democratic process is still individual preferences, however, which can be derived from the objective function in (1) and the constraints outlined in (2) - (4). Furthermore, since the desirability of current investment derives from the expected tradeoff between school quality and private consumption in future periods, preferences will depend on the expected growth rates of the exogenous variables, $Y, \tau, R,$ and $N$, and on the expected future paths of $K$ and $D$. We assume individuals formulate their preferences for current investment based on rational expectations about the future levels of local public capital investment, but this assumption is not essential to the analysis.

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4 Brueckner and Joo (1991) and Sprunger and Wilson (1998) develop models in which local public capital provides additional returns to homeowners through increased property values. Following more traditional models of demand for public goods we have abstracted from such capitalization effects, which would make permanent income in the current model endogenous to capital investment.
We express the value of bond-financed investment in any given period, $I_t$, in terms of the compensating surplus, $s_t$. Specifically, $s_t$ is the monetary amount that makes the individual indifferent between consuming $(X_t - s_t)$ with $I_t$, and consuming $X_t$ with no bond-financed investment.\[\Box\]

**Figure 1: Compensating Surpluses and Desired Investment**

![Figure 1: Compensating Surpluses and Desired Investment](image)

Figure 1 depicts three $s$ functions. Each must pass through the origin by the definition of a compensating surplus. As long as individuals have positive and decreasing marginal utility of $X$ and $Q$, preferences are single-peaked as depicted. Nothing constrains desired bond-financed investment to be positive, as suggested by the preferences depicted by $s_1$ in Figure 1. In such a case the individual desires to divest some of the current capital stock.\[\Box\]

As a surplus measure, $s(I)$ is a function of the exogenous and predetermined variables in the constraints (2) – (4), and their expected growth rates; that is, $s_t = s(I_t, Y_t, \tau_t, p_t, K_t, R_t, D_t, N_t^{-\gamma}, g)$.

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5 Formally, $s_t$ solves: $U(X_t, Q_t, I_t) + \beta E[V_{t+1}(K_{t+1}^0, I_t, p_t, D_{t+1}^0, I_t)] = U(X_t, Q_t) + \beta E[V_{t+1}(K_{t+1}^0, D_{t+1}^0)]$, where $K_{t+1}^0$ and $D_{t+1}^0$ denote the capital stock and debt level in period $t + 1$ with no bond-financed investment. Notice that $s_t$ is a true *surplus* measure, not demand or willingness-to-pay, since the financing of bond revenue is already expressed through the increase in $D_{t+1}$.

6 Indirect mechanisms may exist through which such divestment can occur. For example districts have frequently rented out publicly financed buildings for private use, effectively trading infrastructure for revenue that could then be used to service (or avoid) debt.
where $g$ is a vector that contains the expected growth rates of $Y, \tau, R,$ and $N$. The individual’s desired investment in period $t$, $I_t^*$, is the level at which $s(I)$ is maximized, and is therefore an implicit function of the same variables:

$$I_t^* = I^*(Y_t, \tau_t, p_t, K_t, R_t, D_t, N_t^{-\tau}, g).$$ (5)

Notice the investment level labeled $I_{2}^{\text{max}}$, where $s_2$ intersects the horizontal axis. The individual gains surplus from any positive level of bond-financed investment up to this point, and negative surplus beyond it. Formally, $I^{\text{max}}$ is defined for any individual by:

(a) \quad s(I^{\text{max}}) \equiv 0

(b) \quad I^{\text{max}} \equiv 0 \text{ iff } I^* \leq 0.

For individuals who desire some positive level of bond-financed investment $I^{\text{max}}$ is positive and greater than $I^*$. For individuals who desire zero or “negative” bond-financed investment (as in $s_1$ in the Figure 1), $I^{\text{max}}$ is zero. Appendix A summarizes the comparative statics for $I^*, I^{\text{max}}$, and $s(I)$.

**Monopolistic and Competitive Agenda Setting**

In traditional decisive voter models, agenda-setters target the desired level of spending of the decisive voter. Underlying these models is the assumption of a competitive political process in which any agenda deviating from the desires of the decisive voter loses to the one that does not. Niskanen (1975) and Romer and Rosenthal (1979 and 1982) have suggested an alternative model for circumstances in which an agenda-setter is insulated from political competition and can therefore exert control over the agenda to pursue other objectives. The common alternative is to assume a monopolistic agenda-setter whose objective is to maximize the budget used for provision of a public good. With budget-maximizing agenda setting, the setter targets the maximum amount the decisive voter will approve.

In California, a proposed bond issue requires the support of two-thirds of the voters within a community. As a result, the decisive voter is the voter whose desired level of bond-financed investment corresponds to the 33rd percentile of all desired investment levels in the community. Let $I_{33}^*$ denote the desired level of investment by the decisive voter and $I_{33}^{\text{max}}$ denote the maximum level of investment the decisive voter will approve. We assume a constant proportional relationship between $I^*$ and $I^{\text{max}}$ across

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7 In November of 2000 California voters passed Proposition 39, which reduced the required passage rate for school bond referenda from 66.7% to 55%.
individuals: \( I_{\text{max}} = I^* \cdot \theta \), where \( \theta > 1 \) is a constant. Let \( I^A \) denote the agenda-setter’s proposed level of investment: with competitive agenda setting \( I^A = I_{33}^* \), and with budget-maximizing agenda setting \( I^A = I_{33}^{\text{max}} = I_{33}^* \cdot \theta \).

Due to the inherent difficulty in observing individual preferences, especially for public goods, the setter cannot know \( I_{33}^* \) with certainty. Following Romer, Rosenthal, and Munley (1992) we assume the agenda amount under consideration also depends on a “setter-error” resulting from this imperfect information. We specify that a normally distributed error term, \( \varepsilon \), shifts the agenda around the setter’s targeted level of investment:

\[
I^A = \nu \cdot I_{33}^* + \varepsilon, \tag{6}
\]

where \( \nu = 1 \) under competitive agenda setting, \( \nu = \theta \) under budget-maximizing agenda setting and \( \varepsilon \sim N(0, \sigma_\varepsilon) \). Since \( I_{33}^* \), and therefore \( I_{33}^{\text{max}} \), are functions of the income and tax share of the decisive voter as well as the community-level variables all shown in (5), the agenda amount under consideration by the setter in (6) is a function of these same variables, plus the setter-error, \( \varepsilon \):

\[
I^A = \nu \cdot I_{33}^* \left( Y_{33}, \tau_{33} \cdot p, K, R, D, N^{-\gamma}, g \right) + \varepsilon. \tag{7}
\]

The setter presents \( I^A \) to voters as a take-it or leave-it proposal and the proposal passes if two-thirds of voters support it. Applying the simple rule that voters support a proposed bond issue only when it provides positive surplus for them individually, voter \( j \)'s vote on a referendum agenda amount \( I^A \) is described by the dichotomous variable:

\[
\phi_j(I^A) = \begin{cases} 
1 & \text{if } s_j \geq 0 \quad \left( \text{if } I^A \leq I_{33}^{\text{max}} \right) \\
0 & \text{if } s_j < 0 \quad \left( \text{if } I^A > I_{33}^{\text{max}} \right)
\end{cases},
\]

where 1 indicates a ‘yes’ vote on the proposition and 0 indicates a ‘no’ vote. The fraction of voters supporting a proposal, and a linear approximation of that fraction can then be written:

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8 This imposes a restriction on individual preferences reflected in the \( \phi \) function. As noted by Rothstein (1994) this assumption (or something similar) is widely used in voting and budget-maximizing agenda-setter models. See for example, Banks (1993), Ingberman (1983), Rothstein (1994), Romer, Rosenthal and Munley (1992), Romer and Rosenthal (1979 and 1982), and Rubinfeld (1977).
\[ \%\text{yes} = \frac{1}{J} \sum_{j=1}^{J} \phi_j(\mathbf{v} \cdot I^{*}_{33} + \epsilon) \equiv \frac{2}{3} + \kappa \cdot I^{*}_{33} \cdot (\mathbf{v} - \theta) + \kappa \epsilon, \]  

(8)

where the first term in the linear approximation derives from the identity \( \frac{1}{J} \sum_{j=1}^{J} \phi_j(I^{\text{max}}_{33}) \equiv \frac{2}{3} \), and \( \kappa \equiv \frac{1}{J} \left[ 1 \frac{\partial}{\partial I} \phi_j(I) \right] \) captures the marginal effect of changes in the agenda on the proportion of ‘yes’ votes.

With budget-maximizing agenda setting \( \mathbf{v} = \theta \) and the linear approximation above simplifies to

\[ \%\text{yes} \equiv \frac{2}{3} + \kappa \epsilon. \]

Even though the agenda itself (\( I^A \)) depends critically on the characteristics of the decisive voter and on the community-level variables detailed in (7), with budget-maximizing agenda setting the vote outcome is independent of these variables as long as \( \epsilon \) is determined by an independent process. Taking this a step further, if budget-maximizing agenda-setters had perfect information about voter preferences (\( \epsilon = 0 \)), every agenda amount, \( I^A \), under consideration by voters would receive exactly two-thirds of the vote and therefore pass by the narrowest of margins. More likely, the presence of setter errors will shift the fraction of ‘yes’ votes around the setter’s targeted vote outcome of two-thirds of the popular vote. For example, a positive setter error reduces the proportion of ‘yes’ votes because \( I^A \) rises above the \( I^{\text{max}} \) threshold first for the decisive voter, but potentially also for voters with preferences in the neighborhood of the 33rd percentile. The density of voters with preferences in this range, and therefore the impact of a given \( \epsilon \) on the vote outcome, is captured by \( \kappa \). A community consisting of voters with similar preferences will have a distribution of \( I^{\text{max}} \) with greater density in the range around the 33rd percentile, and therefore a larger \( \kappa \), than a community with greater heterogeneity of preferences. Thus, when setters have imperfect information about voter preferences the budget-maximizing model predicts votes outcomes depend on the heterogeneity of voter preferences.

With competitive agenda setting \( \mathbf{v} = 1 \) and the linear approximation in (8) is:

\[ \%\text{yes} \equiv \frac{2}{3} + \kappa \cdot I^{*}_{33} \cdot (1 - \theta) + \kappa \epsilon. \]

Because \( \kappa < 0 \) and \( \theta > 1 \), the sign of the second term, \( \kappa \cdot I^{*}_{33} \cdot (1 - \theta) \), is positive. Consequently, with competitive agenda setting, the fraction of voters favoring any agenda amount, \( I^A \), is greater than two thirds. Intuitively, some voters’ preferences will be such that their \( I^{\text{max}} \) thresholds fall in the range between \( I^{*}_{33} \) and \( I^{\text{max}}_{33} \), implying they are willing to vote for the competitive agenda when they are not willing to vote for the larger budget-maximizing agenda. The density of voters in this range is again captured by \( \kappa \). Romer et al. (1992) demonstrate that with
competitive agenda setting and perfect setter information (i.e. $\varepsilon = 0$), the fraction of yes votes is decreasing in heterogeneity. Equation (8) leads to the same conclusion. Specifically, greater heterogeneity leads to a smaller $\kappa$ and therefore a smaller increase in the fraction of yes votes above two-thirds. Furthermore, note that with competitive agenda setting the fraction of ‘yes’ votes is a function of $I_{33}^*$ and thus clearly depends on the characteristics of the decisive voter and community-level variables.

To summarize, with budget-maximizing agenda setting the expected value of yes votes equals two-thirds and is independent of the characteristics of the decisive voter. In contrast, with competitive agenda setting, the expected value of yes votes is greater than two-thirds and depends on the characteristics of the decisive voter. Furthermore, note the negative relationship between (7) and (8) introduced by $\varepsilon$: a positive setter-error increases $I^*$ and decreases the proportion of ‘yes’ votes (because $\kappa < 0$), and a negative $\varepsilon$ does the opposite. This holds for both the competitive and budget-maximizing models. The setter-error makes the election outcome stochastic, indicating the possibility of both unsuccessful elections and elections passing by a comfortable margin. Furthermore, the random nature of setter-errors has an important implication for the empirical work that follows: unsuccessful elections should be regarded as valid observations of demand as these are simply observations for which the setter-error is positive and sufficiently large. Finally, the role of $\kappa$ in (8) demonstrates that vote outcomes depend on the heterogeneity of community preferences except under the rather strict conditions of budget-maximizing agenda setting with perfect information.

**Election and Flotation Costs**

In the absence of any further constraints, our model predicts a pattern of investment characterized by relatively small and frequent spending proposals. Casual observation suggests however that school capital investment is quite lumpy: we observe relatively large and infrequent spending proposals. To explain that pattern we consider the institutional costs associated with placing an agenda on the ballot, providing information to voters, and the actual flotation of approved general obligation bonds. The evidence indicates that these costs are substantial and can generally be separated into costs associated with 1) the election itself, and 2) floating the bonds. Election costs include the hiring of campaign

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9 Rothstein (1994) provides a detailed discussion of the relationship between vote outcomes and spending proposals with competitive and budget-maximizing agenda-setters. Using a slightly different model he also demonstrates that with competitive agenda setting the vote logit increases with any factor that increases the decisive voter’s ideal point. Equation (8) can be used to demonstrate the same result.

10 Romer, Rosenthal and Munley (1992) derive a similar result. Specifically, they demonstrate that vote outcomes will depend on the heterogeneity of voter preferences except in the special case where a budget-maximizing agenda-setter proposes a budget that exactly equals the maximum amount the decisive voter is willing to accept.

11 The authors are grateful for information on costs provided by Orrick, Herrington & Sutcliffe LLP, Better Schools for California; and school officials from several of California’s school districts.
consultants, purchase of advertising time, and other miscellaneous costs, all of which must be privately financed.\footnote{School district funds can be used directly in the election phase only to conduct a survey of the community to provide guidance on how much should be requested, a step that alone costs between $30,000 and $40,000 for typical districts.} There are also substantial indirect costs associated with the volunteer time of PTA and other interest groups for mailings and grass roots campaigning. Flotation costs are primarily associated with professional financial advice and the underwriting of bonds, but miscellaneous costs accumulate for obtaining a bond rating, filing fees, court fees, certification, printing, and delivery. According to Steiss (1975), “No single cost is large, but in the aggregate these costs can amount to a considerable sum.” Finally, experts emphasize that the largest associated costs may be political. School boards desire to remain in the good graces of the community and its voters and fear that frequent requests for property tax overrides will jeopardize this.

Suppose that the fixed costs associated with bond financing are exogenous and amount to $C$ in a given school district. These costs must be paid out of the surplus pool created among referendum supporters. Thus, we should expect to observe an election only if the surplus pool is sufficiently large to cover $C$, or:

\[(1 − ψ)^N \phi_j \cdot s_j(I^A) > C,\]

where $ψ \in (0,1)$ represents the degree of free-riding and other coordination problems associated with the pooling of surpluses among referendum supporters. If $C$ or $ψ$ is sufficiently large this condition will not be satisfied for small proposed bond issues, as the surpluses generated by the small capital improvements would be insufficient to motivate the voluntary contributions of money and time necessary to see the process through. In practice school boards recognize this absence of political support, and no bond issue is proposed under such circumstances.

Thus, the setter must not only determine the agenda amount, $I^A$, but also whether or not to hold an election. Although an agenda amount exists for each district in each time period, we only observe this amount when an election is held. It is therefore appropriate to view the observation of $I^A$ as subject to the following selection condition:

\[\frac{N \phi_j \cdot s_j (υ \cdot I^* + ε) - C}{(1 − ψ)} = \Lambda^*(C, ψ, (Y_{j3}, τ_{j3}, p, K, R, D, N^{-γ}, g; ε) > 0 \quad (9)\]
In this notation \( Z \) represents the income and tax share characteristics of the other voters (besides the decisive voter) in the community, whose surpluses critically contribute to the selection process. Notice that the determination of the agenda amount in (7) is independent of \( Z, C \) and \( \psi \).

III. Empirical Framework

Equations (7), (8), and (9) represent a three-equation system that forms the basis of our empirical work. The decisive voter’s demand for bond-financed investment is embedded in the “proposed spending equation” detailed in (7). The predictions of two competing agenda setting models: competitive agenda setting, in which the setter targets the desired level of spending of the decisive voter and budget-maximizing agenda setting, in which the setter targets the maximum amount the decisive voter is willing to accept, are nested in the “vote equation” detailed in (8). The final critical component of the model is the “selection equation” detailed in (9). As the primary objective is to make use of referenda data to estimate demand for public capital, it is imperative to recognize that these referenda are not observed randomly, but are subject to a selection process that can be modeled and incorporated in the empirical specification.

Following Bergstrom and Goodman (1973) and others we assume the spending equation is log-linear, implying equation (7) can be expressed:

\[
\ln I^* = \beta_0 + \beta_1 \ln Y_{33} + \beta_2 \ln Y_{33} + \beta_3 \ln W + \beta_4 \nu + \nu_1
\]

where \( W \) is a vector that contains the existing capital stock, \( K \), other government revenue available for capital investment, \( R \), existing debt, \( D \), the price of capital goods, \( p \), and district enrollment, \( N \). The \( \beta' \)'s are parameters to be estimated and \( \nu_1 \) is a normally distributed error term that consists of two components: \( \nu_1 \), an econometric error associated with measurement error and omitted variables in the underlying individual demand function, \( I^* \).

We assume the following functional form for the vote equation:

\[
\ln I^v = \beta_0 + \beta_1 \ln Y_{33} + \beta_2 \ln Y_{33} + \beta_3 \ln W + \beta_4 \nu + \nu_1
\]

\( \nu_1 \) is a normally distributed error term that consists of two components: \( \nu_1 \), the setter-error discussed in the theory section and \( \nu_1 \), an econometric error associated with measurement error and omitted variables in the underlying individual demand function, \( I^v \).

\[\text{(10)}\]

\[\text{13}\] Recall that with budget-maximizing agenda setting \( \nu = \theta \) and hence the constant term, \( \beta_0 \), contains two components: the constant from the underlying individual demand function, \( I^* \), and \( \beta_0 \), the constant that captures the proportional relationship between \( I^* \) and \( I^{\max} \). Furthermore, in the theory section we assumed the setter-error entered the proposed spending equation linearly, but in (10) we have assumed it enters multiplicatively. It can be demonstrated that if we start from a multiplicative structure of the setter-error in equation (6) all the results from the theory section hold.
\[ V = \alpha_0 + \alpha_1 \ln \tau_{33} + \alpha_2 \ln Y_{33} + \alpha_3 \ln W + \alpha_4 g + \alpha_5 Z + \mu_2 \]
\[ \mu_2 = \kappa \epsilon + \nu_2, \]

where \( V = \ln(pyes/(1 - pyes)) \) is the logit of the vote outcome associated with a given spending proposal, \( Z \) is a vector that contains measures of the heterogeneity of preferences for school infrastructure investment, and \( \mu_2 \) is a normally distributed error term. As with \( \mu_1 \), \( \mu_2 \) consists of two components: \( \kappa \epsilon \), the shift in the vote logit due to the setter-error, and \( \nu_2 \), a random disturbance term arising from factors such as uncertainty about voter turnout. In the budget-maximizing model with perfect setter information, theory predicts the proportion of yes votes is independent of both the characteristics of the decisive voter and the heterogeneity of voter preferences, implying \( \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0 \). In the budget-maximizing model with imperfect setter information, theory predicts the vote equation is independent of the characteristics of the decisive voter \( (\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0) \) but depends on the heterogeneity of voter preferences. In addition, both budget-maximizing models predict the expected value of yes votes should equal two-thirds. In contrast, the competitive agenda-setting model predicts the expected value of yes votes is greater than two-thirds and depends on both the characteristics of the decisive voter and the heterogeneity of voter preferences.

Finally, we assume the selection equation is log-linear, implying equation (9) can be expressed:

\[ \Lambda^* = \lambda_0 + \lambda_1 \ln \tau_{33} + \lambda_2 \ln Y_{33} + \lambda_3 \ln W + \lambda_4 g + \lambda_5 Z + \lambda_6 C + \mu_3 \]
\[ \mu_3 = \varepsilon + \nu_3, \]

where \( C \) is a vector that captures fixed election and bond flotation costs. The \( \lambda \)'s are parameters to be estimated and \( \mu_3 \) is a normally distributed error term that once again consists of two components: the setter-error, \( \varepsilon \), and a random error, \( \nu_3 \).

Using equations (10), (11), and (12), a model of demand for local capital spending can be written:

\[ \ln I^4 = \beta_0 + \beta_1 \ln \tau_{33} + \beta_2 \ln Y_{33} + \beta_3 \ln W + \beta_4 g + \mu_1 \]
\[ V = \alpha_0 + \alpha_1 \ln \tau_{33} + \alpha_2 \ln Y_{33} + \alpha_3 \ln W + \alpha_4 g + \alpha_5 Z + \mu_2 \]
\[ \ln I^4 \text{ and } V \text{ unobserved} \quad \text{if } \Lambda^* \leq 0. \]

If sample selection were random, the spending equation and the vote equation would form a seemingly unrelated regression model since the two equations are only related through the error terms \( \mu_i \).
and $\mu_2$, both of which contain the setter-error, $\varepsilon$. However, spending proposals and vote outcomes are only observed if an agenda-setter decides to place a proposal on the ballot ($\Lambda^* > 0$). As a result, our model can be viewed as a seemingly unrelated regression model nested within a sample selection model.

The likelihood function for this model is:

$$L = \prod_{\Lambda \leq 0} \text{Prob}(\Lambda^* \leq 0) \prod_{\Lambda > 0} f(ln I^A, V) f(\Lambda^* | ln I^A, V) d\Lambda^*,$$

where $f(ln I^A, V)$ denotes the joint density of $ln I^A$ and $V$, and $f(\Lambda^* | ln I^A, V)$ denotes the density of $\Lambda^*$ conditional on $ln I^A$ and $V$. To complete the model, we assume $\mu_1, \mu_2$ and $\mu_3$ have a trivariate normal distribution, with mean vector zero and covariance matrix:

$$\Omega = \begin{bmatrix}
\sigma_1^2 & \rho_{12}\sigma_1\sigma_2 & \rho_{13}\sigma_1 \\
\rho_{12}\sigma_1\sigma_2 & \sigma_2^2 & \rho_{23}\sigma_2 \\
\rho_{13}\sigma_1 & \rho_{23}\sigma_2 & 1
\end{bmatrix},$$

where $\rho_{12}, \rho_{13},$ and $\rho_{23}$ denote the correlations between $\mu_1$ and $\mu_2$, $\mu_1$ and $\mu_3$, and $\mu_2$ and $\mu_3$ respectively. Since the parameters of the selection equation can only be estimated up to a factor of proportionality, we assume the variance of $\mu_3$ equals unity. The complete model therefore consists of four sets of parameters to be estimated: the $\beta'$s from the proposed spending equation, the $\alpha'$s from the vote equation, the $\lambda'$s from the selection equation and the variance/covariance parameters, $\sigma_1, \sigma_2, \rho_{12}, \rho_{13},$ and $\rho_{23}$. The log-likelihood function for the complete model is given in Appendix B.

Our use of a sample selection model naturally raises the issue of identification. We rely on exclusion restrictions to identify the parameters of both the proposed spending equation and the vote equation. Theory identifies two exclusion restrictions for the proposed spending equation: both $Z$, the measures of voter preference heterogeneity, and $C$, the fixed election and floatation costs, belong in the selection equation but not in the proposed spending equation. Theory also identifies several exclusion

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14 Because $\nu_2$ is the error associated with an aggregate proportion in a logit model, its variance is $1/[J \cdot p \cdot (1 - p)]$, where $p$ is the fraction of the population favoring a given spending proposal and $J$ is the number of voters. Since both $p$ and $J$ vary across districts, the variance of $\nu_2$ is heteroscedastic. As a result we specify the variance of $\mu_2 = \kappa \varepsilon + \nu_2$ as: $\text{Var}(\mu_2) = \sigma_2^2 = \kappa^2 \sigma_\varepsilon^2 + 1/[J \cdot p \cdot (1 - p)]$. Furthermore, since we do not have data on the number of voters, we use the population of a district as a proxy for $J$. 

13
restrictions for the vote equation. Under the null hypothesis of budget-maximizing agenda setting, the fixed election and flotation costs and all the characteristics of the decisive voter belong in the selection equation but not the vote equation. Under the alternative hypothesis of competitive agenda setting, the fixed election and flotation costs belong in the selection equation but not the vote equation.

IV. Data

Our study is based on data for 304 unified school districts in California over the academic years 1995-1996 to 1999-2000. Data on school district bond proposals (spending proposals) and corresponding vote outcomes were obtained from the California Department of Education and Ed Source, a nonprofit organization that conducts research on K-12 educational issues in California. The dependent variable for the proposed spending equation is the proposed bond issue in district \( i \) in year \( t \). The dependent variable for the vote equation is the vote logit corresponding to the proposed bond issue in district \( i \) in year \( t \). Proposed bond issues were converted to real 1999 dollars using the producer price index. Consistent with the theory, we include both successful and unsuccessful bond proposals in the proposed spending equation and the corresponding vote logits in the vote equation. Of the 304 school districts in the sample, 152 (50\%) held at least one bond election between 1995-96 and 1999-2000. Furthermore, these 152 districts held a total of 201 elections, 115 of which were successful.

Recall that the decisive voter is the voter whose desired level of spending is at the 33.3 percentile of all desired spending levels in the community. Following the tradition of median voter studies, we assume the decisive voter is also the voter with the 33.3 percentile level of income in the community. We constructed estimates of the decisive voter’s income using data from the School District Data Book, a special tabulation of the 1990 Census. The Data Book provides information on the distribution of household income in each district grouped into 25 income categories. We used this grouped income data and linear interpolation to estimate the 33.3 percentile level of income in each district. Note that this estimate of the decisive voter’s income is from the 1990 Census, yet the time period of our analysis spans

\[ \text{14} \]
the years 1995-1996 to 1999-2000. To obtain better estimates of the decisive voter’s income over this
time period we used county-level data on the growth rate of per-capita income from Rand California to
update the decisive voter’s income. We first calculated the growth rate of per-capita income in each
then for each district within a county multiplied income in 1990 by 1 plus these countywide growth rates.
This updating procedure provides us with yearly estimates of the decisive voter’s income within a district.

We used a similar procedure to estimate the decisive voter’s tax share. Because bond issues are
financed through the local property tax, the decisive voter’s tax share is $A_{V_i}$, where $A_{V_i}$ is the assessed
value of the decisive voter’s home and $AV$ is the total assessed value of all property within a district. We
assume the decisive voter lives in the home with the 33.3 percentile level of assessed value. For each
district, we used data from the School District Data Book on the distribution of 1990 house values (which
are also grouped into 25 categories) to estimate the 33.3 percentile level of assessed value and divided this
estimated house value by the total assessed value of all property within the district. Data on the total
assessed value of all property within a district in 1995 were obtained from the Coalition for Adequate
School Housing (CASH), a California school advocacy organization. To update the decisive voter’s tax
share we used the same procedure we used for income.$^{17}$

In the theoretical model, proposed spending is also a function of the existing capital stock, the
existing debt, and other revenue sources available for capital investment. Estimates of the existing capital
stock were constructed using the perpetual inventory method, which assumes the capital stock in any
given year is the sum of past infrastructure investment, adjusted for depreciation. Specifically, the capital
for district $i$ in year $t$ was calculated as:

$$K_t = \sum_{j=0}^{t} (1 - \delta)^{t-j} AI_j,$$

where $K_t$ denotes aggregate capital stock in district $i$ in year $t$, $AI_j$ denotes aggregate investment in year
$j$, measured in constant 1999 dollars, and $\delta$ is the geometric rate of depreciation. Holtz-Eakin (1993)
reports an estimate of the depreciation and discard rate of non-residential state and local capital of 4.1%.
Furthermore, this estimate of the depreciation rate is very close to other estimates of depreciation for non-
residential structures obtained by Hulten and Wykoff (1981) and the Bureau of Economic Analysis. We

$^{17}$ We first calculated the growth rate of the median sale price of single-family homes in each county between 1990
and the corresponding year of our analysis and then multiplied the 1990 district house value by 1 plus these county
growth rates. Using county-level data on total assessed value, we followed the same procedure to update total
assessed value within a district.
therefore chose to use this estimate of the depreciation rate to calculate the aggregate capital stock. Data on aggregate investment for various years were obtained from the *Annual Report of Financial Transactions Concerning School Districts of California*, prepared by the California State Controller. Using those reports we calculated the total capital outlay of each school district from 1968 to the beginning of year \( t \) (1995-1996 to 1999-2000). The nominal investment data were converted into constant 1999 dollars using the producer price index.

Over the period of our analysis, a substantial number of California’s elementary and high school districts were consolidated into unified districts. As a result, 75 of the 304 unified school districts in our sample were established in a year following 1968. For those school districts, we used school district consolidation records, obtained from the California Department of Education, to identify the elementary schools and high schools that merged to form a new unified school district. For the years prior to the formation of a unified school district, we measured total capital outlay for that school district as the sum of all capital outlays made by the elementary and high school districts that eventually consolidated to form the unified district. Using that procedure we were able to obtain a complete time series of annual investment flows for all 304 unified school districts in our sample.

Data on existing debt levels and other revenue sources available for capital investment were obtained from yearly school district accounting records prepared by the California Department of Education. Approximately 75 percent of all school infrastructure revenue in California comes from three sources: local general obligation bonds, state aid (matching and non-matching), and developer fees. School districts also receive revenue from interest income, federal aid, revenue from the sale of lease of land and buildings, and other miscellaneous revenue sources. We define our measure of other revenue sources as the sum of all infrastructure revenue available to a school district in a given year less local general obligation bond revenue and matching state aid. Since the matching rate is the same for all school districts, the impact of matching state aid is captured in the constant term of our model. Yearly data on the amount of non-matching state aid received by school districts were obtained from the California Office of Public School Construction.

The theoretical model also suggests that the demand for school infrastructure investment is a function of the expected growth rates of enrollment, income, tax share, and other revenue sources. We assume the decisive voter applies a simple heuristic rule in forming expectations about these growth rates: future growth rates will mirror growth rates in the previous period. We therefore measure the growth rates of enrollment, income, tax share, and other revenue sources in year \( t \) as the annualized growth rate of those variables during the previous five-year period. For example, we measure enrollment growth in 1995-96 as the annualized growth rate of district enrollment over the period 1990-91 to 1994-95. We constructed the growth rates of enrollment and other revenue sources using data from the California
Department of Education. We used county-level data on per-capita income, total assessed value and the median sale price of single-family homes to construct the growth rates of income and tax share.

We included three variables to capture differences in the cost of educational inputs and construction costs across districts. These variables are: (1) the fraction of schools within a district that are located in an urban area, (2) a dummy variable that takes the value of unity if a school district is located in a Metropolitan Statistical Area (MSA) and zero otherwise, and (3) county-level population density. Data on the urban location of schools and location within an MSA are from the California Department of Education while data on population density is from Rand California.

As discussed in the previous section, our instruments for the selection equation include variables that describe the income and tax share characteristics of the other voters (besides the decisive voter) in the community whose surpluses critically contribute to the selection process and variables that describe election and flotation costs. We utilize two distributional variables to measure the income characteristics of voters within a district: the coefficient of variation for household income and the ratio of the 75th to the 25th percentile of income. These variables were constructed using the grouped income from the School District Data Book. To measure the distribution of tax shares within a district, we used the grouped house value data from the Data Book to construct the same two variables we used to measure the distribution of income.

Election costs are not easily observed. As we noted in section II, however, our conversations with local school officials suggest that the largest cost may be political: frequent requests for property tax overrides may undermine the political support of local voters. We chose two variables to serve as proxies for the “political” costs of proposing a bond issue. The first variable is the percentage of neighboring districts that held a bond election in the previous year. The idea behind our choice is that school boards gain information on the political costs associated with proposing a bond issue from the actions of neighboring districts. If a large fraction of neighboring districts proposed to issue bonds, agenda-setters may conclude that the political costs within their own district are low enough to warrant proposing a bond issue. Furthermore, while this variable is likely to be correlated with the decision to propose a bond issue, it is unlikely to be correlated with the amount proposed. To see this, recall that from (7), spending proposals are solely a function of the income and tax share of the decisive voter and other district-specific characteristics (such as enrollment). As a result, while the actions of neighboring districts are likely to affect the agenda-setter’s decision to propose a bond issue, they are unlikely to affect the amount proposed, which is necessary for a valid instrument. The second variable is the percentage of neighboring districts that held a successful bond election in the previous year. Similar to the percentage of

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18 Ideally we would also like to include some measure of municipal bond interest rates. Unfortunately, data on municipal bond interest rates is unavailable for the vast majority of the school districts in our sample.
neighboring districts that held a bond election, the percentage that held a successful election should provide an agenda setter with better information about the costs of holding an election. In constructing these variables, we used eleven geographical regions, developed by the California Department of Education, to define neighboring districts. We then used the total number of districts (elementary, high, and unified) holding an election and the number of districts holding a successful election within a region to construct the two variables.

The data have a number of limitations. One limitation is that the School District Data Book does not provide data for 14 of the 58 counties in California. Of the 304 school districts in our sample, 25 are located in one of these 14 counties. For these districts, we used county level data to construct estimates of the distribution of income and tax shares within a district and estimates of the decisive voter’s income and tax share. A second limitation concerns school districts that held more than one election in a given year. Of the 150 school districts in our sample that held an election over the sample time period, 12 held two elections in a given year. Since the unit of observation in our analysis is district in year , we averaged the two proposed bond issues and corresponding vote outcomes for these 12 districts to obtain one observation per year on proposed bond issues and vote outcomes.

Our data are summarized in Table 1. Proposed bond issues, the existing capital stock, and other revenue sources and existing debt are reported in per pupil terms for ease of interpretation. Furthermore, the income variable reported in Table 1 represents the decisive voter’s social income as defined in equation (4). Inspection of the table reveals several interesting facts. First, the average fraction of yes votes among the 201 proposed bond-issues was 0.69, a value surprisingly close to 0.667. Second, a comparison of columns three and four reveals that tax shares tended to be substantially lower while incomes tended to be higher in districts that held bond elections. Similarly, both the existing capital stock per pupil and other revenue per pupil tended to be lower in districts that held bond elections.

V. Results

Maximum likelihood parameter estimates for the budget-maximizing model with perfect setter information, the budget-maximizing model with imperfect setter information, and the competitive agenda-setting model are reported in Tables 2 and 3. For comparison across models, Table 2 presents parameter estimates for the proposed spending equation, vote equation and correlation coefficients of each model while Table 3 presents the parameter estimates for the selection equation of each model. The reported standard errors in Tables 2 and 3 are adjusted for clustering within districts to account for the

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19 The eleven geographical regions consist of clusters of adjacent California Counties.
20 The counties are: Butte, El Dorado, Humboldt, Kings, Madera, Mono, Monterey, Napa, San Benito, Shasta, Siskiyou, Tehama, Trinity, and Yolo. With the exception of Monterey, all of these counties are located in rural areas.
fact that unobserved factors that affect proposed bond issues and corresponding vote outcomes within a
district are likely to be correlated.21

Results for the budget-maximizing model with perfect setter information (i.e. no setter errors) are
reported in column 1 of Tables 2 and 3. Recall that if school boards possess perfect information about
voter preferences, theory predicts the fraction of voters favoring a bond issue is independent of both the
characteristics of the decisive voter and the heterogeneity of voter preferences. As a result, the vote
equation for this model contains only a constant term.

The estimated parameters of the proposed spending equation reported in column 1 of Table 2 are
generally consistent with our expectations. The estimated price and income elasticities of demand are
both of the expected sign and statistically significant. Similarly, both the coefficients on the existing
capital stock and other revenue sources are negative and statistically significant while the coefficient on
enrollment growth is positive and statistically significant. Our estimated price and income elasticities are
also generally consistent with those obtained in studies that have examined demand for current school
spending. For example, Bergstrom, Rubinfeld and Shapiro (1982) report estimates of the price elasticity
of demand for current school spending that range from –0.57 to –0.43 and estimates of the income
elasticity that range from 0.83 to 0.38. Other studies report estimates of similar magnitudes. Our
estimates of the price and income elasticities of demand for school infrastructure are -0.64 and 0.84,
slightly higher than estimated price and income elasticities of demand for current school spending.22

The estimated parameters of the selection equation reported in column 1 of Table 3 are also
generally consistent with our expectations. Our results indicate that the probability of an agenda-setter
proposing a bond issue is negatively related to the decisive voter’s tax share and positively related to her
income. Furthermore, consistent with the theory, the probability of proposing a bond issue is negatively
related to the existing capital stock and other revenue sources available for capital investment.

While the results reported in column 1 of Tables 2 and 3 are generally consistent with our
expectations, they are nevertheless inconsistent with the predictions of the budget-maximizing model with
perfect setter information. With perfect information, the correlation between the error in the vote
equation and spending equation, $\rho_{12}$, should be zero since setter-errors don’t enter the model. In contrast,

21 This is particularly true for districts that held a sequence of unsuccessful elections leading up to a successful
election. For sequential elections it seems natural to assume that the agenda-setter gains information from past
elections and uses that information to update their bond proposal. This type of updating will cause the setter-errors
in the system to be correlated within districts.

22 Recall that the income and tax share variables used in our analysis were constructed by updating 1990 district-
level data on income and housing values using county-level growth rates. We examined the sensitivity of our results
to this updating procedure by re-estimating our model using the “untouched” 1990 income and housing value data.
When the 1990 values are used the estimated price elasticity falls from -0.64 to –0.62 and the estimated income
elasticity falls from 0.84 to 0.80. Using the 1990 values has little effect on the remaining coefficients.
if school boards possess imperfect information about voter preferences, theory predicts $\rho_{12}$ should be negative. The estimate of $\rho_{12}$ reported in column 1 of Table 2 is negative and statistically significant, suggesting that school boards possess imperfect information about voter preferences. Furthermore, recall that if school boards act as budget maximizing agenda-setters the expected value of yes votes should equal 0.667, which corresponds to a vote logit of 0.693. Our estimate of the expected value of yes votes is 0.80, which corresponds to a vote logit of 1.43 (i.e. the estimate of $\alpha_0$ in the vote equation). That finding is inconsistent with the predictions of the budget-maximizing agenda setting model.

The results reported in column 1 of Table 2 also suggest that observed spending proposals and vote outcomes suffer from nonrandom sample selection: the estimates of $\rho_{13}$ and $\rho_{23}$ are both statistically significant. The bias introduced by ignoring sample selection is most clearly seen in the vote equation. To illustrate that point note that, assuming $\nu_2$ is independent of $\varepsilon$ and $\nu_3$, the expected value of the vote logit, conditional on a bond issue being proposed is:

$$E[V | A^* > 0] = \alpha_0 + \kappa \cdot E[\varepsilon | \varepsilon > -w\lambda - \nu_3],$$

(13)

where $w$ is a vector that contains all the variables in the selection equation. Equation (13) clarifies the source of the sample selection: a large setter-error makes it more likely that an agenda-setter will propose a bond issue, implying $E[\varepsilon | \varepsilon > -w\lambda - \nu_3] > 0$. In other words, the error term in the selected sample is not random since it contains a disproportionate number of observations for with $\varepsilon > 0$. Since the sign of $\kappa$ is negative, ignoring sample selection biases $\alpha_0$ towards zero. The results reported in column 1 of Table 2 suggest the bias introduced by ignoring sample selection in substantial. Specifically, if sample selection is ignored, and $\alpha_0$ is estimated by simply regressing the vote logit on a constant using the selected sample, the resulting estimate of $\alpha_0$ is 0.80. In contrast, controlling for nonrandom sample selection yields the estimate of $\alpha_0$ reported in column 1 of Table 2, namely 1.43. Note that $\alpha_0 = 0.80$ corresponds to an expected value of yes votes of 0.669 while $\alpha_0 = 1.43$ corresponds to an expected value of yes votes of 0.80. Thus, ignoring nonrandom sample selection not only biases the estimate of $\alpha_0$ downwards by 44% (from 1.43 to 0.80), but would erroneously lead one to conclude that the expected

\[23\] To see this, note that assuming $\varepsilon$, $\nu_1$ and $\nu_2$ are independent $\rho_{12} = \frac{\kappa \sigma_2^2}{\sigma_1 \sigma_2}$. The sign of $\rho_{12}$ therefore depends on $\kappa$, which theory predicts should be negative.
value of yes votes is surprising close to two-thirds, the value predicted by the budget-maximizing agenda setting model.

The results reported in column 1 of Table 2 provide evidence against the budget-maximizing model with perfect information. Consequently, we now turn to testing between the budget-maximizing agenda-setting model with imperfect setter information and the competitive agenda-setting model. Recall that with imperfect setter information, the budget-maximizing model predicts vote outcomes are independent of the characteristics of the decisive voter but depend on the heterogeneity of voter preferences. To control for the heterogeneity of voter preferences we added six variables to the vote equation. The first variable is district enrollment. As noted by Romer et al. (1992), heterogeneity of voter preferences is likely to be greater in large districts than in small districts. That prediction is supported by the work of Munley (1982) who finds that the heterogeneity of voter preferences tends to increase with community size. The second variable is the dummy variable for location outside an MSA. As noted by Kim (1999), residents located in communities located outside an MSA are likely to face a restricted residential choice set leading to greater heterogeneity in voter preferences. The last four variables are measures of the distribution of income and tax shares in a community, namely the coefficient of variation for household income and house values and the ratio of the 75th to the 25th percentile of household income and house values.

Results based on the budget-maximizing model with imperfect setter information are reported in column 2 of Tables 2 and 3. Since the magnitude and statistical significance of the estimates in the proposed spending and selection equations are nearly identical to those reported in column 1 of Tables 2 and 3, we refrain from discussing them again here. The inclusion of the six heterogeneity measures leads to a substantial improvement in the log-likelihood, which increases from -780 to -762. Using a likelihood ratio test, we easily reject the null hypothesis that these additional variables can be excluded from the vote equation. However, while the inclusion of heterogeneity measures in the vote equation substantially improves the log-likelihood of our model, they have little effect on our estimate of the expected value of yes votes. In particular, based on the results reported in column 5 of Table 2, the expected value of yes votes is 0.81, a value that is substantially greater than the value predicted by theory of 0.667. Thus, our results once again appear inconsistent with the budget-maximizing agenda-setter model.

**24** Differences across communities in the monopoly power of agenda-setters provides an alternative rational for including district enrollment and location outside an MSA in the monopolistic agenda-setting model. Specifically, Epple and Zelenitz (1981) demonstrate that the monopoly power of local bureaucrats, and hence the ability of local bureaucrats to pursue their own objectives, is positively related to the size of a jurisdiction and negatively related to the degree of inter-jurisdictional competition.

**25** Furthermore, even though enrollment and location outside of an MSA have a statistically significant effect on the vote logit, those effects are relatively small in magnitude. For example, holding all other variables at their means, our model predicts that in districts located outside an MSA the fraction of voters approving a proposal would be

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Results based on the competitive agenda-setting model are reported in column 3 of Tables 2 and 3. With competitive agenda setting, theory predicts vote outcomes depend on both the variables that determine the decisive voter’s desired level of spending and the heterogeneity of voter preferences. As a result, all the variables that enter the proposed spending equation plus the measures of heterogeneity are included in the vote equation for this model. Column 3 of Table 2 reveals that none of the coefficients on the variables that determine the decisive voter’s desired level of spending (for example income or tax price) are statistically significant in the vote equation. More importantly, adding these variables to the vote equation leads to only a modest improvement in the log-likelihood, from -762 to -755. Based on a standard likelihood ratio test, we fail to reject the null hypothesis that the coefficients on these additional variables are jointly equal to zero.26

To summarize, the results reported in column 2 of Table 2 indicate that the expected value of yes votes is substantially greater than 0.667. That finding is inconsistent with predictions of the budget-maximizing agenda-setting model. Furthermore, the results reported in column 3 of Table 2 indicate that vote outcomes are independent of the characteristics of the decisive voter. That finding is inconsistent with the predictions of the competitive agenda-setting model. Our results therefore present a puzzle: if school boards are not seeking to maximize their budgets, nor are they seeking to target the preferences of the decisive voter, what are they seeking to do?

One possibility is that school boards do indeed act like budget-maximizing agenda-setters but they are risk averse. That is, due to the political and monetary costs associated with holding an election and uncertainty about vote outcomes, the school board’s targeted level of spending is lower than the maximum amount the decisive voter is willing to accept. Risk aversion on the part of the setter can be incorporated formally into our model by redefining the setter-error in equation (6) as:

\[ \varepsilon = c + \eta \]
\[ \eta \sim N(0, \sigma^2) \]

where \( c \) is a constant that captures the degree of risk aversion and \( \eta \) is the random component of the setter error. For risk-neutral setters, \( c \) equals zero. For risk-averse setters, \( c \) is negative. Using equation (14), the vote equation in (8) with risk-averse budget-maximizing agenda setting now becomes:

0.78, while in districts located within an MSA the fraction of voters approving a proposal would be 0.84. District size has an even smaller effect on vote outcomes.

26 The likelihood ratio test statistic is distributed chi-squared with 11 degrees of freedom. At the five-percent significance level, the critical value for our test statistic is 19.68. Using only the selected sample, we also estimated the proposed spending equation by OLS and the vote equation that included all the variables that are in the proposed spending equation by GLS. The adjusted \( R^2 \) of the proposed spending equation was 0.80. In contrast, the adjusted \( R^2 \) of the vote equation was only 0.16.
\begin{equation}
pyes = \frac{2}{3} + \kappa c + \kappa \eta.
\end{equation}

Since both \( \kappa \) and \( c \) are negative, the expected value of yes votes is now greater than two-thirds. In addition, (15) shows that the vote outcome is determined only by the new setter shift, \( \kappa \eta \), and the constant that represents the degree of risk aversion, \( \kappa c \). None of the characteristics of the decisive voter, such as income or tax share, enter the vote equation. The budget-maximizing model with risk aversion is therefore consistent with the results reported in column 2 of Table 2: the expected value of yes votes is greater than two-thirds and vote outcomes are independent of the characteristics of the decisive voter.

While the budget-maximizing model with risk aversion represents a reasonable alternative to the competitive model, it is not the only other alternative. Rothstein (1994) considers two other alternative models: rule-ideal and rule-reversion. The rule-ideal model is similar in spirit to the budget-maximizing model with risk aversion in that spending proposals represent a “compromise” between the decisive voter’s desired level of spending and the maximum amount the decisive voter will approve. However, in contrast to the risk aversion model, the rule-ideal model predicts that vote outcomes depend on the characteristics of the decisive voter.\(^{27}\) That prediction is inconsistent with the results reported in the third column of Table 2. In the rule-reversion model, developed by Denzau and Mackay (1983), spending proposals simply reflect the preferences of the agenda-setter. That is, when formulating a spending proposal, an agenda-setter targets her own desired level of spending. As a result, this model predicts spending proposals should be independent of the characteristics of the decisive voter: a prediction that is clearly inconsistent with the proposed spending equation results reported in Table 2.

**Extensions of the Baseline Specification**

In the results presented so far, we omitted several socio-demographic variables that are often found in studies of demand for locally provided public goods. The exclusion of these variables raises the concern that our results may suffer from omitted variable bias. To address that concern, we added four additional variables to both the proposed spending equation and the selection equation and re-estimated the parameters of the model presented in column 2 of Tables 2 and 3. Those four variables are: (1) the fraction of households that are renters, (2) the fraction of the population age 65 or older, (3) the fraction of the population age 25 or older with a college education, and (4) the fraction of students in a district that are nonwhite. These are all standard variables found in studies that examine the demand for locally provided goods and services. Data on the fraction of households that are renters, the fraction of the

\(^{27}\) See Rothstein (1994) and Denzau and Mackay (1983) for details on the rule-ideal and rule-reversion models.
population age 65 or older, and the fraction of the population with a college education are from the
School District Data Book. Data on the fraction of students in a district that are nonwhite are from yearly
demographic reports prepared by the California Department of Education.

Results based on this expanded set of explanatory variables are reported in Table 4. The
magnitude and statistical significance of the estimated parameters in the vote equation and selection
equation were nearly identical to those reported in column 2 of Tables 2 and 3. As a result, we have
refrained from reporting them again in Table 4. To facilitate comparisons between results, the
parameter estimates for the proposed spending equation reported in column 2 of Table 2, are replicated in
column 2 of Table 4. The inclusion of these additional variables has only a modest effect on our
parameter estimates. The estimated price elasticity decreases from 0.64 to 0.62 while the estimated
income elasticity increases from 0.83 to 0.85. The most notable change is the coefficient on the existing
capital stock. That coefficient decreases from −0.30 to −0.17 and becomes statistically insignificant.
Finally, note that the inclusion of the four socio-demographic variables increases the magnitude and
statistical significance of all three of the estimated correlations. Thus, our results once again suggest that
ignoring sample selection would lead to biased estimates of the parameters in the proposed spending and
vote equations.

As we noted previously, our results suggest that ignoring sample selection leads to an estimate of
the unconditional mean of the vote equation that is biased towards zero. It is also instructive to see how
ignoring sample selection affects the estimated parameters in the proposed spending equation. Columns 4
and 5 of Table 4 present the results obtained when the proposed spending equation was estimated by
ordinary least squares, ignoring sample selection. The results suggest that failure to control for sample
selection causes attenuation bias in the estimates. For example, comparing the results reported in
columns 2 and 4, we see that ignoring sample selection causes the estimated coefficient on income to fall
by 19 percent, from 0.83 to 0.67. Similarly, the magnitude of the estimated coefficient on the existing
capital stock falls by 27 percent, from −0.30 to −0.22. A comparison of the results reported in columns 3
and 5 leads to a similar conclusion.

Scale Economies in Producing School Quality

In the model developed thus far, the parameter $\gamma$, which measures the degree of scale economies
in producing school quality, is unidentified. By imposing a restriction on the school quality production

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28 Among the four variables added to the selection equation, only the fraction of renters was statistically significant.
The coefficient on that variable was positive, suggesting that an increase in the fraction of renters increases the
likelihood that an agenda-setter will propose a bond issue.
function \( f() \) in (2), the model can be recast in a manner that allows us to identify \( \gamma \). Specifically, if we assume that \( f() \) is homogeneous of degree 1 (HOD1), (2) can be written:

\[
Q_t = f\left( \frac{L_t}{N^\gamma}, \frac{K_t}{N^\gamma} \right), \quad (2')
\]

where the variables \( \frac{K}{N^\gamma} \) and \( \frac{L}{N^\gamma} \) can be regarded as “effective” levels of labor and capital in the education production function. It is straightforward to show that if the model is recast in terms of “effective” inputs, the proposed spending equation defined in (7) can be re-written:

\[
\frac{I^A}{N^\gamma} = \upsilon \cdot I^*(Y_{33}, (p \cdot \tau_{33} \cdot N^\gamma), (K \cdot N^{-\gamma}), (R \cdot N^{-\gamma}), D, g) + \varepsilon, \quad (7')
\]

where the term \( p \cdot \tau_{33} \cdot N^\gamma \) denotes the tax price facing the decisive voter. Assuming this function is log-linear, (7') can be expressed as:

\[
\ln I^A = \beta_0 + \beta_1 \ln \tau_{33} + \beta_2 \ln Y_{33} + \beta_3 \ln K + \beta_4 \ln R + \beta_5 \ln N + \beta_6 \ln p + \beta_7 \ln D + \beta_8 g + \mu_1, \quad (10')
\]

where the coefficient on enrollment, \( \beta_5 \), equals \( \gamma \cdot (1 + \beta_1 - \beta_3 - \beta_4) \). Thus, under the assumption that the education production function is HOD1, \( \gamma \) can be estimated by computing the ratio \( \beta_5 / (1 + \beta_1 - \beta_3 - \beta_4) \).

Using the parameter estimates on enrollment, tax share, the existing capital stock and other revenue sources reported in the second column of Table 4 the implied estimate of \( \gamma \) is 1.01, an estimate that is surprisingly close to unity. Similarly, based on the parameter estimates from the expanded specification reported in the third column of Table 4 the implied estimate of \( \gamma \) is 1.03. Thus, our results suggest that school infrastructure is highly congestible: a doubling of enrollment requires a doubling of spending on school infrastructure to keep school quality constant.

VI. Conclusion

In California, like most states, the primary responsibility for financing school infrastructure rests at the local level. Despite that fact, very little research has been conducted on the demand for local school infrastructure investment. This stands in sharp contrast to the large body of literature on demand for current school spending. In this paper, we developed a framework for estimating demand for school
We applied our framework to the estimation of demand for school infrastructure investment among California’s unified school districts. Our key findings can be summarized as follows. First, our results indicate that, all else equal, agenda-setters in communities with lower tax prices and/or higher incomes are more likely to propose bond issues and will propose higher spending levels when they do. Second, our results support the hypothesis that observed bond proposals are not randomly observed. Furthermore, we find that failure to control for nonrandom sample selection can substantially bias estimates of key demand parameters such as estimates of the price and income elasticity of demand. Third, we find that school infrastructure is essentially a private good in the sense that it appears to be highly congestible. Our estimates of the crowding parameter, $\gamma$, range between 1.01 and 1.03 suggesting that a doubling of enrollment requires approximately a doubling of spending on school infrastructure to keep school quality constant. Finally, our results shed some light on the objective function of local school boards: they appear to act like risk-adverse budget-maximizing agenda setters. This last finding is consistent with the results of Rothstein (1994), who uses referenda proposals for current school spending to examine the objective function of local school boards. Specifically, Rothstein notes that his results are “consistent with a model of budget maximization in which the setter is poorly informed about voter preferences (Rothstein pp. 385).” Our findings lead to a similar conclusion.

On a final note, we want to stress that although we have taken particular care to incorporate the institutional environment of bond referenda into our framework, we have also abstracted from one critical component of local public goods provision, namely Tiebout sorting. To the extent that families sort themselves among school districts based on the quality of a district’s capital stock, our estimates of the price and income elasticity of demand for school infrastructure will be biased. We do not know how serious a problem Tiebout sorting poses for school capital; however, within the context of local demand for current school spending, Rubinfeld, Shapiro and Roberts (1987) and Reid (1990) find that Tiebout sorting does bias estimates of the price and income elasticity of demand for schooling. Of course, relative to current school spending, school capital spending represents a much smaller fraction (approximately ten percent) of total school spending and thus is likely to have a smaller effect on residential location choices. Nevertheless, examining the impact of Tiebout sorting on the demand for school infrastructure represents a natural extension of the work we have begun in this paper.
References


Table 1  
Summary Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>All Districts</th>
<th>Districts With Proposed G.O. Bond Revenue</th>
<th>Districts Without Proposed Bond Revenue</th>
</tr>
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<tr>
<td>Proposed Bond Revenue per Pupil</td>
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<td>(3,096)</td>
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<td>(0.09)</td>
<td>(0.09)</td>
</tr>
<tr>
<td>Tax Share <em>(times 1,000)</em></td>
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<td>(0.55)</td>
<td>(0.55)</td>
</tr>
<tr>
<td>Income</td>
<td>32,523</td>
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<td>(13,571)</td>
</tr>
<tr>
<td>Capital Stock Per Pupil</td>
<td>6,050</td>
<td>(3,684)</td>
<td>(3,684)</td>
</tr>
<tr>
<td>Other Revenue Per Pupil</td>
<td>649</td>
<td>(531)</td>
<td>(531)</td>
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<tr>
<td>Debt per Pupil</td>
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<td>(2,545)</td>
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<td>(41,049)</td>
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<td>(0.35)</td>
<td>(0.35)</td>
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<td>Tax Share Growth</td>
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<td>(0.30)</td>
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<tr>
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<td>(1,361)</td>
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<td>(0.23)</td>
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<tr>
<td>Home Value CV</td>
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<td>(0.15)</td>
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<tr>
<td>75th / 25th Income</td>
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<td>(0.56)</td>
<td>(0.56)</td>
</tr>
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<td>75th / 25th Home Value</td>
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<td>(0.37)</td>
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<td>Fraction of Neighboring Districts w/Election</td>
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<tr>
<td>Fraction of Neighboring Districts w/Successful Election</td>
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<td>(0.04)</td>
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Table 2
Proposed Spending and Vote Equations

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<th>Variable</th>
<th>Budget-Maximizing Perfect Information</th>
<th>Budget-Maximizing Imperfect Information</th>
<th>Competitive</th>
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</thead>
<tbody>
<tr>
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<td>Proposed Spending</td>
<td>Vote</td>
<td>Proposed Spending</td>
</tr>
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<td>1.43 a (0.26)</td>
<td>2.14 (1.75)</td>
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<td>-0.64 a (0.12)</td>
<td>-0.63 a (0.12)</td>
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<tr>
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<td>0.83 a (0.14)</td>
<td>0.82 a (0.15)</td>
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<td>-0.30 a (0.12)</td>
<td>-0.30 a (0.12)</td>
</tr>
<tr>
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<td>-0.012 (0.013)</td>
<td>-0.012 (0.013)</td>
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<tr>
<td>Enrollment</td>
<td>0.79 a (0.17)</td>
<td>0.82 a (0.17)</td>
<td>-0.12 a (0.03)</td>
</tr>
<tr>
<td>Enrollment Growth</td>
<td>4.32 a (1.93)</td>
<td>4.36 a (1.93)</td>
<td>4.16 a (1.98)</td>
</tr>
<tr>
<td>Other Revenue Growth</td>
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<td>-0.19 (0.13)</td>
<td>-0.21 (0.10)</td>
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<td>Tax Share Growth</td>
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<tr>
<td>Income Growth</td>
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<td>0.23 b (0.14)</td>
<td>0.23 b (0.14)</td>
<td>0.21 (0.15)</td>
</tr>
<tr>
<td>Outside MSA</td>
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<td>0.23 b (0.13)</td>
<td>-0.34 a (0.09)</td>
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<td>Population Density</td>
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<td>-0.24 (0.19)</td>
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<td>75th / 25th Income</td>
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<td>0.08 (0.17)</td>
<td>0.17 (0.18)</td>
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<td>0.20 (0.24)</td>
<td>0.15 (0.23)</td>
</tr>
<tr>
<td>$\rho_{12}$</td>
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<td>-0.37 a (0.15)</td>
<td>-0.34 (0.27)</td>
</tr>
<tr>
<td>$\rho_{13}$</td>
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<tr>
<td>$\rho_{23}$</td>
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<td>-0.74 a (0.13)</td>
<td>-0.67 (0.42)</td>
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Notes: (1) Standard errors are shown in parentheses. (2) The spending equations in columns 1, 2, and 3 and the vote equations in columns 2 and 3 also include year dummies. (3) a indicates significant at the five-percent level, b indicates significant at the ten-percent level.
<table>
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<th>Variable</th>
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<th>Budget-Maximizing Imperfect Information</th>
<th>Competitive Model</th>
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<td>-6.04 (^a)</td>
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<td>(1.87)</td>
<td>(1.96)</td>
</tr>
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<td>-0.16 (^a)</td>
<td>-0.14 (^a)</td>
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<tr>
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<td>(0.08)</td>
<td>(0.08)</td>
<td>(0.09)</td>
</tr>
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<td>0.54 (^a)</td>
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<td>(0.14)</td>
<td>(0.16)</td>
</tr>
<tr>
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<td>-0.19 (^a)</td>
<td>-0.16 (^a)</td>
<td>-0.18 (^a)</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.08)</td>
<td>(0.08)</td>
</tr>
<tr>
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<td>-0.20 (^a)</td>
<td>-0.19 (^a)</td>
</tr>
<tr>
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<td>(0.05)</td>
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<tr>
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<td>-0.007</td>
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<td>(0.02)</td>
<td>(0.02)</td>
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<td>0.36 (^a)</td>
<td>0.40 (^a)</td>
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<td>(0.11)</td>
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<td>0.89</td>
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<td>4.77</td>
</tr>
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<td>(4.35)</td>
<td>(4.87)</td>
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<td>-0.06</td>
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<td>0.31 (^a)</td>
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<td>(0.12)</td>
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<td>0.08</td>
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<tr>
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<td>(0.16)</td>
<td>(0.19)</td>
<td>(0.20)</td>
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<td>0.16</td>
</tr>
<tr>
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<td>(0.35)</td>
</tr>
<tr>
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<td>0.16</td>
</tr>
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<td>(0.27)</td>
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<td>75(^{th}) / 25(^{th}) Home Value</td>
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<td>(0.25)</td>
</tr>
<tr>
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<td>4.28 (^a)</td>
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<td>w/Election</td>
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<td>Fraction of Neighboring Districts w/Successful Election</td>
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<tr>
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<td>(2.31)</td>
<td>(2.24)</td>
<td>(2.92)</td>
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Notes: (1) Standard errors are shown in parentheses. (2) All equations also include year dummies. (3) \(^a\) Indicate coefficient is significant at the five-percent level, \(^b\) indicates coefficient is significant at the ten-percent level.
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<td>Proposed Spending Expanded</td>
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<td>Proposed Spending Expanded</td>
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<td>(0.12)</td>
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<td>(0.12)</td>
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<td>(0.15)</td>
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<td>(0.17)</td>
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<td>Enrollment Growth</td>
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<td>4.31&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>(1.95)</td>
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<td>Tax Share Growth</td>
<td>2.60</td>
<td>4.16&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.09</td>
<td>4.95&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>(2.75)</td>
<td>(2.52)</td>
<td>(2.80)</td>
<td>(2.68)</td>
</tr>
<tr>
<td>Income Growth</td>
<td>0.07</td>
<td>-2.52</td>
<td>-0.79</td>
<td>-2.58</td>
</tr>
<tr>
<td></td>
<td>(5.81)</td>
<td>(5.30)</td>
<td>(5.81)</td>
<td>(5.36)</td>
</tr>
<tr>
<td>Urban</td>
<td>0.23</td>
<td>0.09</td>
<td>0.14</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>(0.14)</td>
<td>(0.15)</td>
<td>(0.14)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>Outside MSA</td>
<td>0.23&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.42&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.15</td>
<td>0.28&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>(0.13)</td>
<td>(0.15)</td>
<td>(0.14)</td>
<td>(0.16)</td>
</tr>
<tr>
<td>Population Density</td>
<td>-0.034</td>
<td>-0.076&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.033</td>
<td>-0.065&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>(0.036)</td>
<td>(0.033)</td>
<td>(0.038)</td>
<td>(0.035)</td>
</tr>
<tr>
<td>Fraction Renters</td>
<td>0.96&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td>0.66</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.55)</td>
<td></td>
<td>(0.57)</td>
<td></td>
</tr>
<tr>
<td>Fraction Age 65 or Older</td>
<td>1.55</td>
<td></td>
<td>1.46</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.15)</td>
<td></td>
<td>(1.32)</td>
<td></td>
</tr>
<tr>
<td>Fraction Nonwhite</td>
<td>0.58&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.26)</td>
<td></td>
<td>(0.27)</td>
<td></td>
</tr>
<tr>
<td>Fraction College Educated</td>
<td>1.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td>1.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
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<tr>
<td></td>
<td>(0.43)</td>
<td></td>
<td>(0.43)</td>
<td></td>
</tr>
<tr>
<td>ρ₂₁</td>
<td>-0.37&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.49&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ρ₂₃</td>
<td>0.57&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.61&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.16)</td>
<td>(0.13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ρ₃₃</td>
<td>-0.74&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.13)</td>
<td>(0.08)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log-Likelihood / Adjusted R²</td>
<td>-762</td>
<td>-753</td>
<td>0.80</td>
<td>0.81</td>
</tr>
<tr>
<td>Observations</td>
<td>1,520</td>
<td>1,520</td>
<td>189</td>
<td>189</td>
</tr>
</tbody>
</table>

Notes: (1) Standard errors are shown in parentheses. (2) The spending equation, vote equation, and selection equation also include year dummies. (3) <sup>a</sup> indicates significant at the five-percent level, <sup>b</sup> indicates significant at the ten-percent level.
Appendix A
Comparative Statics

<table>
<thead>
<tr>
<th>Variable</th>
<th>$I^*$, $I^{max}$, $S(I)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M$</td>
<td>+</td>
</tr>
<tr>
<td>$t$</td>
<td>-</td>
</tr>
<tr>
<td>$K$</td>
<td>-</td>
</tr>
<tr>
<td>$D$</td>
<td>-</td>
</tr>
<tr>
<td>$R$</td>
<td>-</td>
</tr>
<tr>
<td>$N$</td>
<td>?</td>
</tr>
</tbody>
</table>

For the most part these are intuitively clear. For example, higher income leads to a higher level of desired investment, and a larger existing capital stock leads to a lower desired level of investment. However, the effect of greater enrollment is ambiguous. On the one hand, higher enrollment reduces school quality through equation (2), and thus increases the willingness to trade consumption for larger investments in school quality. On the other hand, higher enrollment reduces the return to investment since it makes improvements in school quality more expensive. Derivations of these comparative static results are available upon request.
Appendix B
The Log-Likelihood Function

To simplify notation, redefine equations (10)-(12) respectively as:

\[ y_1 = x_1 \beta + \mu_1 \]
\[ \mu_1 = \epsilon + \nu_1 \]
\[ y_2 = x_2 \alpha + \mu_2 \]
\[ \mu_2 = \kappa \epsilon + \nu_2 \]
\[ y_3 = z \delta + \mu_3 \]
\[ \mu_3 = \epsilon + \nu_3 \]

Assume \( \mu_1, \mu_2 \) and \( \mu_3 \) have a trivariate normal distribution, with mean vector zero and covariance matrix:

\[
\Omega = \begin{bmatrix}
\sigma_1^2 & \rho_{12} \sigma_1 \sigma_2 & \rho_{13} \sigma_1 \\
\rho_{12} \sigma_1 \sigma_2 & \sigma_2^2 & \rho_{23} \sigma_2 \\
\rho_{13} \sigma_1 & \rho_{23} \sigma_2 & 1 \\
\end{bmatrix}
\]

For the \( i^{th} \) observation, the log likelihood function for the model is:

\[
\ln L = \ln \Phi \left( \frac{z \delta + \frac{1}{\left(1 - \rho_{12}^2\right)} \left[ \rho_{13} \omega_1 - \rho_{12} \rho_{23} \omega_1 + \rho_{23} \omega_2 - \rho_{12} \rho_{13} \omega_2 \right]}{\sqrt{1 - \frac{1}{\left(1 - \rho_{12}^2\right)} \left[ \rho_{13}^2 + \rho_{23}^2 - 2 \rho_{12} \rho_{13} \rho_{23} \right]}} \right) - \ln(2\pi) - \ln(\sigma_1 \sigma_2 \sqrt{1 - \rho_{12}^2}) - \frac{1}{2} \left( \frac{\omega_1^2 + \omega_2^2 - 2 \rho_{12} \omega_1 \omega_2}{(1 - \rho_{12}^2)} \right)
\]

where, \( \omega_1 = \frac{y_1 - x_1 \beta}{\sigma_1}, \quad \omega_2 = \frac{y_2 - x_2 \alpha}{\sigma_2} \).