

Modeling the Spending and Welfare Effects of School Finance Reforms

Aaron Goodman*
MIT

December 24, 2020

Abstract

The dual nature of American education funding complicates the analysis of school finance policy, since districts can adjust their local revenue collection in response to state funding changes and use accumulated savings buffers to divorce spending choices from current revenue levels. Focusing on the helpful institutional setting in the state of Ohio, I address this challenge and evaluate the long-run consequences of school finance reforms. I first build a dynamic model of school district behavior and validate its reduced-form predictions about levy-proposal and spending-saving decisions. Leveraging the variation induced by a statewide freeze on nominal property-tax revenue, I estimate the model and use the structural results to compute the spending and welfare effects of counterfactual policy reforms. By targeting districts with the most favorable behavioral responses and the highest valuations of marginal funds, budget-neutral reallocations of state aid can attain welfare increases equal to 4% of Ohio's current education expenditures.

*Contact: agoodm@mit.edu. For helpful advice and comments, I thank David Autor, Jon Cohen, Amy Finkelstein, Jonathan Parker, Jim Poterba, Tobias Salz, and the participants of the MIT third-year and public finance lunches. I also thank Adam Isen for graciously sharing his 1990s levy-voting data. This material is based upon work supported by the National Science Foundation Graduate Research Fellowship Program under Grant No. 1122374. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

1 Introduction

In the American education finance system, school districts rely on both funding from state governments and their own local tax collection. Discussions of school finance policy, however, are often incomplete, neglecting the ways in which districts' independent financial decisions shape the long-run consequences of state-level reforms. Because districts can adjust their local revenue collection in response to state funding changes, and can use savings buffers to divorce spending choices from current revenue levels, evaluating prospective state-level finance reforms is not a straightforward accounting exercise. It is instead an equilibrium problem, requiring quantitative predictions about districts' likely behavioral responses. State funding increases may crowd out local revenue collection, state funding cuts may be replaced by local tax hikes, and short-run shifts in state aid may be smoothed away by districts' savings buffers. The ability of districts to substitute between funding sources and run unbalanced budgets complicates the analysis of school finance policy.

I address these challenges, and fill a gap in the education finance literature, by developing a method to predict the long-run effects of school finance reforms. I exploit a unique institutional setting in the state of Ohio, where a 1970s law fixes school districts' property tax revenue in nominal terms. Since input costs like teacher salaries are not nominally capped, the law causes districts' real spending power to decline constantly with the rate of inflation between passed levies. The nominal freeze on property tax revenue combines with large state funding shifts during the period of study to create a substantial amount of year-to-year variation in districts' financial resources. To maintain stable spending levels in this environment, districts must put large numbers of local tax levies on the ballot and use careful spending-saving decisions to manage their precautionary asset buffers.

These spending-saving and levy-proposal decisions provide exactly the type of information needed to conduct counterfactual policy analysis. Intuitively, school districts' observed responses to past fluctuations in financial resources are informative about their likely reaction to hypothetical future changes in state funding. Districts save less, and are more likely to put levy proposals on the ballot, when their marginal utility of spending is high. Their historical behavior can thus be used to predict how counterfactual state funding changes would shift their marginal utility of spending and alter their financial choices. The underlying preferences that rationalize empirical spending and levy decisions also allow the cross-district marginal-utility comparisons that are necessary to evaluate the welfare consequences of redistributing state aid.

I develop a dynamic model of school district behavior and show that its qualitative predictions regarding levy-proposal and spending-saving decisions hold empirically. The key primitives of the model are districts' concave utility functions and a no-borrowing constraint, which together cause the marginal utility of spending to be highest when cash on hand is low. Districts must also bear a fixed cost whenever they propose a levy to voters. As a result, the model predicts that levy proposals are more likely when low cash-on-hand levels raise the value of incremental local tax revenue. Optimizing districts in the model also show a positive correlation between budget surpluses and current revenue; particularly given the continuous downward trajectory of real property tax receipts, asset buffers should be replenished when revenue is high (in anticipation of future revenue decreases) and drawn on when revenue is low (in anticipation of future levy proposals). Straightforward reduced-form tests confirm

these patterns in the data and demonstrate that districts perform the dynamic optimization posited in the model.

After estimating a fully parameterized version of the model and recovering the utility functions and levy-proposal costs that govern district behavior, I proceed to policy analysis. The structural estimates allow me to simulate the reactions of individual districts to changes in their state funding levels, and to compute the effects of policy changes accounting for these predicted behavioral responses. The full effects of school finance reforms on spending levels take several years to appear, as districts react in the short run by saving into or drawing down their existing asset buffers. Long-run spending effects are determined by the extent of districts' offsetting adjustments to local revenue collection, which vary because of differences in estimated structural parameters and initial financial conditions. Suburban and lower-poverty rural districts – with relatively concave utility functions and low levy-proposal costs – experience larger shifts in marginal utility and are more likely to alter their levy-proposal decisions following state aid changes. In expectation, the most responsive of these districts replace about 12% of moderate state aid cuts by proposing and passing additional local tax levies; they also allow moderate state aid increases to crowd out levy proposals and reduce local revenue collection by about 8%. Urban and higher-poverty rural districts, in contrast, allow state funding changes to pass through roughly one-for-one into long-run spending levels.

Finally, I use the structural estimates and simulation results to make normative statements about optimal policy. Doing so requires stronger assumptions than the descriptive analysis; most importantly, I must treat the recovered district utility functions as welfare-relevant measures of the social value of educational spending. Conditional on these assumptions, I can solve for the optimal budget-neutral school finance reform that reallocates Ohio's state aid expenditures to maximize the long-run change in statewide average welfare. By redirecting state aid dollars to districts with the most favorable behavioral responses and the highest valuations of marginal funds, the solution raises statewide welfare by a consumption-equivalent amount of \$216 per student (about 4% of state expenditures). Because suburban districts have the least favorable behavioral responses and lowest marginal utilities of spending, optimal policy reduces their state funding levels by an average of about \$1,500 per student and uses the proceeds to boost state aid for urban and rural districts. The substantial welfare increase attained by a budget-neutral reform suggests that state aid is currently misallocated, and in particular that policymakers have not gone far enough in redistributing away from wealthier suburban communities.

I add to a well-developed empirical literature on school finance reforms. Most papers in this literature use historical state-level finance reforms as exogenous policy shocks and examine their effects on the distribution of education spending (Manwaring and Sheffrin 1997; Murray, Evans, and Schwab 1998; Hoxby 2001; Card and Payne 2002; Dee 2004; Chung 2015) as well as student outcomes like test scores and future labor earnings (Downes and Figlio 1997; Guryan 2001; Papke 2005; Roy 2011; Jackson, Johnson, and Persico 2016; Lafortune, Rothstein, and Schanzenbach 2018; Biasi 2019).¹ These reduced-form studies

¹Hoxby (2001) deserves special mention because she comes closest to putting the type of economic structure on the school district's problem that I do here. In particular, she writes down the budget constraints imposed on districts by various types of school finance systems and summarizes state funding policies with intuitive price and income effects. Her modeling is insightful but not detailed enough to serve as the basis

provide rigorous evidence on the effects of past reform efforts and together constitute an impressive base of knowledge about the empirical operation of school finance policy. They also establish the relevance of state financing decisions to real education outcomes, since they generally conclude that shifts in state funding have the power to raise student achievement in disadvantaged districts. Motivated by these findings, I approach the school finance question from a different angle: rather than using observed finance reforms as a source of exogenous variation in district expenditures, I model the underlying spending-saving and levy-proposal decisions that determine how state funding shifts ultimately map into the distribution of spending across districts. I can then ask forward-looking policy-evaluation questions: which districts exhibit the largest behavioral responses to policy changes? Exactly how much of a counterfactual state funding change would be undone by districts’ offsetting adjustments in saving and local revenue collection? Among a menu of feasible policy options, which would be most cost-efficient or welfare-enhancing?

The modeling and empirical work that I undertake also builds upon the contributions of several related strands of the public finance literature. In modeling school districts as forward-looking agents, I follow the lead of [Holtz-Eakin and Rosen \(1989\)](#), who provide the first evidence of dynamic behavior among local government entities. Though ensuing papers disagree on the extent to which municipal governments are forward-looking (see [Holtz-Eakin, Rosen, and Tilly 1994](#); [Dahlberg and Lindstrom 1998](#); [Borge and Tovmo 2007](#); [Craig et al. 2016](#)), I present compelling evidence of Ohio districts’ dynamic behavior and use it to estimate my structural model. In studying how state funding changes pass through to districts’ spending levels, I address questions closely related to those examined in the “flypaper effect” literature ([Henderson 1968](#), [Gramlich 1969](#), [Wyckoff 1991](#), [Hines and Thaler 1995](#)), which documents that local governments’ propensity to spend out of intergovernmental transfers is often much higher than the elasticity of local public goods spending with respect to residents’ incomes. By treating school districts as independent decision-makers that are distinct from their residents and explicitly modeling the levy-proposal process that mediates the long-run effects of state funding shifts, I provide microfoundations for the existence of flypaper effects and offer an empirical method for determining their quantitative importance when evaluating policy. My treatment of the levy-proposal decision also draws on the “proposal games” literature ([Romer and Rosenthal 1979](#); [Romer and Rosenthal 1982](#); [Rothstein 1994](#); [Balsdon, Brunner, and Rueben 2003](#)), though I expand on this literature’s generally static analysis by embedding levy decisions within a larger dynamic model of revenue and spending choices.² Finally, I add to a small group of papers that exploit the large volume of property tax levies in Ohio: [Isen \(2014\)](#) examines fiscal spillovers between neighboring school districts and municipalities, while [Enami \(2018\)](#) uses close levy votes as a source of variation in a regression-discontinuity study of the returns to educational expenditures.

The remainder of the paper is organized as follows. Section 2 briefly discusses the institutional environment in Ohio and Section 3 describes the data used in the paper. Section 4 outlines the main model of school district behavior. Section 5 presents reduced-form evidence that confirms the model’s key qualitative predictions. Section 6 describes the strategy I use

of structural estimation, and her empirical analysis, like the rest of the prior literature, is reduced-form.

²My approach also differs from that of [Cellini, Ferreira, and Rothstein \(2010\)](#); [Enami \(2018\)](#); [Baron \(2019\)](#); and [Abbott et al. \(2020\)](#), who use observed school district levy votes as sources of exogenous variation in regression-discontinuity setups rather than modeling the levy-proposal decision itself.

to estimate a fully parameterized version of the model, and Section 7 uses the structural estimates to conduct counterfactual policy analysis. Section 8 concludes.

2 Ohio’s School Finance System

Several features of the school finance system in Ohio make the state an opportune setting for studying school districts’ financial behavior. First, under Ohio law, school districts are distinct, autonomous entities that operate independently from the cities and counties in which they are located.³ As a result, districts maintain their own budgets and make their own levy-proposal decisions, without the aid or interference of other municipal authorities. This simplifies the analysis considerably relative to settings where school districts are fiscally dependent on their localities:⁴ I do not have to make inferences about the share of larger municipal budgets or levy revenue streams dedicated to school districts, nor do I have to model municipal governments’ spending allocation decisions (where schools compete for funds with, e.g., fire, police, and public works departments). In the model described in Section 4, the decision-maker is a school district with an independent budget and a utility function that depends only on its current level of education spending.

Second, school districts in Ohio rely heavily on both state and local funding: the average district in my sample receives 45% of its annual revenue from the state and 49% from local taxes, with the remaining 6% coming from the federal government. Since the goal of this paper is to study the equilibrium problem in which state funding changes prompt districts to adjust their financial decision-making and alter their local revenue collection, the model and counterfactual analysis are most applicable to settings where both state and local funding are important components of school districts’ budget constraints. Ohio is not special in this regard; in the 2015-16 school year, only school districts in Hawaii, New Mexico, and Vermont received an average of less than 20% of their revenue from local taxes.⁵ I merely note that the interaction between state and local funding is indeed present in Ohio, and that the presence of this interaction in the vast majority of other states makes the analysis here broadly applicable.

Third, Ohio school districts’ property tax collections are governed by a unique regulation that creates helpful empirical variation. Commonly referred to as HB 920 and passed during the era of steep property value inflation in the 1970s, this law freezes the nominal value of property tax levies for their entire lives. For example, suppose voters in a school district approve a 5-year, 1% property tax levy and that the aggregate value of property in the district is initially \$1,000,000. The levy thus raises \$10,000 in revenue in its first year. Suppose further that the following year, the property base appreciates in value to \$1,100,000. Then without any action from the school district or from voters, the tax rate is automatically reduced by the same factor, to 0.909%, so that the levy again raises exactly \$10,000 in its

³Indeed, it is common for Ohio school districts to cross municipal boundaries and accept students from multiple cities and/or counties.

⁴See, for example, the school finance systems in Alaska, Connecticut, Hawaii, Maine, Maryland, Massachusetts, New Hampshire, and North Carolina, where some or all school districts are fiscally dependent on larger municipal authorities.

⁵See Table 2 in [Skinner \(2019\)](#).

second year. The same adjustments are made annually so that the levy raises a constant nominal value of \$10,000 each year until it expires after the fifth year.⁶

The institutional environment created by HB 920 is particularly useful for estimation. Since districts' input costs rise naturally with the rate of inflation, the nominal freeze on property tax revenue creates a large degree of year-to-year variation in districts' real financial resources. This revenue volatility makes districts' annual spending-saving and levy-proposal decisions especially consequential, and allows the econometrician to make high-frequency observations about districts' responses to financial shocks. Another consequence of the nominal freeze is a large sample of historical levy votes, since districts must frequently return to the ballot and request local tax increases in order to maintain the real value of their revenue streams. This sample of levy votes is just as essential to policy analysis as the estimated structural parameters. Since levy proposals do not actually affect districts' revenue unless they successfully secure voter approval, in order to conduct counterfactual simulations, I need to predict both the probabilities with which districts propose levies *and* the probabilities with which these out-of-sample levy proposals pass. With the 2,792 incremental levy votes that I observe – an average of about 4.5 votes per district during my 21-year sample period – I am able to estimate a detailed model of levy passage and accurately predict levy-passage probabilities in the counterfactual simulations.⁷

Finally, government officials in Ohio are currently engaged in an active debate about school finance reform. In a landmark case in 1997, the Ohio Supreme Court declared the state's school finance system to be unconstitutional, arguing that the state had “fail[ed] to provide for a thorough and efficient system of common schools” and “permitted to continue vast wealth-based disparities among Ohio's schools, depriving many of Ohio's public school students of high quality educational opportunities” ([Ohio Supreme Court, 1997](#)). The state legislature responded during the following years with several attempts to increase the overall level of education spending and distribute funding more equitably among school districts (thereby creating helpful variation in state funding during my sample period). As a result, the state's current funding system is a complicated patchwork of foundation aid policies⁸ that

⁶The tax-reduction factor is computed using price growth for existing property, so districts' real tax receipts still rise when new property is constructed. There are also some minor exceptions to the nominal freeze. Overlapping local jurisdictions (i.e., cities, counties, and school districts) may levy up to a combined 1% of property tax without voter approval; school districts typically receive a fraction of this un-voted 1% (referred to as “inside millage”). Only taxes levied in excess of school districts' share of this un-voted 1% (which account for the vast majority of school districts' property tax revenue) are approved by voters and subject to the nominal freeze. Additionally, there is a “floor” at 2%: if a district currently has an effective tax rate in excess of 2% and HB 920's inflation adjustment would cause the rate to fall below 2%, then the rate becomes fixed at 2%.

⁷To illustrate how common levy proposals are in Ohio, compare the 4.5 votes per district during my 21-year sample period to regression-discontinuity studies that use school district levy-voting data from other states. [Cellini, Ferreira, and Rothstein \(2010\)](#) observe 1.28 votes per district during a 21-year sample period in California; [Baron \(2019\)](#) observes 2.88 votes per district during a 26-year sample period in Wisconsin; and [Abbott et al. \(2020\)](#) observe 0.92 votes per district during a 16-year sample period pooling districts in Arkansas, Louisiana, Michigan, Missouri, Pennsylvania, Texas, and Wisconsin.

⁸Ohio uses a foundation aid system rather than a “guaranteed tax revenue” or “power equalization” system. This means that districts keep 100% of the local property tax revenue that they raise and the state allocates funding based only on district demographics, without regard to districts' current property tax receipts. The demographics accounted for in the foundation aid formula do, however, include factors that

allocate funds based on districts’ property wealth, mean income, and student demographics. Though the state has made considerable progress since 1997, there is wide agreement that these funding formulas could be revised to reduce complexity and uncertainty and more effectively target state funds to the highest-need districts. The ongoing education finance debate in Ohio and recent attention to specific legislative reform proposals⁹ provide me the opportunity to analyze timely, policy-relevant counterfactuals in the same environment used to estimate the structural model of school district behavior.

3 Data and Descriptive Statistics

3.1 Data

From the National Center for Education Statistics and the Ohio Department of Education, I obtain annual financial data on school districts’ revenue, spending, and asset holdings, as well as data on the size and demographic makeup of their student bodies. The Ohio Department of Taxation provides additional detail about districts’ tax bases and local revenue collection. Finally, the Ohio Secretary of State maintains the historical election records that I use in constructing my database of local tax levy votes. These election records are only available in digitized form since 2013, so I hand-coded the levy voting data for all prior years.¹⁰ The sample period runs from the 1996-97 school year to the 2016-17 school year, with a panel of 609 school districts.¹¹

Table 1 presents means and standard deviations for the data on school districts’ finances and demographics. All monetary figures in the paper are reported in 2017 dollars. The summary statistics are shown for the entire sample as well as four smaller groups (based on classifications assigned by the Ohio Department of Education): rural and small town districts with higher-than-average poverty, rural and small town districts with lower-than-average poverty, suburban districts, and urban districts. In order to allow for heterogeneity in structural parameters across districts, I estimate the structural model separately for each of these four groups (see Section 6). I use this particular categorization for two reasons. First, the rural-suburban-urban division is the ex-ante grouping most likely to capture differences in the “education production” process (student body size and socioeconomic makeup, teacher salaries, curriculum types and extracurricular programming, voter attitudes toward levies)

represent districts’ local taxation capacity (e.g., property value per student).

⁹Most notable is the comprehensive reform bill introduced by state representatives Robert R. Cupp and John Patterson in June 2019, which would significantly increase aggregate state education expenditures and “rewrite the rules on how schools are funded” by simplifying the allocation policies that determine the distribution of foundation aid among districts (Hancock, 2019).

¹⁰The Secretary of State’s office could not locate some of the relevant levy-voting records before 1995, so for years prior to 1995 I supplement the official election records with data graciously provided by Adam Isen, which he digitized himself for use in Isen (2014). Although my sample period begins in the 1996-1997 school year, I need earlier levy votes in order to observe, for each district-year observation, the time that has elapsed since the district last passed a levy (this elapsed-time measure is a state variable in the model of district behavior; see Section 4.1).

¹¹I drop the Union County-College Corner Joint School District, which crosses the Ohio-Indiana border, and the Kelleys Island Local School District, an extremely small district on an island in Lake Erie that had fewer than 10 students enrolled in 2016-17.

Table 1: School District Summary Statistics

	All Districts	Rural/Town, High Poverty	Rural/Town, Low Poverty	Suburban	Urban
Students	2,840 (4,520)	1,828 (1,011)	1,399 (707)	4,536 (3,029)	8,665 (12,128)
Black Student Share	0.05 (0.14)	0.02 (0.06)	0.00 (0.01)	0.07 (0.12)	0.33 (0.28)
Hispanic Student Share	0.02 (0.04)	0.02 (0.04)	0.01 (0.02)	0.02 (0.02)	0.04 (0.07)
FRPL Student Share	0.31 (0.20)	0.40 (0.17)	0.26 (0.15)	0.16 (0.13)	0.55 (0.22)
Median Income	38,719 (9,011)	33,774 (4,418)	38,717 (4,769)	50,263 (10,809)	31,992 (5,832)
Property Value per Student	149,416 (74,598)	124,597 (42,735)	132,719 (60,583)	227,690 (93,486)	136,416 (55,398)
Current Expenditures per Student	9,988 (1,960)	9,616 (1,456)	9,327 (1,428)	11,136 (2,549)	11,478 (2,072)
Total Revenue per Student	10,395 (2,837)	10,272 (2,636)	9,760 (2,646)	10,717 (2,770)	12,665 (3,209)
Federal Revenue per Student	740 (529)	896 (529)	616 (390)	432 (249)	1,318 (760)
State Revenue per Student	5,556 (2,641)	6,150 (2,620)	5,743 (2,626)	3,642 (1,050)	6,800 (3,102)
Local Revenue per Student	4,099 (2,294)	3,226 (1,388)	3,401 (1,588)	6,643 (2,705)	4,547 (2,211)
Asset Holdings per Student	2,612 (2,082)	2,339 (1,773)	2,729 (2,061)	2,926 (2,526)	2,507 (2,030)
Number of Districts	609	213	218	123	55
Observations	12,730	4,440	4,566	2,573	1,151

Note: Standard deviations are in parentheses. FRPL students are those that receive free or reduced-price lunch.

that the structural parameters reflect. And second, any counterfactual state funding change that redistributes on the basis of average income, property wealth, or student demographics is likely to make more transfers between these groups than within them. Urban and poor rural districts have lower incomes, less property wealth per student, and more students who receive free or reduced-price lunch (with urban districts also containing a much higher share of minority students than all other districts). Low-poverty rural districts fare slightly better along these dimensions, while suburban districts are significantly wealthier than the other three groups. The state's current efforts to redistribute along these dimensions is also evident: rural and urban districts receive a larger share of their revenue from the state, while suburban districts finance their relatively high expenditure levels with larger amounts of local tax revenue.

Table 2 summarizes the data on local tax levy voting. All levy votes require simple majority approval for passage. I show summary statistics separately for two groups: renewal levies, which ask voters to extend a currently operative tax that is about to expire, and incremental levies, which ask voters to approve a new tax that would increase the district's

Table 2: Levy Voting Summary Statistics

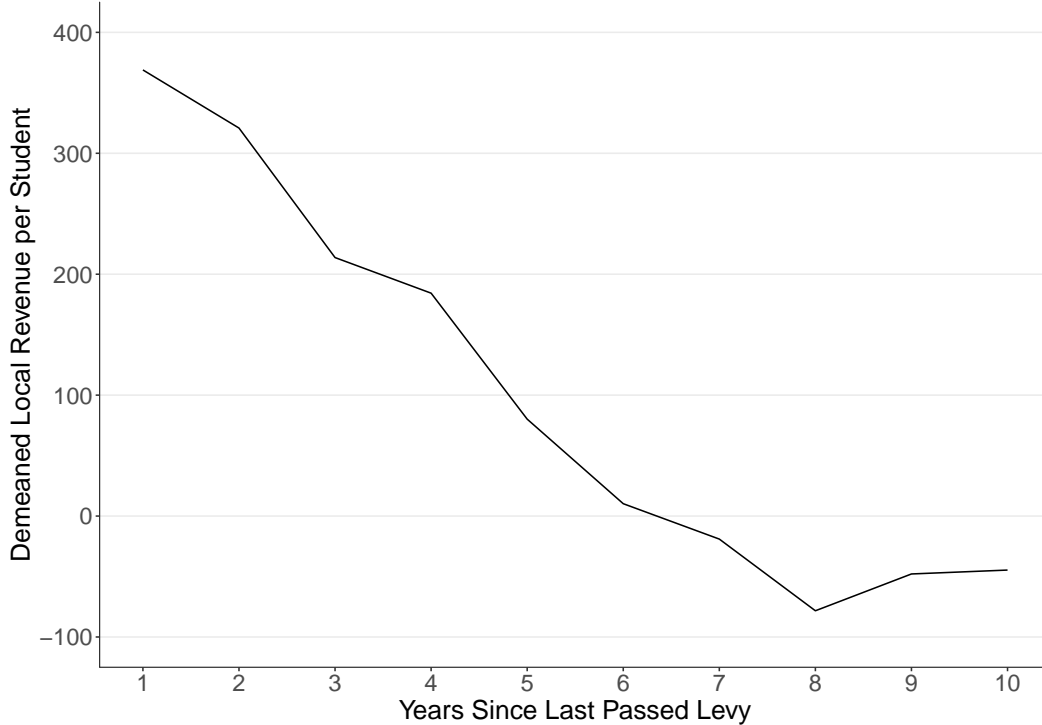
	Renewal	Incremental
Tax Rate * 100	0.61 (0.31)	0.67 (0.27)
Duration (Excluding Perpetual)	5.20 (1.65)	5.27 (2.32)
Share Perpetual	0.09 (0.29)	0.34 (0.48)
Yearly Revenue per Student	898 (523)	1,059 (547)
Vote Share in Favor	0.59 (0.09)	0.47 (0.09)
Passed	0.86 (0.34)	0.36 (0.48)
Total Votes	4,453 (8,314)	6,443 (10,746)
Number of Levies	2,231	2,792

Note: Standard deviations are in parentheses. Renewal levies ask voters to extend an expiring tax, while incremental levies ask voters to approve a new tax that would increase the district's local revenue collection. All levy votes require simple majority approval for passage.

local revenue collection. As discussed in Sections 4 and A.2, I model districts' decisions to put incremental levies on the ballot while leaving renewal levies as an exogenous shock that I account for in the estimation process but do not explicitly incorporate into the model. I am comfortable with this implicit treatment of renewal levies because they are not a meaningful source of revenue risk for districts; the vast majority (86%) receive voter approval. The outcomes of incremental levy votes, which have a passage rate of 36%, are much more uncertain. The average incremental levy requests about \$1,000 in yearly revenue per student, and among those with a finite duration, the average length is 5.27 years. About a third of incremental levy proposals are perpetual taxes without a specified expiration date.

It is worth noting that the vast majority, though not all, of the tax levies summarized in Table 2 and considered in this paper are property tax levies. Since 1989, school districts in Ohio have also had the option of placing income taxes on the ballot. Of the 609 districts in my sample, about a third (199) have exercised this option and had operative income taxes in place during the 2016-17 school year; among income-taxing districts, income taxes account for an average of 11% of total revenue. Of the incremental levy votes in my sample, 80% are for property taxes, with the remaining 20% for income taxes. The remainder of the paper does not distinguish between property and income tax levies; in the model described

Figure 1: Local Revenue Between Passed Levies



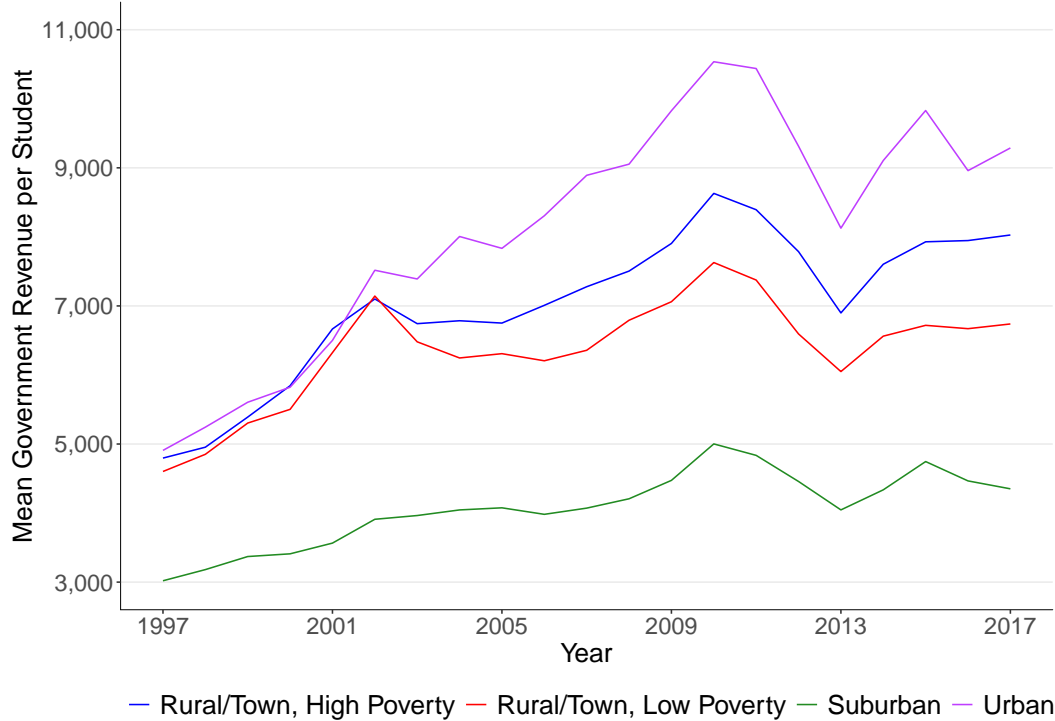
in Section 4, levies are completely described by the amount of annual revenue per student they request. I find this to be a reasonable assumption, since voters presumably care more about the final tax burden of a levy than the tax base with which it is determined. I also note that since income taxes are used by a minority of districts and account for only a small share of revenue when used, the nominal freeze on property tax revenue imposed by HB 920 is an important financial constraint for most districts.

3.2 Variation in Financial Resources

Variation in districts' financial resources is crucial to the paper's empirical analysis. Without high-frequency observations about districts' responses to historical financial shocks, I cannot test the qualitative predictions of the model (which specify how spending and levy decisions should vary with revenue and asset levels) or estimate its underlying structural parameters (which are similarly identified by year-to-year variation in cash on hand).

Figures 1 and 2 highlight the two principal factors that generate the necessary variation in financial states. As discussed in Section 2, the nominal freeze imposed by HB 920 causes districts' local property tax revenue to decline consistently with the rate of inflation. Figure 1, which plots districts' demeaned local revenue per student against the elapsed time since their last successful levy proposal, makes this fact clear. Whereas in normal settings we would expect real property tax revenue to remain roughly constant between passed levies (or even increase if property values rise faster than the general rate of inflation), Ohio districts' local revenue decreases monotonically without action from their voters.

Figure 2: Government Revenue During the Sample Period



Additionally, as Figure 2 shows, the state funding that constitutes the remainder of districts’ revenue displays substantial variability during the sample period. As Ohio increased state aid levels following the 1997 court decision that declared its funding system unconstitutional, each of the four district groups experienced a large secular increase in government revenue through 2010, with a temporary leveling-off between 2001 and 2005. The usefulness of this general time trend in identifying districts’ reactions to positive revenue shocks is, of course, dependent on my assumption that the underlying structural parameters are time-invariant. The upward trend in state funding abruptly reversed itself in 2011, when the newly elected administration under Governor John Kasich closed a large budget deficit in part by making a \$700 million cut to education spending (Vardon, 2011). The state spending cuts caused all four district groups to suffer significant declines in government revenue through 2013. Finally, beginning in 2014, state budgets used heightened tax revenue to finance a new expansion of education funding (Patton, 2013), leading government revenue to increase at a rate comparable to the 1997-2001 period.

Table 3 gives a more quantitative description of the volatility in districts’ financial resources. For each of the four district groups, I summarize the variability of government revenue, local revenue, and asset holdings during the sample period with coefficients of variation (standard deviation divided by mean). The “Across” columns pool districts and divide the group-wide standard deviation by the group-wide mean, while the “Within” columns report the average of individual districts’ coefficients of variation. As might be expected given the patterns shown in Figures 1 and 2, the magnitudes are large. Looking across districts, the standard deviation of government revenue is between 29% and 45% of its mean, while

Table 3: Coefficients of Variation for Financial Variables

	Rural/Town, High Poverty		Rural/Town, Low Poverty		Suburban		Urban	
	Across	Within	Across	Within	Across	Within	Across	Within
Government Revenue per Student	0.40	0.29	0.43	0.29	0.29	0.16	0.45	0.27
Local Revenue per Student	0.43	0.18	0.47	0.19	0.41	0.12	0.49	0.17
Assets per Student	0.76	0.55	0.76	0.52	0.86	0.52	0.81	0.57

Note: This table presents coefficients of variation (standard deviation divided by mean) for district financial variables. The “Across” columns divide the group-wide standard deviation by the group-wide mean, while the “Within” columns report averages of individual districts’ coefficients of variation.

the standard deviation of local revenue is between 41% and 49% of its mean. Even when restricting to within-district variation, the figures generally remain in the 15%-30% range. My assumption of uniform structural parameters within each of the four district groups means that the across-district variation is itself sufficient for identification. The within-district volatility is nonetheless reassuring, since it means that a large portion of the identifying variation in revenue levels comes from time-varying, district-specific shocks, rather than persistent differences between high- and low-revenue districts. The fact that assets are far more volatile than revenue suggests that districts optimize dynamically and use their savings buffers to smooth spending over time, a point that I discuss in more detail in Sections 4 and 5.

4 A Model of School District Behavior

This section presents the main model of school district behavior, in which districts make dynamic spending-saving and levy-proposal decisions to maximize expected utility from educational expenditures. By outlining a version of the model without functional-form assumptions, I aim to highlight the key economic tradeoffs faced by school districts and organize the empirical analysis undertaken in the remainder of the paper.

4.1 Timing and State Variables

Time, indexed by t , is discrete and measured in years. The decision-maker is an autonomous school district that maintains its own budget and operates independently from other municipal bodies like cities or counties. Five state variables, whose combination I denote with s , describe the environment:

$$s_t \equiv (a_t, g_t, p_t, q, j_t). \tag{1}$$

The first state variable, a_t , gives the district’s asset holdings per student. The savings represented by a_t allow the district to smooth spending in the face of revenue volatility. Government revenue per student – the sum of state and federal funding received by the district – is given by g_t . As shown in Table 1, federal funding constitutes a relatively small share of districts’ annual budgets, so g_t should be viewed primarily as the state funding levels controlled by Ohio’s state government that are the subject of policy analysis in Section 7.

Local revenue per student – which, as discussed in Section 3.1, is comprised mostly of local property taxes and in small part by local income taxes – is given by p_t .¹²

The final two state variables determine the likelihood with which local tax levies proposed by the district secure voter approval. The variable q , which is the only time-invariant state variable without a t subscript, summarizes the willingness of voters in the district to approve local tax levies, with higher values of q indicating that proposed levies are more likely to secure voter approval. A wealthy suburban district with high levels of income and property value per student, for example, would tend to have a higher value of q than an urban district with low median income and less valuable property. As will be made clear in Sections 5.1 and 6.1, the set of q values (one for each district) can be thought of as the district fixed effects from a regression, estimated on the full sample of incremental levy votes, with an indicator for levy passage as the dependent variable and a full set of district dummies included among the independent variables. The final state variable, j_t , gives the number of years since the district last successfully passed a local tax levy. Section 5.1 will show that, even conditional on the district fixed effect q , the elapsed time since the district’s last passed levy is important in predicting levy-passage probabilities.

4.2 State Evolution and Levy Passage

Aside from the time-invariant levy-passage fixed effect q , the state variables evolve from year to year. Assets earn a riskless net return r and therefore evolve deterministically¹³ according to

$$a_{t+1} = (1 + r)(a_t + g_t + p_t - e_t). \quad (2)$$

I assume that government revenue per student evolves according to a stochastic Markov process, so that

$$g_{t+1} \sim F^g(\cdot; g_t), \quad (3)$$

with F^g the cumulative distribution function that depends on the current value g_t . Uncertainty in the year-to-year evolution of government funding arises primarily from changes in the state of Ohio’s education budget and in state policymakers’ allocation decisions regarding the distribution of foundation aid among districts.

The evolution of local revenue per student depends on the proposal and passage of tax levies. Legacy local revenue – i.e., revenue from all local taxes that are already operative in year t – evolves according to a stochastic Markov process analogously to government revenue. Denoting legacy local revenue with \tilde{p} , we have

$$\tilde{p}_{t+1} \sim F^p(\cdot; p_t). \quad (4)$$

¹²I specify the asset and revenue variables in real, rather than nominal, terms (an important distinction given the nominal freeze imposed by HB 920). As noted in Section 3.1, I adjust all monetary variables to 2017 dollars.

¹³This assumption reflects Ohio law, which requires school districts and other municipal bodies to invest their savings only in low-risk, low-yield instruments like government debt, money-market mutual funds, commercial paper, and bank deposits. See [Section 135.14 of the Ohio Revised Code](#).

Uncertainty in the year-to-year evolution of legacy local revenue arises primarily from variation in the inflation rate (recall the nominal freeze imposed by HB 920) and the construction and destruction of property within the district. Local revenue also jumps if the district successfully proposes and passes a levy. Let m_t be the annual revenue per student that the district requests in its year t levy proposal (with m_t undefined if the district does not propose a levy in year t). A levy passed in year t first yields revenue in year $t + 1$,¹⁴ so local revenue evolves according to

$$p_{t+1} = \begin{cases} \tilde{p}_{t+1} + m_t & \text{if levy proposed and passed in year } t \\ \tilde{p}_{t+1} & \text{otherwise.} \end{cases} \quad (5)$$

The state variable j_t , which gives the elapsed time since the district last passed a levy, evolves deterministically in the expected way:

$$j_{t+1} = \begin{cases} 1 & \text{if levy proposed and passed in year } t \\ j_t + 1 & \text{otherwise.} \end{cases} \quad (6)$$

Finally, I assume that in years where a district proposes a levy, its passage probability depends on three factors: the levy-passage fixed effect q , the time since the last passed levy j , and the levy's requested annual revenue per student m . Denoting with π the function that aggregates these three inputs into a levy-passage probability, we have, for a levy proposal in year t requesting m_t in annual revenue per student,

$$\Pr(\text{levy passes}) = \pi(q, j_t, m_t). \quad (7)$$

Levy-passage probability is increasing in the fixed effect q , increasing in j_t (voters are more likely to approve a levy if they have not approved one recently), and decreasing in m_t (voters are less likely to approve a levy that requests more revenue per student and creates a larger tax burden), so

$$\frac{\partial \pi}{\partial q} > 0; \quad \frac{\partial \pi}{\partial j_t} > 0; \quad \frac{\partial \pi}{\partial m_t} < 0. \quad (8)$$

4.3 Preferences

I assume that the district's preferences are represented by an increasing, concave function $u(\cdot)$ defined over current expenditures per student e . Because borrowing to fund current expenditures is rare and tightly regulated under Ohio law,¹⁵ I impose a no-borrowing constraint and require that spending be less than cash on hand, so that

$$e_t \leq a_t + g_t + p_t. \quad (9)$$

¹⁴This assumption again reflects Ohio law, under which the tax revenue requested by a levy cannot be collected until the calendar year after the date of the corresponding levy vote.

¹⁵The 90th percentile of outstanding short-term debt among all district-year observations is \$0. Districts do borrow to fund capital expenditures (generally by floating a long-term bond issue and passing a tax levy whose revenue is dedicated to servicing the debt), but such long-term borrowing does not appear in the model because I only consider spending and levy proposals for current operating expenditures.

It is important to emphasize that the expenditures variable e_t represents only current operating expenditures (teacher salaries, student support services, etc.) and does not include capital spending on things like school buildings or buses. I focus on current expenditures for several reasons. First, they constitute most of districts’ spending: the average district in my sample devotes 91% of its annual spending to operating expenditures and only 9% to capital projects. Second, the capital spending that districts do undertake is financed almost exclusively by local property taxes, so the changes in state funding policy considered in Section 7 are only capable of shifting current expenditures. Third, it is easy to distinguish between the current and capital expenditures of Ohio districts; the two spending categories are reported separately in the data and all local tax levies must explicitly specify whether the requested revenue will support operating expenses or capital spending. Throughout the paper, I only consider levy proposals earmarked for current expenditures. Finally, recent empirical evidence, such as [Enami \(2018\)](#) and [Baron \(2019\)](#), shows that incremental capital spending does not have any noticeable effect on student outcomes.

I also note that $u(\cdot)$ should be interpreted as the district’s utility function over per-student spending, and not necessarily as an “education production function” that maps schooling inputs to observed student outcomes like test scores or labor earnings (as in, e.g., [Card and Krueger 1992](#) or [Krueger 1999](#)). Since district officials’ preferences determine their spending-saving and levy-proposal decisions, their utility function is the relevant object for predicting counterfactual behavior and conducting policy analysis. My revealed-preference approach is also advantageous if, as is likely the case, many important student outcomes are hard to measure or unobservable. Rather than assuming that observable outcomes like test scores represent the entire “education production” process, I instead assume that school district officials know the full set of relevant outcomes and make optimal spending and levy decisions in pursuit of them.

4.4 District Optimization

The core economic content of the model lies in the two decisions that the school district must make annually. First, the district decides whether to propose a levy; if it does place a levy on the ballot, it also chooses the amount of additional revenue m_t to request from voters. Second, after making its levy decision, the district chooses its spending level e_t , which is a nontrivial problem since it can save into or spend out of its asset holdings a_t .

To characterize the district’s optimal behavior, I state the problem recursively, with the value function $V(\cdot)$ defined over the state s . The district has an infinite horizon and an annual discount factor β . It is also helpful to define the choice-specific value functions $V^L(\cdot)$ and $V^N(\cdot)$, which again take the state s as their argument and give the maximized values of holding and not holding a levy, respectively.

First, consider the simpler case where the district chooses not to propose a levy. The district’s decision then reduces to a standard consumption-saving problem, with

$$V^N(s_t) = \max_{e \leq a_t + g_t + p_t} u(e) + \beta \mathbb{E}[V(s_{t+1}) | s_t, e], \quad (10)$$

where the expectation on the right-hand side is taken over the revenue variables that evolve stochastically (g_{t+1} and p_{t+1}). The optimal spending level is determined by weighing the

marginal utility of spending $u'(e)$ against the marginal cost of foregone asset holdings next year, since $a_{t+1} = (1+r)(a_t + g_t + p_t - e_t)$. The foregone asset holdings are valuable because future revenue is uncertain, and a buffer stock of assets insures the district against the possibility that its marginal utility of spending is higher next year. An interior solution requires that the familiar Euler condition holds (with V_a denoting the derivative of the value function with respect to the assets argument):

$$u'(e) = \beta(1+r)\mathbb{E}[V_a(s_{t+1})|s_t, e]. \quad (11)$$

Next, consider the case where the district decides to propose a levy. There are now two choice variables: in addition to the spending level e , the district must also choose the revenue amount m to request with the levy.¹⁶ Expanding the state-variable notation for clarity, the maximized value is now defined by

$$\begin{aligned} V^L(s_t) = & \max_{m, e \leq a_t + g_t + p_t} u(e) - c \\ & + \beta \left(\pi(q, j_t, m) \mathbb{E}[V(a_{t+1}, g_{t+1}, \tilde{p}_{t+1} + m, q, 1)|s_t, e] \right. \\ & \left. + (1 - \pi(q, j_t, m)) \mathbb{E}[V(a_{t+1}, g_{t+1}, \tilde{p}_{t+1}, q, j_t + 1)|s_t, e] \right), \quad (12) \end{aligned}$$

where c is a fixed utility cost of holding a levy. With probability $\pi(q, j_t, m)$, the levy passes, next year's legacy local revenue \tilde{p}_{t+1} is incremented by m , and the state variable j_{t+1} (giving the elapsed time since the last passed levy) is reset to 1. With complementary probability, the levy fails, next year's local revenue is not incremented by m , and j_{t+1} evolves to $j_t + 1$. The levy utility cost c captures any factors (diversion of district officials' effort from educational operations to communication and campaigning, an inherent aversion to increasing residents' taxes, etc.) that tend to dissuade districts from proposing levies. Such factors must exist, since setting $c = 0$ would make it optimal to propose a levy every year and would clearly contradict the empirical levy-proposal rate of about 20% during the sample period.

The optimality conditions for m and e in the levy case are again intuitive. Districts prefer to have more revenue, but raising the proposal amount m decreases the levy's passage probability, since $\frac{\partial \pi}{\partial m} < 0$. The district therefore chooses m to balance the marginal benefit of additional revenue conditional on passage against the diminished probability of passage. Formally, with V_p denoting the derivative of the value function with respect to the local

¹⁶Note that I do not model the district's choice of levy duration (i.e., the number of years that the proposed tax would remain in force if passed). I do this for practical reasons, since modeling duration would require additional state variables accounting for the number of years remaining on each of the district's active local taxes and would quickly make the problem intractable. Instead, I effectively assume that all passed levies remain in force perpetually (with their real revenue continuously declining due to HB 920's nominal freeze). In the Ohio setting, this is not an unrealistic assumption. About a third of all proposed incremental levies are in fact perpetual (see Table 2). And since renewal levies almost never fail (their sample-wide passage rate is 86%; see again Table 2), even finitely-lived levies are effectively perpetual, since voters renew them at expiration with very high probability. I also note that conditional on district fixed effects, the elapsed time since the last passed levy, and the requested revenue amount, duration does not predict levy-passage probabilities (see Table 4).

revenue argument, the optimal m satisfies

$$\pi(q, j_t, m) \mathbb{E}[V_p(a_{t+1}, g_{t+1}, \tilde{p}_{t+1} + m, q, 1) | s_t, e] = -\frac{\partial \pi(q, j_t, m)}{\partial m} \left(\mathbb{E}[V(a_{t+1}, g_{t+1}, \tilde{p}_{t+1} + m, q, 1) | s_t, e] - \mathbb{E}[V(a_{t+1}, g_{t+1}, \tilde{p}_{t+1}, q, j_t + 1) | s_t, e] \right), \quad (13)$$

with the left-hand side giving the marginal benefit and the right-hand side giving the marginal cost of raising m slightly. An interior solution for optimal spending e satisfies an Euler condition analogous to the no-levy case in (11), with the right-hand side now accounting for the possibility that the levy passes and alters the marginal benefit of assets next year:

$$u'(e) = \beta(1+r) \left(\pi(q, j_t, m) \mathbb{E}[V_a(a_{t+1}, g_{t+1}, \tilde{p}_{t+1} + m, q, 1) | s_t, e] + (1 - \pi(q, j_t, m)) \mathbb{E}[V_a(a_{t+1}, g_{t+1}, \tilde{p}_{t+1}, q, j_{t+1}) | s_t, e] \right). \quad (14)$$

Finally, to close the model, I use the fact that the district makes optimal levy decisions each year, proposing a levy if and only if doing so yields higher value than not proposing a levy. This defines the relationship between the three value functions,

$$V(s_t) = \max \{V^L(s_t), V^N(s_t)\}, \quad (15)$$

and makes (10), (12), and (15) a solvable system.

4.5 Empirical Predictions

The model described above generates testable empirical predictions. If my assumptions regarding levy-passage probabilities are true, and if Ohio school districts make dynamic spending-saving and levy-proposal decisions in accordance with the model's optimality conditions, a number of reduced-form relationships should be apparent in the data.

Levy-Passage Determinants Straightforwardly, the derivatives in (8) should hold empirically, with the probability of levy passage increasing in the elapsed time since the last passed levy and decreasing in the requested revenue amount, conditional on district fixed effects. If the π function gives a complete representation of levy-passage probability, then other observable characteristics of levies should not systematically predict passage rates.

Levy-Proposal Determinants Districts' levy-proposal decisions should not be random. Instead, they should depend on the state variables that govern the relative values of holding and not holding a levy within the model. Because proposing a levy requires the district to incur the fixed cost c , levies should be held only when the benefit from doing so is sufficiently high to justify this cost.

What determines the benefit of holding a levy? Since the utility function $u(\cdot)$ is concave, and the no-borrowing constraint bounds spending from above, districts' marginal utility of spending is highest when cash on hand $a_t + g_t + p_t$ is low. The increase in local revenue that

follows a successful levy is therefore most valuable when negative revenue shocks and/or the depletion of asset holdings have lowered cash on hand. Formalizing this logic within the expression for $V^L(\cdot)$, the concavity of $u(\cdot)$ and the no-borrowing constraint together imply (with subscripts again denoting partial derivatives)¹⁷

$$V_{pa}(\cdot) < 0; \quad V_{pg}(\cdot) < 0; \quad V_{pp}(\cdot) < 0. \quad (16)$$

This means that on the right-hand side of (12), the value of the additional levy revenue m increases when any of the three components of cash on hand decrease. Empirically, we should therefore observe that levy-proposal rates are negatively correlated with current asset holdings and revenue levels.

Since proposed levies only increase revenue if they actually secure voter approval, the benefit of holding a levy also increases with its likelihood of passage. In the limit, if a district knew that its next levy would fail with certainty, there would be no benefit to proposing it and the district would surely be unwilling to incur the fixed cost c . Equation (12) makes this clear: as the passage probability $\pi(q, j_t, m)$ goes to 0, the value-function term containing the increase in revenue m disappears from the right-hand side. Among the arguments to the π function, the levy-passage fixed-effect q is time-invariant and districts choose m only after deciding to propose a levy. We are thus left with one additional empirical prediction about levy timing: levy-proposal rates should increase with the elapsed time since the last levy, since $\frac{\partial \pi}{\partial j_t} > 0$.

Buffer Stocks and Non-Hand-to-Mouth Behavior As in standard buffer-stock saving models, districts should maintain nonzero asset holdings. The concavity of the utility function $u(\cdot)$, along with the stochastic evolution of revenue, should generally lead districts to carry asset buffers as insurance against the possibility that future cash on hand is lower, and future marginal utility of spending higher, than their current values. The precise size of these buffer stocks will depend on the extent of the utility function's concavity, but districts should completely exhaust their asset holdings only in rare cases when current revenue is very low.

If districts do use asset buffers to smooth spending dynamically, then we should be able to clearly reject a null hypothesis of hand-to-mouth or myopic behavior. Spending should be less volatile than revenue, and districts should not simply spend their current revenue each year.

Budget Surpluses and Current Revenue In addition to predicting nonzero asset buffers, the model also implies a systematic relationship between the state variables and districts' spending-saving decisions. As long as the distribution functions F^g and F^p in (3) and (4) have sufficient support, there is always a nonzero probability that cash on hand will be lower next year than this year. But this probability increases when current revenue is higher, particularly given the operation of HB 920: after the passage of a levy temporarily boosts local revenue, the nominal freeze makes large future revenue decreases more likely. The motivation to save should therefore be stronger when revenue is high, since districts perceive a higher probability that the marginal utility of spending will increase in the future. As a result, we should observe a positive correlation between budget surpluses and current

¹⁷I cannot easily prove this analytically since the value function can only be solved for computationally, but the partial derivatives in (16) hold for all computational solutions of the value function.

revenue: districts should save more and build up their asset buffers when revenue is high, while running smaller surpluses (or even dipping into their savings buffers by running deficits) when revenue is low.

5 Reduced-Form Evidence

Before proceeding to structural estimation, I first discuss several reduced-form features of the data. By confirming the model’s key assumptions and qualitative predictions, the empirical facts established in this section justify the quantitative applications in Sections 6 and 7.

5.1 Levy-Passage Probabilities

Among the key assumptions of the model are the rules governing levy-passage probabilities. Equation (7) stipulates that the only systematic determinants of levy passage are district fixed effects, the elapsed time since the district’s last passed levy, and the levy’s requested revenue amount. From (8), we have that passage probabilities are increasing in the time since the last passed levy and decreasing in the requested revenue amount, conditional on the district fixed effects. It is important to verify these assumptions, since they play a significant role in determining districts’ optimal levy-proposal behavior.

Table 4 presents linear probability models of levy passage, estimated using the full sample of incremental levy votes and with district fixed effects included in all specifications. The coefficient estimates confirm the model’s assumptions. In the simplest specification in column (1), each additional year since the district’s last passed levy is associated with a 4.5 percentage-point increase in the probability of passage. This is a substantial effect given the sample-wide passage rate of 36%, but it also masks important nonlinearity. Columns (2)-(5) allow for a nonlinear effect by replacing the elapsed time variable with a set of dummies for two-year buckets (with levies held one or two years after the previous passed levy comprising the omitted group). Passage probabilities are largely flat through the fourth year, then increase by large and statistically significant amounts in years five through ten. In years nine and ten, passage probabilities have increased by a full 23 percentage points relative to years one and two. Also as predicted, the yearly revenue per student requested by the levy is negatively correlated with passage rates, though the effect is relatively small: a \$1,000 increase in requested revenue decreases passage probabilities by 3 percentage points. Finally, the π function in (7) does appear to give a complete representation of passage probabilities, since the other observable factors one might reasonably expect to influence passage rates (the district’s contemporaneous local tax burden and the duration of the levy) do not enter with economically or statistically significant coefficients.

Figure 3 illustrates the results from Table 4 graphically, using the specification in column (3). The figure plots passage probabilities (conditional on levy proposal), for the district with the median estimated fixed effect and for various requested revenue amounts, against the elapsed time variable. The 23-percentage point increase between years one and ten takes passage probabilities from just under 40% to just over 60%, with the fastest increase occurring in years four through six. The requested revenue amount matters, though not

Table 4: Linear Probability Models of Levy Passage

	Dependent Variable: Levy Passed				
	(1)	(2)	(3)	(4)	(5)
Years Since Last Passed Levy	0.045*** (0.006)				
$3 \leq \text{Years Since} \leq 4$		-0.032 (0.052)	-0.029 (0.052)	-0.029 (0.052)	-0.020 (0.053)
$5 \leq \text{Years Since} \leq 6$		0.139** (0.055)	0.138** (0.054)	0.139** (0.055)	0.143*** (0.055)
$7 \leq \text{Years Since} \leq 8$		0.149** (0.065)	0.148** (0.065)	0.150** (0.066)	0.144** (0.066)
$9 \leq \text{Years Since} \leq 10$		0.232*** (0.077)	0.232*** (0.078)	0.233*** (0.078)	0.227*** (0.079)
Years Since ≥ 11		0.423*** (0.071)	0.422*** (0.071)	0.424*** (0.073)	0.414*** (0.074)
Requested Yearly Revenue per Student			-0.030 (0.042)	-0.030 (0.042)	-0.030 (0.042)
Contemporaneous Local Revenue per Student				0.006 (0.022)	0.010 (0.022)
Duration					-0.003* (0.001)
District Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	1,225	1,225	1,225	1,225	1,224

Note: This table presents linear probability models where the observations are levy votes and the dependent variable is an indicator for passage. All levy votes require a simple majority for passage. The yearly value per student and local revenue per student coefficients have been rescaled so that they can be interpreted as the effect of a \$1,000 increase. In columns (2)-(5), the omitted category is comprised of levy votes that took place one or two years after the district's last passed levy. Clustered standard errors are in parentheses, and asterisks indicate statistical significance at p-values of 0.1, 0.05, and 0.01.

Figure 3: Levy-Passage Probabilities for Median District

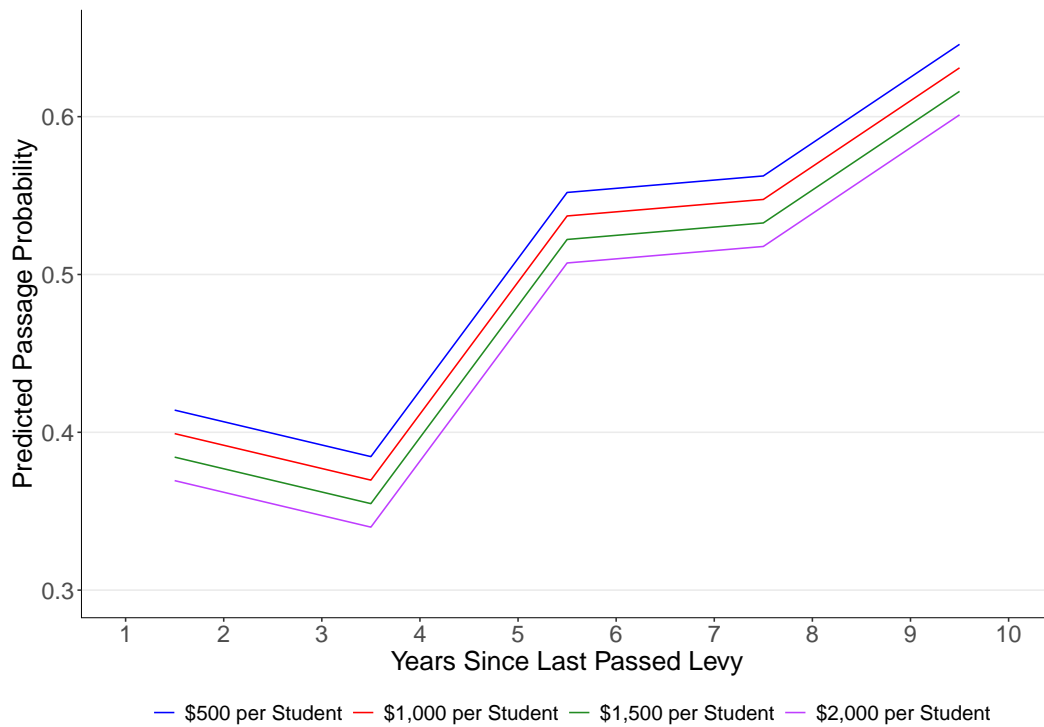
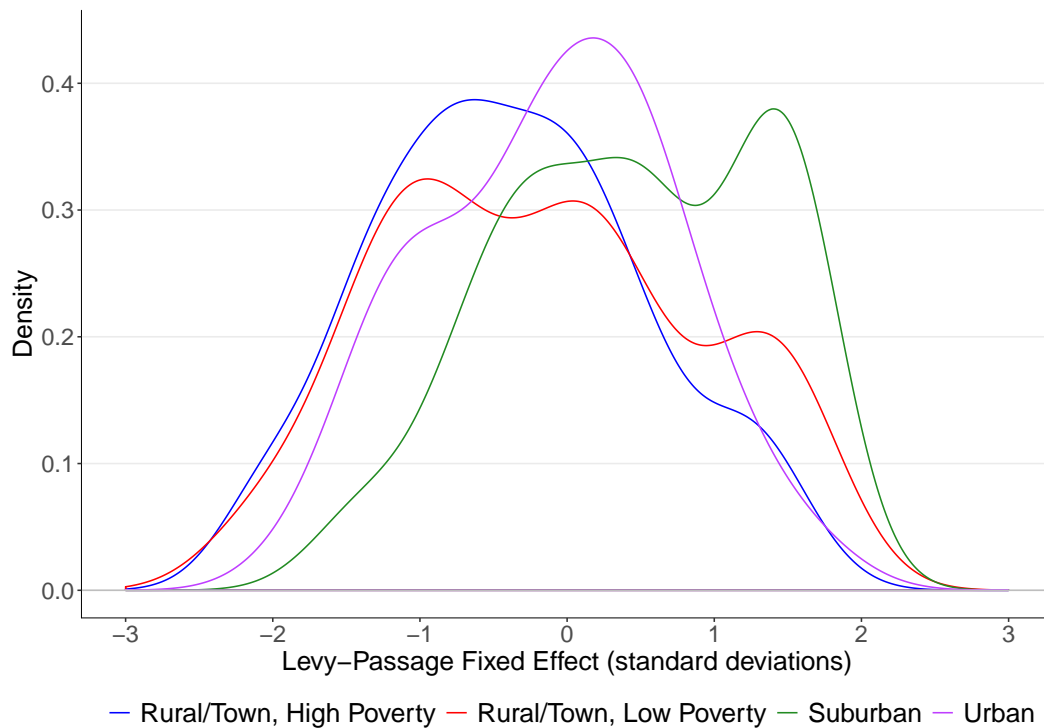


Figure 4: Distribution of Standardized Levy-Passage Fixed Effects



as much as the elapsed time variable, as the vertical distances between the four lines are generally smaller than their slopes.

Finally, the estimated district fixed effects from the linear levy-passage model (again using specification (3) in Table 4) are intuitive. Figure 4 plots the distribution of these fixed effects, after scaling them to be in units of standard deviations. Since suburban districts rely much more heavily on local revenue than the other groups (see Table 1), we would expect their voters to be more amenable to approving tax levies; this is indeed the case, with the suburban distribution shifted noticeably to the right of the other three. Urban and high-poverty rural districts have the lowest estimated fixed effects, while a substantial right tail of low-poverty rural districts enjoy levy success rates similar to those of suburban districts.

5.2 The Levy-Proposal Decision

The model makes two clear predictions about districts' levy-proposal decisions. First, since the concavity of the utility function and the no-borrowing constraint cause the marginal utility of spending to be highest when cash on hand is low, levy-proposal rates should be negatively correlated with current revenue and asset levels. And second, since levy-passage probabilities increase with the elapsed time since the last passed levy (as confirmed in the previous subsection), levy proposals should be more likely when districts' previous successful levy attempts are further in the past.

Table 5, which presents a linear probability model of levy proposals estimated separately for each of the four district groups, is consistent with the model's predictions. For all four of the groups, asset levels have a large and significant effect on levy timing: conditional on district fixed effects and the elapsed time since the previous levy vote, a \$1,000 decrease in asset holdings per student increases levy-proposal rates by between 4.5 and 8.5 percentage points. Revenue levels also have the predicted negative correlation with levy-proposal rates (all of the relevant coefficients have the correct negative sign), though the magnitudes are more heterogeneous across the four district groups. Suburban districts are the only group to show significant coefficients on both revenue variables, with \$1,000 decreases in local and government revenue raising proposal rates by 7.6 and 3.6 percentage points, respectively. With the exception of low-poverty rural districts' response to local revenue, all of the other revenue coefficients are either statistically insignificant or economically small.

These estimates, considered in light of the model structure and preceding empirical evidence, sketch a sensible story. Suburban districts rely most heavily on local revenue and enjoy the highest levy-passage rates (see Figure 4). They therefore feel a greater need to propose levies when their local revenue is below average (since the HB 920 nominal freeze acts on a larger share of their budgets) and perceive a greater benefit in responding proactively to state funding cuts with levy proposals (since those levy proposals are more likely to pass). The significant local revenue coefficient for the low-poverty rural group arises from its right tail of districts that, with high local tax burdens and levy-passage fixed effects (see again Figure 4), act much like suburban districts. Urban and high-poverty rural districts are less reliant on nominally-frozen local revenue and less confident in their abilities to pass levies; as a result, they do their best to weather revenue shocks by drawing on their savings buffers and propose levies only when their asset levels have become too low.

Conditional on revenue and asset levels, levy-proposal rates also increase with the elapsed

Table 5: Linear Probability Model of Levy Proposals

	Dependent Variable: Levy Proposed			
	Rural/Town, High Poverty	Rural/Town, Low Poverty	Suburban	Urban
Time Since Last Levy	-0.022*** (0.005)	-0.040*** (0.007)	-0.059*** (0.014)	-0.046*** (0.008)
Last Levy Passed	-0.507*** (0.032)	-0.551*** (0.040)	-0.697*** (0.046)	-0.583*** (0.062)
Time Since Last Levy * Last Levy Passed	0.061*** (0.006)	0.061*** (0.008)	0.134*** (0.015)	0.104*** (0.015)
Government Revenue per Student	-0.014*** (0.004)	-0.001 (0.003)	-0.036** (0.018)	-0.002 (0.009)
Local Revenue per Student	-0.005 (0.013)	-0.042*** (0.014)	-0.076*** (0.015)	-0.019 (0.021)
Asset Holdings per Student	-0.069*** (0.008)	-0.045*** (0.007)	-0.057*** (0.007)	-0.085*** (0.013)
District Fixed Effects	Yes	Yes	Yes	Yes
Mean Dependent Variable	0.172	0.170	0.234	0.215
Observations	2,398	2,370	2,005	773

Note: This table presents linear probability models where the observations are district-years and the dependent variable is an indicator for a levy being proposed. The government revenue per student, local revenue per student, and asset holdings per student coefficients have been scaled so that they can be interpreted as the effect of a \$1,000 increase. Clustered standard errors are in parentheses, and asterisks indicate statistical significance at p-levels of 0.1, 0.05, and 0.01.

time since the last passed levy. The specification in Table 5 flexibly controls for the time since the previous levy vote and whether the previous levy vote passed or failed. In cases where the previous levy vote passed, the likelihood of a levy proposal increases by between 2.1 and 7.5 percentage points each year (obtained by summing the coefficients in the first and third rows), confirming the model's prediction. Additionally, the flexible specification allows us to see that the time since the last *passed* levy is the relevant state variable with which proposal rates increase: in cases where the previous levy vote failed, proposal rates actually decrease with each successive year.

Figure 5: Hazard Rates of Levy Proposals,
by Time Since Last Levy

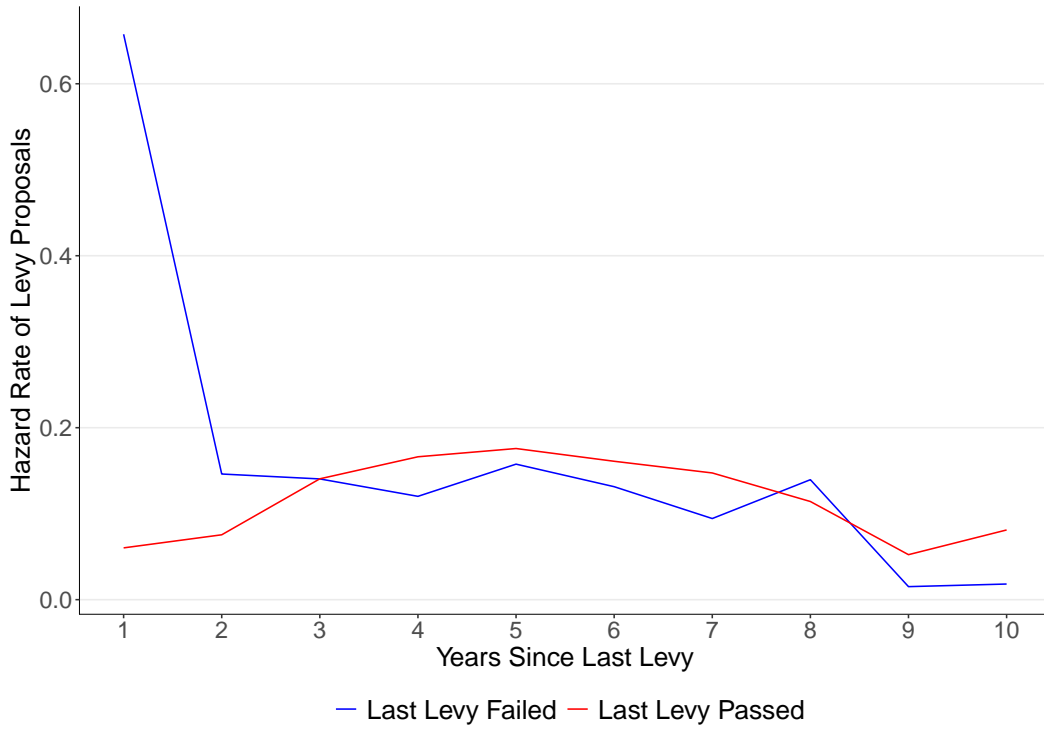
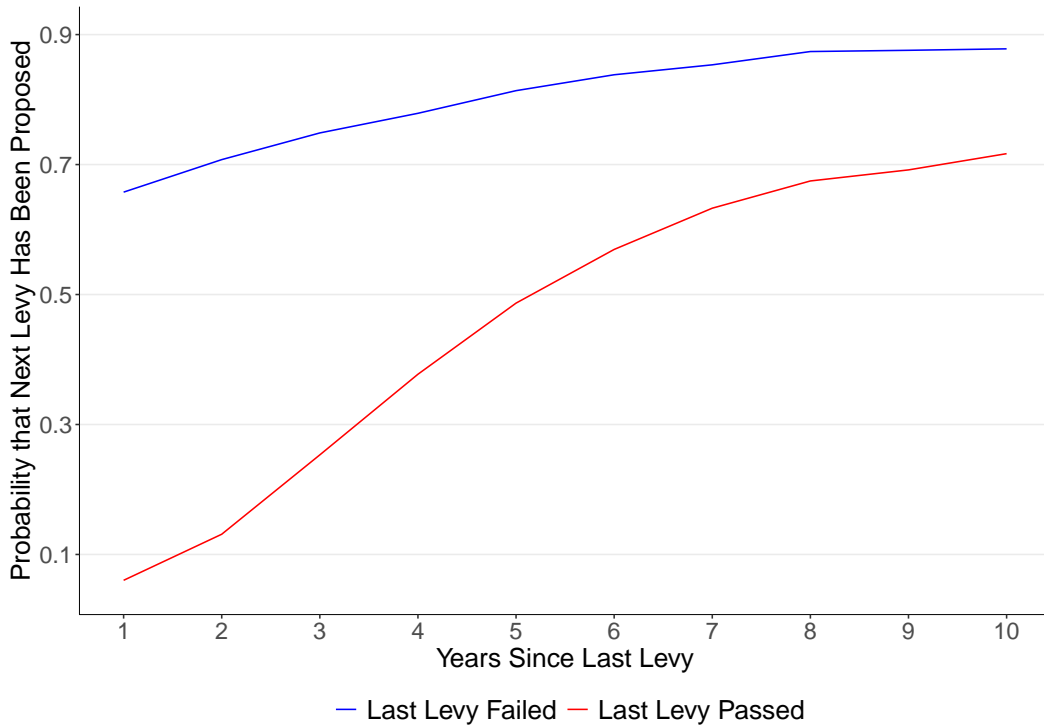


Figure 6: Cumulative Probabilities of Levy Proposals,
by Time Since Last Levy



Figures 5 and 6 make these points graphically. After a successful levy, the levy-proposal hazard rate (i.e., the probability that a levy proposal is made t years after the previous proposal) is highest in years three through eight, at just under 20%. By year five, the cumulative probability that the district has held its next levy is about 50%, and by year eight, this probability has risen to about 65%. Districts' behavior after a failed levy vote is quite different. In the year immediately following a failed levy vote, over 60% of districts propose another levy. The hazard rate then drops sharply in years two through ten, causing the cumulative-probability line to remain relatively flat as time elapses after the failed vote. Again, these empirical patterns are intuitive within the model's theoretical framework. A levy proposal indicates that the district's marginal utility of spending is high; if the levy fails and revenue does not change, the district's marginal utility of spending remains high the next year and the district is likely to propose another levy. If the original levy proposal succeeds, districts use the additional revenue to boost spending and replenish their asset buffers, then return to the ballot gradually in future years as HB 920 reductions and negative state funding shocks again raise the marginal utility of spending.

5.3 The Spending-Saving Decision

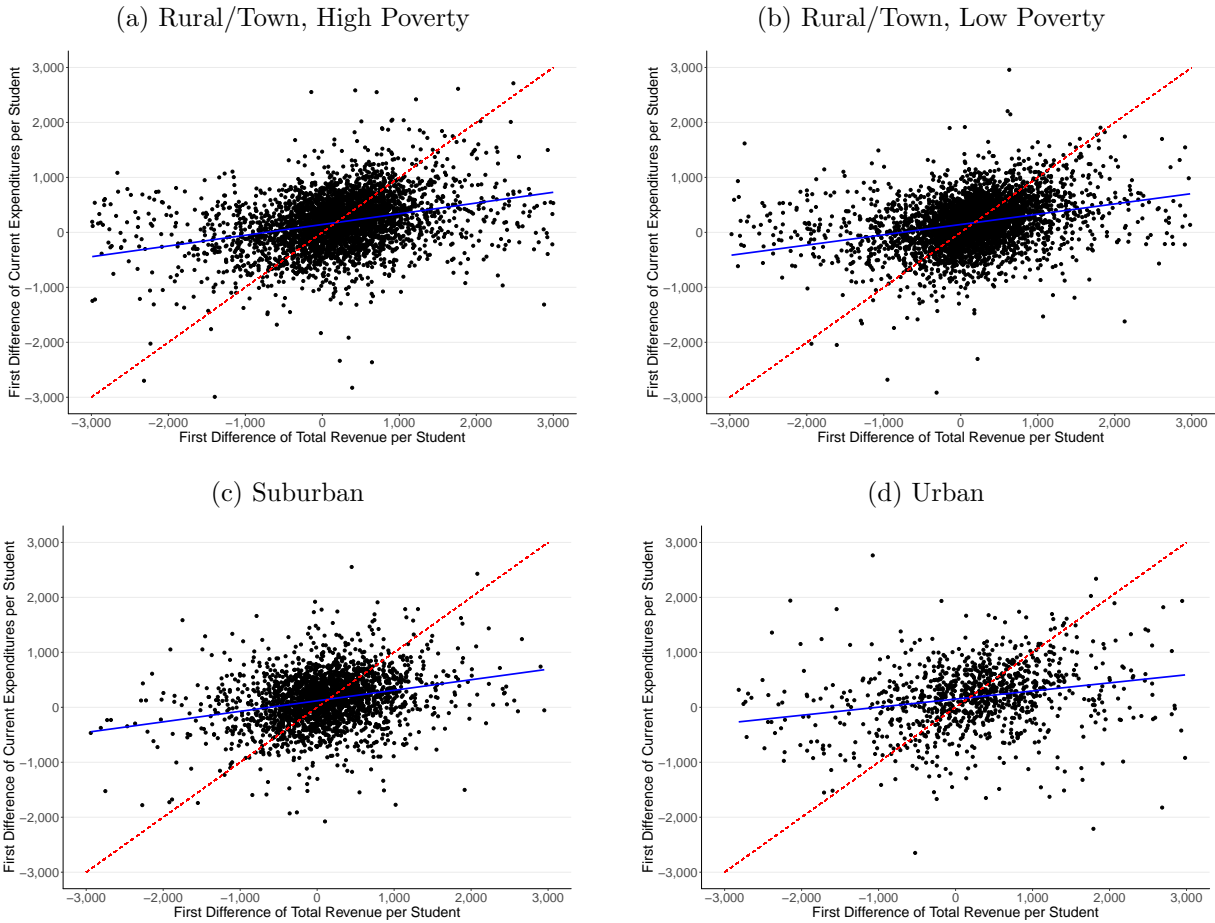
The model's first prediction regarding the spending-saving decision is simple: districts should not live hand-to-mouth, and should instead use asset buffers to smooth spending dynamically in the presence of revenue volatility and concave utility functions.

As first proposed by [Holtz-Eakin, Rosen, and Tilly \(1994\)](#), a straightforward way to test for dynamic spending behavior among local government bodies is to measure the pass-through of annual revenue changes to spending levels. Figure 7, which plots the first difference of total revenue against the first difference of current expenditures for each of the four district groups, performs this test and clearly rejects the null hypothesis of hand-to-mouth behavior. If districts consumed their revenue each year, then we would expect revenue changes to pass through one-for-one into spending changes, causing most points to lie near the red 45-degree line. Ohio districts' spending choices, in contrast, are much less sensitive to current revenue, as all four of the blue regression lines have slopes less than 0.2.

Districts are able to divorce spending choices from current revenue levels because, as shown in Figure 8, they do indeed maintain substantial savings buffers.¹⁸ The modal district in each of the four groups holds enough assets to cover between 15% and 20% of its annual current expenditures, and a noticeable fraction of districts in the right tail of the distributions holds upwards of 40%. Savings buffers of this size indicate significant concavity in districts' utility functions; if districts were close to risk-neutral, they would perceive little future risk to their marginal utility of spending and would not find it optimal to maintain such large cash reserves.

¹⁸I take asset holdings data from the National Center for Education Statistics' F-33 survey, which asks districts to report their asset holdings at the end of the fiscal year. I then lag this measure by one year to obtain the asset holdings available to the district at the beginning of the next fiscal year. The important point is that, since they are measured at the end of the fiscal year, reported asset holdings do not simply reflect temporary balances caused by timing differences between revenue inflows and spending outflows. The asset holdings analyzed in the paper arise from districts' active decisions to maintain precautionary savings buffers.

Figure 7: Pass-Through of Annual Revenue Changes



Beyond the maintenance of asset buffers and the absence of hand-to-mouth behavior, the model predicts a relationship between districts' spending-saving decisions and their current revenue levels. Given the nominal freeze on local revenue imposed by HB 920 (as well as any mean-reverting tendencies in the evolution of state funding), high revenue today means that large future revenue decreases are more likely. Forward-looking districts should therefore tend to run budget surpluses and replenish their asset buffers when revenue is higher than usual, and save less (or dissave) when revenue is unusually low. Large budget surpluses indicate that the marginal utility of spending is likely to be higher in the future than it is today; conversely, small surpluses (including deficits) imply that the current marginal utility of spending is high relative to the value of buffer-stock savings.

Figure 9, which plots local linear regressions of budget surplus against demeaned revenue, confirms the predicted positive correlation between the two variables. When revenue is below average, districts spend most or all of their current revenue: the average district in three of the four groups runs budget deficits while the average urban district chooses surpluses just above zero. As demeaned revenue becomes positive, all four lines move upward with a slope of about 1, reaching to surpluses of about \$4,000 per student when revenue per student is \$4,000 above average. Districts do appear to be making a careful, state-dependent tradeoff

Figure 8: Distribution of Assets per Dollar of Current Expenditure

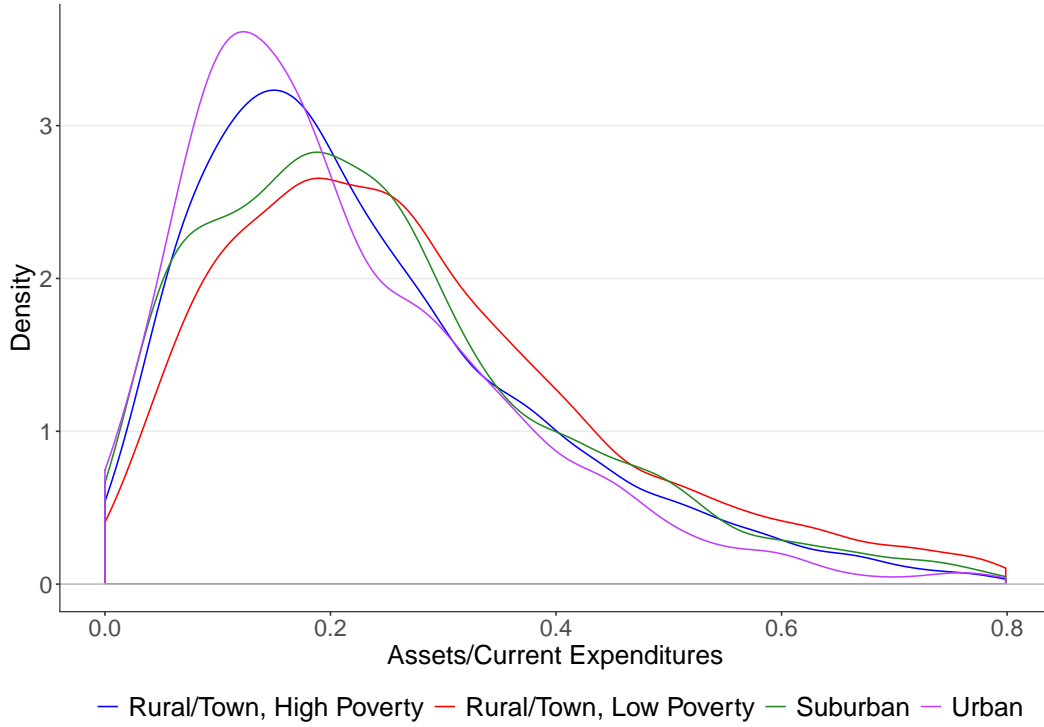


Figure 9: District Budget Surpluses and Current Revenue

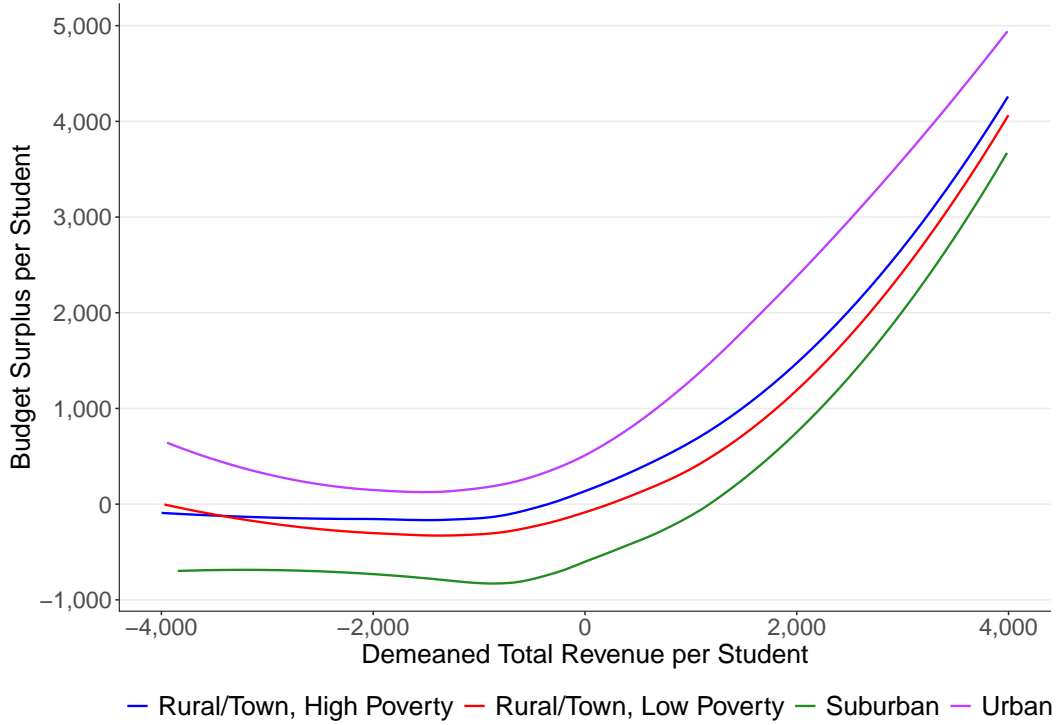


Table 6: District Budget Surpluses and Current Finances

	Dependent Variable: Budget Surplus per Student			
	Rural/Town, High Poverty	Rural/Town, Low Poverty	Suburban	Urban
Demeaned Revenue per Student	1.10*** (0.01)	1.11*** (0.01)	0.85*** (0.05)	1.04*** (0.03)
Demeaned Revenue per Student < 0	243.43*** (39.35)	284.63*** (37.44)	61.93 (60.67)	-156.86* (88.29)
Demeaned Revenue per Student * Demeaned Revenue per Student < 0	-1.03*** (0.02)	-1.08*** (0.02)	-0.87*** (0.07)	-1.05*** (0.05)
Demeaned Asset Holdings per Student	-0.07*** (0.01)	-0.07*** (0.01)	-0.02** (0.01)	-0.10*** (0.02)
Constant	-115.61*** (41.11)	-336.76*** (36.75)	-771.53*** (48.65)	648.88*** (95.93)
Observations	4,450	4,572	2,576	1,151
R ²	0.82	0.83	0.27	0.73

Note: This table presents linear regressions where the observations are district-years and the dependent variable is the district's budget surplus per student. Clustered standard errors are in parentheses, and asterisks indicate statistical significance at p-values of 0.1, 0.05, and 0.01.

between spending and precautionary saving, with observed variation in revenue sufficient to push them from running deficits of several hundred dollars per student to running surpluses of several thousand dollars per student.

The fact that the regression lines are nearly flat to the left of zero before sloping upward suggests that districts have some sort of target or reference spending level, roughly equal to their average revenue, above which the marginal utility of spending drops sharply. Table 6 presents the information in Figure 9 quantitatively and confirms the kink in budget surpluses. When demeaned revenue is negative, the derivative of budget surplus with respect to revenue is roughly zero (obtained by summing the coefficients in the first and third rows); when demeaned revenue is positive, each additional dollar of revenue passes through roughly one-for-one into increased saving (except for suburban districts, who save about 85 cents of the marginal dollar). Motivated by the evidence here, I account for the possibility of a target spending level when parameterizing the model in Section 6.

6 Estimating the Model

Having confirmed the qualitative predictions of the model and established its empirical relevance, I now introduce and estimate a fully parameterized specification that can serve as the basis of quantitative policy analysis.

6.1 Parameterization

6.1.1 State Evolution and Levy Passage

As in Section 4, time is measured in years and is indexed by t . I introduce an additional subscript i to index districts. The five state variables discussed in Section 4.1 continue to describe the environment, so district i in year t conditions its decisions on the state

$$s_{i,t} \equiv (a_{i,t}, g_{i,t}, p_{i,t}, q_i, j_{i,t}). \quad (17)$$

I assume that revenue shocks are proportional rather than additive, so I specify the revenue evolution processes as linear in logs:

$$\log(g_{i,t}) = \alpha_g + \rho_g \log(g_{i,t-1}) + \eta_t, \quad (18)$$

$$\log(\tilde{p}_{i,t}) = \alpha_p + \rho_p \log(p_{i,t-1}) + \xi_t, \quad (19)$$

$$\eta_t \sim N(0, \sigma_g), \quad (20)$$

$$\xi_t \sim N(0, \sigma_p), \quad (21)$$

where again $\tilde{p}_{i,t}$ denotes legacy local revenue (i.e., revenue from all taxes already operative for district i in year $t-1$, excluding any additional revenue from levies passed in year $t-1$). I estimate the parameters $(\alpha_g, \rho_g, \sigma_g, \alpha_p, \rho_p, \sigma_p)$, separately for each of the four district groups, directly from the data in a first step.

In parameterizing the π function that gives levy-passage probabilities, I aim for a flexible specification that reflects the reduced-form patterns in Section 5.1 while providing more quantitative accuracy and bounding predicted values between zero and one. I assume that passage probabilities follow a logit model, with inputs that include the district fixed effects q_i and second-order polynomials of the elapsed-time variable $j_{i,t}$ and requested revenue amount $m_{i,t}$. Formally, for district i proposing a levy in year t ,

$$\Pr(\text{levy passes}) = \pi(q_i, j_{i,t}, m_{i,t}) = \frac{\exp(X'_{i,t}\lambda)}{1 + \exp(X'_{i,t}\lambda)},$$

$$X_{i,t} \equiv (q_i, j_{i,t}, j_{i,t}^2, m_{i,t}, m_{i,t}^2)'. \quad (22)$$

I again estimate the parameter λ directly from the levy-voting data in a first step. Because the levy-voting data contain fewer observations than the district panel (the annual levy-proposal rate is about 20%), and because the π specification already includes district fixed effects, I estimate λ once rather than separately for each of the four district groups.

6.1.2 Preferences

The key structural objects to be recovered are districts' utility functions over current expenditures per student. I use the standard constant relative risk aversion form, while also allowing for the reference spending levels that appear to drive the target spending behavior documented in Section 5.3. The utility function for district i is

$$u_i(e) = \begin{cases} \frac{1}{1-\gamma} \left(\left(\frac{e}{\phi_i} \right)^{1-\gamma} \right) & \text{if } e \leq \phi_i \\ \frac{1}{1-\gamma} \left(1 + \delta \left(\frac{e}{\phi_i} - 1 \right) \right)^{1-\gamma} & \text{if } e > \phi_i, \end{cases} \quad (23)$$

where γ is the coefficient of relative risk aversion, ϕ_i is district i 's reference spending level, and $\delta \in [0, 1]$ allows the marginal utility of spending to drop discretely above the reference level (while nesting the baseline CRRA case with $\delta = 1$). Motivated by the clear reduced-form pattern in Figure 9 and Table 6 (where the relationship between budget surplus and demeaned revenue displays a sharp kink at zero), I set ϕ_i equal to district i 's mean total revenue during the sample period. In addition to being supported by the reduced-form evidence, this assumption is also intuitive: state funding shocks and HB 920 reductions cause year-to-year revenue variation, but as districts make dynamic levy-proposal decisions to achieve their long-run spending targets, their realized average revenue over a 21-year sample period will reflect their reference spending levels.

To account for unobservable year-to-year variation in spending needs, I introduce a multiplicative shock to the utility function. I denote these spending shocks with $\psi_{i,t}$, so that the flow utility from spending for district i in year t is

$$\psi_{i,t} u_i(e_{i,t}). \quad (24)$$

I assume the spending shocks are lognormally distributed with mean zero and are independent of the state, so that

$$\log(\psi_{i,t}) \sim N(0, \sigma_\psi), \quad (25)$$

$$\psi_{i,t} \perp s_{i,t}. \quad (26)$$

Finally, I make the standard assumption that the district's discrete levy choice is influenced by Type 1 extreme value shocks ϵ^L and ϵ^N (corresponding to the levy and no-levy choices, respectively). These discrete-choice shocks are independent of the state and the spending shock $\psi_{i,t}$:

$$(\epsilon_{i,t}^L, \epsilon_{i,t}^N) \perp s_{i,t}, \quad (27)$$

$$(\epsilon_{i,t}^L, \epsilon_{i,t}^N) \perp \psi_{i,t}. \quad (28)$$

The fact that levies do not provide revenue until the year after they are passed makes (28) a reasonable assumption: $\psi_{i,t}$ reflects unobservable shocks to current marginal utility that affect the spending-saving choice in year t , while $(\epsilon_{i,t}^L, \epsilon_{i,t}^N)$ reflect unobservable shocks to levy-proposal costs that influence the conceptually distinct decision to ask voters for increases in future revenue.

6.1.3 District Optimization

Accounting for the spending and discrete-choice utility shocks, the choice-specific value function for the no-levy case in (10) becomes

$$V^N(s_{i,t}; \epsilon^N) = \mathbb{E}_\psi \left[\max_{e \leq a_{i,t} + g_{i,t} + p_{i,t}} \psi u_i(e) + \epsilon^N + \beta \mathbb{E}[V(s_{i,t+1}) | s_{i,t}, e] \right], \quad (29)$$

and that of the levy case in (12) becomes

$$V^L(s_{i,t}; \epsilon^L) = \mathbb{E}_\psi \left[\max_{m, e \leq a_{i,t} + g_{i,t} + p_{i,t}} \psi u_i(e) - c + \epsilon^L + \beta \left(\pi(q_i, j_{i,t}, m) \mathbb{E}[V(s'_{i,t+1}) | s_{i,t}, e] + (1 - \pi(q_i, j_{i,t}, m)) \mathbb{E}[V(s_{i,t+1}) | s_{i,t}, e] \right) \right], \quad (30)$$

where for brevity $s'_{i,t+1} \equiv (a_{i,t+1}, g_{i,t+1}, \tilde{p}_{i,t+1} + m, q_i, 1)$ gives the state evolution conditional on levy passage.

After observing their realized utility shocks $(\psi_{i,t}, \epsilon_{i,t}^L, \epsilon_{i,t}^N)$, districts make the discrete levy choice that yields higher value. Defining the mean choice-specific values as $\tilde{V}^L(s_{i,t}) \equiv V^L(s_{i,t}; 0)$ and $\tilde{V}^N(s_{i,t}) \equiv V^N(s_{i,t}; 0)$, the extreme-value assumption for (ϵ^L, ϵ^N) gives a closed-form expression for the levy-proposal probability:

$$\Pr(\text{levy proposed} | s_{i,t}) \equiv L(s_{i,t}) = \frac{\exp(\tilde{V}^L(s_{i,t}))}{\exp(\tilde{V}^L(s_{i,t})) + \exp(\tilde{V}^N(s_{i,t}))}. \quad (31)$$

Finally, after making their discrete levy decision, districts choose spending according to modified versions of the Euler conditions in (11) and (14). In the no-levy case, spending satisfies

$$\psi_{i,t} u'_i(e_{i,t}) = \beta(1+r) \mathbb{E}[V_a(s_{i,t+1}) | s_{i,t}, e_{i,t}], \quad (32)$$

while in the levy case spending satisfies

$$\psi_{i,t} u'_i(e_{i,t}) = \beta(1+r) \left(\pi(q_i, j_{i,t}, m_{i,t}) \mathbb{E}[V_a(s'_{i,t+1}) | s_{i,t}, e_{i,t}] + (1 - \pi(q_i, j_{i,t}, m_{i,t})) \mathbb{E}[V_a(s_{i,t+1}) | s_{i,t}, e_{i,t}] \right). \quad (33)$$

6.2 Estimation Strategy

After obtaining the revenue-evolution and levy-passage parameters in the first step,¹⁹ the structural parameters θ that remain to estimate are the risk-aversion coefficient, reference-spending-level sensitivity, spending-shock dispersion, and levy-proposal cost:

$$\theta = (\gamma, \delta, \sigma_\psi, c). \quad (34)$$

¹⁹I also set the discount factor to $\beta = 0.97$ and the interest rate to $r = 0.02$.

I estimate θ by maximum likelihood. For a posited value of θ , I first perform value-function iteration to obtain $\tilde{V}^L(\cdot)$, $\tilde{V}^N(\cdot)$, and $V(\cdot)$. Then, using the Euler equations above, I can back out the spending shocks necessary to rationalize districts' observed spending decisions. For each district-year observation, I check whether a levy was proposed and take the relevant optimality condition from (32)-(33). Defining $z(s_{i,t}, e_{i,t})$ as the right-hand side of the relevant optimality condition, we have:

$$\begin{aligned} \psi_{i,t} u'_i(e_{i,t}) &= z(s_{i,t}, e_{i,t}) \\ \implies \psi_{i,t} &= \frac{z(s_{i,t}, e_{i,t})}{u'_i(e_{i,t})}. \end{aligned} \quad (35)$$

With the spending shocks $\psi_{i,t}$ inferred from (35),²⁰ the state-dependent levy-proposal probabilities $L(s_{i,t})$ given by (31), and the independence of the utility shocks assumed in (28), it is straightforward to write the log-likelihood function:

$$\mathcal{L}(\theta) = \sum_i \sum_t \log \left(f \left(\frac{\log(\psi_{i,t})}{\sigma_\psi} \right) \right) + I_{i,t} \log \left(L(s_{i,t}) \right) + (1 - I_{i,t}) \log \left(1 - L(s_{i,t}) \right), \quad (36)$$

where $f(\cdot)$ is the standard normal density function and $I_{i,t}$ is an indicator equal to one if district i proposed a levy in year t . The structural estimate $\hat{\theta}$ maximizes the log-likelihood function,

$$\hat{\theta} = \underset{\theta}{\operatorname{argmax}} \mathcal{L}(\theta). \quad (37)$$

Appendix sections A.1-A.2 provide more detail about the estimation procedure.

6.3 Identification

The likelihood function in (36) is designed to choose structural parameters that explain as much of districts' spending and levy decisions as possible. At the true value of θ , the utility function $u_i(\cdot)$ and value function $V(\cdot)$ in (32)-(33) will provide an accurate description of districts' spending-saving tradeoff, and the implied log spending shocks $\log(\psi_{i,t})$ will be symmetrically distributed around zero with the correct dispersion σ_ψ . At incorrect values of θ , the $u_i(\cdot)$ and $V(\cdot)$ functions will poorly approximate the relative returns to spending and saving, forcing the spending shocks to do most of the work in rationalizing districts' decisions and leading to $\log(\psi_{i,t})$ values that are extreme, asymmetric, or otherwise unlikely under the assumed normal distribution. Similarly, the true value of θ will accurately capture the state-dependent cost-benefit consideration involved in the levy-proposal decision, producing predicted levy probabilities $L(s_{i,t})$ that are higher in states where levy proposals are more common empirically. Incorrect values of θ will fail to make $\tilde{V}^L(\cdot)$ higher than $\tilde{V}^N(\cdot)$ in states where levies are actually proposed, leading to implied discrete-choice shocks $(\epsilon_{i,t}^L, \epsilon_{i,t}^N)$ that are unlikely under the assumed Type 1 extreme value distribution.

²⁰Of course, the Euler conditions only apply for interior spending solutions. I therefore drop $\psi_{i,t}$ values obtained from observations where the district exhausts its asset holdings and spends all of its cash on hand.

More concretely, the utility parameters γ and δ are identified by differences in district behavior between high- and low-cash-on-hand states. The concavity of $u_i(\cdot)$ causes the marginal utility of spending to be higher when revenue and asset levels are low; as demonstrated in Section 5, this concavity causes districts to save less and propose more levies in low cash-on-hand years. The risk-aversion coefficient γ controls the rate at which the marginal utility of spending diminishes, and is therefore responsible for matching the empirical differences in saving and levy-proposal rates between high- and low-cash-on-hand years. If the relationships between cash on hand and district behavior are discontinuous – i.e., if there are discrete jumps in saving and levy-proposal rates around the reference spending levels ϕ_i – then γ alone will be insufficient to describe the data, and δ will be pushed below 1 to reflect the kink in marginal utility at the reference spending level. The large amount of empirical variation in revenue and asset levels (documented in Section 3.2) makes identification of γ and δ possible; since I assume uniform structural parameters within each of the four district groups, variation both across and within districts provides identifying information.

The identification arguments for σ_ψ and c are also intuitive. The σ_ψ parameter is identified by a fixed-point condition: it must match the distribution of the spending shocks that are, in turn, generated by the full parameter vector θ (since the ratio in (35) that implies $\psi_{i,t}$ depends on θ). The levy cost c does not vary with the state and is therefore identified by the unconditional levy-proposal rate across the sample.

6.4 Estimation Results

Table 7 presents the estimation results. The structural parameters matter primarily for the district behavior they produce in the counterfactual simulations, and the estimated parameter values indicate some important differences between the four district groups that will yield heterogeneous responses to state funding changes. The suburban and low-poverty rural districts have similar parameter estimates, with relatively high risk-aversion values (0.775 and 0.880, respectively) and noticeable marginal-utility jumps at their reference spending levels (with δ values of 0.844 and 0.947 that are substantially less than 1). Conversely, urban and high-poverty rural districts are less risk averse (with γ values of 0.228 and 0.453, respectively) and do not display marginal-utility jumps at their reference spending levels, with estimated δ values very close to 1. As discussed in Section 7.2, higher risk aversion (created by large γ values and small δ values) leads to larger behavioral reactions after state policy shifts: for a given change in state funding, a more risk-averse district will experience a larger change in marginal utility, and will therefore be more likely to adjust its saving and levy-proposal decisions in response. We should expect suburban and low-poverty rural districts to display the largest behavioral responses to state funding changes, and the counterfactual analysis in the next section shows that this is indeed the case. The higher risk-aversion estimates for suburban and low-poverty rural districts also reflect directly observable reduced-form patterns in Section 5: these two district groups maintain larger precautionary asset buffers (Figure 8) and display a stronger relationship between current revenue and levy-proposal rates (Table 5).

The estimated levy-proposal costs c are another important input to the counterfactual analysis. For ease of interpretation, I divide the c estimates (originally in utils) by the flow utility value associated with districts’ reference spending levels, i.e., $\frac{1}{1-\gamma}$ (see Equation 23).

Table 7: Structural Estimation Results

	Rural/Town, High Poverty	Rural/Town, Low Poverty	Suburban	Urban
γ	0.453 (0.031)	0.880 (0.084)	0.775 (0.084)	0.228 (0.008)
δ	0.988 (0.005)	0.947 (0.008)	0.844 (0.016)	0.993 (0.003)
σ_ψ	0.151 (0.012)	0.259 (0.018)	0.121 (0.008)	0.052 (0.007)
c (scaled)	2.363 (0.143)	0.722 (0.240)	1.108 (0.213)	2.778 (0.096)

Note: This table presents structural estimation results for the parameterized model described in Sections 6.1-6.2. For ease of interpretation, the levy-proposal cost c is scaled by the flow utility value associated with districts' reference-spending levels, i.e., $\frac{1}{1-\gamma}$ (see Equation 23). For example, the scaled levy-proposal cost for suburban districts implies that they suffer a utility loss equal to 1.108 years of reference-level spending by proposing a levy. Standard errors are in parentheses.

The suburban estimate, for example, implies that suburban districts suffer a utility loss equal to 1.108 years of reference-level spending by proposing a levy. Because levies are proposed when the benefit of additional local revenue outweighs the proposal cost, the level of c helps determine which districts are on the margin of making the proposal decision. If c is very high (very low), then many districts will be far below (far above) the levy-proposal hurdle, and even state funding changes that significantly raise (lower) the marginal utility of spending will be unlikely to alter many districts' levy-proposal decisions. The proposal-cost estimates thus reinforce the behavioral implications of the risk-aversion estimates. With moderate proposal costs (equal to about a year's worth of typical spending), suburban and low-poverty rural districts are more likely to be marginal and pushed to alter their levy-proposal behavior by a state funding change; urban and high-poverty rural districts' high proposal costs (equal to about 2.5 years' worth of typical spending) mean that districts are more likely to be far away from the proposal margin and are less likely to change their proposal decisions after a state funding shock.

Appendix section A.3 provides more information about model fit by describing the distributions of spending shocks and predicted levy probabilities generated by the structural estimates. In general, the model succeeds in producing spending shocks that are lognormally distributed around a mean of zero. Although a substantial amount of variation in levy-proposal decisions remains attributable to the random Type 1 extreme value shocks, the model also yields predicted levy probabilities that are systematically higher for states in

which districts actually propose levies.

7 Counterfactual Analysis

I can now put the estimation results to work in evaluating policy. I begin by describing the simulation method I use to predict the dynamic effects of counterfactual policy changes. To illustrate the method and show how heterogeneous district responses shape long-run policy effects, I analyze simple counterfactual policies that increase or decrease statewide funding levels by a constant amount. Finally, I use the revealed-preference estimates of districts' utility functions to solve for optimal policy and find the reallocations of state aid that maximize statewide welfare.

7.1 Simulation Method

After obtaining the first-step estimates, structural parameters, and corresponding value functions, simulating districts' responses to state policy changes is straightforward. I first choose a starting year t_0 (in all applications here, I set $t_0 = 2017$, the last year of the sample) and initialize districts' state variables at the empirically observed values $s_{i,t_0} = (a_{i,t_0}, g_{i,t_0}, p_{i,t_0}, q_i, j_{i,t_0})$. Any school finance reform can be described by a vector $\{d_i\}$ of state funding changes for each district. Letting hats denote simulated values, I impose the policy reform by perturbing each district's initial state to $\hat{s}_{i,t_0} = (a_{i,t_0}, g_{i,t_0} + d_i, p_{i,t_0}, q_i, j_{i,t_0})$. I then let time move forward:

- (a) Districts propose levies with the state-dependent probabilities in (31) and choose the corresponding requested revenue amounts according to the first-order condition in (13). I probabilistically draw spending shocks $\hat{\psi}_{i,t_0}$ according to (25) and let districts choose spending \hat{e}_{i,t_0} according to the Euler conditions in (32)-(33).
- (b) Proposed levies pass with probabilities given by (22). Assets evolve according to (2), the elapsed-time variable j evolves according to (6), and legacy local revenue evolves according to (19) and (21). To isolate the effect of the initial state funding change, I keep government revenue fixed at $g_{i,t_0} + d_i$ throughout the simulation. I thus obtain each district's next state, \hat{s}_{i,t_0+1} .
- (c) I repeat steps (a) and (b) for years $t_0 + 1, t_0 + 2, \dots, t_{max}$. In all simulations, I consider a five-year time horizon with $t_{max} = t_0 + 4$.

Because levy proposal, levy passage, and local revenue evolution are probabilistic, the result of any one simulation is not very meaningful. I therefore repeat the entire process in steps (a)-(c) many times and take averages over the simulations.²¹ Letting k index simulations, the key outcomes are the average total revenue $\bar{y}_{i,t}$, spending $\bar{e}_{i,t}$, and utility $\bar{u}_{i,t}$ for each district i and year $t \in (t_0, t_0 + 1, \dots, t_{max})$, as a function of the initial state funding

²¹I repeat the simulation 500 times for each state funding change d that I consider.

change d :

$$\bar{y}_{i,t}(d) \equiv \frac{1}{K} \sum_{k=1}^K g_{i,t_0} + d + \hat{p}_{i,t}^{k,d}, \quad (38)$$

$$\bar{e}_{i,t}(d) \equiv \frac{1}{K} \sum_{k=1}^K \hat{e}_{i,t}^{k,d}, \quad (39)$$

$$\bar{u}_{i,t}(d) \equiv \frac{1}{K} \sum_{k=1}^K u_i(\hat{e}_{i,t}^{k,d}). \quad (40)$$

The effect of the policy change can be determined by comparing $\bar{y}_{i,t}$, $\bar{e}_{i,t}$, and $\bar{u}_{i,t}$ to the results of “status-quo” simulations where there is no state funding shift at t_0 (i.e., simulations with $d_i = 0 \forall i$). Formally, for district i and year t , define the effects of a state funding change d on revenue, spending, and utility as

$$\Delta \bar{y}_{i,t}(d) \equiv \bar{y}_{i,t}(d) - \bar{y}_{i,t}(0), \quad (41)$$

$$\Delta \bar{e}_{i,t}(d) \equiv \bar{e}_{i,t}(d) - \bar{e}_{i,t}(0), \quad (42)$$

$$\Delta \bar{u}_{i,t}(d) \equiv \bar{u}_{i,t}(d) - \bar{u}_{i,t}(0). \quad (43)$$

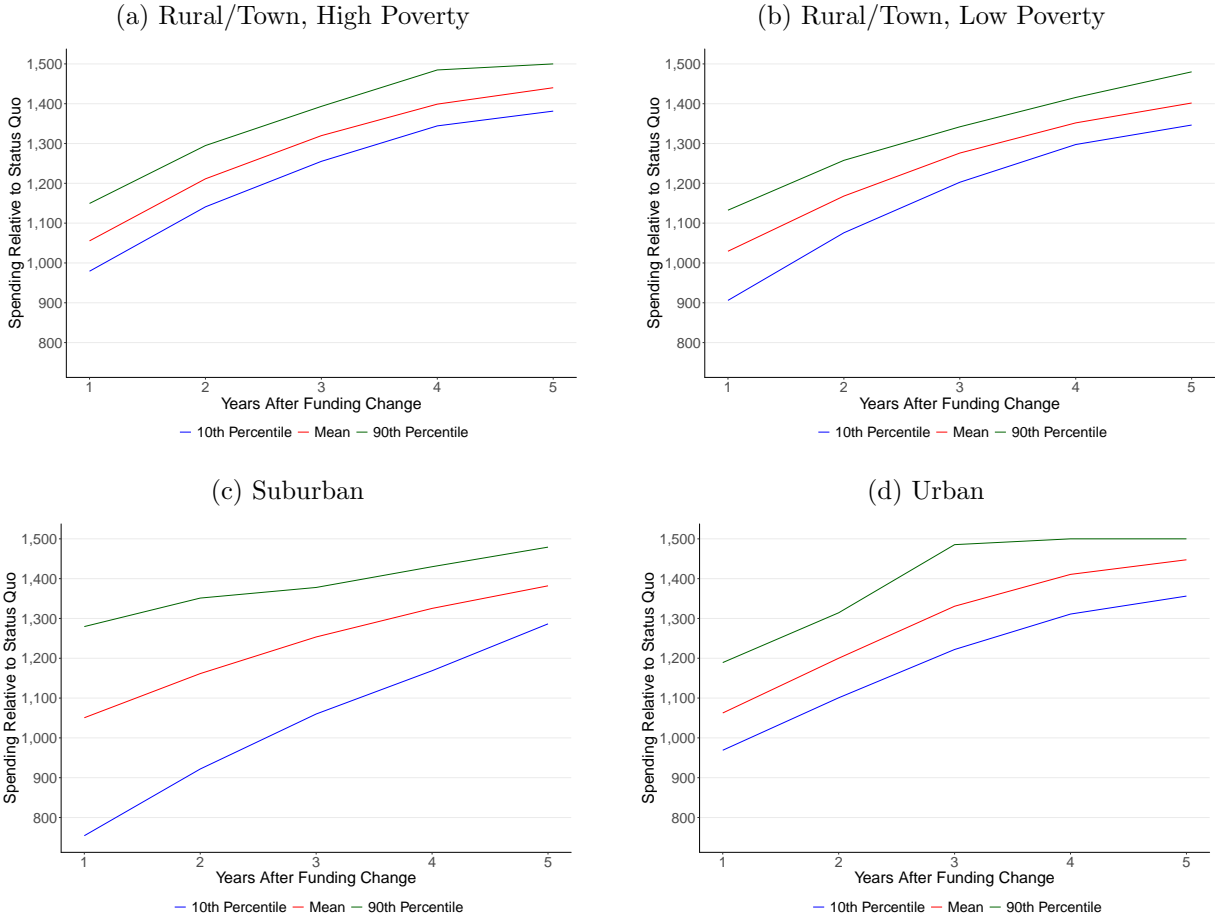
In the year the policy change is imposed, its effect on revenue is entirely mechanical: the state funding perturbation changes the district’s government revenue by exactly d and any proposed levies do not pay off until the next year, so $\Delta \bar{y}_{i,t_0}(d) = d$. The initial spending effect $\Delta \bar{e}_{i,t_0}(d)$ need not equal d , since districts can save into or spend out of their existing asset buffers a_{i,t_0} . In all future years after t_0 , the revenue effect reflects both the initial mechanical change in government revenue *and* districts’ behavioral responses. If increases (decreases) in state funding lead districts to propose and pass fewer (more) levies than they otherwise would have, then $\{\Delta \bar{y}_{i,t}(d) : t > t_0\}$ will be smaller in absolute value than d . The future spending effects $\{\Delta \bar{e}_{i,t}(d) : t > t_0\}$ will reflect both the revenue effects and the spending-saving decisions that districts make conditional on their realized revenue levels.

7.2 Heterogeneous District Responses to State Funding Changes

I begin the counterfactual exercises by analyzing two simple, hypothetical policy changes: a uniform increase and a uniform decrease of \$1,500 in state funding per student for all districts. I do so in order to demonstrate the simulation method, and to show how the structural estimates combine with variation in initial conditions to produce heterogeneity in districts’ responses to state funding changes. The \$1,500 amount is of course arbitrary but serves as a useful example since it is both large enough to provoke meaningful behavioral responses and within the realm of empirical possibility if Ohio were to experience a substantial change in its education budget (\$1,500 per student represents about 20% of total state aid in 2017).

Figures 10 and 11 show how districts’ spending evolves over the five-year period following the counterfactual changes of \$1,500 in state funding per student. Each panel focuses on one of the four district groups, with lines displaying the distribution (10th percentile, mean, and 90th percentile) among districts of the policy-induced spending change $\Delta \bar{e}_{i,5}(d)$ defined

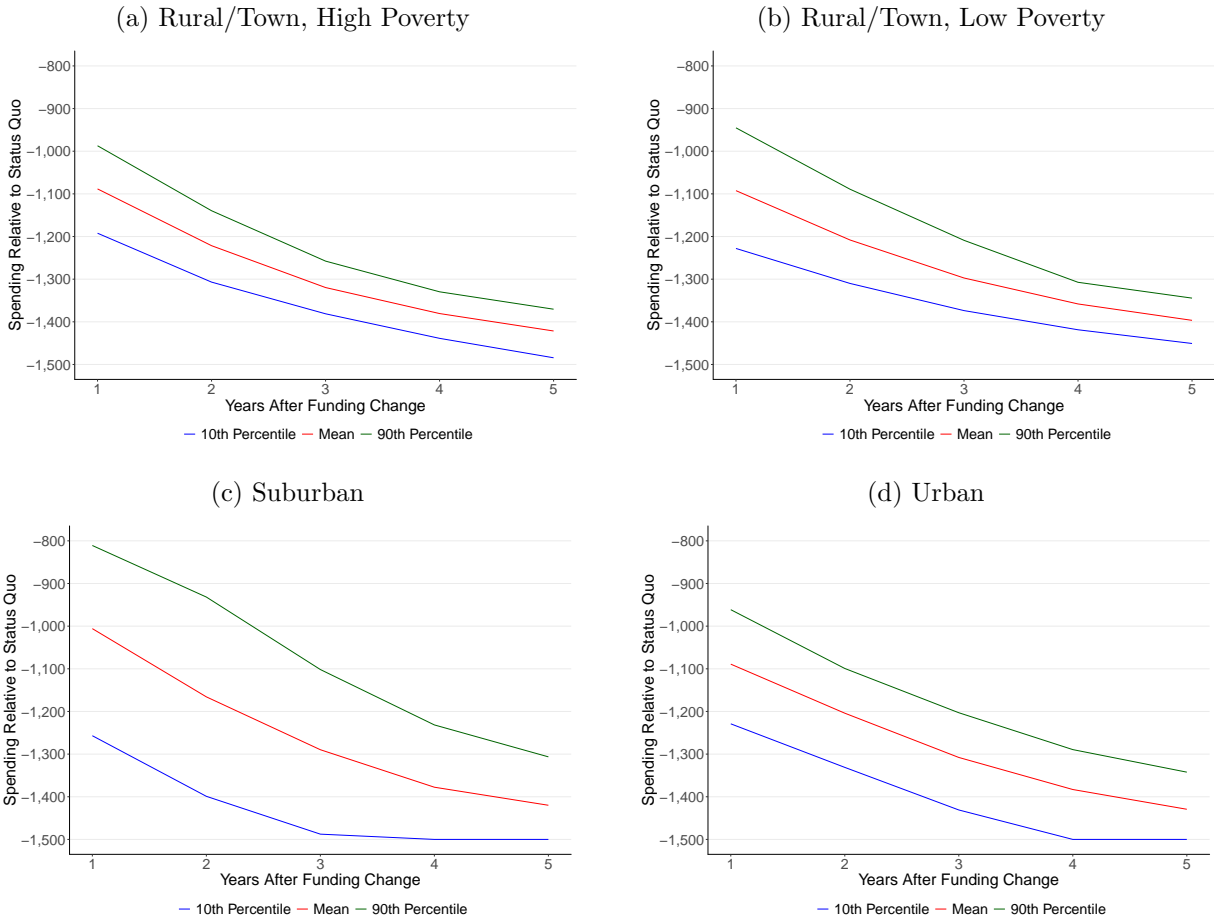
Figure 10: District Spending Responses to \$1,500 Increase in State Funding



in (42), with $d \in \{-\$1,500, \$1,500\}$. In all of the graphs, the offsetting behavioral responses that reduce the spending impact of the state funding change are largest in the first year – accounting for between \$400 and \$500 of the initial \$1,500 shock for the mean district – before fading gradually over time. These stronger behavioral responses earlier in the post-policy-change period are primarily driven by adjustments in saving rates: districts use some of the \$1,500 funding increase to replenish their precautionary savings buffers before gradually spending down the additional assets; conversely, districts dip into their existing savings buffers in order to blunt the initial shock of the \$1,500 funding decrease and delay more painful spending cuts for as long as possible. As discussed in Section 6.4, the higher risk-aversion and reference-spending-sensitivity estimates for the suburban and low-poverty rural groups mean that these districts experience a larger change in marginal utility after the state funding shock and therefore tend to make larger adjustments in saving rates. The larger saving responses for suburban and low-poverty rural districts (particularly after a funding cut) are also driven by the fact that they have slightly larger existing asset buffers to draw upon (see Figure 8).

Offsetting saving adjustments do not continue indefinitely, since districts eventually accumulate the desired amount of additional assets or draw down too much of their existing asset

Figure 11: District Spending Responses to \$1,500 Decrease in State Funding



buffers. Longer-run spending effects at the end of the five-year horizon are instead driven by adjustments in levy behavior. Following a state funding increase, districts induced to forgo a levy that they would have otherwise proposed and passed have lower total revenue than the status-quo scenario and tend to spend less; following a state funding decrease, districts that respond by proposing and passing an additional levy have higher total revenue and tend to spend more. Again echoing the discussion in Section 6.4, the fact that suburban and low-poverty rural districts have more estimated concavity in their utility functions causes state funding changes to induce larger shifts in their marginal utility and therefore produce stronger levy-proposal responses; the lower estimated levy-proposal costs for these districts also mean that they are more likely to be pushed across the levy-proposal margin by a given shift in marginal utility. The fifth-year spending changes accordingly tend to be smaller in absolute value for suburban and low-poverty rural districts, though the levy-driven variation in long-run spending effects is smaller both across and within district groups than the saving-driven variation in shorter-run spending effects.

The adjustments in levy behavior responsible for long-run spending effects are more easily seen in Figures 12 and 13. The density plots in Figure 12 show the distribution of the change in levy proposals induced by the \$1,500 state funding changes (for example, a value

Figure 12: Long-Run Levy-Proposal Behavior After \$1,500 Changes in State Funding

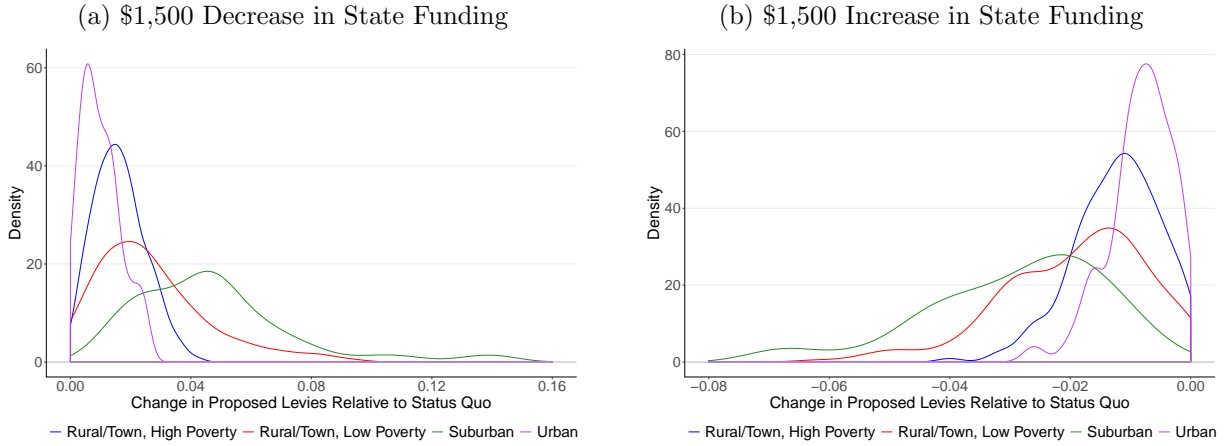
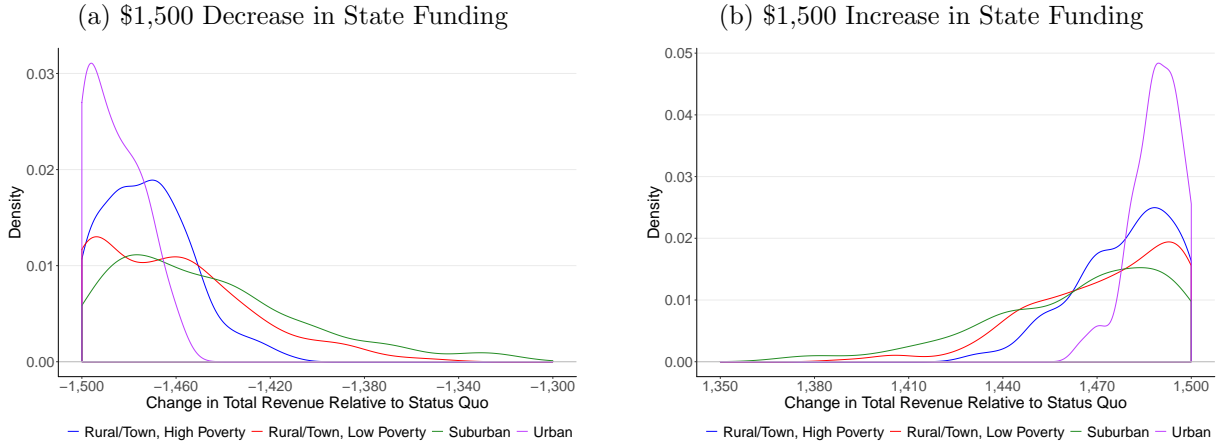


Figure 13: Long-Run Total Revenue Collection After \$1,500 Changes in State Funding



of 0.05 means that a district is 5 percentage points more likely to propose a levy within the five-year time horizon following the state funding change, relative to the status-quo scenario without a funding change). Whereas urban and high-poverty rural districts have most of their mass at or very close to zero, the suburban and low-poverty rural distributions are more dispersed with tails stretching away from zero. Levy responses also appear to be slightly larger following negative state funding changes. For example, after a \$1,500 funding cut, the modal suburban district raises its levy-proposal rate by 5 percentage points and the most responsive district does so by 16 percentage points; after a \$1,500 state funding increase, the modal suburban district reduces its levy-proposal rate by 3 percentage points and the most responsive district does so by 8 percentage points. These magnitudes are relatively modest, but are meaningful relative to baseline annual levy-proposal rates (varying between 17% and 23% depending on district group) and comparable to the linear reduced-form relationships between cash-on-hand components and levy-proposal rates (see Table 5).

Figure 13 plots the distributions of policy-induced revenue changes $\Delta \bar{y}_{i,5}(d)$ (for $d \in$

Table 8: Variation in Long-Run Revenue-Collection Responses to State Funding Changes

	Dependent Variable: Long-Run Change in Total Revenue	
	Following \$1,500 Funding Increase	Following \$1,500 Funding Decrease
Rural/Town, High Poverty	16.25*** (2.10)	-27.03*** (3.07)
Rural/Town, Low Poverty	4.40** (2.18)	-9.13*** (3.18)
Urban	25.25*** (2.70)	-40.57*** (3.93)
Initial Cash on Hand per Student	1.55*** (0.16)	-2.38*** (0.23)
Initial Years Since Last Passed Levy	-2.389*** (0.18)	2.998*** (0.26)
Levy-Passage Fixed Effect (std. devs.)	-9.78*** (0.78)	14.44*** (1.14)
Constant	1,461.83*** (3.11)	-1,436.62*** (4.54)
Observations	606	606
R ²	0.457	0.459

Note: This table presents regressions where the observations are districts and the dependent variables are the five-year changes in total revenue collection following counterfactual state funding changes of \$1,500 per student. The initial cash on hand coefficient has been scaled so that it can be interpreted as the effect of a \$1,000 increase. Suburban districts are the omitted group. Standard errors are in parentheses, and asterisks indicate statistical significance at p-values of 0.1, 0.05, and 0.01.

$\{-\$1,500, \$1,500\}$). These graphs show how shifts in levy-proposal rates – after accounting for passage rates conditional on proposal and the requested revenue amounts chosen by districts – ultimately translate into offsetting changes in local revenue collection. Again, the suburban and low-poverty rural distributions are shifted away from zero, and response magnitudes are larger following state funding cuts. In expectation, the most responsive suburban rural districts recover about \$180 (12%) of a \$1,500 state funding cut by proposing and passing additional levies, while forgoing levies worth about \$120 (8%) following a \$1,500 state funding increase.

Heterogeneity in the estimated structural parameters drives much of the variation in long-run behavioral responses between the four district groups, but as is evident in Figures 12-13, there remains substantial variation within the district groups (particularly for the non-urban groups). Table 8, which presents regressions where the dependent variables are the five-year revenue changes from Figure 13, shows that this within-group variation depends on districts' initial conditions in ways that reflect the model structure. The district-group dummies reflect the parameter heterogeneity discussed above: conditional on initial state variables, suburban and low-poverty rural districts display larger offsetting revenue-collection responses, with revenue changes that are smaller in absolute value after both state funding increases and state funding decreases. Conditional on the structural parameters reflected in

the district-group dummies, revenue changes are also smaller in absolute value for districts with less initial cash on hand, more initial years since their last passed levy, and larger levy-passage fixed effects. The coefficient magnitudes are of less interest here (the point of the simulation process is to allow these counterfactual behavioral responses to be flexibly nonlinear), but the signs are as expected given the setup of the model. Districts with more initial cash on hand have lower initial marginal utility and are further away from the levy-proposal margin, so state funding changes are less likely to alter their levy-proposal decisions. Districts with more elapsed time since their last passed levy and higher levy-passage fixed effects expect a higher passage probability for their next levy proposal, so they are closer to the levy-proposal margin and more likely to have their levy-proposal decisions altered by a state funding change. The higher passage probabilities for these districts also mean that the levies proposed or forgone as a result of the state funding change are more likely to receive voter approval, and therefore more likely to have a realized effect on the districts' total revenue collection.

In summary, districts display heterogeneous behavioral responses to state funding changes, with the heterogeneity driven by differences between the district groups' estimated structural parameters as well as variation in districts' initial state variables. The offsetting behavioral responses are largest in the first few years as districts alter their saving rates, then fade as short-run adjustments to asset buffers cease. The smaller long-run behavioral responses are governed by changes in levy-proposal decisions: districts with more estimated concavity in their utility functions (i.e., the suburban and low-poverty rural groups) and whose initial conditions place them closer to the proposal margin are more likely to alter their levy-proposal decisions and realize offsetting changes in local revenue collection.

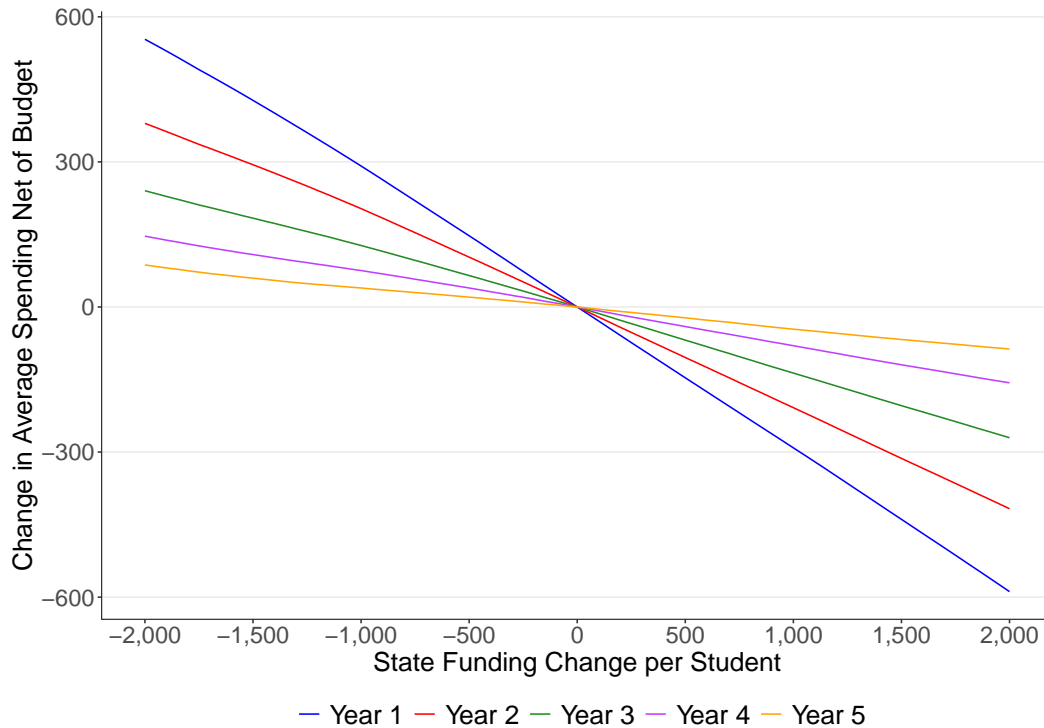
7.3 Implications for Long-Run Policy Effects

The district behavioral responses discussed above have important implications for the dynamic effects of state funding changes on the distribution of education spending. Figures 14 and 15 summarize these dynamic spending effects.

Figure 14 plots the statewide spending effects that result from uniform state funding changes, but allows the size of the funding change (on the x-axis) to vary rather than fixing it at the example \$1,500 amount from Section 7.2. The five lines show the evolution of spending effects over the five years within the policy-analysis horizon. The y-axis gives the change in statewide average spending (pooling all four district groups) that arises from the corresponding state funding shift, net of the funding change itself (e.g., a uniform \$1,000 increase in state funding raises statewide average spending by about \$700 in the first year, so the blue line passes through the point (\$1,000, -\$300)).

Two facts are clear in Figure 14. First, all five of the lines are downward-sloping. The negative slopes are a direct consequence of districts' offsetting behavioral responses. Following a state funding cut, lower saving and higher levy-proposal rates cause the realized effect on average spending to be larger than the mechanical drop in state aid, so the net-of-budget spending change is positive for negative funding changes. Similarly, following a state funding increase, higher saving and lower levy-proposal rates cause the realized effect on average spending to be smaller than the mechanical increase in state aid, so the net-of-budget spending change is negative for positive funding changes. State funding changes

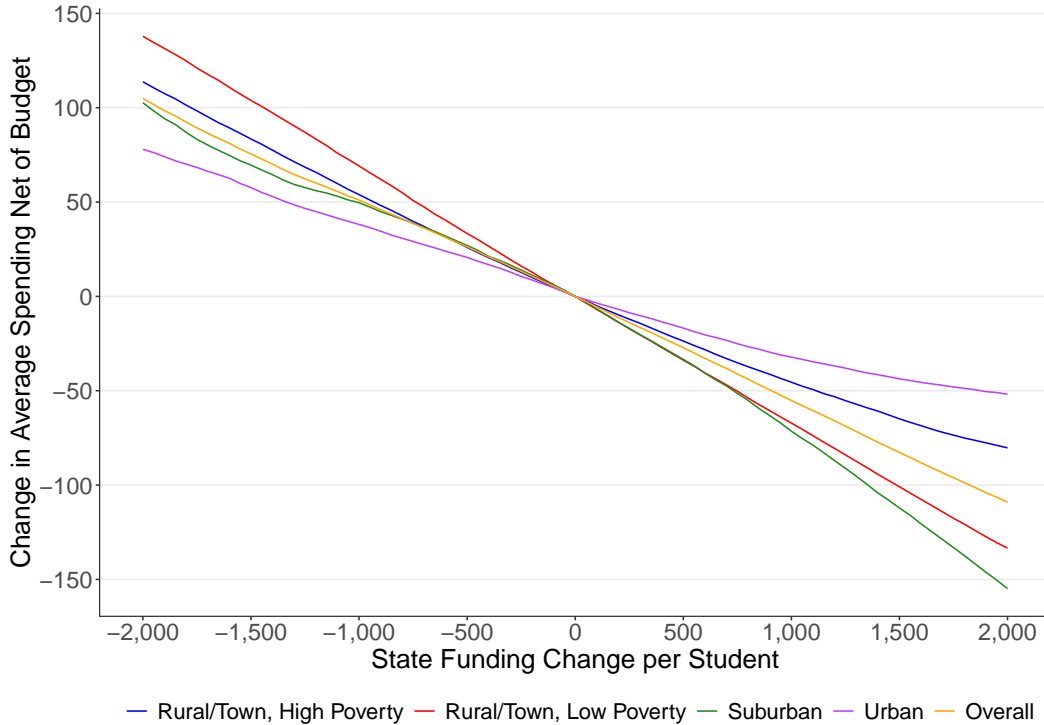
Figure 14: Spending Effects of Uniform State Funding Changes, by Time Horizon



of larger magnitudes provoke larger offsetting behavioral responses, so the lines move away from zero as the x-axis becomes larger in absolute value. In short, districts’ ability to run unbalanced budgets and substitute between revenue sources blunts the ultimate spending impact of state funding changes, so that there are substantial gaps – ranging roughly from \$100 to \$600 per student depending on the time horizon – between the mechanical change in state aid and the ultimate spending effect. The second fact made clear by Figure 14 is that these gaps between mechanical state aid changes and ultimate spending effects fade over time. As discussed in Section 7.2, short-run adjustments to asset buffers are larger than the long-run changes in local revenue collection caused by shifts in levy-proposal behavior. As time progresses and levy responses come to dominate saving adjustments, the spending effect of a policy shift moves closer to (but does not reach) the initial mechanical change in state aid.

Figure 15 has same the same x- and y-axes as Figure 14 but only considers the long-run spending effect in the fifth and final year of the policy-analysis horizon, with the separate lines now showing the statewide average spending effect as well as the average spending effects for each of the four district groups. Once again, offsetting behavioral responses cause the lines to slope downward. The disaggregation now shows how heterogeneity in structural parameters and initial conditions between the district groups alters the relationship between state funding changes and long-run spending effects. As discussed in Section 7.2, suburban and low-poverty rural districts display the largest behavioral responses to policy changes, so the negative relationship between state funding changes and net-of-budget spending effects

Figure 15: Long-Run Spending Effects of Uniform State Funding Changes, by District Group



is steeper for these districts. The overall statewide net-of-budget spending effect is pulled closer to zero by the smaller behavioral responses of urban and high-poverty rural districts.

Together, Figures 14 and 15 highlight several considerations relevant to state policymakers. First, the ultimate effects of school finance reforms on districts' spending levels are not equal to the initial mechanical changes in state aid: spending reductions are not as deep as state funding cuts, and spending increases are not as large as state aid expansions. Second, the consequences of a school finance reform depend heavily on its expected duration. Since short-run adjustments in asset buffers are more effective in moderating the impact of state funding shifts than longer-run changes to levy-proposal behavior, the spending effects of school finance reforms are smallest at short horizons and grow over time. Temporary changes to state aid awards (perhaps due to unforeseen shocks to the state's tax revenue or budgeting process) are therefore less consequential for spending levels than more permanent reforms to the state funding system, and forward-looking communication (e.g., promising a return to normal funding levels after a short period of necessary cuts) can shape the realized effects of policy changes. Third and finally, districts' behavioral responses to policy changes are heterogeneous, depending both on systematic behavioral differences between broad groups (like the four typology categories employed here) and idiosyncratic variation in districts' current financial states. The effect of a given change in state aid depends on the district that receives it. This fact of course raises the possibility that changes in the state's education budget can be targeted efficiently toward the districts with the most favorable behavioral responses and greatest valuations of marginal funds. The next subsection considers

this optimal policy problem.

7.4 Optimal Policy

The counterfactual analysis thus far has used the structural estimates to predict districts' behavioral responses and evaluate the effects of uniform state funding changes on the long-run distribution of education spending. With additional assumptions, I can also use the recovered structure to make normative statements and solve for the optimal policies that maximize a standard linear welfare function. In particular, whereas the preceding descriptive analysis uses the estimated utility functions $u_i(\cdot)$ only to predict district behavior, normative analysis requires an assumption that the utility functions are also welfare-relevant measures of the social value of education spending. The remainder of the paper operates under this assumption, but readers who prefer not to treat the utility functions as direct welfare measures may focus on the policy-evaluation results already discussed in Sections 7.2-7.3.

7.4.1 Planning Problem

Assuming the state uses a linear welfare function to aggregate districts' utility values, its long-run objective function is

$$\sum_i \omega_i \Delta \bar{u}_{i,t_{max}}(d_i), \quad (44)$$

where $\Delta \bar{u}_{i,t_{max}}(\cdot)$ is the policy-induced change in district utility defined in (43) and $\{\omega_i\}$ are weights that give district i 's fraction of statewide student enrollment in the initial year t_0 . Because utility units are difficult to interpret, it is helpful to state welfare changes in terms of a consumption-equivalent measure, which I denote with ζ and define implicitly with

$$\sum_i \omega_i \Delta \bar{u}_{i,t_{max}}(d_i) = \sum_i \omega_i u_i(e_{i,t_0} + \zeta). \quad (45)$$

In words, accounting for districts' behavioral responses up to time t_{max} , the welfare effect of the policy change is the same as would occur if all districts exogenously spent ζ dollars more per student in the initial year t_0 .

Denoting the state's budget constraint with B , the optimal policy reform is the vector of state funding changes that maximizes the long-run welfare objective,

$$\begin{aligned} \{d_i^*\} &= \operatorname{argmax}_{\{d_i\}} \sum_i \omega_i \Delta \bar{u}_{i,t_{max}}(d_i) \\ &\quad \text{s.t.} \\ &\quad \sum_i \omega_i d_i \leq B. \end{aligned} \quad (46)$$

Because I must perform the simulation process described in Section 7.1 for each possible d_i value, the solution process is too computationally intensive when the state funding changes are continuous choice variables. I therefore discretize the problem, considering only funding

changes at \$50 increments that are smaller in absolute value than \$3,000 per student, i.e., $d_i \in \{-\$3,000, -\$2,950, \dots, \$2,950, \$3,000\}$. The resulting integer programming problem can be solved relatively easily.

A natural starting point is to analyze is the budget-neutral optimization problem with $B = 0$. If the budget-neutral solution to (46) substantially increases statewide welfare relative to the status quo, then state aid is currently misallocated along one (or both) of two dimensions. First, state aid may be misallocated along the dimension of behavioral responsiveness: too much funding may be awarded to districts that would replace state aid cuts with higher local taxes or dissaving, and too little may be awarded to districts that would accept additional funding without allowing the aid to crowd out local revenue collection or increase saving rates. And second, state aid may be misallocated along the dimension of marginal utility, with too much funding awarded to districts that (according to the estimated utility functions) have relatively low valuations for the marginal dollar of spending.

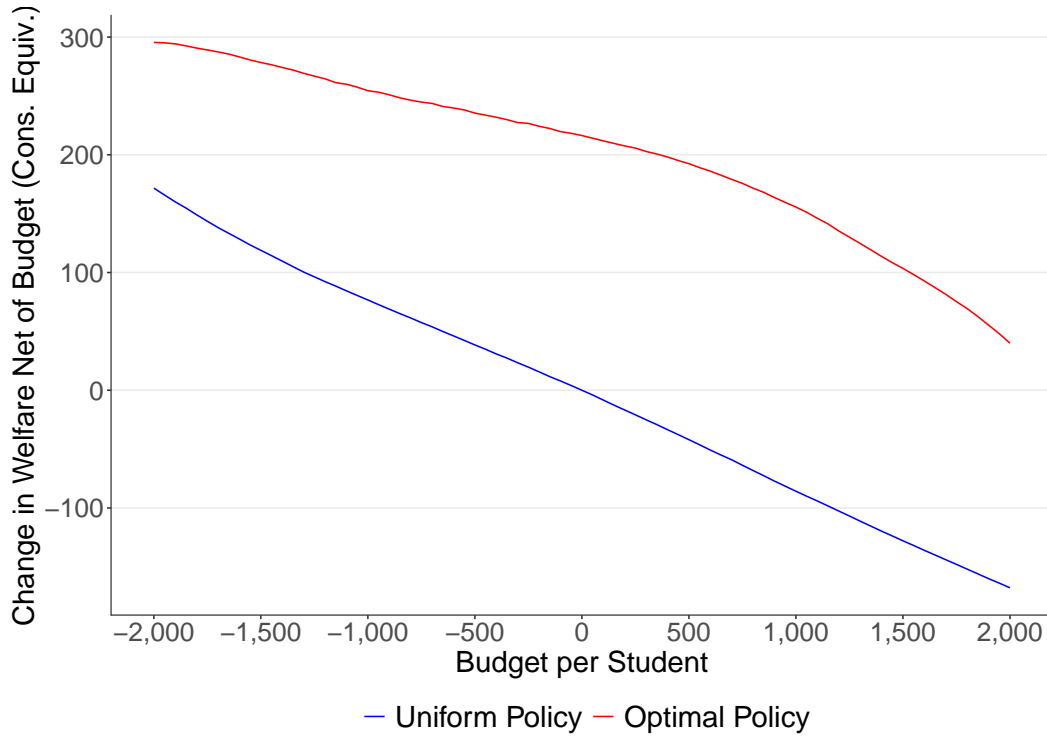
Solving (46) for nonzero values of B characterizes optimal policy for the state when it faces a change in education budgeting that it must pass on to districts. For $B > 0$, optimal policy allocates a given increase in state education expenditures (perhaps arising from growth in state income tax collection) among districts in order to maximize the resulting welfare increase. For $B < 0$, optimal policy allocates a given reduction in state education spending (perhaps arising from a recessionary decrease in income tax collection or a budgetary shift toward other programs like Medicaid) among districts in order to minimize the resulting welfare loss.

7.4.2 Results

Figure 16 plots the solution to the optimal-policy problem in (46), as a function of the state's budget per student B . The red line shows the consumption-equivalent welfare increase attained by the optimal policy, while the blue line gives the consumption-equivalent welfare increase that occurs if the state's budget is instead distributed uniformly across districts (i.e., if all districts receive a state funding change of B per student). I subtract the corresponding state budget B from the consumption-equivalent welfare measures before plotting them in Figure 16, so the resulting net-of-budget values can be interpreted as the welfare effect of the policy in excess of the state's exogenous fiscal resources B .

As is the case in Figures 14-15, districts' offsetting behavioral responses cause both lines in Figure 16 to be downward-sloping. If districts could not run unbalanced budgets or adjust their levy proposals, then they would have no choice but to let state funding changes pass through one-for-one into spending levels; the resulting blue uniform-policy line would then be horizontal at zero, since the consumption-equivalent measure ζ would mechanically become equal to the state budget B (see again Equation 45). Because districts can adjust their saving and levy-proposal behavior to offset the impact of state policy changes, net-of-budget welfare changes for uniform policy are instead positive for $B < 0$ and negative for $B > 0$. The vertical distance between the uniform-policy line and optimal-policy line represents the value of optimal policy planning in this setting. By targeting the state's budget toward the districts with the most favorable behavioral responses and greatest marginal utility of spending, the state can achieve substantially larger welfare changes than those produced by

Figure 16: Long-Run Welfare Changes Attained by Uniform and Optimal Policy



treating all districts equally (and keep all net-of-budget welfare changes positive, rather than seeing them dip into negative territory for $B > 0$). The gap between uniform and optimal policy, which ranges between about \$100 and \$250 per student, is largest for moderate positive budgets (roughly, for $0 \leq B \leq \$1,500$) and smallest for large negative budgets as B approaches $-\$2,000$. These results are intuitive: positive and moderate negative budgets leave the state room to efficiently reallocate funding among districts, while large negative budgets require indiscriminate cuts (consider the limiting case where the state must withdraw all of its current education funding; its choice set would consist of one action and uniform and optimal policy would be identical). In the budget-neutral case with $B = \$0$, optimal policy attains a considerable consumption-equivalent welfare increase of \$216 per student (about 4% of state education spending in 2017), indicating that the budget-neutral solution to (46) finds a reallocation of funding that substantially improves upon the current distribution of state aid.

Tables 9-10 characterize optimal policy in the budget-neutral case and show how the solution reallocates state aid. First, as can be seen from the district-group dummies in Table 9 and from the mean funding changes listed in Table 10, state aid is reallocated away from suburban districts (mean funding loss of \$1,547 per student) toward the other three district groups, with urban (\$540) and high-poverty rural districts (\$2,017) receiving the largest funding increases. Second, conditional on the district groupings, larger state aid changes are given to districts with less initial cash on hand, fewer initial years since their last passed levy, and lower levy-passage fixed effects. These results reflect the behavioral-responsiveness and marginal-utility dimensions that guide optimal policy. Suburban districts display the

Table 9: Characterizing Optimal Policy for the Budget-Neutral Case

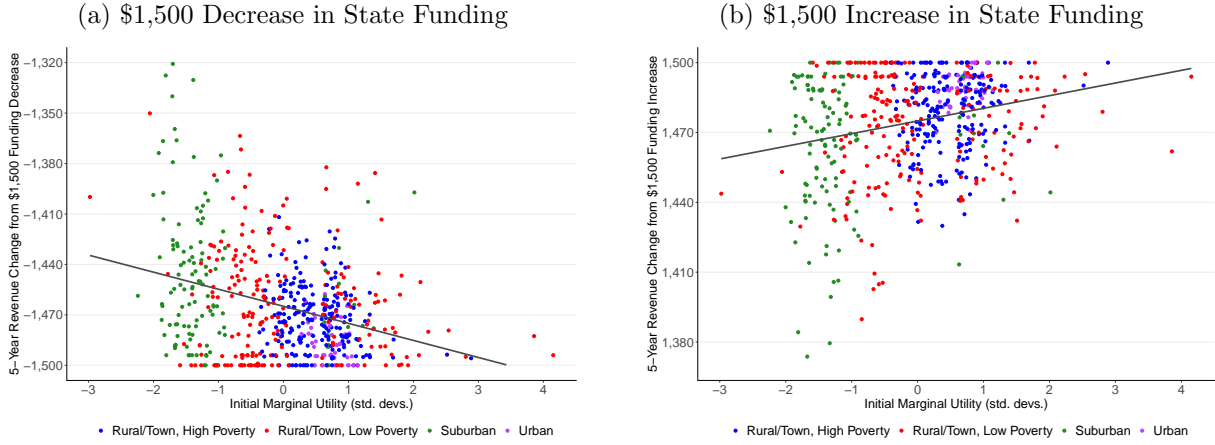
	Dependent Variable: Optimal State Funding Change per Student		
	(1)	(2)	(3)
Rural/Town, High Poverty	3,564*** (191)	3,471*** (148)	3,534*** (165)
Rural/Town, Low Poverty	1,835*** (190)	1,739*** (147)	1,721*** (172)
Urban	2,087*** (273)	2,467*** (212)	2,515*** (212)
Initial Cash on Hand per Student		-248.70*** (12.33)	-244.99*** (12.36)
Initial Years Since Last Passed Levy			-38.85*** (14.09)
Levy-Passage Fixed Effect (std. devs.)			-111.14* (61.43)
Constant	-1,547*** (152)	2,472*** (231)	2,736*** (245)
Observations	606	606	606
R ²	0.371	0.625	0.632

Note: This table presents regressions where the observations are districts and the dependent variable is the state funding change per student received under the solution to the optimal-policy problem in (46) with $B = 0$ (i.e., the budget-neutral case). The initial cash on hand coefficient has been scaled so that it can be interpreted as the effect of a \$1,000 increase. Suburban districts are the omitted group. Standard errors are in parentheses, and asterisks indicate statistical significance at p-values of 0.1, 0.05, and 0.01.

Table 10: Summary of Optimal Policy for the Budget-Neutral Case

	Rural/Town, High Poverty	Rural/Town, Low Poverty	Suburban	Urban
Mean State Funding Change per Student	\$2,017	\$288	-\$1,547	\$540

Figure 17: Relationship Between Initial Marginal Utility and Long-Run Revenue-Collection Response



least favorable response to state funding increases by allowing incremental state aid to crowd out local revenue collection (see Figures 12-13 and 15) and tend to have the lowest initial marginal utility of spending (see Figure 17). Within district groups, higher initial cash on hand implies lower marginal utility, and higher initial values for the elapsed-time and levy-passage fixed effect variables signal districts that are more likely to offset state aid changes by adjusting their levy-proposal behavior. The R^2 values at the bottom of Table 9 show the relative importance of the factors governing the solution. Cross-group heterogeneity in behavioral responses (arising from differences in the estimated structural parameters and accounted for by the district-group dummies) and within-group variation in marginal utility (accounted for by initial cash on hand) are roughly equally important and together explain about 63% of the variation in the vector of optimal state funding changes. The elapsed-time and levy-passage fixed effect variables, which reflect within-group variation in levy-proposal responsiveness, explain only a small amount of the remaining variation (though they do have nonzero and statistically significant coefficients).

Figure 17 gives a graphical depiction of the behavioral-responsiveness and marginal-utility dimensions. The left panel plots initial marginal utility against the long-run change in total revenue following a state funding decrease (again using the example \$1,500 amount from Section 7.2), and the right panel plots the same initial marginal utility against the long-run change in total revenue following a state funding increase. In this setting, the behavioral-responsiveness and marginal-utility factors are positively correlated and reinforce each other in determining optimal policy: the downward-sloping relationship in the left panel means that districts with the lowest initial marginal utility display the most favorable responses to state funding cuts (by replacing a larger portion of the cut with higher local revenue), and the upward-sloping relationship in the right panel means that districts with the lowest marginal utility display the least favorable responses to state funding increases (by allowing a larger portion of the increase to crowd out local revenue collection). The graphs also show that suburban communities – despite the state’s existing efforts to redistribute funding toward the other three groups (see Figure 2) – constitute the overwhelming majority of districts

with the lowest valuations of marginal funds.

The optimal policy results described in Tables 9-10 and Figure 17 tell a coherent story about the current condition of school finance in Ohio and the possibilities for improvement. Policymakers have correctly concluded that suburban districts, whose wealthier residents consistently approve large local tax levies, are able to support high spending levels with relatively small amounts of state funding support. Ohio's decision to allocate most of its education budget toward rural and urban districts is therefore sound; the main weakness of current policy is that it does not go far enough in redistributing educational resources away from suburban communities. Suburban districts still spend substantially more than rural districts, and because their utility functions are relatively concave, they also value the marginal dollar less than urban districts that spend a comparable amount per student (see again the spending summary statistics in Table 1). The concavity of suburban preferences (along with their low estimated levy-proposal costs) also implies behavioral responses that further disincentivize state aid: suburban districts are most likely to let aid increases crowd out local revenue and to replace aid cuts with higher local taxes. The roughly \$4,000 per student that the average suburban district currently receives from the state is thus too high, and optimal policy reduces this amount by about \$1,500 in order to redistribute more heavily toward rural and urban districts.

8 Conclusion

Exploiting the helpful institutional setting in the state of Ohio, I develop a framework for evaluating the spending and welfare effects of counterfactual school finance reforms. I first build a dynamic model of school district behavior and verify its empirical relevance with reduced-form analysis that confirms its key qualitative predictions. Using the identifying variation provided by the nominal freeze on local property tax revenue and historical volatility in state funding, I then estimate the model and recover the structure necessary to simulate districts' responses to policy changes. These behavioral responses vary across districts and over time, and the counterfactual analysis shows quantitatively how heterogeneous adjustments in districts' spending-saving and levy-proposal decisions shape the long-run effects of school finance reforms. Taking the structural estimates further as revealed-preference measures of welfare, I can also solve for the budget-neutral finance reform that optimally reallocates Ohio's state education aid. I find that optimal policy – with marginal-utility and behavioral-response considerations reinforcing each other – redistributes from suburban to rural and urban districts, implying that current state efforts to redirect funding away from wealthier suburban communities have not gone far enough.

Some of the quantitative findings about the exact nature of district behavior and optimal policy are particular to the Ohio setting, but the methodology and broader conclusions about school finance policy are not. Although levy proposals are particularly frequent and spending-saving decisions particularly consequential in Ohio, reactive adjustments to local revenue collection and saving have the potential to shape long-run policy effects in any setting where districts are free to collect local taxes and accumulate assets. The vast majority of school districts in the United States fit this description, and their historical financial decisions can be used to form predictions about their likely responses to state funding changes. With

knowledge of districts' preferences, states should direct scarce aid toward districts with the highest propensity to spend it and the largest welfare gains from doing so.

References

- Abbott, Carolyn, Vladimir Kogan, Stephane Lavertu, and Zachary Peskowitz. 2020. "School District Operational Spending and Student Outcomes: Evidence from Tax Elections in Seven States." *Journal of Public Economics* 183:104–142.
- Balsdon, Ed, Eric J. Brunner, and Kim Rueben. 2003. "Private Demands for Public Capital: Evidence from School Bond Referenda." *Journal of Urban Economics* 54:610–638.
- Baron, E. Jason. 2019. "School Spending and Student Outcomes: Evidence from Revenue Limit Elections in Wisconsin." Florida State University Working Paper.
- Biasi, Barbara. 2019. "School Finance Equalization Increases Intergenerational Mobility: A Simulated-Instruments Approach." National Bureau of Economic Research Working Paper.
- Borge, Lars-Erik and Per Tovmo. 2007. "Myopic or Constrained by Balanced-Budget Rules? The Intertemporal Spending Behavior of Norwegian Local Governments." Norwegian University of Science and Technology Working Paper.
- Card, David and Alan B. Krueger. 1992. "Does School Quality Matter? Returns to Education and the Characteristics of Public Schools in the United States." *Journal of Political Economy* 100 (1):1–40.
- Card, David and A. Abigail Payne. 2002. "School Finance Reform, the Distribution of School Spending, and the Distribution of Student Test Scores." *Journal of Public Economics* 83 (1):49–82.
- Cellini, Stephanie Riegg, Fernando Ferreira, and Jesse Rothstein. 2010. "The Value of School Facility Investments: Evidence from a Dynamic Regression Discontinuity Design." *Quarterly Journal of Economics* 125 (1):215–261.
- Chung, Il Hwan. 2015. "Education Finance Reform, Education Spending, and Student Performance: Evidence from Maryland's Bridge to Excellence in Public Schools Act." *Education and Urban Society* 47 (4):412–432.
- Craig, Steven G., Wided Hemissi, Satadru Mukherjee, and Bent E. Sorensen. 2016. "How Do Politicians Save? Buffer-Stock Management of Unemployment Insurance Finance." *Journal of Urban Economics* 93:18–29.
- Dahlberg, Matz and Tomas Lindstrom. 1998. "Are Local Governments Governed by Forward Looking Decision Makers." *Journal of Urban Economics* 44 (1):254–271.
- Dee, Thomas S. 2004. "Lotteries, Litigation, and Education Finance." *Southern Economic Journal* 70 (3):584–599.
- Downes, Thomas A. and David N. Figlio. 1997. "School Finance Reforms, Tax Limits, and Student Performance: Do Reforms Level Up or Dumb Down?" Institute for Research on Poverty Discussion Paper.

- Enami, Ali. 2018. "Labor versus Capital in the Provision of Public Services: Estimating the Marginal Products of Inputs in the Production of Student Outcomes." Cornerstone Research Working Paper.
- Gramlich, Edward M. 1969. "State and Local Governments and Their Budget Constraint." *International Economic Review* 10 (2):163–182.
- Guryan, Jonathan. 2001. "Does Money Matter? Regression-Discontinuity Estimates from Education Finance Reform in Massachusetts." National Bureau of Economic Research Working Paper.
- Hancock, Laura. 2019. "New Ohio Ed Funding Bill Introduced With at Least \$600 Million More for Schools." Cleveland Plain Dealer: [Article Link](#).
- Henderson, James M. 1968. "Local Government Expenditures: A Social Welfare Analysis." *The Review of Economics and Statistics* 50 (2):156–163.
- Hines, James R. and Richard H. Thaler. 1995. "The Flypaper Effect." *Journal of Economic Perspectives* 9 (4):217–226.
- Holtz-Eakin, Douglas and Harvey S. Rosen. 1989. "The 'Rationality' of Municipal Capital Spending." *Regional Science and Urban Economics* 19:517–536.
- Holtz-Eakin, Douglas, Harvey S. Rosen, and Schuyler Tilly. 1994. "Intertemporal Analysis of State and Local Government Spending: Theory and Tests." *Journal of Urban Economics* 35:159–174.
- Hoxby, Caroline M. 2001. "All School Finance Equalizations Are Not Created Equal." *Quarterly Journal of Economics* 116 (4):1189–1231.
- Isen, Adam. 2014. "Do Local Government Fiscal Spillovers Exist? Evidence from Counties, Municipalities, and School Districts." *Journal of Public Economics* 110:57–73.
- Jackson, C. Kirabo, Rucker C. Johnson, and Claudia Persico. 2016. "The Effects of School Spending on Educational and Economic Outcomes: Evidence from School Finance Reforms." *Quarterly Journal of Economics* 131 (1):157–218.
- Krueger, Alan B. 1999. "Experimental Estimates of Education Production Functions." *Quarterly Journal of Economics* 114 (2):497–532.
- Lafortune, Julien, Jesse Rothstein, and Diane Whitmore Schanzenbach. 2018. "School Finance Reform and the Distribution of Student Achievement." *American Economic Journal: Applied Economics* 10 (2):1–26.
- Manwaring, Robert L. and Steven M. Sheffrin. 1997. "Litigation, School Finance Reform, and Aggregate Education Spending." *International Tax and Public Finance* 4 (2):107–127.
- Murray, Sheila E., William N. Evans, and Robert M. Schwab. 1998. "Education-Finance Reform and the Distribution of Education Resources." *American Economic Review* 88 (4):789–812.

- Ohio Supreme Court. 1997. *Derolph v. State*, 78 Ohio St. 3d 193 (Ohio 1997).
- Papke, Leslie E. 2005. “The Effects of Spending on Test Pass Rates: Evidence from Michigan.” *Journal of Public Economics* 89 (5):821–839.
- Patton, Wendy. 2013. “Overview: Ohio’s 2014-2015 Budget.” Policy Matters Ohio Research Report: [Report Link](#).
- Romer, Thomas and Howard Rosenthal. 1979. “Bureaucrats versus Voters: On the Political Economy of Resource Allocation by Direct Democracy.” *Quarterly Journal of Economics* 93 (4):563–587.
- . 1982. “Median Voters or Budget Maximizers: Evidence from School Expenditure Referenda.” *Economic Inquiry* 20 (4):556–578.
- Rothstein, Paul. 1994. “Learning the Preferences of Governments and Voters from Proposed Spending and Aggregated Votes.” *Journal of Public Economics* 54 (3):361–389.
- Roy, Joydeep. 2011. “Impact of School Finance Reform on Resource Equalization and Academic Performance: Evidence from Michigan.” *Education Finance and Policy* 6 (2):137–167.
- Skinner, Rebecca R. 2019. “State and Local Financing of Public Schools.” Congressional Research Service Report: [Report Link](#).
- Vardon, Joe. 2011. “Gov. Kasich Signs ‘New Day’ Budget for Ohio.” Columbus Dispatch: [Article Link](#).
- Wyckoff, Paul Gary. 1991. “The Elusive Flypaper Effect.” *Journal of Urban Economics* 30 (3):310–328.

Appendix A Estimation Details

A.1 First-Step Estimates

Before estimating the structural parameters θ , I must obtain estimates of the revenue-evolution processes in (18)-(21) and the levy-passage-probability function π in (22). I estimate the former directly from the panel of school district finances, and the latter directly from the levy-voting data.

Tables A1 and A2 show the estimated evolution processes for government and local revenue, respectively. The coefficients on the lagged dependent variables correspond to ρ_g and ρ_p , the constant terms correspond to α_g and α_p , and the standard deviations of residuals correspond to σ_g and σ_p . Note that because the local revenue process is supposed to capture evolutions in legacy revenue (i.e., revenue from local taxes already in force in year t), I drop all district-year observations with successful incremental levies or failed renewal levies before estimating the equations in Table A2.

Table A3 shows the estimated logit model that corresponds to the levy-passage-probability function π in (22).

Estimation of the levy-passage model is complicated by several factors. First, a single levy proposal may be voted on multiple times in one year, because Ohio has several election days per year (for example, in presidential election years, voting takes on the first Tuesday after the first Monday of March, August, and November). Local issues like school district levies can appear on more than one of these ballots; for instance, a levy proposal that fails in March may be resubmitted and receive a second vote in August. The fitted value from a logit model estimated on the entire sample of individual levy votes would thus weakly understate the passage probability of an out-of-sample levy proposal, since it would ignore the district's option to resubmit the proposal after a failure. I address this issue by collapsing all votes on a particular levy proposal into a single observation, using the maximum of the binary passage indicators. For example, if a levy proposal fails in March but is resubmitted and passes in August, I treat this as a single levy vote with a passage indicator equal to one. Similarly, a proposal that fails in March and fails again in August would be treated as a single levy vote with a passage indicator equal to zero. The fitted values resulting from the logit model are slightly higher than they would be if all levy votes were treated individually, and account for the observed rate at which districts successfully resubmit failed levy proposals. This approach also causes the observation count in Table A3 to be smaller than the total number of incremental levy votes reported in Table 2.

Second, the levy-passage model in (22) includes district fixed effects in order to account for persistent differences between districts in their ability to pass levies; these fixed effects become the time-invariant state variable q in (17). The estimation of these fixed effects is imprecise for districts with few levy proposals during the sample period (and impossible for the 81 of 609 districts that do not propose a levy during the sample period). To address this issue, I estimate the model in Table A3 using only levy votes from districts that proposed at least three levies during the sample period. I then project the estimated fixed effects onto a collection of observable district characteristics (averaged over the sample period), and use the resulting coefficient estimates to generate fixed-effect values for the districts that were excluded from the original levy-passage model estimation. The regression I use to project

estimated fixed effects onto observable district characteristics is shown in Table A4, and the distribution of fixed effects (given in units of standard deviations) is shown in Figure A1. It is reasonable that the distribution of fixed effects generated from the projection onto observables is shifted to the left of the distribution of directly estimated fixed effects: districts that proposed few or no levies during the sample period may have stayed off the ballot in part because they expected that their levy proposals were relatively unlikely to pass.

A.2 Nested Fixed-Point Algorithm

I use a nested fixed-point algorithm to estimate the structural model. For each guess of the parameter vector θ , I first use value-function iteration to obtain the value functions that characterize optimal district behavior, then use the results to evaluate the maximum-likelihood criterion function.

As specified in (17), the model has five state variables. Since the district’s problem also depends on the reference spending level that is an input to the utility function in (23), I add the reference spending level ϕ as a sixth, time-invariant state variable. I discretize the state space into a six-dimensional grid, using six points for the assets state variable a , five to seven points for the government revenue and local revenue state variables g and p (depending on the district group), five points for the elapsed-time state variable j , three points for the levy-passage fixed effect q , and four points for the reference spending level ϕ . The grid points are not evenly spaced and are instead more dense in regions of the state space that are more common empirically. I evaluate the value functions away from grid points using linear interpolation.

The estimation process begins by initiating the unconditional value function $V(s)$ as constant and equal to zero. Then, for each point on the six-dimensional state space grid, I solve the optimization problems in (10) and (12) (optimizing over spending e in the former, and optimizing over both spending e and the requested revenue amount m in the latter) in order to obtain the choice-specific value functions $V^N(s; \epsilon^N)$ and $V^L(s; \epsilon^L)$. Defining (as I do in Section 6.1.3) the mean choice-specific value functions as $\tilde{V}^N(s) \equiv V^N(s; 0)$ and $\tilde{V}^L(s) \equiv V^L(s; 0)$, the assumption that the utility shocks (ϵ^N, ϵ^L) follow a Type 1 extreme value distribution gives a closed-form expression for the updated unconditional value function:

$$\begin{aligned} V(s) &= \mathbb{E}_{\epsilon^N, \epsilon^L} \left[\max \{ V^N(s; \epsilon^N), V^L(s; \epsilon^L) \} \right] \\ &= \log \left(\exp(\tilde{V}^N(s)) + \exp(\tilde{V}^L(s)) \right). \end{aligned} \quad (47)$$

I then repeat this process, continually re-solving (10) and (12) and updating the unconditional value function with (47), until convergence. After completing the iteration process and obtaining the value functions $V(s)$, $\tilde{V}^N(s)$, and $\tilde{V}^L(s)$, I can form the predicted levy probabilities $L(s)$ according to (31), infer the spending shocks ψ using (35), and evaluate the log-likelihood function in (36).

All shocks in the model that require integration – the spending shocks ψ and the revenue-evolution innovations η and ξ (18)-(19) – are normally distributed. I therefore perform all integration numerically with Gauss-Hermite quadrature, using five nodes.

The model does not explicitly account for renewal levies (i.e., levies that ask voters to extend a tax that is currently in force and about to expire). I exclude renewal levies from the model for two main reasons. First, renewal levies are not a meaningful source of revenue risk for most districts, since they have a passage rate of 86% (see Table 2). Second, accounting for levy expiration and the resulting renewal votes would require modeling the district's choice of levy duration and adding state variables to keep track of the time remaining on each active levy, which would be too computationally burdensome. I do, however, account for empirically observed renewal levies when inferring the spending shocks ψ that enter the log-likelihood function. For district-year observations where there is a renewal levy on the ballot for m_t in revenue per student, instead of using the Euler condition in (32), I use

$$\psi_{i,t}u'(e_{i,t}) = \beta(1+r)\left(\pi_R\mathbb{E}[V_a(s_{i,t+1})|s_{i,t}, e_{i,t}] + (1-\pi_R)\mathbb{E}[V_a(\tilde{s}_{i,t+1})|s_{i,t}, e_{i,t}]\right), \quad (48)$$

where π_R is the empirically observed renewal-levy passage rate (computed separately for each of the four district groups) and $\tilde{s}_{i,t+1} = (a_{t+1}, g_{t+1}, \tilde{p}_{i,t+1} - m_t, q_i, j_t + 1)$ gives the state evolution conditional on the levy failing and local revenue falling by m_t next year. Modifying the Euler condition in this way accounts for the (relatively small) probability that the renewal levy fails and raises the marginal benefit of assets next year, thereby making the resulting inference about the spending shock $\psi_{i,t}$ slightly more accurate.

A.3 Model Fit

Figure A2 shows the distributions of normalized log spending shocks $\frac{\log(\psi_{i,t})}{\sigma_\psi}$ generated by the estimated structural parameters. The maximum-likelihood estimation procedure described in Section 6.2 aims to make these distributions close to a standard normal distribution.

Figure A2 shows the distributions of predicted levy probabilities generated by the estimated structural parameters, separately for district-year observations where levies are and are not proposed. The maximum-likelihood estimation procedure aims to make predicted levy probabilities higher for observations where levies are actually proposed.

Table A1: First-Step Estimates of Government Revenue Processes

	Dependent Variable: $\log(g_{t+1})$			
	Rural/Town, High Poverty	Rural/Town, Low Poverty	Suburban	Urban
$\log(g_t)$	0.889 (0.007)	0.887 (0.006)	0.917 (0.006)	0.928 (0.009)
Constant	0.999 (0.059)	1.002 (0.056)	0.707 (0.053)	0.674 (0.079)
Std. Dev. of Residuals	0.144	0.134	0.089	0.089
Observations	4,041	4,115	2,431	1,066
R ²	0.815	0.822	0.895	0.912

Table A2: First-Step Estimates of Local Revenue Processes

	Dependent Variable: $\log(\tilde{p}_{t+1})$			
	Rural/Town, High Poverty	Rural/Town, Low Poverty	Suburban	Urban
$\log(\tilde{p}_t)$	0.965 (0.003)	0.970 (0.003)	0.975 (0.004)	0.985 (0.006)
Constant	0.284 (0.026)	0.255 (0.027)	0.219 (0.037)	0.118 (0.048)
Std. Dev. of Residuals	0.088	0.090	0.074	0.074
Observations	3,804	3,842	2,071	958
R ²	0.958	0.957	0.962	0.969

Table A3: First-Step Logit Model of Levy Passage

Dependent Variable: Levy Passed	
Years Since Last Passed Levy	-0.397 (0.149)
Years Since Last Passed Levy ^{^ 2}	0.064 (0.014)
Requested Revenue Amount	-0.839 (0.432)
Requested Revenue Amount ^{^ 2}	0.0001 (0.0001)
Constant	-2.429 (1.483)
District Fixed Effects	
Observations	Yes 1,058

Table A4: First-Step Projection of Levy-Passage Fixed Effects onto Observables

	Dependent Variable: Estimated Levy-Passage Fixed Effect
Median Income	0.021 (0.037)
Property Value per Student	-0.001 (0.003)
Residential Property Value Share	-4.666 (2.373)
Agricultural Property Value Share	-0.826 (3.093)
Commercial Property Value Share	-0.773 (3.859)
Minority Student Share	2.108 (1.427)
FRPL Student Share	-5.006 (2.299)
Rural/Town, High Poverty	-0.433 (0.674)
Rural/Town, Low Poverty	-1.602 (0.600)
Urban	0.981 (0.724)
Constant	6.330 (3.005)
Observations	176
R ²	0.193

Figure A1: Distribution of First-Step Levy-Passage Fixed Effects

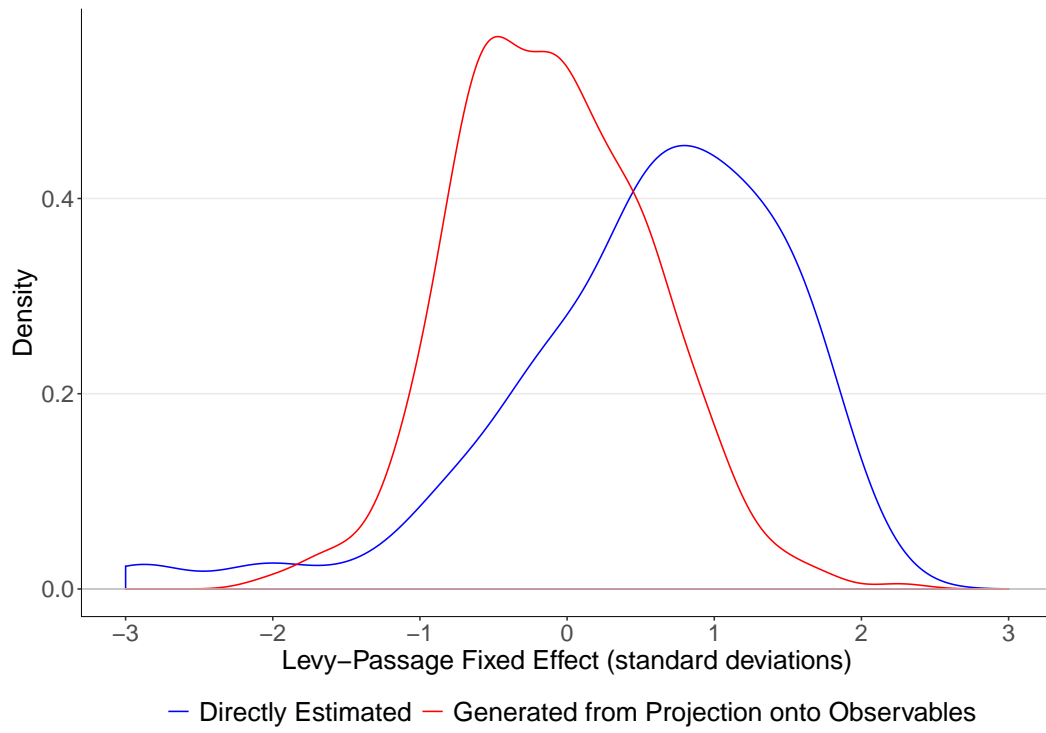


Figure A2: Distribution of Estimated Spending Shocks

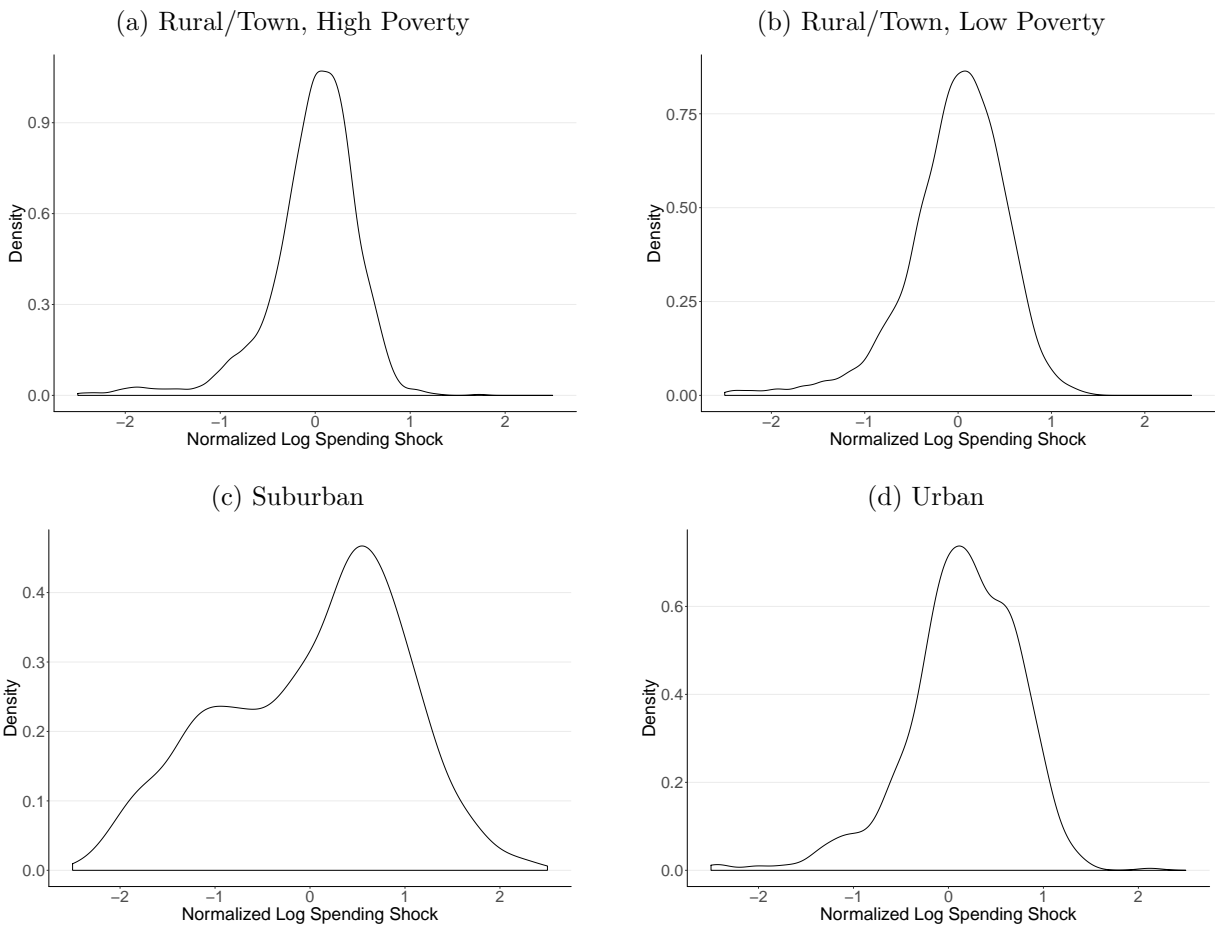


Figure A2: Distribution of Predicted Levy Probabilities

