Estimating the Effects of Private School Vouchers in Multi-District Economies*

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Abstract

This paper estimates a general equilibrium model of school quality and household residential and school choice for economies with multiple public school districts and private (religious and non-sectarian) schools. The estimates are used to simulate two large-scale private school voucher programs in the Chicago metropolitan area: universal vouchers, and vouchers restricted to non-sectarian schools. In the simulations, both programs increase private school enrollment, and affect household residential choice. Under universal vouchers enrollment grows at all private schools, yet under non-sectarian vouchers private school enrollment expands less, and religious school enrollment declines with the voucher level. Fewer households benefit from non-sectarian vouchers. (JEL I22, H73, H42, C51).

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1. Introduction

Private school vouchers play a central role in the debate about education reform in the United States. Vouchers, it is argued, give households the opportunity to enroll their children in private schools and access the type of education that they prefer for their children. Currently, some households prefer private schools over the public schools in their metropolitan areas, but face budget constraints that restrict them to public schools. Although public schools have no explicit tuition, in metropolitan areas where public schools have residence requirements, households must choose public schools and residences as *bundles*, whose costs are determined by housing prices and property taxes. Therefore, in order to gain access to their preferred public schools, households might choose to live in places they would not have selected in the absence of bundling. Vouchers, it is claimed, would break this bundling by allowing households to choose private schools, which have no residence requirements.

Thus, vouchers may not only give households more school choices, but also alter household residential decisions. As a result, public school districts may experience changes in their property values, school funding, and the composition of their student populations. To gain insight into the potential impact of large-scale private school voucher programs, these general equilibrium effects should be examined.

In this paper I estimate a general equilibrium model that jointly determines school quality and household residential and school choices within an economy with multiple public school districts and private schools. I then use the parameter estimates to simulate two different voucher programs.

Models of household sorting across jurisdictions originated in 1956 with Tiebout's work.[1] Only

[1] See Epple and Sieg (1999) for a review of the literature on public good provision since Tiebout's work, and on the early tests of the Tiebout model. In particular, the provision of public education in a multi-district framework has been theoretically examined by Inman (1978), de Bartolome (1990, 1997), Glomm and Ravikumar (1992), Benabou (1993, 1996), Silva and Sonstelie (1995), Durlauf (1996), Fernandez and Rogerson (1996, 1997a, 1997b, 1998), Nechyba (1999, 2000, 2003), and Epple and Romano (2003). Furthermore, Nechyba (1999, 2000, 2003) includes private schools in multi-district economies.

recently have researchers attempted to estimate them (Bajari and Kahn (2002), Bayer, McMillan and Rueben (2002), Epple and Sieg (1999), Epple, Romer and Sieg (2001), Nesheim (2003), Sieg et al (2003), Timmins (2003)), although without including mechanisms for the formation of private schools. In particular, while researchers who have evaluated the general equilibrium effects of private school vouchers in the United States have relied on calibration to simulate voucher experiments (Cohen-Zada and Justman (2002), Epple and Romano (1998), Fernandez and Rogerson (2003), Glomm and Ravikumar (1999), Nechyba (1999, 2000, 2003)), I use estimates to simulate such experiments.

The few voucher programs enacted to date in the United States have included a small number of voucher recipients, and have often restricted the set of eligible private schools.[2] Thereby, researchers have insufficient data to evaluate the general equilibrium effects of potential large-scale voucher programs, and must turn to simulation to investigate them. In this context, structural estimation using data from settings without vouchers can prove particularly helpful by providing parameter estimates that capture the behavior of households and schools, which can then be used to evaluate the general equilibrium effects of potential large-scale voucher programs.

One school attribute demanded by numerous households is religious education. According to the 1989 Private School Survey, 85% of the private school enrollment in grades 9 through 12 was in religious schools. Moreover, the considerable variation in private school markets among metropolitan areas is related to geographic differences in the distribution of adherents to various religious denominations. In other words, the consideration of religious preferences appears to be relevant in order to understand how private school markets differ across metropolitan areas, and how voucher effects may differ accordingly. Nevertheless, previous research on the general equilibrium effects of vouchers has typically not

[2] For descriptions of these programs, see, for instance, Howell and Peterson (2002).

incorporated religious preferences as a determinant for the existence of some private schools.[3]

Thus, I extend Nechyba's (1999) theoretical work to include household religious preferences and two types of private schools, Catholic and non-Catholic. Moreover, households of a given religion in the model vary in their taste for each type of private school; for instance, some Catholics like Catholic schools better than other Catholics. The inclusion of religion in the model has important implications for the analysis of voucher policies, as it provides an answer to questions such as what type of private schools would expand under vouchers, and at what rate; how religious preferences would affect the distributional effects of vouchers; how vouchers would affect the religious composition of each type of school; where Catholics would choose to reside under a voucher regime; and the minimum necessary voucher level in order to make a household better off given its wealth and religious preferences.

Furthermore, a contentious issue related to publicly-funded vouchers is their use to underwrite tuition at religious schools. Although the Supreme Court upheld voucher use at religious schools in Zelman v. Simmons-Harris (06.27.02), when designing voucher programs states can choose whether or not to include religious schools.[4] By including religious preferences and schools, the model I employ is able to consider the effects of banning voucher use in religious schools.

Among private schools, I focus on Catholic schools for several reasons. First, Catholic schools are the largest and most homogeneous group of schools within the private school market.[5] Second, in

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[3] Downes and Greenstein (1996), and Hoxby (1994) have examined the role of religious preferences in private school markets, although these frameworks do not allow for the analysis of the general equilibrium effects of vouchers. While Cohen-Zada and Justman (2002) undertake this analysis, their work differs from mine in that they calibrate a single-district economy.

[4] Many states have constitutional provisions ("Blaine amendments") with more prohibitive criteria for the separation of church and state than those found in the First Amendment. See Bolick (2003) and Viteritti (1999) for further reference on this issue.

[5] According to the 1989 Private School Survey, 58% of private school enrollment in grades 9 through 12 in secondary and combined schools was in Catholic schools, 27% in other religious schools, and the remaining 15% in

states where it has been debated whether religious schools should be eligible to participate in voucher programs or not, most of the students attending religious schools are enrolled in Catholic schools. Third, the majority of the current voucher proposals attempt to increase choices for low-income students in inner cities where Catholic schools have historically had a strong presence, often times targeting economically disadvantaged students through subsidized tuition and privately-funded vouchers.

To estimate the model I use a minimum distance estimator with 1990 data on the metropolitan areas of New York, Chicago, Philadelphia, Detroit, Boston, St. Louis, and Pittsburgh, from sources such as the 1990 School District Data Book, the 1989 Private School Survey, and the 1990 Churches and Church Membership in America survey. In spite of the many simplifications made in order to render the problem tractable, my estimates succeed at capturing the pattern of income stratification, and the distribution of housing values across districts within a metropolitan area. In addition, they replicate private school enrollment patterns for large school districts reasonably well.

Currently, I have assessed the effects of two hypothetical policies, the introduction of universal vouchers, and of vouchers restricted to non-sectarian private schools ("non-sectarian vouchers")[6] for the Chicago metropolitan area. Although universal (non-targeted) vouchers have not been implemented to date, their analysis gives insight into the impact of an unrestricted voucher program, which is helpful given that any other program may be seen as a restricted version of universal vouchers. In these simulations, a voucher is a set amount of money that a household receives from the state for the exclusive purpose of paying private school tuition.

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non-sectarian schools in the United States in 1989. When restricted to secondary schools, the same survey reports that Catholic schools captured 75% of the total private school enrollment. Neal (2002) reviews the literature that documents the positive effects of Catholic school attendance, and makes conjectures regarding the behavior of Catholic schools under potential large-scale voucher programs.

[6] For simplicity, this paper considers only one type of religious schools, namely Catholic schools. Thus, the simulation of non-sectarian vouchers is, strictly speaking, the simulation of vouchers restricted to non-Catholic private schools, although it is meant to capture the effects of restricting vouchers to non-sectarian schools.

According to my simulation results, both programs increase private school enrollment, and affect household residential choice. In particular, at low voucher levels, households using vouchers migrate towards neighborhoods with lower tax-inclusive housing prices, and send their children to private schools. This, in turn, reduces the residential stratification generated by the current public school system. The two programs increase average school quality. Furthermore, households with a wealth of about $35,000 experience not only the largest proportional school quality gains in both programs, but also the largest welfare gains from vouchers relative to their wealth.

However, universal and non-sectarian vouchers differ in important ways. Universal vouchers increase enrollment at both Catholic and non-Catholic private schools, yet when vouchers are restricted to non-sectarian schools, the overall private school enrollment expands less at moderate voucher levels, and enrollment in Catholic schools tends to decline, relative to the non-voucher equilibrium, as the dollar amount of the voucher increases. In addition, fewer households benefit from non-sectarian vouchers. Further, whereas at each endowment level households with a strong preference for Catholic schools experience the largest gains relative to their endowment, they lose the most under non-sectarian vouchers.

The remainder of this paper is organized as follows: section 2 provides descriptive statistics that highlight the income-sorting of households among districts and the geographic variation in private school markets among the metropolitan areas of interest. Section 3 presents the model, and section 4 discusses the computable version of the model used for estimation purposes. Section 5 describes the estimation procedure, and section 6 discusses the estimation results. Section 7 analyzes voucher effects in policy simulations, and section 8 concludes.

2. Descriptive Statistics

My analysis focuses on the metropolitan areas of New York, Chicago, Philadelphia, Detroit, Boston, St. Louis, and Pittsburgh, and the secondary and unified school districts therein. As of 1990, these were among the twenty largest metropolitan areas in the United States, had a high level of dependence on local

sources for public school funding, and had populations that were at least 25% Catholic.[7] Table 1 lists some of their relevant features.

As shown by the summary statistics in Table 2, the school districts in these metropolitan areas vary widely in the fraction of households with children in private schools, in average household income, in average housing rental value, in average spending per student and, to some extent, in sources of public school funding. Moreover, households with children in private schools tend to have higher incomes and to live in houses with higher rental values than households with children in public schools.

In the metropolitan areas included in my sample, the central city district is the largest one, comprised of multiple neighborhoods with different housing stocks and geographic amenities. The fraction of households with children in private schools is relatively high in the central city district and in some suburban districts. Among households that live in central city districts and send their children to private schools are middle-income families who reside in the districts' most expensive neighborhoods, and low-income families whose children attend private schools with subsidized tuition.

Thus, factors such as income distribution, the distribution of housing quality within and across districts, and public school funding are related to private school enrollment. In addition, the geographic variation in private school markets also seems to be shaped by the geographic variation in the distribution of adherents to different religions. Among the twenty largest metropolitan areas in the United States, those with a higher fraction of students in private schools also have a higher fraction of private school students enrolled in Catholic schools. Furthermore, these metropolitan areas have a higher fraction of Catholics, and the correlation between the fraction of students enrolled in Catholic schools and the fraction of Catholics equals 0.79.

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[7] To avoid the complexity of multiple types of religious schools, the model treats Catholic schools as synonymous with religious schools. In addition, the model presumes property tax funding supplemented by a flat state grant. Hence, I select metropolitan areas where public schools are indeed predominantly funded by local property taxes, and where most of the religious population is Catholic.

To summarize, the selected metropolitan areas display significant variation in the dimensions of interest, and the data provide evidence of household sorting across districts and into schools within a given metropolitan area. The theoretical model presented below captures the elements associated to this sorting.

3. The Model

The model extends Nechyba's (1999) model by including household religious preferences and different types of private schools. In the model, an economy is a set of public school districts with fixed boundaries that contain neighborhoods of different qualities. There are three types of schools: public, private Catholic, and private non-Catholic. The economy is populated by households that differ in endowment and religious preferences, yet all maximize utility by choosing a location and a school for their children and by voting for property tax rates used to fund public schools. In equilibrium, no household wants to move, switch to a different school, or vote differently.

Households and Districts

The economy is populated by a continuum of households, each one endowed with one house. The set of houses in the economy is partitioned into school districts. Every district d is in turn partitioned into neighborhoods, and there are H neighborhoods in total in the economy. Houses may differ across neighborhoods, but within a given neighborhood are homogenous and have the same housing quality and rental price.

Each household has one child, who must attend a school, either public or private. One public school exists in each district,[8] and the child may attend only the public school of the district where the household resides. If parents choose to send their child to a private school, Catholic or non-Catholic, they

[8] The assumption of one public school per district rules out the existence of neighborhood schools, such as those in Epple and Romano (2003).

are not bound to any rule linking place of residence and school.

In addition to a house, households are endowed with a certain amount of income, and there are I income levels. Besides endowment, households differ in their religious orientation, which is given by their valuation of Catholic schools relative to non-Catholic schools. Thus, a household has one of K possible religious types, where types $1,\ldots,L$ are Catholic, and the others non-Catholic. Not all the L Catholic types are necessarily identical, for they may differ in their relative valuation of Catholic schools, and the same is true for the non-Catholic types. The combination of all endowment and religious types yields a total of $H \times I \times K$ household types.

Household preferences are described by the following Cobb-Douglas utility function:

$$U(\kappa, s, c) = s^{\alpha} c^{\beta} \kappa^{1-\beta-\alpha}, \quad \kappa = k_{dh} \tag{1}$$

where $\alpha, \beta \in (0, 1)$, k_{dh} is an exogenous parameter representing the inherent quality of neighborhood h in district d, (i.e., housing size and age, geographic amenities, etc.), c is household consumption, and s is the parental valuation of the quality of the school attended by the child, which, in turn, depends on the household's religious preferences. Household n seeks to maximize utility (1) subject to the following budget constraint:

$$c + (1 + t_d) p_{dh} + T = (1 - t_y) y_n + p_n \tag{2}$$

where y_n is the household's income, t_y is a state tax rate, and p_n is the rental price of the household's endowment house. Given its per-period total income, represented by the right-hand side of (2), the household chooses to live in location (d, h) with housing price p_{dh} and local property tax rate t_d. It also chooses a school for its child with tuition T, and $T = 0$ for public schools. Remaining income is used for consumption c.

Production of school quality

All schools in the economy produce school quality $\tilde{s}$ according to the following Cobb-Douglas

production function:

$$\tilde{s} = q^{\rho} x^{1-\rho} \tag{3}$$

where $\rho \in [0,1]$, q stands for the school's average peer quality, and x is spending per student at the school. Denote by S the set of households whose children attend the school, and by $\bar{y}(S)$ the average income of these households. Then the school's average peer quality is defined as $q = \bar{y}(S)$.[9] The spending per student x equals tuition T if the school is private, and it equals the spending per student in district d, x_d, if the school is public and run by the local government.

The parental valuation of school quality (see s in equation (1)), depends on each household's religious preferences. A household of religious type $k = 1, \ldots, K$ whose child attends a school with religious orientation $j = 1, 2$ (Catholic or non-Catholic respectively)[10] and quality $\tilde{s}_j$ perceives the school's quality as follows:

$$s_{kj} = R_{kj} \tilde{s}_j \tag{4}$$

where $R_{kj} > 0$ is a preference parameter.

Public Schools

The quality of the public school in district d is $\tilde{s}_d = q_d^{\rho} x_d^{1-\rho}$, where q_d is the average income of households in district d with children attending this school. Under a regime of local financing, the public spending in education is funded by local property taxes, possibly aided by the state. Thus, the spending per student in district d is given by $x_d = t_d P_d / n_d + AID_d$, where n_d is the measure of households

[9] For simplicity, this assumes that peer effects operate through parental involvement and monitoring, which are increasing in income (McMillan (1999)). Epple and Romano (2003) and Fernandez and Rogerson (2003) provide references to the theoretical literature that considers peer effects in the production of education.

[10] Public schools are nonsectarian and, therefore, non-Catholic.

choosing public school in district d, AID_d is the amount of state aid per student (henceforth called state aid) for district d, funded through a state income tax, and P_d is the value of residential property in the district.

Private Schools

Private schools are modeled as clubs formed by parents under an equal cost-sharing rule. Since the school production function in (3) creates incentives for a household to join a school with households of an equal or higher endowment, and the production of school quality features constant returns to scale, households of a given endowment type may optimally segregate themselves into a private school and reject lower endowment types. Therefore, a private school formed by households of income level y_n has peer quality $q = y_n$.

Households of a given endowment type share costs equally at a private school. Thus, the tuition equals the households' optimal spending on education, holding their residential locations fixed. That is, after choosing a location (d, h) with quality k_{dh}, household n of religious type k with income y_n may choose to send its child to a private school with tuition T and religious orientation $j = 1, 2$ (Catholic or non-Catholic) that maximizes utility (1) subject to the budget constraint (2) and the perception of school quality $s = R_{kj} q^{\rho} x_j^{1-\rho}$, where $q = y_n$, and $x_j = T$. Notice that the optimal tuition T determined by solving this optimal choice problem does not depend upon R_{kj}. Parents who decide to open a private school choose the school religious orientation (Catholic or non-Catholic) for which they have a higher taste. Thus, if households of a given endowment type with religious preferences $R_{k1} > R_{k2}$ or $R_{k2} > R_{k1}$ decide to form a private school, they will segregate themselves into a Catholic or non-Catholic private school, respectively.[11]

[11] Households care about the makeup of the student body because of peer quality and other households' willingness and ability to pay for school quality. However, households do not care about the religious preferences of other

Household Decision Problem

Households are utility-maximizing agents that choose locations (d,h) and schools simultaneously, while taking tax rates t_d, district public school qualities s_d, prices $p_{dh,}$, and the composition of the communities as given. Household n chooses among all locations (d,h) in the budget set determined by the constraint $(1+t_d)p_{dh} \leq (1-t_y)y_n + p_n$. For each location, the household compares its utility under public, Catholic private, and non-Catholic private schools. Migrating among locations is costless in the model, and the household may choose to live in a house other than its endowment house.

Absolute Majority Rule Voting

Households also vote on local property tax rates. At the polls, households vote for property taxes taking their location, their choice of public or private school, property values, and the choices of others as given when voting on local tax rates. Households that choose private schools vote for a tax rate of zero, whereas households that choose public schools vote for a nonnegative tax rate. Because voters choose the tax rate conditional on their school choice, taking everything else as given, their preferences over property tax rates are single peaked, and property tax rates are determined by majority voting. Since there is a one-to-one mapping between property tax rates and spending per student for a given property tax base and number of students in public schools, voting for property tax rates is equivalent to voting for school spending.

The state cooperates in funding public education in district d by providing an exogenous aid amount per student, AID_d. This aid, which operates as a flat grant, is in turn funded by a state income tax whose rate t_y is set to balance the state's budget constraint.

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students in the school; they only care about the religious orientation *of the school* (see equation (4)). Introducing households' preferences for the religious orientation of other households in the school is straightforward, but I have not done it here for simplicity.

Equilibrium

An *equilibrium* in this model specifies a partition of the population into districts and neighborhoods, local property tax rates t_d, a state income tax t_y, house prices p_{dh}, and a partition of the population into subsets of households whose children attend each type of school (public, private Catholic, and private non-Catholic), such that: (a) every house is occupied; (b) property tax rates t_d are consistent with majority voting by residents who choose public versus private school, taking their location, property values, and the choices of others as given when voting on local tax rates; (c) the budget balances for each district; (d) the state budget balances, and (e) at prices p_{dh}, households cannot gain utility by moving and/or changing schools. The existence of equilibrium with public and private schools is proved in Nechyba (1999), and a similar logic can be applied to prove the existence of equilibrium with several types of private schools. With sufficient variation in mean neighborhood quality across districts, the equilibrium assignment of households to locations and schools is unique (Nechyba, 1999).[12]

4. The Computable Version of the Model

In the computational version of the model the concept of "an economy" corresponds to a metropolitan area. Moreover, the estimation strategy consists of simulating the equilibrium for each metropolitan area at alternative parameter points, then choosing the point that minimizes a well-defined distance between the equilibrium data simulated by the model and the observed data. Since the equilibrium cannot be solved analytically, I use an iterative algorithm to compute it for a tractable representation of each metropolitan area. Thus, this section describes the setup of districts and neighborhoods in this representation, the construction of household types, the state financial regime applied in computing the equilibrium, and the algorithm employed.

[12] Due to the discreteness of housing types, there may be a *range* of housing prices, local property taxes, and public school qualities associated with a given partition of households into districts, neighborhoods, and subsets of households attending each type of school. The range decreases as the number of housing types increases.

Community Structure

In the computable version of the model there are an integral number of houses and households in each metropolitan area, organized into districts and neighborhoods.[13] I measure the size of neighborhoods, districts, and metropolitan areas by the number of housing units. For computational tractability I aggregate the actual districts of each metropolitan area into *quasi-districts* in order to compute the equilibrium, such that the largest district is a quasi-district in itself, while smaller, contiguous districts are pooled into larger units. The actual 671 districts thereby yield 58 quasi-districts. For illustrative purposes, Figure 1 depicts Census tracts, and school districts and quasi-districts for the Chicago metropolitan area. Once the quasi-districts (henceforth called districts) are constructed, I split them into neighborhoods of approximately the same size, such that some districts have only one neighborhood, while others have several. Larger metropolitan areas have larger neighborhoods.

Neighborhood Quality Parameters

In the theoretical model each neighborhood is composed of a set of homogeneous houses, such that neighborhood h in district d has a neighborhood quality index equal to k_{dh}. Since neighborhood quality is not measured in standard datasets, I construct an index that captures housing quality and neighborhood amenities, *excluding* public school quality.

The Census geographical concept that best approximates a neighborhood is the Census tract. Therefore, I first compute the neighborhood quality index for each Census tract in a metropolitan area. To do so, I pool the tracts from the twenty largest metropolitan areas, and regress the logarithm of the tract average rental price on a set of neighborhood characteristics and school district fixed effects.[14] The

[13] Metropolitan areas are independent from one another, and households do not migrate across metropolitan areas.

[14] In principle I would use a set of variables that reflect neighborhood *physical* amenities, such as quality of houses in the neighborhood, presence of parks and open spaces, distance to major landmarks and business centers, and distance to public transportation, if applicable. This version employs only tract average physical housing

neighborhood quality index for a tract is the tract's fitted rental value, net of school district fixed effects. The motivation for this regression is that, roughly speaking, rental prices reflect housing characteristics, neighborhood amenities, and public school quality. The district fixed effect has the purpose of netting out the school quality component from the measure of neighborhood quality. After obtaining the neighborhood quality index for each Census tract, I construct neighborhoods of the desired size by pooling contiguous tracts with a similar value for the neighborhood quality index. Finally, I assign each neighborhood the median neighborhood quality of all the tracts belonging to that neighborhood.

For an example of the final representation of a metropolitan area through quasi-districts and neighborhoods, see Figure 2 for the Chicago metropolitan area. The central city of Chicago overlaps entirely with the central district. Unlike the suburban districts, which have one neighborhood each, the central district has seven neighborhoods which differ in housing quality. On average, the central district has the lowest housing quality in the metropolitan area, although some neighborhoods in the central district are of higher housing quality than others in the suburbs.

Household Types

I consider five income levels, whose incomes are equal to the 10th, 30th, 50th, 70th and 90th percentile of the income distribution of households with children in public or private schools in grades 9 through 12 in a given metropolitan area.

For computational purposes, the joint distribution of housing and income endowment is as follows. At the beginning of the equilibrium computation, the distribution of income in each neighborhood is initially the same, and equal to the one that prevails for the metropolitan area as a whole.

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characteristics, which are readily available from the Census, and a linear and quadratic term in tract distance to the metropolitan area center (easily calculated by the researcher) interacted with metropolitan area dummies. See Ferreyra (2002) for more details on the computation of the neighborhood quality parameter and for a list of the data sources used to compute rental values and neighborhood characteristics.

In other words, income and housing endowments are independently distributed. Furthermore, religious preferences and endowments are independently distributed.[15]

Recall that each household is characterized by two religious matches, one with respect to Catholic schools and another with respect to non-Catholic schools. If household *n* is Catholic, its religious preferences are described by its match with respect to Catholic schools, $R^n_{C,C}$, and its match with respect to Non-Catholic schools, $R^n_{C,NC}$. If household *n* is non-Catholic, its religious preferences are given by its match with respect to Catholic schools, $R^n_{NC,C}$, and its match with respect to non-Catholic schools, $R^n_{NC,NC}$.

Since there are two types of schools, I make $R^n_{C,NC} = R^n_{NC,NC} = 1$ and focus on the relative valuation of Catholic schools. Unlike income, whose distribution comes straight from the data, the distribution of religious matches $R^n_{C,C}$ and $R^n_{NC,C}$ needs to be estimated. Therefore, I construct a discrete distribution of religious matches by assuming an underlying continuous distribution. In particular, I assume that $R^n_{C,C}$ is distributed uniformly over the interval $[(1+r)(1-\pi),(1+r)(1+\pi)]$, and that $R^n_{NC,C}$ is distributed uniformly over the interval $[(1-r)(1-\pi),(1-r)(1+\pi)]$, where $0<r<1$ and $0<\pi<1$. The parameter *r* is both the premium enjoyed by the average Catholic from attending a Catholic school, and the negative of the discount suffered by the average non-Catholic from attending a Catholic school, while the parameter π is proportional to the coefficient of variation of each distribution. Faced with the choice

[15] For computational convenience I place ten households in each (house endowment, income) combination. For instance, if the proportions of Catholics and Non-Catholics in the metropolitan area are 28% and 72% respectively, then out of the ten households in each (house endowment, income) combination, I make three Catholic and seven non-Catholic, respectively. The fraction of Catholics is the same for each endowment type, based on the lack of empirical evidence against income and religion being independently distributed (Ferreyra (2002)). Data on the fraction of Catholics in a metropolitan area come from the 1990 Church and Church Membership in America survey.

between schools that are identical in everything except religious orientation, at least some Catholics would choose non-Catholic schools if $\pi > r/(1+r)$, whereas at least some non-Catholics would choose Catholic schools if $\pi > r/(1-r)$.[16]

State Aid

Although the metropolitan areas included in my analysis fund their public schools primarily through local sources, they still differ in the actual (and extremely complex) formulas used by the states to allocate funds among districts (see, for instance, Hoxby (2001)). Therefore, I simplify the financial rules by setting the same mechanism for all metropolitan areas – a local funding system with a state flat grant per student which may differ across districts, and whose value equals the state aid reported by the 1990 School District Data Book.

The Algorithm

In the model, the parameter vector is $\theta = (\alpha, \beta, \rho, \mathrm{r}, \pi)$. Computing the equilibrium for each parameter point and metropolitan area is an iterative process in which households make residential and school choices and vote for the property taxes used to fund public schools. The process continues until no

[16] For an example on how I determine each household's corresponding religious match, I continue with the case presented in the preceding footnote. Suppose that $r = 0.2$ and $\pi = 0.1$. This implies that $R^n_{C,C}$ is uniformly distributed between 1.08 and 1.32, and $R^n_{NC,C}$ is uniformly distributed between 0.71 and 0.88. Therefore, I assign a match equal to 1.08, 1.20 and 1.32 to the first, second, and third Catholic household types, and a match equal to 0.72, 0.75, 0.77, 0.80, 0.83, 0.85, and 0.88 to the first through seventh non-Catholic household types. Since religious preferences and endowment are independently distributed, the first, second, and third Catholic household types initially placed in *every* (house endowment, income) combination have religious matches equal to 1.08, 1.20, and 1.32 respectively, and similarly for the religious matches of non-Catholic households.

household gains any utility by moving, switching to a different school, or voting differently. The input for the algorithm consists of the community structure, initial distribution of household types, initial housing prices, and state aid for each district. The output is the computed equilibrium, from which I extract the variables whose predicted and observed values I match in the estimation.[17]

To summarize, this section has presented the computable version of the model used for estimation and voucher simulation purposes. The next section provides details on the estimation of the parameters of the model.

5. Estimation

In this section, I present the strategy followed to estimate the model. In addition, I comment on the computational aspects of the estimation, and on the identification of the model's parameters.

I estimate the model using a minimum distance estimator. I match the observed and simulated values of the following district-level variables, which I construct based on the 1990 School District Data Book: y_1 = average household income, y_2 = average housing rental value, y_3 = average spending per student in public schools, and y_4 = fraction of households with children in public schools. In addition, I match y_5, the fraction of households with children in Catholic schools at the metropolitan area level, calculated from the 1989 Private School Survey.[18] All these variables are scaled to have unit variance in the sample.

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[17] For estimation purposes, I assume the existence of a unique equilibrium. Dealing correctly with potential multiple equilibria implies finding them for every parameter point evaluated in the parameter space. For computational reasons I do not do this here, although future research should explore this issue.

[18] The fraction of households who reside in a district and send their children to Catholic schools is not available, since no data source links households' residences with different *types* of private schools. However, it seems reasonable to assume that households with children enrolled in Catholic schools located in a given *metropolitan area* are residents of that metropolitan area, which allows me to match the fraction of households with children in Catholic schools at the metropolitan area level.

Let D denote the total number of districts in the sample (D=58), M the number of metropolitan areas (M=7), and N_j the number of observations available for variable y_j, $j=1, \ldots 5,$ so that $N_1 = N_2 = N_3 = N_4 = D,$ and $N_5 = M$. Assume that district i is located in metropolitan area m. Then, denote by X_i the set of exogenous variables for district i, such that $X_i = x_i \cup x_m \cup x_{-i}$. Here, x_i is district i's own exogenous data (state aid, number of neighborhoods, neighborhood quality in each neighborhood), x_m is exogenous data pertaining to metropolitan area m (10th, 30th, 50th, 70th and 90th income percentiles, and the fraction of Catholic households in the metropolitan area), and x_{-i} is the "own" data from the other districts in metropolitan area m (their state aid, number of neighborhoods, and neighborhood quality in each neighborhood). In addition, the set of independent variables for y_{5m} is X_m, which is the union of all the X_i sets corresponding to the districts that belong to metropolitan area m. Finally, let n_i denote the actual number of housing units in district i, and let n_m denote the actual number of housing units in metropolitan area m.

I assume the following:

$$E(y_{ji} \mid X_i) = h_j(X_i, \theta) \qquad j = 1,\ldots 4;\ \mathrm{i} = 1,\ldots \mathrm{N_j} \tag{5}$$

$$E(y_{5m} \mid X_m) = h_5(X_m, \theta) \qquad \mathrm{m} = 1,\ldots \mathrm{M} \tag{6}$$

where the h's are implicit nonlinear functions. Since the y_{ji}'s are (district-level) sample means, $C(y_{ji}, y_{ki'} \mid X_i, X_{i'}) = \dfrac{\sigma_{jk}}{n_i}$ if $i = i'$, and 0 otherwise, with $V(y_{ji} \mid X_i) = \dfrac{\sigma_{jj}}{n_i} = \dfrac{\sigma_j^2}{n_i} = \sigma_{ji}^2$.

Similarly, given that the y_{5m}'s are also sample means, $C(y_{ji}, y_{5m} \mid X_i, X_m) = \dfrac{\sigma_{j5}}{n_i}$ if district i is located in metropolitan area m, and $C(y_{ji}, y_{5m} \mid X_i, X_m) = 0$ otherwise. Also, $V(y_{5m} \mid X_m) = \dfrac{\sigma_{55}}{n_m} = \dfrac{\sigma_5^2}{n_m} = \sigma_{5m}^2$.

Estimation Strategy

Because the number of observations is rather small, I estimate the model using Feasible Weighted Least Squares to account for heteroskedasticity across observations, and then use the cross-equation covariances to obtain correct standard errors.

Feasible Weighted Least Squares proceeds in two stages. The first stage determines the value for θ that minimizes the following loss function:

$$L(\theta) = \sum_{j=1}^{4} \sum_{i=1}^{N_j} \left(y_{ij} - \hat{y}_{ij}(\theta) \right)^2 + \sum_{m=1}^{M} \left(y_{5m} - \hat{y}_{5m}(\theta) \right)^2 \tag{7}$$

and the residuals from this regression are used to compute $\hat{\sigma}_j^2$ and $\hat{\sigma}_5^2$. The second stage runs Nonlinear Least Squares on variables transformed to account for heteroskedasticity, and seeks to minimize the following loss function in the transformed variables:

$$\widetilde{L}(\theta) = \sum_{j=1}^{4} \sum_{i=1}^{N_j} \left(y_{ji}^* - \hat{y}_{ji}^*(\theta) \right)^2 + \sum_{m=1}^{M} \left(y_{5m}^* - \hat{y}_{5m}^*(\theta) \right)^2 \tag{8}$$

where * denotes division by $\hat{\sigma}_{ji}$ or $\hat{\sigma}_{5m}$. The value of θ that minimizes this function, $\hat{\theta}$, is my estimate for the parameter vector.

Computational Considerations

I use a refined grid search to find the parameter estimates. In a grid search, the objective function can be evaluated at each point independently of its evaluation at other points. This feature allows for parallel computing, which I exploit in order to estimate the model. However, the disadvantage of a grid search is that the size of the grid grows exponentially with the number of parameters, which limits the number of parameters that can be estimated within a reasonable amount of time. This explains, for instance, why my

parameterization of religious preferences is extremely parsimonious.[19]

I use Condor to estimate the model.[20] On average, this lets me evaluate the objective function at about 250 parameter points simultaneously. Since these function evaluations are independent of each other, Condor uses one processor for each function evaluation. A function evaluation takes approximately ten minutes on an Intel processor at an average speed of 1 Ghz, and the full two-stage procedure takes about a week.

Identification

The model is identified if no two distinct parameter points generate the same equilibrium for each metropolitan area. While the discreteness of housing and household types entails a positive probability that a sufficiently small change in the parameters leaves the equilibrium unchanged in each metropolitan area, this probability falls as the number of metropolitan areas, housing, and household types grows. Thus, identification in this model refers to identification up to an arbitrarily small neighborhood of the true parameter point.

A sufficient condition for local identification is that the matrix of first derivatives of the predicted variables with respect to the parameter vector has full column rank when evaluated at the true parameter points. This requires sufficient variation in the exogenous variables across districts and metropolitan

[19] While strictly speaking the loss function is discontinuous because of the discreteness of household types, a sufficiently large number of household types would yield a smooth objective function. Hence, I proceed as if I had a good approximation to it, and compute numerical derivatives of the objective function in order to obtain standard errors.

[20] Condor is a project of the Computer Science Department at the University of Wisconsin-Madison (http://www.cs.wisc.edu/condor). It is a software system harnessing the power of a cluster of UNIX or NT workstations on a network. For a detailed discussion of how Condor was used to estimate the current model, see http://access.ncsa/uiuc.edu/CoverStories/vouchers.

areas. Evaluated at my parameter estimates, the matrix of first derivatives has full column rank in my sample.

6. Estimation Results

In this section I analyze the parameter estimates and discuss their implications for household and school behavior. In addition, I analyze the fit of the individual variables matched in my estimation and discuss the limitations of these fits.

Analyzing the parameter estimates

The parameter estimates, which are shown in Table 3, have reasonable magnitudes. For instance, if housing quality were continuous and housing prices were proportional to housing quality, the optimal household budget shares for school spending, consumption, and housing would be equal to $\frac{\alpha(1-\rho)}{1-\alpha\rho}$, $\frac{\beta}{1-\alpha\rho}$, and $\frac{1-\alpha-\beta}{1-\alpha\rho}$ respectively. Using the observed data to compute an approximation to these shares, I calculate the school spending share as the ratio between the average spending per student and the average wealth, the housing share as the ratio between the average rental value and the average wealth, and the consumption share as one minus the sum of the schooling share and the housing share. This yields a schooling share of 0.11 and a housing share of 0.17, which are reasonably close to the shares implied by my estimates, equal to 0.09 and 0.16 respectively.[21]

In addition, the estimates imply that for Catholic households, $R_{C,C}$ is distributed uniformly between 0.83 and 1.39, and for non-Catholic households, $R_{NC,C}$ is distributed uniformly between 0.67 and

[21] I compute average wealth as average income plus average rental value. Both the sample school spending share and the one implied by my estimates are higher than those in other studies (see Epple and Romano (1998)). Nechyba (2000) discusses this issue.

1.11. These estimates generate sufficient overlap that Catholics may enroll in non-Catholic schools, and non-Catholics may enroll in Catholic schools. Furthermore, the estimated parameters lead to the rejection of the hypothesis that the preferences of Catholics and non-Catholics for Catholic schools follow the same distribution.[22] All the parameter estimates have very small standard errors, because my observations are sample means computed from Census data based on thousands of observations. However, the reported standard errors may understate the true variability to the extent that they have not been adjusted for any of the numerical approximations employed throughout.

Analyzing the fit of the individual variables

Figures 3a through 3e depict the predicted and observed values for each variable. In analyzing the fit of the model, it is important to bear in mind that the aggregation and coarse discretization imposed by computational limitations reduce the model's ability to match the data more closely.

As can be seen in the figures, the model fits the district average rental value and household income reasonably well, particularly for the large districts. The fact that the parameter estimates capture the pattern of household sorting across jurisdictions is a promising result, especially given the parsimonious parameterization of the model.

The model fits the district average public school spending per student less closely. Although the metropolitan areas included in the estimation predominantly rely on local sources for public school funding, they differ considerably in the specifics of their financial regimes, and even districts within the same state are often subject to different public school funding regimes. The under-spending implied by my estimates may in some way reflect a failure of my simple funding rule to capture incentives in actual

[22] Interestingly, when the model is estimated without including household religious preferences or religious schools, the estimated elasticity of school quality with respect of peer quality (ρ) turns out to be higher, as it captures *all* factors different from spending which lead to the formation of private schools, including preferences for religious education.

funding formulas, though it is not clear why this should be the case. In light of the under-spending implied by my estimates, I check the robustness of my voucher findings by sensitivity analyses that place some lower bounds on public school expenditure levels per students, as detailed in Section 7.

The limited number of household types also affects the fit of the district-level fraction of households with children in public schools, and of the metropolitan area-level fraction of households with children in Catholic schools. For example, the low number of neighborhoods and households types imposed by computational constraints implies that often all the households that choose a particular district are relatively homogeneous and make the same school choices, especially in small districts. In these cases, the district predicted fraction of households with children in public schools is either zero or one.

Finally, Table 4 shows the correlations between the matched variables, both for the observed and fitted values. The correlations that do not involve predicted spending per student resemble the actual correlations reasonably well.

To summarize, in this section I have presented and discussed my estimation results. In the next section I discuss the outcomes of voucher programs simulated with my parameter estimates.

7. Simulating Private School Vouchers

I simulate two types of voucher programs for the Chicago metropolitan area. The first type is a universal voucher program in which every household in the metropolitan area receives a voucher that may be used to attend any type of private school. The second program ("non-sectarian vouchers") differs in that the voucher may only be used to attend non-Catholic schools. In either program, households may supplement the voucher with additional payments towards tuition, but cannot retain the difference if the tuition is lower than the voucher level. Consequently, tuition is never set below the voucher level.

Furthermore, in these simulations the voucher level, ν, is set exogenously by the state. Vouchers are funded through a state income tax in the same manner as the state aid per student. Thus, the state income tax has to fund both the flat grants given to public school students and the vouchers given to

private school students. Moreover, during the policy simulations, household *n*'s budget constraint differs from the one given in (2) as follows:

$$c + (1+t_d)p_{dh} + \max(T - v, 0) = (1-t_y)y_n + p_n \tag{9}$$

Notice that when forming private schools, households of a given endowment level residing in a certain neighborhood choose their optimal tuition *taking into consideration voucher availability and dollar amount*. Other things equal, vouchers lead to a higher tuition and school quality level while reducing the share of tuition paid by parents.

In the remainder of this section I first describe the Benchmark Equilibrium, which is the equilibrium simulated using the parameter estimates for a non-voucher regime. Then I analyze the outcomes of a universal voucher program, and contrast them with those of a voucher program for non-Catholic private schools.

Benchmark Equilibrium

The first column of Tables 5a and 5b are from the data, whereas the second column of Tables 5a and 5b present the benchmark equilibrium. In addition, Figure 4 depicts the geographic distribution of income, rental value, private school enrollment and public school spending in the benchmark equilibrium. While the fit of the data is obviously limited, such limitations are due to the factors described in the previous section. Nonetheless, the benchmark equilibrium replicates the overall pattern of income and residential stratification observed in the data. Although the equilibrium also replicates the fact that districts with higher average spending per student in public schools have higher average income and property values, the per-pupil spending in public schools is under estimated in several districts, perhaps because of the omission of non-residential property from the property tax base.[23] In particular, in the simulated

[23] The inclusion of non-residential property in the central district does improve the fit of the district average spending per student, but worsens the fit of other variables, most importantly the district fraction of public school enrollment. This is because a higher spending in the central district improves the public school quality in that district

equilibrium the predicted average household income and property values are sufficiently low in the central district that it is optimal for households in the central city to vote for a property tax rate of zero, and have their public school funded exclusively by the state through the (observed) per-student state aid of approximately $2,200. Nonetheless, the simulated benchmark equilibrium correctly predicts that the central city district has the lowest spending and peer quality of all districts in the entire metropolitan area.

In the benchmark equilibrium, households that attend private schools live in the better neighborhoods of the central district, whose tax-inclusive housing prices are relatively low as a reflection of low housing and public school quality. The top panel of Figure 5 identifies the household types that choose private schools in the benchmark equilibrium. Private school households are, on average, wealthier than public school households, but live in houses of lower quality and property values. In addition, private school households also have a taste for Catholic schools that is above the estimated average (0.978). Per-pupil spending, peer quality and overall school quality are lower, on average, in public than in private schools, although with greater variation around the mean because of their more heterogeneous student body and financial conditions.

Finally, in the benchmark equilibrium Catholic schools are primarily attended by children from

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and discourages private school enrollment. In order to obtain the right level of private school enrollment, one would need either low productivity in public schools in the central district, or tuition subsidies for private schools. In addition, the productivity differential or the tuition subsidy should differ among districts and possibly metropolitan areas, as suggested by some experiments I conducted. Since either possibility requires additional parameters, they are computationally not feasible at this time. However, at the end of this section I present voucher simulation results with a lower bound on public school spending per student. An additional explanation for the under estimation of spending per student may be that a district's actual residential property tax base includes property owned by households with school-age children, *and* by households without school-age children. In contrast, in the model a district's residential property tax base only includes property owned by households with school-age children, since all households have children in the model, which causes the model to under predict property tax revenue per child in public schools. The implications of the one-child assumption are further discussed in Nechyba (2000).

Catholic households (84%) whereas public schools are mostly attended by children from non-Catholic households. In fact, only 31% of the public school enrollment comes from Catholic households.

Universal Vouchers

Below I analyze the effects of universal vouchers on school choices, residential decisions, and school quality in both public and private schools. In addition, I discuss the welfare implications of universal voucher policies.

Household Sorting across Schools and Jurisdictions under Universal Vouchers

Table 5a presents some results from the simulation of universal vouchers for $1,000, $3,000, $5,000 and $7,000.[24] As the table shows, private school enrollment grows as the dollar amount of the voucher increases, and reaches a maximum of 0.93 of the entire population for a $7,000-voucher. Voucher availability gives rise to both new Catholic and private non-Catholic schools yet the private school market share for Catholic schools decreases with the voucher level.[25]

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[24] A few figures may help to put the choice of voucher amounts in context. In the simulated benchmark equilibrium, the highest per-student public school spending levels are $8,900 and $9,200 while the highest spending levels are $9,200 and $10,200 in the data. Among actual voucher programs, voucher amounts are up to $5,300, $2,250 and $5,500 in the Milwaukee, Cleveland and Florida programs, respectively, whereas per-pupil spending in public schools in 2001 equaled $9,000, $6,413 and $6,049 in these places, respectively. For further information, see www.heritage.org.

[25] The parameterization of religious preferences implies that the non-Catholics who most dislike Catholic schools form private non-Catholic schools only when the voucher level is high enough to guarantee a school quality higher than what they would be able to obtain in the public system. This result merits two comments. First, if the model allowed non-Catholics to have a relative preference for non-Catholic private schools over public schools, voucher use would perhaps be higher at each voucher amount. Second, the current estimates for religious preferences also capture Catholic schools subsidies. Therefore, one possible interpretation of the current results is that low voucher

The second row of Figure 5 depicts household sorting across public, Catholic and private non-Catholic schools for a couple of universal voucher levels. When their dollar amount is low (less than $3,000), vouchers are used either by households with children in private schools prior to vouchers, or by middle and high income households with children in suburban public schools who migrate to the central district and enroll their children in private schools given this district's low tax-inclusive property values. In other words, vouchers may indeed break the bundling of residence and public schools. In addition, they may attenuate the residential stratification generated by the residence-based public school system.

Since middle and high-income households have the ability to supplement the voucher in order to attain higher school quality at a private school and/or a better religious match with it, it is optimal for them to take up vouchers even when their dollar amount is low. On the other hand, low-income households, which are taken to include those whose wealth is less than or equal to $20,000, do not have the means to supplement the voucher. Thus, they require a higher voucher amount to compensate both for the good public school peers they would lose in a private school, and for their foregone spending per student at public school. In fact, most low-income households only take up vouchers above per-pupil spending in the central district. Yet as the dollar amount of the voucher increases households of all income levels adopt vouchers, and private schools arise in poor and wealthy districts alike. Interestingly, voucher availability reduces the housing premium in the best public school districts but increases it in the locations favored by voucher users, thus causing capital losses or gains, respectively, to homeowners in those places. [26]

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levels only permit the choice of Catholic schools, given their lower tuition relative to other private schools. This implies that if one goal of the voucher program is to diversify the supply of private schools, then the program must offer relatively high voucher levels.

[26] California's Proposition 174 was a statewide voucher initiative defeated by California voters in 1993, which unlike other proposals featured universal vouchers. Using precinct returns on the ballot, Brunner, Sonstelie and Thayer (2001) find evidence that homeowners in good public school districts were less likely to vote for the voucher, as they perceived it as a threat to their property values.

Given that vouchers are funded by a state income tax in these simulations, fiscal burdens progressively shift from district property taxes onto the state income tax. Whereas the average property tax rate falls, largely due to the increasing number of private school users who favor zero property taxes, the income tax rate rises as the net outcome of lower state aid expenditure for public schools and higher voucher expenditure for private schools.

Regarding the religious composition of private schools, under universal vouchers Catholic schools are predominantly attended by Catholic households, and non-Catholic schools are mostly chosen by non-Catholic households. However, as the voucher level grows Catholic schools attract an increasing number of non-Catholic students, while public schools capture fewer Catholic students.

Universal Voucher Effects on School Quality

By affecting household residential and school choices, vouchers affect the quality of public and private schools. Table 5b shows the evolution of school quality indicators under vouchers. Most households, including those in the low-income segment, gain school quality for vouchers of at least $3,000. Furthermore, the average quality grows with the voucher level; under a $7000-voucher the average school quality is 28% higher than in the benchmark equilibrium, a gain which amounts to 4.4% of the average household endowment. At the same time, the variation in spending and school quality decreases with the voucher amount as schools converge to a tuition equal to the voucher level. While (the remaining) public schools lose quality under universal vouchers, such losses are spread throughout all districts. In particular, public schools in the suburbs suffer because of lower property values, and the loss of public school constituency and good peers to private schools.

To evaluate how school quality gains and losses are distributed in the population, Figure 6 depicts the average school quality for the 10th, 30th, 50th, 70th and 90th percentile endowments in the benchmark and voucher equilibria. Not surprisingly, school quality is increasing in endowment in all scenarios. The households that gain the most school quality at all voucher levels are those whose endowment is around the 30th percentile of the distribution (about $35,000). The reason is that in the benchmark equilibrium

they attend the central district public school, where they mix with peers of lower wealth, whereas through vouchers they access higher quality schools. At low voucher levels some of them take advantage of lower housing prices in other districts and move there yet remain in the public system. However, as vouchers increase all these households switch into private schools.

Since an important policy issue concerning vouchers is their ability to improve school quality for the low-income segment, an important caveat is in order. My simulation results imply that vouchers of at least (approximately) $3,000 attract all low-income households into private schools and provide them with a higher school quality. While empirical evidence from actual voucher programs indicates that many low-income households do take vouchers below $3,000 (Howell and Peterson (2002)), in my simulations this threshold is mainly driven by the predicted spending in the central district public school for the non-voucher equilibrium, which equals $2,200. Given adequacy clauses in state constitutions that would likely prevent actual public school expenditure values from being so low, I conduct simulations for a regime in which every district sustains a minimum per-pupil public school spending equal to the observed spending in the central district ($5,500). To offset the fact that this spending level would generate such high public school quality in the central district that virtually no household would choose private schools, I impose a subsidy rate of 50% for Catholic schools in the central district.[27] Henceforth this regime will be termed "floor spending regime" as opposed to the baseline regime without minimum public school spending or

[27] Detailed results are available from the author upon request. The task of raising the simulated public school spending in the central district may be accomplished either by imposing a minimum spending, as is done here, or by introducing non-residential property. Likewise, keeping the predicted private school enrollment in the central district close to the observed values may be done either through Catholic school subsidies, or through public schools that are less productive than private schools. The combination of minimum public school spending and Catholic school subsidy used here is simply one that replicates the observed data better than other alternatives. In this scenario, the observed central district public school spending ($5,500) and private school share in the central district (20%) are perfectly replicated. For simplicity, I assume that the Catholic school subsidy is funded exogenously, and that the subsidy rate does not change with the voucher amount.

Catholic school subsidies.

In the floor spending regime, the higher public school quality in the central district slows down voucher adoption at each voucher level, whereas Catholic school subsidies create additional incentives for voucher use. The net result of these opposing forces is significantly less voucher use at each voucher amount, although with higher Catholic school share in the private school market. Whereas low-income households with a relative preference for Catholic schools take up vouchers below $5,000 and benefit from Catholic school subsidies, only a voucher higher than $7,000 yields school quality gains for the *whole* low-income segment. In other words, simulations in both the baseline and the floor spending regime provide evidence that improving school quality for the economically most disadvantaged households requires vouchers approximately above the per pupil spending in their public schools.

Since the benchmark equilibrium public school quality is higher for most households in the floor spending than in the baseline regime, the fraction of households that gain school quality with vouchers is lower. As in the baseline regime, the 30th percentile endowment households experience the largest proportional gains in school quality for vouchers *of at least $3,000*. At lower voucher levels, most households below the 30th percentile of the wealth distribution lose school quality given that they remain in the central district public school, which loses good peers to private schools.

Welfare Implications of Universal Vouchers

Among the most important issues concerning vouchers are their effects on social welfare, and who wins or loses[28] when they are introduced. As Table 5b shows, the majority of the population benefits from vouchers of at least $3,000. Furthermore, the average welfare gain is maximized at $250 for vouchers of $3,000, and minimized at -$650 for $7,000-vouchers. Whereas these outcomes, which amount in absolute value to 0.5 and 1.2% of the average household endowment respectively, show that the average welfare

[28] Welfare gains and losses are measured by compensating variation, and computed relative to the benchmark equilibrium.

gain from universal vouchers is small relative to the average wealth for all voucher levels, the distributional effects are large, as explained below.

For instance, the average gain among winners is no larger than $1,200 in these simulations, yet the average loss among losers can be as high as $5,800. The average winner has a higher taste for Catholic education than the average loser and enjoys school quality gains as well as a better religious match with his school relative to the non-voucher equilibrium. At low voucher levels, the average winner is a wealthier-than-average household who takes up the voucher. However, wealthy households tend to lose under high voucher levels *regardless of their school choices* because of the high income tax burden and capital losses they experience. This, in turn, explains why the average school quality and the fraction of households with higher school quality are monotonically increasing in the voucher amount, while the average welfare gain and the fraction of households that benefit from vouchers rise first and fall afterwards.

The top row of Figure 7 gives additional insights on the distributional effects of universal vouchers. Households with a stronger preference for Catholic schools experience the largest gains at each endowment level. The largest welfare gains relative to wealth accrue to households close to the 30th percentile endowment level, who reap gains of about 5% of their wealth. Moreover, all households that remain in private schools win for vouchers below $7,000, whereas most households that move from public to private schools win as well. While most households that remain in public schools lose with vouchers, some of them do benefit from housing price changes that allow them to move into better neighborhoods and access better public schools. Sensitivity analyses indicate the qualitative robustness of these findings in the floor spending regime, although the fraction of households that win with vouchers is lower at each voucher level, partly because public school quality is higher for most households in the floor spending regime's benchmark equilibrium.

Having examined the outcomes of universal vouchers, I now turn to the analysis of vouchers restricted to non-sectarian schools.

Non-sectarian vouchers

Non-sectarian vouchers raise the price of Catholic schools relative to non-Catholic private schools,[29] which induces some households, depending on their religious preferences and budget constraints, to substitute non-Catholic private schools for Catholic schools. Tables 5a and 5b contrast the results of universal vouchers with those of non-sectarian vouchers. As can be seen there, at moderate voucher levels (about $3,000) non-sectarian vouchers induce *less* private school enrollment than universal vouchers precisely because many households that would use the voucher if it were universal would attend Catholic schools. Yet, the private school enrollment is the same or even more at voucher levels high enough as to ensure school quality gains to most of the private school population. Whereas enrollment grows in all private schools under universal vouchers, it grows at private non-Catholic but falls at Catholic schools under non-sectarian vouchers, because only households with a high taste for Catholic schools and the ability to pay for them remain there (see the third row of Figure 5). Moreover, no household chooses Catholic schools if the voucher level is sufficiently high.

Restricting the eligibility of private schools also makes the religious composition of each type of school different from the one induced by universal vouchers. On the one hand, as the dollar amount of the voucher grows, enrollment in Catholic schools (while they still exist) becomes progressively more Catholic, since households with a low taste for Catholic schools choose other options. On the other hand, the religious composition of enrollment in public and private non-Catholic schools becomes more diverse as the dollar amount of the voucher increases, given that many Catholic households enroll there now.

The results above are qualitatively mirrored in the floor spending regime, although in this regime

[29] Notice that if the voucher is *universal*, households of a given endowment forming a private school set the same optimal tuition regardless of the religious orientation chosen for the school. In contrast, when vouchers may *only* be used at non-Catholic schools, the optimal tuition and school quality at a Catholic school formed by households of a given endowment are lower than at a private non-Catholic school formed by households of the same endowment. In addition, Catholic school households must bear the full tuition and reduce their consumption of all other goods.

non-sectarian vouchers are used at a much lower rate than in the baseline regime not only because public school quality is higher in the benchmark equilibrium, but also because Catholic school subsidies create additional demand for these schools. In addition, in the floor spending regime the minimum voucher level necessary to improve school quality for *all* households in the low-income segment is higher than under universal vouchers (and higher than $7,000) given that private non-Catholics schools do not subsidize their tuition.

Since both universal and non-sectarian voucher programs subsidize private school attendance, they produce some qualitatively similar effects. They induce residential changes, reduce residential stratification, and generate comparable effects on property values. In addition, they have a similar impact on school quality and public schools. Both programs progressively shift the fiscal burden from local property taxes to state taxes, thus redistributing income from the wealthy to the poor. The combination of a higher fiscal burden, capital losses, and relatively small gains in school quality makes the average loser wealthier than the average winner in both programs. Moreover, households on or below the 30th percentile of wealth reap the largest proportional school quality gains and the largest welfare gains relative to wealth.[30]

Despite these similarities, universal and non-sectarian vouchers differ in other important ways.

[30] Although qualitatively similar, the effects mentioned in this paragraph are indeed quantitatively different across voucher regimes. For instance, at low levels of the non-sectarian vouchers, non-Catholic households who use vouchers find it easier to migrate to the central district under non-sectarian vouchers, given that Catholics do not compete for housing there. Likewise, since fewer households leave the suburban districts for the sake of private schools, housing prices in the suburbs fall less rapidly, which severs the loss of public school quality in those districts. Finally, *in the floor spending regime* the central district public school *benefits* from non-sectarian vouchers of low level, while it does not under universal vouchers. The reason is that the minimum public school spending forces a positive tax rate in every district. When combined with the higher property tax rate in the central district, this rate yields a higher property tax revenue per child in public school, which more than offsets the loss of good peers. Therefore, the low income segment experiences positive (albeit quite small) effects on public school quality.

For instance, fewer households benefit from non-sectarian vouchers. Moreover, the average welfare gain from non-sectarian vouchers is also smaller. Whereas at each endowment level Catholic households experience the largest gains relative to their endowment under universal vouchers, they lose the most under non-Catholic vouchers (see the bottom row of Figure 7). In particular, households with children in Catholic schools in the benchmark equilibrium are outbid in the central district by voucher users and face increased income tax pressure. Although they sometimes gain school quality by switching to public or private non-Catholic schools, the higher school quality fails to compensate them for the loss of their best possible school religious match.

At least half of the households that switch from public to private (non-Catholic) schools win with non-sectarian vouchers, and on average they gain school quality. However, the fraction of households in this group that benefits from non-sectarian vouchers is lower than for universal vouchers due to the absence of religious motivations to form private schools. As for households that remain in public schools, the qualitative effects for them are the same as under universal vouchers, except that losses among the wealthy for low voucher levels are smaller now, since the smaller number of people attracted into private schools reduces their capital and public school quality losses.

Most households that are winners under one program are also winners under the other, and likewise for losers. However, at least 20% of all households win under universal vouchers of at least $3,000 yet lose under non-sectarian vouchers (this fraction is even higher in the floor spending regime due to the presence of Catholic school subsidies). Such households, that have a strong preference for Catholic schools and either attend Catholic schools in the absence of vouchers or choose them under universal vouchers, now choose public or private non-Catholic schools at moderate or high voucher levels. The average difference in their welfare gains across voucher regimes ranges between 2 and 4% of their average wealth depending on the voucher amount, which makes them the households with the largest welfare difference across voucher regimes.

To sum, in this section I have explored the effects of universal and non-sectarian vouchers. In the next section, I conclude with a summary of my main findings, and a brief discussion on further uses of the

current framework.

8. Concluding Remarks

Few policies are as controversial in the United States as private school vouchers. Although no large-scale voucher program has been implemented, one can learn about the potential effects of this type of program through policy simulation within a general equilibrium framework. Thus, in this paper I estimate a general equilibrium model with multiple public school districts and private schools, and use the parameter estimates to simulate voucher programs. An important contribution in this paper is the inclusion of religious schools and household religious preferences, which has enabled me to compare the effects of a universal voucher program with those of a program with vouchers for only non-sectarian schools in the Chicago metropolitan area.

These programs are similar in several respects. They both expand private school enrolment and induce residential changes. In particular, when their level is low, vouchers may sever the residential stratification created by the current public school system. The two programs increase average school quality. Improving the educational condition of the low-income segment takes a voucher whose lower bound is approximately equal to the per-pupil spending in their public schools. In addition, the average winner in both programs is poorer than the average loser. Whereas the average welfare effects are small in each case, the distributional effects are large.

Perhaps more interesting than the similarities between these programs are their differences. Under universal vouchers, both Catholic and non-Catholic schools expand their enrollments, and the market share for Catholic schools decreases as the voucher level grows. However, under non-sectarian vouchers Catholic schools lose enrollment as the voucher level grows. Furthermore, at each voucher level the overall private school enrollment grows less under non-sectarian than under universal vouchers. Fewer people benefit from non-sectarian vouchers, and the average welfare gain is lower than under universal vouchers. While those with the strongest preference for Catholic education gain the most relative to their

wealth under universal vouchers, they lose the most under non-sectarian vouchers.

That the households who care the most about religion are the ones who lose the most in a non-sectarian program may seem an obvious result, and a skeptical reader may question its usefulness. However, it is important to bear in mind the tradition in federal jurisprudence in the United States that upholds parents' right to choose the type of education they want for their children – including, of course, religious education (see Viteritti (1999), Bolick (2002), and the references therein). Moreover, the US Supreme Court upheld the Cleveland voucher program as "entirely neutral with respect to religion", and as a "program of true private choice" (Zelman v Simmons-Harris (2002), p. 2473).[31] Given that many state constitutions contain Blaine amendments that might be invoked in order to restrict vouchers to non-sectarian schools, the question arises about the consequences of such restrictions in those specific states. The tools presented in this paper can be directly applied to answering these questions.

Furthermore, the framework provided here may be applied to analyze other relevant issues for the voucher policy debate, such as voucher targeting, child-centered funding policies, and changes in the public school financial regime. Moreover, through this framework one could also simulate the expansion of current programs, and the effects of voucher proposals originated in the last ten years although not implemented to date.[32] While no simulation exercise will be able to replace the actual enactment of a large-scale voucher program, developing and estimating general equilibrium models of local jurisdictions that incorporate private school markets can still shed much light on the potential outcomes of school reform programs.

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[31] In his concurring opinion, Justice Thomas wrote: "The Cleveland scholarship program… simply gives parents a greater choice as to where and in what manner to educate their children. This is a choice that those with greater means have routinely exercised" (Zelman vs. Simmons-Harris, p. 2482).

[32] Among the metropolitan areas included in my study, see, for instance, New York City's former Mayor Giuliani's 2001 proposal of a $12 million program, modeled after the Milwaukee choice program, to reach students in some school districts for a three-year period. For more details, see www.heritage.org/schools/new_york.html.

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TABLE 1
Selected Metropolitan Areas

Metropolitan Area	1990 Census Population (in thousands)	No. of School Districts	Largest District's Relative Size	Fraction of Catholic Population	Share of Local Sources
Boston, MA	2,871	87	.158	.49	.72
Chicago, IL	6,070	50	.472	.41	.68
Detroit, MI	4,382	110	.261	.35	.78
New York-Long Island, NY	11,156	167	.644	.43	.76
Philadelphia, PA—NJ	4,857	106	.315	.34	.57
Pittsburgh, PA	2,057	80	.141	.47	.63
St. Louis, MO-IL	2,444	71	.146	.26	.65

Secondary and Unified School Districts included. District Relative Size = number of housing units in district / number of housing units in metropolitan area. Share of local sources for public school funding is the district average share in each metropolitan area.
Source: 1990 Census and School District Data Book (SDDB), and 1990 Churches and Church Membership in America.

TABLE 2
School Districts in Selected Metropolitan Areas: Summary Statistics

	Mean	Std. Dev.	1st Percentile	99th Percentile
Fall Enrollment	1,988	10,741	115	10,698
No. Households	1,970	11,829	37	10,619
Fraction of hhs. w/ children in private schools	.150	.074	.009	.348
In Central District	.194	.042	.096	.268
Avg. Household Income ($)–All Households	53,469	22,872	28,870	145,046
Hhs. w/ Children in Public Schools	49,743	22,036	24,792	131,120
Hhs. w/ Children in Private Schools	74,560	34,354	39,764	220,896
Avg. Housing Rental Value ($)–All Households	10,667	6,390	3,870	35,226
Hhs. w/ Children in Public Schools	10,295	6,255	3,748	32,803
Hhs. w/ Children in Private Schools	12,772	7,622	4,189	40,781
Avg. Spending per Student in Public Schools ($)	6,866	2,066	3,541	13,315
District Size Relative to Metro Area	.210	.262	.001	.644
Share of Local (District) Revenues for Pub. Sch.	.590	.196	.143	.979
Share of State Revenues	.351	.165	.011	.754

No. observations: 671 school districts - Household data and Fall Enrollment are for grades 9 through 12. District size = number of housing units in the district / number of housing units in the metropolitan area. Weighted statistics. Weight = number of households for income and rental value and fraction private, fall enrollment for everything else.
Source: 1990 SDDB and 1989 Common Core of Data.

TABLE 3
Parameter Estimates

Parameter	Estimate
α	0.12 (0.001)
β	0.72 (0.001)
ρ	0.24 (0.001)
R	0.11 (0.009)
π	0.25 (0.001)
Sum of Squared Residuals	376.56

Standard Errors in parentheses. Number of observations: see section 5.

TABLE 4
Goodness of Fit : Some Correlations

a. Observed Data

	Average Hh. Income	Average Rental Value	Spending per Student	Fraction Public
Average Hh. Income	1			
Average Rental Value	0.98	1		
Spending per Student	0.52	0.61	1	
Fraction Public	0.25	0.21	-0.13	1

b. Fitted Data

	Average Hh. Income	Avg. Rental Value	Spending per Student	Fraction Public
Average Hh. Income	1			
Average Rental Value	0.82	1		
Spending per Student	0.95	0.78	1	
Fraction Public	0.41	0.37	0.63	1

Number of observations: 58 districts.
Weighted correlations - weight: number of households in the district

TABLE 5a

Universal and Non-Catholic Vouchers in Chicago: School Choice, Demographic, and Fiscal Effects

	Data	B.E. (1)	Universal Voucher Amount				Non-Catholic Voucher Amount			
			$1,000	$3,000	$5,000	$7,000	$1,000	$3,000	$5,000	$7,000
Private School Enrollment										
Fraction Households in Private Schools	0.16	0.17	0.27	0.73	0.87	0.93	0.27	0.60	0.87	1.00
Fraction Hhs. in Catholic Schools w.r.t. Private Schools	0.84	1.00	1.00	0.62	0.58	0.53	0.51	0.03	0.00	0.00
School Choice before and after Vouchers										
Fraction Hhs. choosing Public-Public (2)			0.73	0.27	0.13	0.07	0.70	0.33	0.11	0.00
Fraction Hhs. choosing Public-Private			0.11	0.56	0.70	0.76	0.13	0.51	0.72	0.83
Fraction Hhs. choosing Private-Public			0.00	0.00	0.00	0.00	0.03	0.07	0.02	0.00
Fraction Hhs. choosing Private-Private			0.16	0.17	0.17	0.17	0.14	0.09	0.15	0.17
Fraction Hhs. Choosing Catholic-Catholic			0.16	0.17	0.17	0.17	0.14	0.02	0.00	0.00
Fraction Hhs. Choosing Catholic-Non-Catholic			0.00	0.00	0.00	0.00	0.00	0.07	0.15	0.17
Religious Composition of Public and Private Schools										
Catholic Schools: fraction of Catholic students		0.84	0.61	0.62	0.60	0.60	0.93	1.00	n/a	n/a
Private Non-Catholic Schools: fraction non-Catholic students		n/a	n/a	0.80	0.80	0.80	0.72	0.61	0.60	0.60
Public Schools: fraction of Catholic students		0.31	0.32	0.23	0.20	0.20	0.32	0.39	0.38	n/a
Demographics										
Average Household Income Ratio (3)	2.42	2.83	2.60	3.38	3.63	3.38	2.62	3.32	3.60	3.66
Average Housing Rental Value Ratio (4)	3.37	2.20	2.18	1.69	1.34	0.99	2.17	1.84	1.36	1.93
Fraction of Hhs. that move			0.56	0.47	0.60	0.64	0.52	0.67	0.61	0.56
Fiscal Effects										
Income Tax Rate		0.03	0.03	0.05	0.10	0.15	0.03	0.05	0.10	0.16
Avg. Property Tax Rate		0.24	0.24	0.17	0.11	0.08	0.24	0.24	0.10	0.00
Avg. Tax Burden (property tax + income tax)		$4,000	$3,900	$4,100	$5,300	$7,100	$3,800	$4,400	$5,400	$7,000

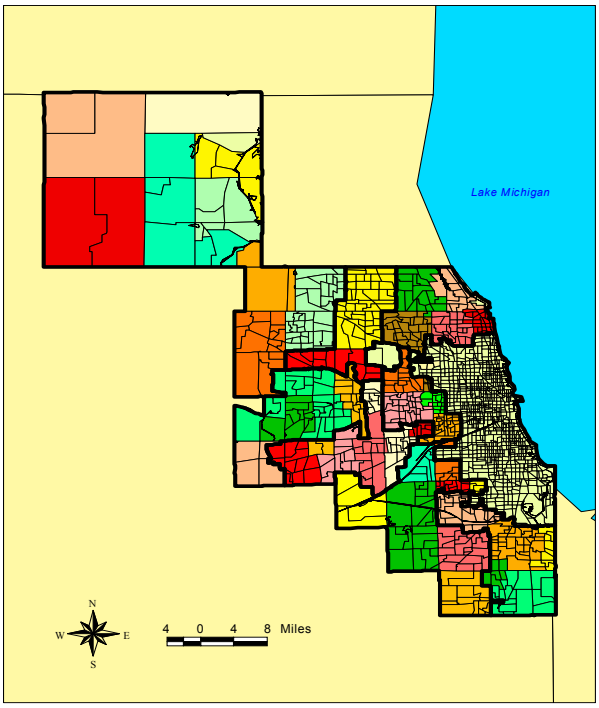
(1) "B.E." denotes "Benchmark Equilibrium"- (2) "Public-Public" is short for "public schools before vouchers, and public schools after vouchers" - (3) Average Household Income Ratio = avg. hh. income in highest housing quality district / avg. hh. income in lowest housing quality district- (4) Average Housing Rental Value Ratio = id. Avg. Hh. Income Ratio, but for housing rental value.

TABLE 5b
Universal and Non-Catholic Vouchers in Chicago: Effects on School Quality and Household Welfare

			Universal Voucher Amt				Non-Catholic Voucher Amt			
All Schools	Data	B.E.	$1,000	$3,000	$5,000	$7,000	$1,000	$3,000	$5,000	$7,000
Avg. Quality (1)		$8,500	$8,600	$8,800	$9,500	$10,800	$8,700	$8,900	$9,500	$10,900
Avg. Spending		$5,000	$5,200	$5,300	$6,000	$7,300	$5,200	$5,400	$6,000	$7,300
Avg. Peer Quality	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000
Fraction of Hhs. w/higher School Quality			0.47	0.61	0.65	0.81	0.54	0.70	0.62	0.81
Public Schools										
Avg. Quality		$7,900	$8,100	$12,300	$12,600	$14,200	$8,200	$11,100	$12,700	n/a
Avg. Spending		$4,700	$4,800	$7,100	$7,300	$8,300	$5,000	$6,600	$7,400	n/a
Central District	$5,500	$2,200	$2,200	n/a	n/a	n/a	$2,200	n/a	n/a	n/a
Suburbs (average)	$7,800	$6,100	$5,900	$7,100	$7,300	$8,300	$6,000	$6,500	$7,400	n/a
Avg. Peer Quality	$49,200	$41,900	$42,000	$69,100	$71,800	$80,900	$41,900	$59,900	$71,100	n/a
Private Schools										
Avg. Quality		$11,400	$10,200	$7,500	$8,900	$10,600	$10,100	$7,400	$9,000	$10,900
Avg. Spending		$6,700	$6,000	$4,700	$5,800	$7,200	$6,000	$4,600	$5,800	$7,300
Avg. Peer Quality	$67,700	$60,700	$53,200	$36,300	$40,900	$42,400	$53,400	$35,100	$41,000	$45,000
Welfare Implications										
Fraction of Households that Win with Vouchers			0.35	0.63	0.85	0.64	0.59	0.45	0.67	0.39
Avg. Welfare Change			$80	$250	-$70	-$650	-$10	-$320	-$550	-$1,040
Avg. Welfare Change / Avg. Hh. Wealth			0.001	0.005	-0.001	-0.012	0.000	-0.006	-0.010	-0.019
Winners										
Avg. Wealth			$57,000	$49,300	$46,600	$39,200	$66,500	$45,500	$46,600	$33,000
Avg. Taste for Catholic Schools			1.11	1.03	0.99	1.01	1.00	0.98	0.96	0.97
Losers										
Avg. Wealth			$52,200	$61,400	$96,500	$79,700	$35,500	$60,800	$96,500	$67,400
Avg. Taste for Catholic Schools			0.91	0.88	0.88	0.93	0.95	0.97	1.04	0.98

(1) this and all dollar values rounded to the closest hundred.

FIGURE 1 - ***Chicago: Census Tracts, School Districts, and School Quasi-Districts***



Note: The small partitions are Census tracts, and different colors identify Census tracts located in different school districts. The thick black lines are the boundaries of the quasi-districts.

FIGURE 2 - ***Chicago: Housing Quality by Neighborhood***

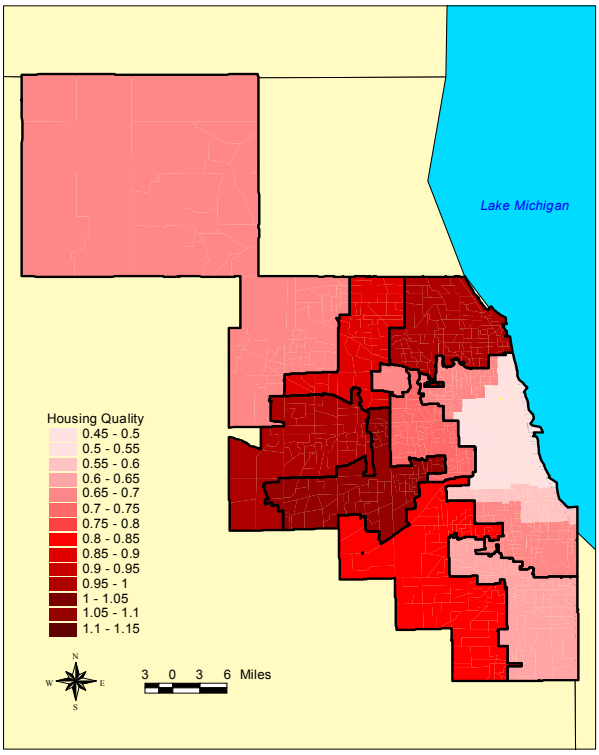


FIGURE 3 - *Fitted vs. Observed Values*

Figure 3a - Fraction of Households w/ children in Public Schools

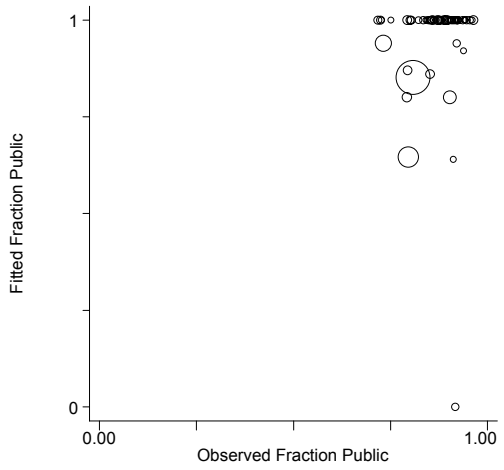


Figure 3b - Average Household Income (in $10,000)

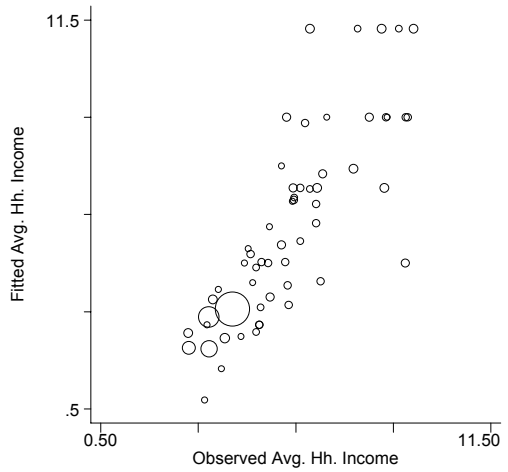


Figure 3c - Average Rental Value (in $10,000)

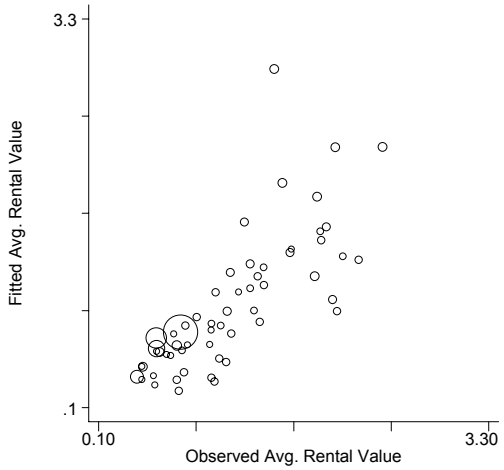


Figure 3d – Spending/Student in Public Schools (in $10,000)

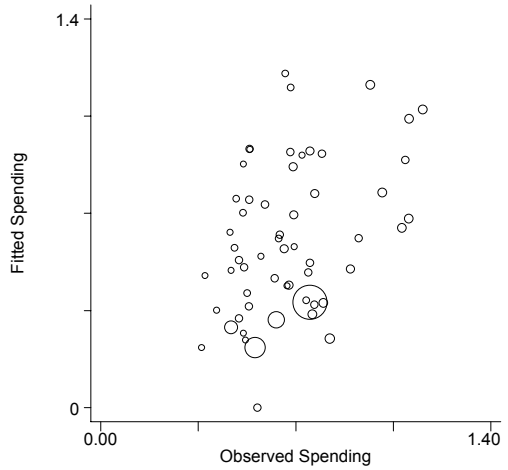
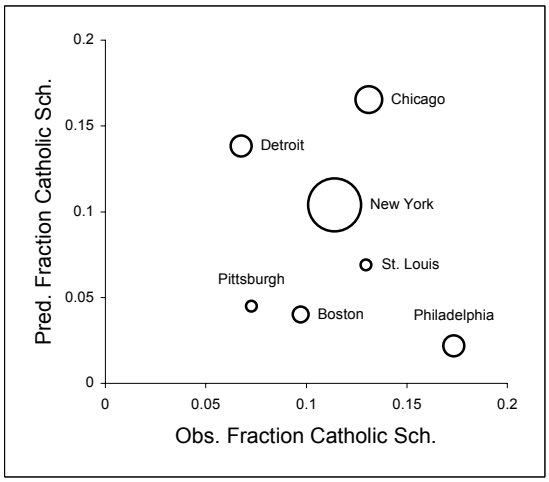


Figure 3e – Fraction of Households with Children in Catholic Schools



Note: observed values on the horizontal axis; fitted values on the vertical axis. Circle size is proportional to the observation's total number of households.

FIGURE 4 - *Chicago: Non-Voucher Equilibrium*

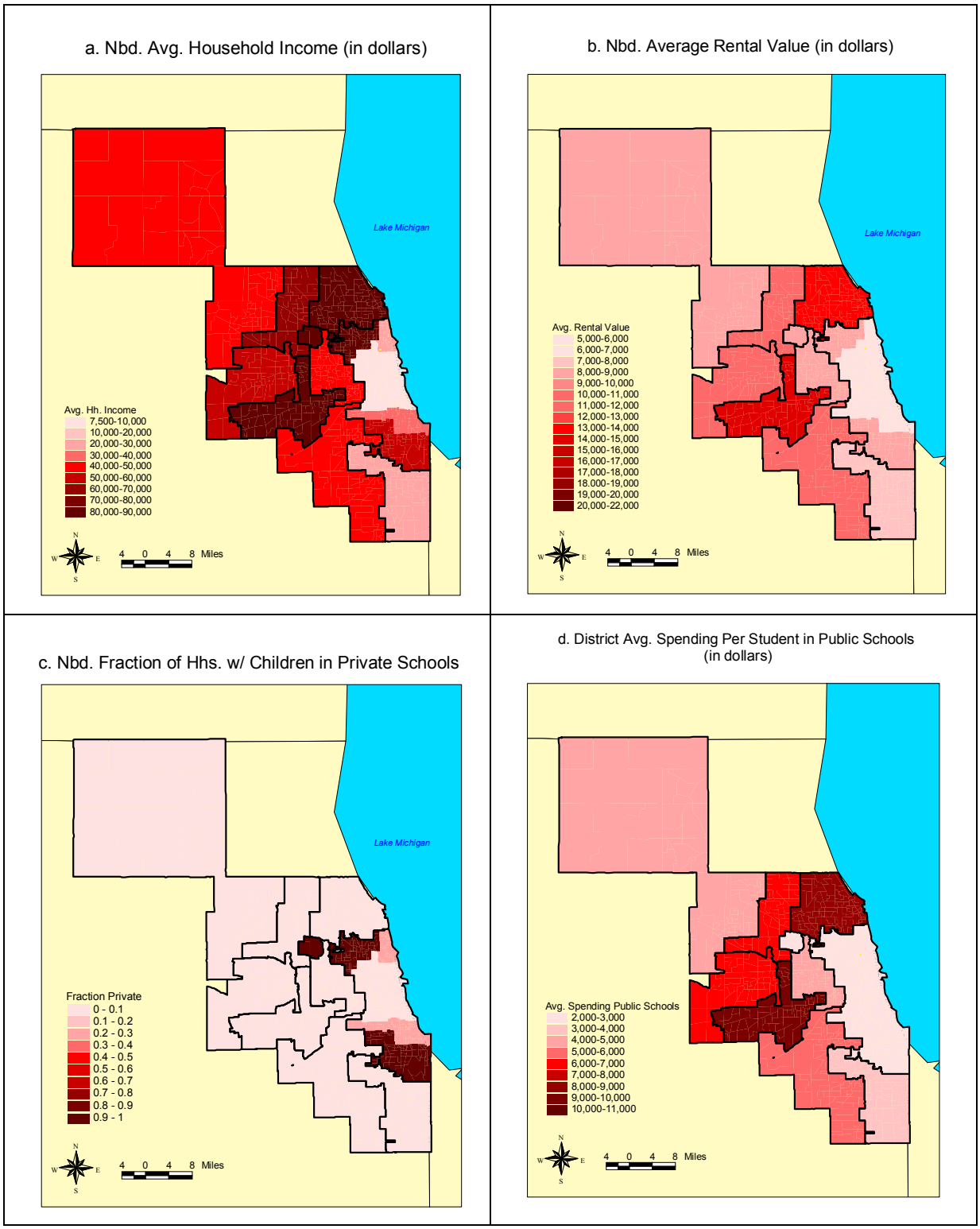
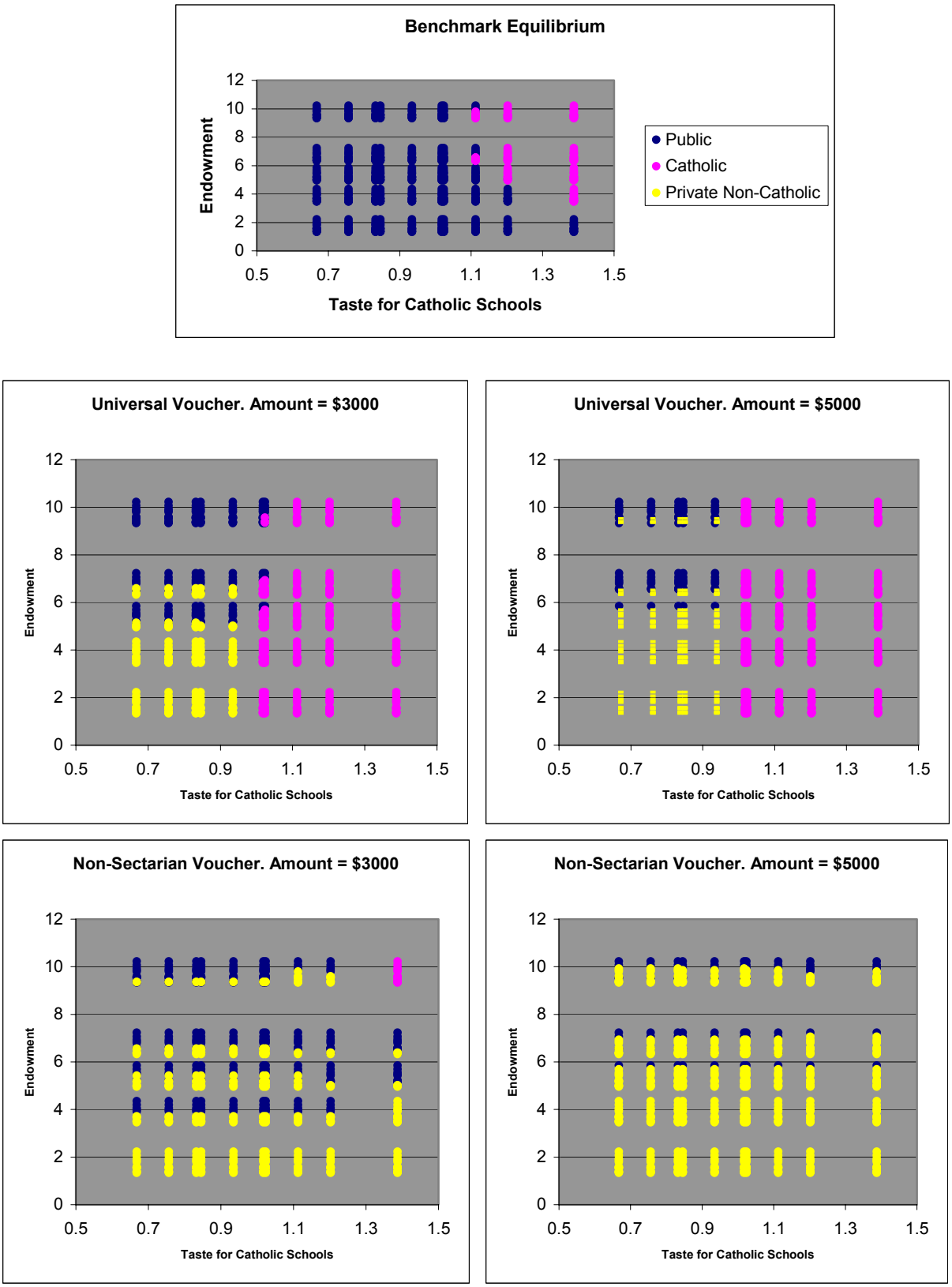


FIGURE 5 - ***Chicago: Predicted Household Sorting Across Schools for Benchmark Equilibrium, and Universal and Non-Sectarian Vouchers***



Note: Endowment expressed in $10,000

FIGURE 6 – ***Chicago: Predicted Effects of Universal Vouchers on School Quality***

Average school quality for the 10th, 30th, 50th, 70th and 90th percentile endowment

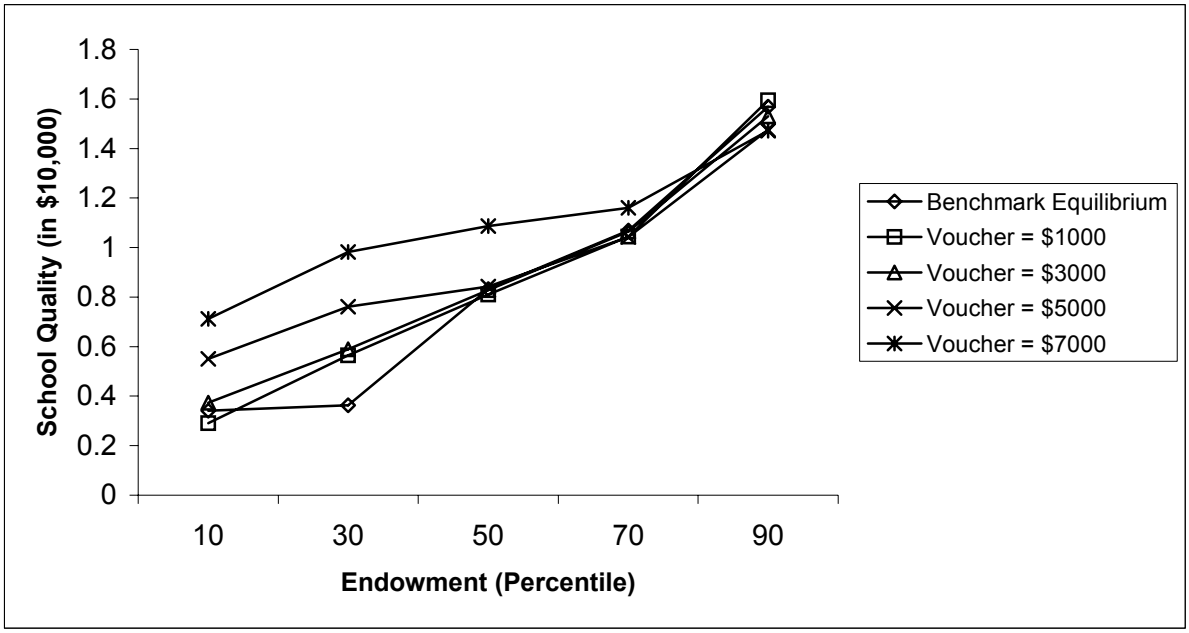
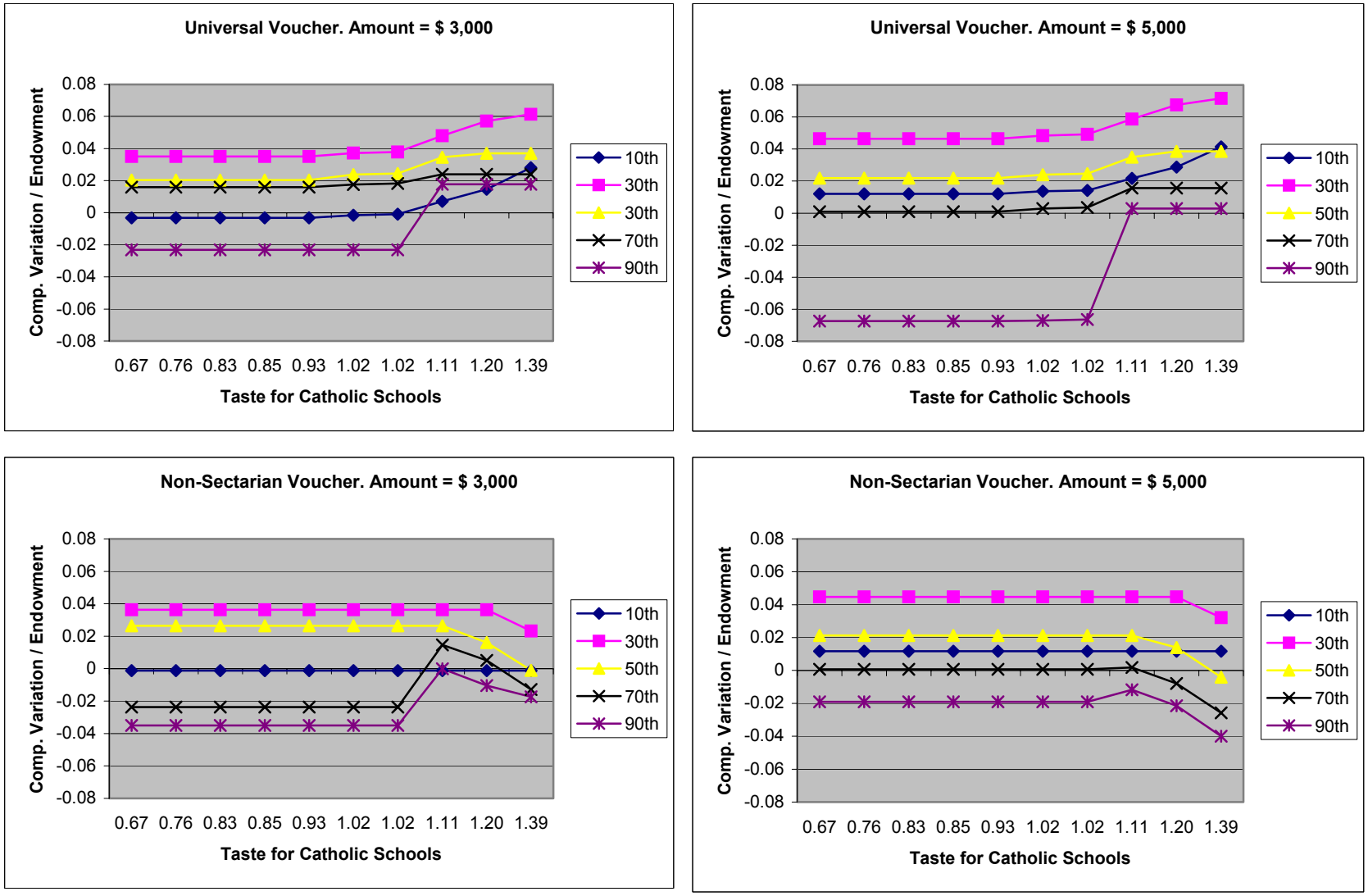


FIGURE 7 – ***Chicago: Predicted Welfare Gains by Household Type under Universal and Non-sectarian Vouchers***



Note: each line represents a household endowment; households in the 10th, 30th, 50th, 70th, and 90th percentile of wealth are plotted.