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Article abstract

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Estimating the relationship between Public and Private Inputs for K-12 Education: Evidence from Longitudinal Microdata

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I examine whether private education expenditures and public K-12 funding are substitutes or complements for households whose children attend public school. Using a longitudinal microdata set, the Panel Study of Income Dynamics, I estimate the response of private household expenditures on education in response to changes in public expenditures. This paper implements a fixed-effects model that controls for unobservable household characteristics. I find evidence of complementarity between public and private education spending with an average elasticity of 2.4.

Keywords: education expenditures; consumption; human capital; public economics
JEL Classifications: D1, E24, H3, I2, J24

1 Introduction

Are private and public expenditures on childhood education substitutes or complements? The answer to this question has important ramifications for policy. However, the degree to which public spending are substituted with these private inputs does not yet have a prevailing empirical answer. Several theoretical studies have relied on this elasticity in order to evaluate policy. For example, Glomm and Kaganovich (2002) explored the effect of increasing public education spending on income inequality where human capital production was assumed to be a function of public education spending and private inputs. They found that the result depends primarily on the elasticity of substitution between private and public inputs in education.

There is currently no published research that finds a precise empirical relationship between public and private school expenditures. The main contribution of this paper is to fill this gap in the literature by providing an estimate for the elasticity of substitution between private and public inputs in the K-12 education production function. Estimating the relationship between public and private education spending understandably raises questions about endogeneity. In an effort to address this, I use microdata from the Panel Study of Income Dynamics which

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records spending by individual households over time in a panel structure. I use this data to control for the unobservable household characteristics that may be correlated with public and private education spending. This paper is structured as follows: section 2 outlines the existing literature, section 3 describes the data used for the analysis, section 4 explains how I impute private schooling into the PSID, section 5 describes the empirical model, section 6 discusses the estimation results, and section 7 is my conclusion.

2 Literature Review

There is a vast literature that has studied the relationship between spending and student outcomes which has largely found a positive and statistically significant causal relationship between them. The literature has consistently found a positive relationship over a long period of time. Card & Krueger (1996) compared student performance between North and South Carolina and found that greater school resources increased educational attainment. Verstegen & King (1998) conducted a meta-analysis of the available literature and determined that 79% of relevant studies found a positive and statistically significant relationship between expenditures per pupil and student achievement. Similarly, Jackson (2020) analyzed the more recent literature of a quasi-experimental nature and found overwhelming support for the idea that greater school spending causes better student outcomes. Some other examples of research in this area include Häkkinen et al (2003), who used panel data from Finland to find a positive relationship between school resources and exam scores, and Shores & Steinberg (2019), who found that schools where funding were most adversely affected by the Great Recession also saw the greatest drops in student performance.

There are a few empirical studies of households in the United States that have discussed the degree of substitutability between private and public inputs in human capital production. However, it is important to distinguish between different types of educational investments examined in empirical studies. One strand of literature explores the impact of parental time investment, as seen in the work of Houtenville & Conway (2008) who examined the relationship between the amount of time parents commit to their children's education and school resources using the National Education Longitudinal Study. This panel data set records the level of funding for the household's school and the degree to which parents are involved in various education related activities biennially starting when their student is in eighth grade. These frequencies are measured in broad bins ("often", "never" etc.). They found that greater school resources resulted in lower parental involvement which suggests that public resources and parental involvement are substitutes. Pop-Eleches & Urquiola (2013) examined the effects of higher-quality schools on academic performance in Romania and found that that parents similarly reduce homework-related help in response to greater public investment. In contrast to these results, Gelber & Isen (2013) found that enrollment in Head Start, a pre-school program,

caused an increase in parental involvement in educational activities such as reading to their children which suggests that public schooling opportunities and private inputs are complementary.

Another area of relevant empirical research is between studies on private educational expenditures for children in public schools and those examining the interplay between public educational expenditure and private tuition. This paper primarily concerns the former, focusing on how private spending by parents of public school students interacts with public education spending. Very little research has been conducted in this particular area, although there are a few notable examples. Yuan & Zhang (2015) found evidence for substitutability between public education spending and private tuition spending in urban China. Das, Dercon & Habyarimana (2013) found evidence for substitution in India and Zambia with a panel data set of fifth graders, but timing is critical. They assumed that rule-based grants are anticipated, and discretionary grants are unanticipated. The study concluded that anticipated changes to public spending offset private inputs and therefore do not improve test scores while unanticipated changes are not offset by households and do result in higher test scores. Yu and Zhao (2021) find evidence of complementarity using household-level panel data from China similar to the US data used in this study. Kim & Lee (2010) explored how private tutoring spending responds to increasing educational demands, showing that households have augmented increasing public spending indicating that there is a complementary relationship between the two. Similarly, Lee, Lee & Jang (2010) examined the attempts of the South Korean government to reduce demand for private tutoring including increasing public education spending. They found that demand for private tutoring remained prevalent despite these investments.

The theoretical literature that uses an education production function relies on the elasticity of substitution between public and private inputs in order to predict household behavior and determine policy prescriptions. For example, Glomm and Kaganovich (2002) compared the effects of social security and public education spending on inequality with an overlapping generations framework in which human capital for the next generation was created with a human capital production function with private and public inputs. This was an essential feature of the model because it allowed changes in public inputs to alter the household's incentive to commit private resources to education. Therefore, whether public education expenditures reduce inequality depends on the elasticity of substitution between public and private inputs in the human capital production function. If they are substitutes, then the displacement of private spending reduces inequality. On the other hand, complementarity would exacerbate inequality by disproportionately improving education outcomes for those with greater private expenditures. This relationship underscores the importance of not only recognizing the substitutability as perceived by households but also understanding the functional interplay of these expenditures in producing educational outcomes. Arcalean &

Schiopu (2010) used a similar model to study interactions between public and private spending with a two-stage education framework. Their calibration implied that public and private inputs are imperfect substitutes, but no estimate for that parameter was available to them.

The main obstacle to estimating the relationship between private and public spending by households is likely the issue of endogeneity through Tiebout sorting which was introduced in Tiebout (1956). In his seminal work, Charles Tiebout described a model in which, under a strict set of assumptions, competition across local jurisdictions induces households to relocate in order to satisfy their preferences for public goods. This model has dominated much of the public policy discussion ever since. Much of the debate in the literature has revolved around whether this is an accurate description of household behavior with respect to public schooling for children. For instance, Rhode & Strumpf (2003) found decreasing heterogeneity in policies across US municipalities in contrast with Tiebout's prediction. By contrast, Cebula and Nair-Reichert (2012) found that migrants do prefer areas with greater per-pupil spending and low tax burdens.

Black (1999) pioneered the use of school assignment boundary fixed effects using data from Massachusetts and found that a school-level standard deviation in test scores results in a 2 percent increase in house prices indicating that there is some degree of sorting but significantly less than estimated by previous studies. Bayer, Ferreira, and McMillan (2003) also found that the direct effect of schooling on housing demand is small, having found an identical 2 percent response to a standard deviation change in test scores. Furthermore, they found that the larger effects that others have estimated were better explained by preferences for peers and neighbors. Kane, Staiger & Riegg (2004) used similar methodology using data from North Carolina and found a ten percent response in house prices, which was substantially larger than the result from Black or Bayer et al but still about 75% less than what cross-sectional studies have found. Rothstein (2003) used data from the National Educational Longitudinal Survey and a theoretical framework and found no relationship between sorting and school quality.

Due to the nature of the data available, I must use public spending aggregated to the state level in conjunction with the microdata set. There are many important works in the education production function literature that use aggregate data to estimate the role of public school spending such as Card and Krueger (1992a and 1992b). Furthermore, there is reason to believe that aggregated spending is a useful approach to the problem posed in this paper. Evans, Oates and Schwab (1992) find that aggregated school characteristics function as valuable instruments for individual school characteristics and reduced specification error. They found that using school-level data introduces a bias because it reflects multiple causes for student success such as peer effects whereas aggregation of school spending eliminates these and only measures the resources allocated to schools. While there are some criticisms of how aggregated data has been used in this literature, they do not apply to my study. For example, Hanushek,

Rivkin & Taylor (1996) and Rivkin (2001) point out that aggregation might introduce bias in the form of omitted variables because it does not measure unobserved household characteristics. This problem presents itself in Card and Krueger's work because their household data is not of a panel nature and therefore does not account for unobserved household characteristics. I conclude that state-level data can be appropriately used for this analysis in conjunction with household-level panel data that accounts for these unobserved family characteristics that are missing from the previous literature.

3 Data

There is a high likelihood that there are unobservable qualities that households possess which could bias the estimates of my model if they are not accounted for. Therefore, a strong candidate for conducting this study is the Panel Study of Income Dynamics (PSID). The PSID tracks a wide variety of economic variables and collects data from households biennially. The data set in this paper uses the family-level releases for the years 1999 through 2017.

The next best alternative to the PSID for this analysis is the Consumer Expenditure Survey (CEX). The CEX has much more detailed data on school expenditures made by the household. It distinguishes between spending on K-12 and college. It also distinguishes between spending on private school tuition and spending on other educational goods and services. However, the fact that the CEX is not longitudinal in nature makes it less suitable for this study than the PSID.

All dollar values across each data set are adjusted with the CPI for all consumption using 2010 as the base year. Table 1 contains the summary statistics and descriptions for the variables used from the PSID. The data set includes a variable that represents all household expenditures on education. It unfortunately does not distinguish between expenditures on K-12 education and expenditures on higher education. To address this problem, I drop all households in which there are adults aside from the parents who might be attending college as well as any households in which either the respondent or spouse report that they are currently attending college. I keep only households that have children at the time of the interview.

The PSID data also contains information on each household's financial characteristics including labor income, value of liquid and illiquid assets, hours worked and employment status. Finally, this data set includes demographic information about each household which includes the education level and marital status of the respondent, the size of the household and the number of children in the household and the age of the youngest child in the household.

In the PSID data set, I exclude households that do not report any school expenditures for any period. I also exclude top-coded and missing observations for all relevant variables. I drop households that report no expenditures on food for home consumption and households that report greater expenditures on food than on all consumption combined.

Table 1: Variable definitions and summary statistics for the PSID

Variable	**Description**		**Non-movers**
Financial		**Mean**	**Std Dev**
Household Education Expenditures	Total expenditures on tuition, tutoring, books, supplies, uniforms and equipment per child	935.193	2,590.059
Δ Household Education Expenditures	Change in education expenditures	173.131	2,057.226
Labor Income	Labor earnings plus retirement benefits	97,374.25	65,414.81
Labor Hours	Hours per week respondent spends at work	45.543	11.593
% Δ Labor Hours	Log difference in labor hours	0.0038	0.285
Wage	Labor income of respondent divided by hours worked	28.719	21.824
Δ Wage		0.998	15.907
Liquid Assets Change	Change in liquid assets	1.653	69,015.99
Illiquid Assets Change	Change in illiquid assets w/o home equity	9,442.253	92,831.4
Demographics			
Prob. Private School	Estimated prob. of private school using the CEX	0.178	0.339
Age	Age of respondent	39.12	7.491
Family Size	Number who belong to family unit	4.204	1.105
Family Size Change	Change in size of family unit	0.053	0.759
Children	Number of children in family unit	2.316	1.017
Δ in Number of Children	Change in number of children	0.13	0.596
Married	Respondent is married	0.891	0.311
Never Married	Respondent was never married	0.03	0.169
Widowed	Respondent is widowed	0.002	0.041
Divorced	Respondent is divorced	0.060	0.238
Separated	Respondent is separated	0.017	0.131
Highest Degree			
High School Dropout	Respondent did not complete high school	0.078	0.268
High School Degree	Respondent has high school degree	0.240	0.427
Undergraduate Degree	Respondent has undergraduate degree	0.527	0.499
Graduate Degree	Respondent has graduate degree	0.154	0.361
Respondent Employment Status			
Employed	Respondent is employed	0.94	0.234
Unemployed	Respondent is unemployed	0.031	0.173
Temporary Leave	Respondent is on leave	0.004	0.063
Retired	Respondent is retired	0.009	0.094
Disabled	Respondent is disabled	0.003	0.055
Keeping House	Respondent keeps house	0.008	0.089

Additionally, I drop observations that reported changes in school expenditures, liquid and illiquid assets and labor income that exceeded three standard deviations from the mean. This is due to the fact that the PSID contains numerous implausibly extreme outliers. For example, the original data set had 15 households that reported an increase in liquid assets of over $2 million over two years. The final PSID data set used in the baseline model has 10,029 observations.

The data set used for public education expenditures is the Annual Survey of School System Finances provided by the United States Census Bureau which provides various categories of spending information by school district throughout the United States. I exclusively use expenditures on instruction for public expenditures. This category includes all spending that pertains to aiding interaction between teachers and students which are: salaries and benefits for teachers, teaching assistants, teacher trainers, student assessment, library staff, curriculum, technology, and supplies for these activities. This measurement reflects funding from federal, state and local revenues. State GDP data is provided by the Bureau of Economic Analysis. The most detailed geographic information provided by the PSID is state of residence, so I aggregate public school spending to the state level and merge it with the PSID. Table 2 contains summary statistics and sources for all of the aggregated data that is used in conjunction with the PSID.

4 Private School Imputation

The PSID contains information on household education expenditures, but it does not distinguish between spending on private school tuition and other educational goods and services. The PSID also does not record whether children within a household attend private or public school. The purpose of this paper is to explore the relationship between public expenditures and private expenditures made by households on behalf of children who attend public schools. Because the CEX does make such distinctions, I use the CEX to estimate the probability that an household in the PSID is sending their children to private school in a given year.

The CEX data set is quarterly from the years 1996 to 2017. It includes various private education spending measures, household income, and other demographic information. The private education spending categories are recreational lessons, day care, tuition, housing, food and board while attending school, tutoring, books, supplies, and other related expenses. I use only expenditures that are reported as pertaining to K-12 education. I drop top coded and missing observations, households whose head is aged less than 20 years, who don't have children and whose reported income is less than food consumption. Dollar values are adjusted with the CPI for all consumption using 2010 as the base year. Finally, residents of Alaska, Hawaii and the District of Columbia are excluded from the analysis. After this process, the CEX data set contains 71,379 observations. Table 3 contains the summary statistics for the CEX data set.

Table 2: Variable definitions and summary statistics for state-level data

Variable	Description		Non-movers
		Mean	Std Dev
Economic			
State GDP	Real GDP per capita	47,398.75	9,326.78
% Δ State GDP	Annual growth rate of state GDP	0.008	0.0467
Real GDP per capita	Real GDP per capita	9,326.776	1,891.213
Log difference in GDP	Log difference in GDP per capita	0.0467	0.0390
Education			
Public Instructional Expenditures	Expenditures directly relating to classroom instruction per pupil	6,266.296	1,891.213
% Δ Public Instructional Expenditures	Annual growth rate of instructional expenditures	0.014	0.039
Centralization	Proportion of school funding that is non-local	0.582	0.143
Political			
Democratic Controlled Senate	Democratic Party controls state senate	0.440	0.496
Republican Controlled Senate	Republican Party controls state senate	0.537	0.498
Republican Proportion of House	Proportion of Republicans in the state house	0.503	0.132
Democratic Proportion of House	Proportion of Democrats in the state house	0.494	0.132
Democratic Controlled House	Democratic Party controls state house	0.499	0.499
Republican Controlled House	Republican Party controls state house	0.501	0.499
Democratic Governor	Governor is a democrat	0.425	0.494
Republican Governor	Governor is a republican	0.561	0.496
Democrats Control Govt	Democrats control both legislative and executive branches	0.214	0.410
Republicans Control Govt	Republicans control both legislative and executive branches	0.320	0.466

Restricted to data that also exists within the PSID, the most reliable predictor that a household is paying for private school is large total school expenditures. For example, while about 7.7% of households in the CEX send a child to private school, more than 80% of those that spend at least $1000 per child do so. Only 2.4% of households that spend less than $1000 are sending a child to private school. Therefore, one can reliably infer which households are sending children to private school with that information alone.

Table 3: Variable definitions and summary statistics for the CEX data

Variable	Description		Non-movers
		Mean	Std Dev
Household Education Expenditures	Total expenditures on tuition, tutoring, books, supplies, uniforms, and equipment per child	456.27	2,925.32
Private School	Household sends a child to private school	0.077	0.267
Wage	Household income divided by hours of work	28.561	19.327

A logistic model is used to estimate the probability that a household sends their children to a private school. The regression is specified as

$$\ln\frac{p}{1-p} = \alpha_0 + \alpha_1 S_i + \alpha_2 S_i^2 + \alpha_3 S_i^3 + \alpha_4 S_i^4 + \alpha_5 W_i + \eta_{\text{year}} + \gamma_{\text{state}} \quad (1)$$

where p is the probability household makes expenditures on tuition. The variable S represents household i's total school expenditures per child and is included as a quartic polynomial to fully capture the non-linear relationship between spending and private schooling. The variable W is the reference person's hourly wage in household i. The parameters η and γ represent fixed effects for the year and state respectively.

Table 4 summarizes the results from this regression reporting the odds ratios for the spending and wage variables. No other household characteristics that were not included in this model were found to have a significant role in predicting private schooling. The pseudo R-squared of the regression is relatively large at 0.68. The results from this estimation are used to calculate the probability that a PSID respondent is paying for private school tuition within a given time period.

Table 4: Logit estimation of the probability of private school in the CEX data set

Variable	Coefficient	Odds ratio
Household Education Expenditures	0.014 (0.000348)	1.014***
Household Education Expenditures²	-0.000348 (4.62e-07)	1.000***
Household Education Expenditures³	4.62e-07 (1.74e-10)	1.000***
Household Education Expenditures⁴	1.74e-10 (1.74e-10)	1.000***
Wage	-0.0032 (0.00130)	0.997**
Constant	-5.809 (0.000672)	0.00300***
Observations	71,113	
R-squared	0.6813	

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

In an effort to measure goodness of fit, I generate a random sub-sample of 80% of the CEX data and estimate the logit model using only this sub-sample. I then use these estimates to forecast whether the remaining 20% of the CEX data sends their children to private school. In the excluded subsample of private school households, the mean estimate for the probability of private schooling is 68.4% and the median estimate is 95.2%. In the excluded subsample of public school households, the mean estimate is 2.7% and the median estimate is 0.3%. I therefore conclude that the logit model presented in this section is highly effective at identifying households that send children to private school.

5 Empirical Model

The baseline model for the relationship between public and private education expenditures is provided by the following regression equation

$$\Delta S_{i,t} = \beta_1 \left(\Delta ln\left(E_{i,t}\right)\right) + \beta_2 \hat{P}_{i,t} \left(\Delta ln\left(E_{i,t}\right)\right) + \beta_3 \hat{P}_{i,t} + X_{i,t}\phi + \zeta_{i,t} + \mu_{\text{state,t}} + \theta_t + \lambda_i + \varepsilon_{i,t} \quad (2)$$

where, in year t, S is the total spending on education per child by household i, E is the instructional spending per pupil in the household i's state of residence, and $\hat{P}$ is the estimated probability that household i sends a child to private school. $X_{i,t}$ is a vector of demographic controls for individual i. The parameter ζ is a fixed effect for the age of the youngest child in the household with a separate dummy variable for each age from one to sixteen. There is a state-wide fixed-effects parameter, $\mu_{\text{state,t}}$, for the current state of residence at time t, λ is the fixed-effects parameter for household i, θ is the fixed-effects parameter for year t, and ε_i is the stochastic error term which are also allowed to be correlated by state. Errors are corrected for clustering by household which allows for correlations within households over time.

The dependent variable is the change in level of private education spending relative to the previous period rather than a log difference due to the fact that private spending is frequently reported as zero. The reason that there is a state-level fixed-effects parameter included along with the parameter for individual households is that in the baseline model households may move between states which means that the state of residence can vary within the household over time. In the specification that excludes households that have moved, the state fixed-effect parameter is dropped.

The estimated probability of private schooling is used both as a control variable and an interaction term with public spending. The purpose of this study is to measure the response of public-school households to changes in public spending. The interaction term isolates the response of private-school households and allows $\hat{\beta}_1$ to estimate the relationship of interest.

The panel nature of the data set addresses concerns about endogeneity arising from omitted variables that vary across households, but it does not address variation within households that

could be correlated with public instructional spending. Therefore, control variables that compose X are chosen on the basis that they vary within a household over time and control for choices that households make that could be correlated with how much the school system spends on their behalf. To this end, X includes financial information such as changes in labor income and household assets. With respect to the respondent to the survey, it contains education level, employment and marital status. To control for the composition of the family, changes in the size of the family and number of children are included. Since the baseline model incorporates households that have moved in the previous period, a dummy variable that reflects whether the household has moved is present. This is intended to control for the fact that households may make the decision to move in order to reside in a favorable district. The variables chosen for the baseline empirical model are consistent with Mauldin, Mimura & Lino (2007) who find that the factors that are significant in determining private spending are after-tax income, parental education and region. Finally, changes in state GDP per capita are accounted for to ensure that the response to instructional spending is not merely a reaction to the state of the economy at large.

6 Results

Table 5 summarizes the linear regressions using the baseline model that includes the control for private tuition spending and a version of the model without the control. The state, year and youngest child effects are suppressed in the table. The model with the private-school control shows that the response of private spending to public spending is highly statistically significant at the 99.9% confidence level with an estimated coefficient of 2,250. This means that a one percent increase in instructional expenditures results in a $22.50 increase per child holding the other variables in the regression constant. Since the average level of household expenditures on education is $935.19, this implies an average elasticity of about 2.4. The fact that the estimate is positive indicates that public and private school expenditures are complementary.

The estimated coefficient for the interaction term is statistically significant at the 90% level of confidence with a value of -3,638. This means that the response in household spending to changes in public spending is around zero or possibly negative for households that are likely to have sent a child to private school. This is consistent with what I would expect given that children in private school are not directly impacted by public school funding, so there would be no response to funding changes at all unless a better-funded school system results in less private schooling altogether. The regression result that excludes the private-school control finds no significant relationship between public spending and private spending indicating that the control is necessary in order to measure the effect on public-school households.

Table 5: Results with Movers

Variable	Without Private School Control	With Private School Control
% Δ Public Instructional Expenditures	153.2 (890.3)	2250*** (679.1)
% Δ Public Instructional Expenditures × Prob. Private School		-3638* (679.1)
Prob. Private School		4638*** (138.7)
% Δ Labor Income	-181.5*** (61.60)	-201.1*** (47.25)
Liquid Assets Change	0.000481 (0.000665)	0.000209 (0.000533)
Illiquid Assets Change	4.53e-05 (0.000305)	-0.000320 (0.000261)
High School Dropout	-408.0 (307.8)	-30.11 (237.1)
Undergraduate Degree	-30.23 (185.9)	-288.3 (195.8)
Graduate Degree	-147.4 (254.8)	-419.6* (247.6)
Employed	136.7 (517.3)	517.3 (484.2)
Temporary Leave	9.949 (536.5)	186.6 (505.5)
Unemployed	385.0 (533.2)	723.0 (494.4)
Disabled	-340.7 (513.3)	492.8 (512.0)
Keeping House	410.9 (589.5)	1181** (572.7)
Married	245.2 (333.6)	-292.5 (239.8)
Never Married	566.6 (387.4)	483.6* (284.8)
Divorced	812.0** (341.2)	115.4 (242.2)
Separated	423.0 (338.6)	-30.62 (228.9)
Family Size Change	27.25 (97.04)	158.9* (86.45)
Δ in Number of Children	-379.1*** (117.8)	-303.8*** (102.0)
Moved	-276.8*** (64.11)	-213.2*** (54.44)
% Δ State GDP	202.4 (1021)	-639.0 (855.0)
Constant	-556.4 (2098)	345.3 (1765)
Observations	10,029	10,029
Number of unique id	3,205	3,205
R-squared	0.084	0.403

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

In the baseline model, households that had moved since the previous period were included in the data set. Movers were left in the baseline model in the interest of having more data and more variation in instructional spending across households. However, moving is a choice made by households and could be plausibly related to the quality of the school district that they are

moving to or from. Table 6 includes results using the same model from table 5 except that observations where the household had moved in the previous period are removed from the sample. The households remaining in the subsample did not change addresses between periods and therefore their school district remains constant. Unobserved qualities of the schools are therefore controlled for. With this subsample, the coefficient of interest is 2,644. This is a statistically significant difference from the original estimate of 2,250 but the economic substance of the result remains the same.

Table 6: Results without Movers

Variable	
% Δ Public Instructional Expenditures	2644*** (813.6)
% Δ Public Instructional Expenditures × Prob. Private School	-5575** (2465)
Prob. Private School	4571*** (158.3)
% Δ Labor Income	-144.1** (60.14)
Liquid Assets Change	0.000537 (0.000604)
Illiquid Assets Change	-0.000312 (0.000319)
High School Dropout	-277.2 (335.4)
Undergraduate Degree	-416.8** (201.5)
Graduate Degree	-377.1 (290.9)
Employed	608.7*** (229.3)
Unemployed	525.7** (261.7)
Retired	-277.3 (493.3)
Disabled	909.5*** (239.5)
Keeping House	1376*** (515.0)
Married	-57.47 (324.7)
Never Married	-754.2* (404.2)
Divorced	653.2* (346.6)
Separated	201.1 (295.6)
Family Size Change	153.4 (162.4)
% Δ State GDP	-3071*** (1072)
Constant	-1960* (1105)
Observations	7786
Number of unique id	2,983
R-squared	0.443

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

7 Robustness

In this section, I introduce some alternative specifications and control variables to the baseline model to demonstrate the robustness of my results.

7.1 State Centralization

States vary in the degree to which their schools are funded by the state or by local districts. Most importantly, the amount of centralization has changed within each state over time. Table 7 summarizes the model with the inclusion of a centralization control and interaction term with public spending. Centralization is defined as the proportion of revenue that is non-local (either from the state or federal government). With this specification the response of private educational spending to a 1% increase in instructional expenditures is $24.98. The coefficient for the interaction term with centralization is statistically significant at -307.4, but its effect on the economic substance is small. For example, the response of a household in a state with 45% centralization is estimated to be $23.59 whereas for a household in a state with 70% the response is $22.83. The numbers 45% and 70% are chosen to approximately represent the bottom and top halves of states in terms of centralization according to the United States Census Bureau.

7.2 Political Controls

Table 8 introduces political controls to ensure that the results aren't affected by the varying politics in each state. Hanushek, Rivkin and Taylor (1996) determined that state political variables are a particular problem for studies that use aggregated data. Public school funding is determined by the political process with each major political party potentially implementing different policies. The political variables used to account for this issue include the proportion of control that each party has in each legislative body, the party of the governor and whether the state government is completely under the control of one party. Independent/third party variables are the excluded category for each of these variables. The political data was collected from Ballotpedia. The substance of the results is unaffected, but the response is larger with an estimated $30.19 increase in private spending for every 1% increase in instructional spending.

The inclusion of political variables, which reflect party dominance and policy orientations, appears to heighten the responsiveness of private educational spending to changes in public spending. This suggests that regional political climates may either encourage or require increased private educational expenditures in reaction to public spending variations. This result highlights the potential influence of political factors on the relationship between public and private contributions to educational funding and necessitates further study.

Table 7: Robustness: Spending Model with Centralization

Variable	
% Δ Public Instructional Expenditures	2498*** (671.5)
% Δ Public Instructional Expenditures × Centralization	-3577* (1992)
Centralization	0.537*** (0.194)
% Δ Labor Income	-194.8*** (47.53)
Liquid Assets Change	0.000199 (0.000547)
Illiquid Assets Change	-0.000233 (0.000264)
High School Dropout	20.21 (243.7)
Undergraduate Degree	-228.5 (190.6)
Graduate Degree	-257.2 (244.8)
Employed	-552.6 (594.2)
Unemployed	-162.0 (601.3)
Temporary Leave	-1011 (616.5)
Disabled	-1184* (661.7)
Keeping House	-565.7 (621.8)
Family Size Change	176.8** (85.90)
Δ in Number of Children	-346.3*** (101.8)
Moved	-216.8*** (54.56)
% Δ State GDP	-841.8 (848.4)
Constant	1632 (1878)
Observations	9797
Number of unique id	3,166
R-squared	0.395

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
Insignificant marital status coefficients are suppressed for the sake of space

7.3 Timing

The base-line model estimates the relationship between changes in private spending and public spending over the same period. This section uses a specification in which the public spending changes are taken from the following year rather than the current year. Based on the theoretical model, household spending should change contemporaneously with public spending as they are both entered into the human capital production function simultaneously. Hence, a significant correlation between private spending changes and future public expenditure changes would suggest endogeneity, indicating that changes in public school spending might be associated

with other variables influencing private spending. Table 9 shows that using a forward for public spending yields no statistically significant response in private spending. This finding reinforces the premise that it is the contemporaneous public expenditures that primarily influence private expenditures, and not other latent factors.

Table 8: Robustness: Spending with Political Controls

Variable	
% Δ Public Instructional Expenditures	3019*** (709.1)
% Δ Public Instructional Expenditures × Prob. Private School	-2796 (2020)
Prob. Private School	4680*** (140.1)
Republican Proportion of Senate	-5348 (3487)
Democratic Proportion of Senate	-6602* (3500)
Democratic Controlled Senate	322.3 (211.7)
Republican Controlled Senate	-340.9* (192.6)
Republican Proportion of House	-8475 (6749)
Democratic Proportion of House	-6796 (6733)
Democratic Controlled House	-95.16 (463.7)
Republican Controlled House	302.9 (458.1)
Democratic Governor	-243.1 (206.3)
Republican Governor	-115.6 (182.9)
Democrats Control Govt	64.02 (122.3)
Republicans Control Govt	109.2 (140.4)
% Δ Labor Income	-225.3*** (47.52)
Graduate Degree	-450.9* (245.7)
Keeping House	1248** (569.7)
Family Size Change	158.8* (86.19)
Δ in Number of Children	-273.7*** (100.8)
Moved	-187.4*** (55.29)
% Δ State GDP	-1701* (873.3)
Constant	14241* (8289)
Observations	9872
Number of unique id	3,150
R-squared	0.408

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
Insignificant financial, marital, education and employment status coefficients are suppressed for the sake of space

Table 9: Robustness Check: Spending Model with Forward

Variable	
% Δ Public Instructional Expenditures Forward	-22.08 (683.7)
% Δ Public Instructional Expenditures Forward × Prob. Private School	2640 (3516)
Prob. Private School	4701*** (132.5)
% Δ Labor Income	-202.7*** (46.93)
Liquid Assets Change	0.000197 (0.000527)
Illiquid Assets Change	-0.000310 (0.000260)
High School Dropout	-24.45 (239.2)
Undergraduate Degree	-275.4 (192.8)
Graduate Degree	-411.3* (244.4)
Employed	551.5 (478.1)
Temporary Leave	259.6 (503.5)
Unemployed	768.4 (487.3)
Disabled	461.1 (507.2)
Keeping House	1243** (569.9)
Married	-241.1 (256.1)
Never Married	481.0 (295.7)
Divorced	150.4 (258.0)
Separated	32.57 (247.6)
Family Size Change	160.5* (84.36)
Δ in Number of Children	-305.2*** (99.98)
Moved	-222.5*** (54.99)
% Δ State GDP	677.1 (538.6)
Constant	256.0 (1710)
Observations	10,029
Number of unique id	3,205
R-squared	0.402

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Another potential timing issue is is the costliness of switching between private and public schooling, potentially leading to persistence in school choice. Such persistence could impact the relationship between current public and private spending changes. To address this, table 10 includes the results from including lagged spending changes and the private school variable. The results from this extended model reveal a marginally significant effect from the lagged

Table 10: Robustness Check: Spending Model including Lag

Variable	
% Δ Public Instructional Expenditures	2741*** (843.1)
% Δ Public Instructional Expenditures × Prob. Private School	-611.4 (2312)
Prob. Private School	4549*** (179.8)
% Δ Public Instructional Expenditures Lag	1152** (559.2)
% Δ Public Instructional Expenditures Lag × Prob. Private School Lag	-441.5 (2931)
Prob. Private School Lag	-4047*** (175.8)
Constant	2201*** (651.6)
Observations	6824
Number of unique id	3,205
R-squared	0.605

public variable, indicating a delayed response in private educational spending. However, the contemporaneous effect of a 1% increase in public spending on private spending is $27.41 which is in line with the other specifications. This consistency in the coefficient underscores the robustness of the model to additional temporal dynamics and reaffirms the immediate impact of public spending on private educational decisions, as initially hypothesized in the theoretical framework.

8 Conclusion

The main empirical finding in this paper is that there is strong evidence for complementarity between public instructional expenditures and private non-tuition spending. I find that an increase of one percent in instructional expenditures per pupil results in a $22.50 increase in household education expenditures per child. With an average spending of $935.19, this implies an average elasticity of about 2.4. This result is robust to a variety of specifications and subsamples.

This study is the only one to my knowledge that provides a precise empirical relationship between private and public educational spending in the United States. These results are therefore useful providing empirical benchmarks for the parameterization of theoretical models which were previously missing.

One avenue for future research is in related theoretical work. A pertinent example is the work of Glomm & Kaganovich, which highlights how complementarity between public and private educational inputs may exacerbate income inequality. My estimates could provide a foundation for deeper exploration of these social and economic impacts. These results could also inform policymakers on likely parental responses to shifts in educational spending. Finally,

there is scope for investigating household leisure time allocation in the context of enhanced public education funding. It is essential to investigate whether this results in more time spent with children or in other leisure activities, providing a clearer picture of the lifestyle implications of educational investment.

Data availability statement:

The data that support the findings of this study are available from:

- The Panel Study of Income Dynamics: https://www.src.isr.umich.edu/projects/panel-study-of-income-dynamics-psid/
- The Consumer Expenditure Survey: https://www.bls.gov/cex/pumd.htm
- Annual Survey of School System Finances: https://www.census.gov/programs-surveys/school-finances.html

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