PUBLIC EDUCATION AND THE DYNAMICS OF INCOME DISTRIBUTION:

A QUANTITATIVE EVALUATION OF EDUCATION FINANCE REFORM

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Abstract

Many states are considering school finance reforms aimed at lessening
inequality in the provision of public education across communities. These
reforms will tend to have aggregate effects on income distribution,
intergenerational income mobility, and welfare. This paper constructs a
dynamic general equilibrium model of public education provision, calibrates
it using US data, and examines the quantitative effects of a major school
finance reforms. The policy reform we analyze is one in which all funding
is done at the federal level (instead of substantially at the local level as
is now the case). We find that this policy increases average income,
intergenerational income mobility, and total spending on education as a
fraction of income. Moreover, there are large welfare gains associated with
this policy: we find that steady-state welfare increases by 7% of steady-
state income.

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1. Introduction

A distinguishing feature of public education in the US is the significant role played by local property taxes and the resulting large disparity in expenditures per student observed across school districts. A series of state Supreme Court rulings and public concern over public education have led many states to consider and/or to enact reforms with the aim of reducing inequality of access to quality public education.

Changes in the system of financing public education can be expected to have wide-reaching effects: the total resources devoted to education, property values, and aggregate welfare may all be affected. Moreover, given education's critical role in determining individual income, reforms which alter total spending on education and/or its pattern across communities should have aggregate effects on income distribution and intergenerational income mobility. Given the complicated and intertemporal nature of the effects of reforms in educational finance, it is difficult to predict the qualitative effects of a reform without an analytical model. Furthermore, to determine the impact of a reform it is necessary to assess the quantitative magnitude of the effects. This paper takes a first step in this direction: we construct a dynamic general equilibrium model of public education provision in a multi-community setting, calibrate it using US data, and use the calibrated model to evaluate the quantitative effects of a major reform.[1]

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[1] A notable early attempt to analyze the quantiative effects of some education reforms is Inman (1978). He estimates a multi-community model using data from the New York metropolitan area and examines the welfare effects of several reforms. One difference between his work and ours is that we model the income distribution dynamics resulting from changes in the quality of education received by children. A second difference is that whereas his model contains more features than does ours, our analysis is explicitly general equilibrium.

We extend to a dynamic setting the model of Fernandez and Rogerson (1992). This is a multi-community model in the tradition of those pioneered by Westhoff (1977) and Epple, Romer and Filimon (1984, 1988). Although our model is highly stylized, it incorporates four features which are central to an analysis of public education finance in the US. First, there is substantial heterogeneity of income across households. Second, individuals are mobile across communities. Third, public education is provided at the community level and fourth, funding for public education is largely determined at the local level.

The population structure is that of a two-period-lived overlapping generations model in which there is a large number of households every period, each consisting of one old and one young member. Households choose in which community to reside. Each community has a local housing market and determines a tax rate on local housing expenditures by majority vote. The proceeds are used to provide public education for its residents. An old individual's income is determined by the quality of education received when young and an idiosyncratic shock.

The equilibrium inter-community population distribution and the tax rates that result in a given period determine the quality of education obtained by each child which, in conjunction with the realization of idiosyncratic income shocks, then determines the equilibrium income distribution over households for the following period. This process repeats itself. The equilibrium for this model has the property that in each period individuals stratify themselves into communities by income. Higher-income communities have higher per student expenditures on education and higher gross-of-tax housing prices.

As a result, children born into higher-income households have higher expected incomes than do children born into lower-income households.

We calibrate the model described above to US data. The calibration uses information on the (cross-sectional) elasticity of educational expenditures per student with respect to community mean income, the elasticity of (subsequent) earnings with respect to quality of education when young, price elasticities of housing demand and supply, mean and median income, and expenditure shares for housing and education.

In the model described above, public education is entirely funded at the local level. The major policy reform we analyze is one in which local financing of education is replaced with national financing (in which spending per student is independent of community residence). In reality, US state public education finance systems vary widely in the extent to which state aid provisions attempt to lessen the inequality in spending across districts. While some state systems closely approximate the extremes of either local or national financing, others lie somewhere in between. A comparison of the two extreme possiblities is a natural starting point in an attempt to gauge the potential significance of educational finance reforms.

Relative to the case of local financing, we find that a policy of national financing leads to higher average income in the steady state, higher average spending on education, greater intergenerational income mobility, and higher welfare. The magnitude of the welfare improvement measured in terms of steady-state income is 2.5%, which is a large gain relative to that found for many policies.

Some simplifying features of the model should be kept in mind when interpreting the above welfare gain. First, our analysis assumes that all

parents send their children to public schools. While under the current system of local finance in the US less than 10% of children attend private schools, it is possible that a move to a national finance system would increase this proportion and thereby diminish public support for public expenditure on education. Second, we assume that the quality of education is only affected by spending per student; in particular, we abstract from any peer effects and assume that parental characteristics do not influence educational outcomes other than through spending on education.[2] Third, this welfare gain presumably overstates the potential gains from reform facing a state whose educational finance system is somewhere between the extremes of local and national financing.[3]

Our work is related to two literatures. The first, a theoretical literature on education, income distribution and growth, includes papers by Durlauf (1992), Benabou (1992), Fernandez and Rogerson (1991), Glomm and Ravikumar (1992), Cooper (1992) and Boldrin (1992). Durlauf studies intergenerational income mobility in a multi-community model with local public education and peer group effects. He shows that there may exist a poverty

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[2]Quantitative evidence on peer effects is mixed. de Bartolome (1990) summarizes empirical findings and provides a theoretical analysis of peer effects in a multi-community model. Parental characteristics are obviously important, but the nature of their importance is the subject of much controversy; here we choose to abstract from them altogether.

[3]In the US, local spending accounts for roughly 45% of all spending on public education. Potential benefits from reforms depend on both the fraction of total expenditures accounted for by state aid and on the rules which govern its allocation. A system whereby state aid simply matches local spending dollar for dollar is obviously quite different from one in which aid is primarily targeted to lower-income communities. The framework developed here can also be used to analyse systems which involve a mix of local and state financing.

trap when education is locally financed. Cooper uses Durlauf's framework to analyze inter-community grants. Benabou studies how local versus national funding affects growth and welfare. His analysis is qualitative and illustrates a tension between welfare effects in the short and long run. Fernandez and Rogerson, Glomm and Ravikumar, and Boldrin study the interaction between the provision of education and income distribution but do not consider local financing of public education. These papers are all qualitative in nature; they do not address the quantitative significance of the effects being studied.

The second related literature is a large empirical literature on the determinants and consequences of expenditures on public education. One aim of this literature is to examine the pattern of expenditures across communities in relation to the cross-community variation of variables such as mean income, and to estimate the effect of state financing provisions on this pattern. Inman (1979) is an early survey of this literature, and Rothstein (1992) is a recent contribution. There is also a literature on the relation between educational spending and outcomes which is too extensive to survey here. Coleman (1966) is an early contribution, Hanushek (1986) surveys the literature, and Card and Krueger (1992) provide new evidence on the issue.

The outline of the paper follows. Section 2 describes the benchmark model. Section 3 discusses the calibration of this model. Section 4 reports the results of the policy reform carried out in the calibrated model and Section 5 performs a sensitivity analysis. Section 6 concludes.

2. The Model

The economy is populated by a sequence of two-period-lived overlapping generations. A continuum of agents with total mass equal to one is born in every time period. Each individual belongs to a household consisting of one old person (the parent) and one young person (the child). All decisions are made by old individuals, each of whom has identical preferences given by:

$$u(c,h) + Ew(y_c), \tag{1}$$

where c is consumption of a private good, h is consumption of housing services, E is an expectations operator, and y_c is next period's income of the household's young individual. The function u is assumed to be strictly concave, increasing in each argument, twice continuously differentiable and defines preferences over c and h that are homothetic. The function w is increasing and concave.

Individual income is assumed to take one of I values: y_1, y_2, ...y_I, with $y_1 < y_2 < ...y_I$. An individual's income when old is determined by q--the quality of education obtained when young--and an idiosyncratic shock. The probability that an individual has income y_i when old given an education of quality q when young is equal to $\phi_i(q)$.

Define v(q) by:

$$v(q) = Ew(y_c) = \Sigma\phi_i(q)w(y_i) \tag{2}$$

We assume that v is increasing, concave and twice continuously differentiable. Preferences can then be defined over c,h and q:

$$u(c,h) + v(q). \tag{3}$$

We now describe the decisions and outcomes that correspond to each time period. The aggregate state variable of the economy is the income

distribution of old agents, which we write as $\lambda=(\lambda_1,\lambda_2,\ldots\lambda_I)$ where λ_i is the fraction (or equivalently mass) of old agents with income equal to y_i. As will be seen shortly, the evolution of this economy can be traced out by considering a sequence of "static" models in which the outcome in period t determines the aggregate state variable for period t+1. The outcome in period t, moreover, is independent of the future evolution of the state variable.[4] For notational convenience the discussion that follows suppresses the time subscript; the analysis applies equally well to any time period.

Old individuals choose to live in one of two communities, denoted by C_j, j=1,2. Each community j is characterized by a proportional tax t_j on housing expenditures, a quality of education q_j and a net-of-tax housing price p_j. Each community has its own housing market, with supply of housing in C_j given by $H_j^S(p_j)$. Note that this function is allowed to differ across communities, reflecting differences in land endowments and other factors. We assume that H_j^S is increasing, continuous, and equal to zero when p_j is zero. The gross-of-tax housing price in C_j is given by $\pi_j=(1+t_j)p_j$. We assume that housing services are rented and, so as not to introduce further complications, the owners of the housing services are assumed to live outside the two communities and simply consume their rental income.

Proceeds from the tax are used exclusively to finance local public education. We assume that the quality of public education is equal to per

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[4]This fact, which greatly simplifies the analysis, follows from the assumption that an old individual cares about the young individual's income rather than utility, thus severing the link between one time period and the next. This is a commonly used device to render this type of analysis tractable. See, for example, Cooper (1992), Durlauf (1992) and Glomm and Ravikumar (1992). See Krussel and Rios-Rull (1993) for an illustration of the difficulties in relaxing this assumption.

pupil spending on education. All residents of a given community receive the same quality of education; education cannot be privately supplemented.

In each period the interaction among individuals and communities can be described as a stage game of the following form. In the first stage, all (old) individuals simultaneously choose a community in which to reside. Thereafter, these individuals are assumed to be unable to move.[5] In the second stage, communities choose tax rates through a process of majority vote, after which individuals make their housing and consumption choices and young individuals receive education. Young individuals receive their education in the community in which their parent has chosen to reside. Uncertainty about next period's income is resolved after obtaining an education and before the residence decision of the following period.

If λ_t is the income distribution of old individuals at the beginning of period t, then an equilibrium to the above game generates a beginning-of-period income distribution for period t+1, λ_{t+1}. We analyze the game's subgame-perfect equilibria, and denote by $\Lambda(\lambda)$ the set of values for λ_{t+1} that correspond to subgame-perfect equilibria of the game given $\lambda_t = \lambda$. In a later section of the paper we focus on the properties of a stationary or steady state for the system i.e. a value λ^* such that $\lambda^* \epsilon \Lambda(\lambda^*)$.

From an individual's perspective, a community is completely characterized by the pair (π, q). Thus, an individual with income y has an indirect utility function $V(\pi, q; y)$ defined by:

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[5]This assumption, while not entirely realistic, allows each individual to take the composition of the community as given when voting. This greatly simplifies the strategic interactions between communities.

$$V(\pi,q;y) = \underset{c,h}{Max}\; u(c,h) + v(q) \tag{4}$$

$$s.t. \quad \pi h + c \leq y, \quad c \geq 0, \quad h \geq 0,$$

where c has been chosen as numeraire.[6] Define $h(\pi,y)$ to be the individual housing demand resulting from this problem. By homotheticity h can be written as $g(\pi)y$. In what follows we assume that the optimization problem in (4) results in interior solutions for c and h.

Given a set of residents of mass N_j and a tax rate t_j in C_j, q_j and p_j must satisfy:

$$N_j g(\pi_j)\mu_j = H_j^S(p_j) \tag{5.1}$$

$$t_j p_j g(\pi_j)\mu_j = q_j \tag{5.2}$$

where μ_j is mean income. The first equation requires that the housing market clear. The second states that the quality of education q_j equals the per (old) person tax revenue of the community. It is straightforward to show that for any positive value of t_j equation (5.1) has a unique solution for p_j. Furthermore, p_j is decreasing in t_j and π_j is increasing in t_j.

Note that for any equilibrium outcome (π_j^*, q_j^*), each individual resides in the community that yields her the greater utility.

The following assumption on preferences greatly facilitates characterization of equilibrium.

Assumption 1: For all π, y, $S = u_{cc}h(1-\pi h_y) + u_{ch}hh_y + u_c h_y < 0$

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[6]Note that we have implicitly assumed that education is the only technology available by which a parent can contribute to her child's income.

The significance of this assumption is easily understood by noting that the slope of an individual's indifference curve in q-π space is:

$$v'/(u_c h) \tag{6}$$

so that Assumption 1 guarantees that the slope of an individual's indifference curve (in q-π space) is increasing in initial income (i.e. $u_c h$ is decreasing in y). The power of this assumption to characterize equilibrium is seen in the next two propositions.

Proposition 1: Given a set of residents, majority voting over tax rates in a community results in the preferred tax rate of the resident with the median income.

Proof: This follows immediately from the property of indifference curves discussed previously. See Fernandez and Rogerson (1993) and Epple and Romer (1991) for detailed proofs in slightly different contexts.||

Proposition 2: If in equilibrium q_1^* is not equal to q_2^* and both communities are non-empty, then:

(i) $(\pi_1^*, q_1^*) >> (\pi_2^*, q_2^*)$

(ii) All individuals in C_1 have income at least as great as all

individuals in C_2

where C_1 is defined as the community with the higher value of q.

Proof: (i) If $\pi_1^* < \pi_2^*$ and $q_1^* \geq q_2^*$ then everyone prefers to live in C_1, which contradicts the assumption that no community is empty.

(ii) Follows directly from Assumption 1 regarding the slope of indifference curves in (q, π) space as a function of y.||

Proposition 2 implies that an equilibrium with $q_1^* \neq q_2^*$ will be characterized by the coexistence of a community with high income residents,

high gross-of-tax housing prices, and high quality education and another community with lower income residents, low gross-of-tax housing prices, and a lower quality of education.

Any equilibrium that displays property (ii) of Proposition 2 is said to be a stratified equilibrium. This type of equilibrium is common to multi-community models, most often as a result of imposing single-crossing conditions on indifference curves (e.g. Westhoff (1977), Fernandez and Rogerson (1992, 1993)). There may also exist equilibria which are not stratified. For example, if the two housing supply functions are identical then there is always an equilibrium in which the two communities are identical, i.e. half of each income group resides in each community, resulting in equal tax rates, prices, and quality of education. In the analysis that follows, however, we only consider stratified equilibria.[7]

Problems of existence and uniqueness of a stratified equilibrium are endemic to multi-community models (see, for example, Westhoff (1977,1979) and Epple, Filimon and Romer (1984) for a discussion, and Fernandez and Rogerson (1993c) for conditions to guarantee existence). In all of the simulations reported later in the paper, however, the specifications are such that a unique equilibrium exists.

Stratified equilibria can be parametrized by the fraction of residents residing in C_1. We denote this fraction as p. Each value of p determines the income distributions of the two communities since it partitions the income

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[7]Note that for $\partial H^S/\partial p$ sufficiently large non-stratified equilibrium will be unstable, i.e. there exist small perturbations in the distribution of the population across communities that result in no individual relocating to her community of origin. See Fernandez and Rogerson (1992) for a discussion in a slightly different context.

space into higher-income individuals that reside in C_1 and lower-income individuals that reside in C_2. Associated with each value of ρ is a highest income individual in C_2; call this value y_{b2}. Let y_{b1} be the lowest income of an individual in C_1. Since the income distribution is discrete, y_{bj} is not continuous as a function of ρ, and y_{b1} need not equal y_{b2}.

Define $W_j(\rho)$ to be the utility of an individual with income y_{bj} residing in C_j given that ρ is used to determine the residents of the two communities and that each community chooses its tax rate via majority vote. An equilibrium can be depicted as a "crossing" of the two W_j curves. More formally, an equilibrium is a value ρ such that either:

(i) $W_1(\rho) = W_2(\rho)$

or

(ii) $[W_1(\rho-\epsilon)-W_2(\rho-\epsilon)][W_1(\rho+\epsilon)-W_2(\rho+\epsilon)] < 0$ for all ϵ in some

neighborhood of 0.

Condition (ii) allows for the possibility that the equilibrium occurs at a point where no income group is split across communities. Figure 1 depicts the two possibilities.

Although a partial characterization of the W_j curves is possible we shall not provide it here. The reader is referred instead to Fernandez and Rogerson (1992, 1993a,1993b) for details in some related settings.

The final point we consider in this section relates to the tax rates generated by majority voting. Using (5.1) and (5.2) one can write $q_j(t,\mu,N)$ as the quality of education in C_j given a tax rate t, community mean income μ and a community population of N. The preferred tax rate for an individual with income y is determined by:

$$\text{Max} \quad u(y-\pi h, h) + v(q(t,\mu,N)) \qquad (7)$$
$$t \geq 0$$

Using the envelope theorem, the first order condition for this problem implies:

$$u_c h[p+(1+t)p_t] = v'q_t \qquad (8)$$

where h is the utility maximizing choices for an individual with income y and $p(t,\mu,N)$ solves (5.1) and (5.2). Denote by Δ the second derivative of the maximand in (7) with respect to t. The second order condition requires that this be non-positive at a maximum.

In a stratified equilibrium C_1 has both higher mean and higher median income than C_2. Two comparative statics exercises, therefore, are of obvious interest; how is the tax rate that solves (8), denoted by $\tilde{t}$, affected by changes in y and μ? Straightforward calculation implies:

$$\partial \tilde{t}/\partial y = S/\Delta > 0 \qquad (9)$$

and

$$\frac{\partial \tilde{t}}{\partial \mu} = \frac{[u_{cc}\pi_\mu(h+\pi h_\pi)-u_{ch}h\,\pi\,\pi_\mu]\pi\,\underset{t}{\overset{u}{=}}u_c\,\pi\,t_\mu + (v''\underset{0}{q}q_t + v'q}{\Delta}\underset{(10)}{)}t_\mu \quad \underset{<}{>}$$

The first expression states that higher income individuals prefer higher tax rates and hence higher quality education. The second expression says that an increase in mean income has an ambiguous effect on an individual's preferred tax rate. While many of the terms in the numerator of (10) can be signed, the overall expression cannot be signed. The two terms involving the function v

have an interesting interpretation. Using (5.2) one can show that these terms have the same sign as $1+(v''q/v')$. This term is ambiguous in sign because increases in μ result in income and substitution effects which work in opposite directions. Holding t constant, an increase in μ increases q, thereby creating an incentive for the individual to decrease t in order to increase c and h. At the same time, however, the increase in μ increases the marginal return to an increase in t, thereby creating an incentive for a higher t. Which effect dominates depends upon the technology which transforms quality of education into earnings. As seen in the next section, evidence on the relationship between community mean income and spending on education suggests that the sign of $\partial t/\partial \mu$ is negative.

3. Calibration

The objective of this work is to quantify the effect that different means of financing education have on income distribution, intergenerational income mobility, and welfare. To do so it is necessary to specify functional forms for the relationships introduced in the previous section and assign parameter values.

3.1 Functional Forms

Three functional relationships need to be specified: preferences, housing supply and the effect of quality of education on subsequent earnings. For preferences we assume:

$$u(c,h) = (a_c c^\alpha + (1-a_c)h^\alpha)/\alpha \qquad w(y_c) = a_q y_c^\gamma/\gamma \qquad 0<a_c<1, \ \alpha, \gamma \leq 1 \qquad (11)$$

The specification for $u(c,h)$ is a transformation of a constant elasticity of substitution utility function. Assumption 1 is satisfied if and only if α is

less than zero. The choice for $w(y_c)$ displays constant relative risk aversion.

We assume constant elasticity housing supply functions for both communities, i.e.

$$H_j^s = a_j p_j^b \tag{12}$$

This specification yields the same price elasticity for both communities (i.e. b); any differences in land endowments or other factors enter through the constants a_j.

The final relationship to be specified is that linking quality of education to subsequent earnings. Consider a log normal distribution of income where log of income has mean $y(q)$ and variance σ^2 and $y(q)$ is defined by:

$$y(q) = y_0 + B(1+q)^\delta/\delta \qquad B>0, \ \delta \leq 1 \tag{13}$$

Given a vector $[\tilde{y}_1, \ldots \tilde{y}_I]$ where y_i is contained in $(\tilde{y}_i, \tilde{y}_{i+1})$ for $i=1,2,\ldots I-1$, and $Y_I > \tilde{y}_I$, we transform the continuous distribution in (13) to a discrete distribution over the I income types obtaining each $\phi_i(q)$ by integrating the above log normal distribution over the interval containing Y_i.

A few comments should be noted concerning this choice. First, B>0 implies that expected income is increasing in q. Second, given the absence of empirical work relating quality of education to the variance of subsequent earnings, we assume that σ is independent of q. Third, recalling the discussion about the income and substitution effects associated with a change in community mean income, the specification $(1+q)^\delta/\delta$ is convenient because δ is closely related to the sign and magnitude of these effects. For example, if $\gamma=0$, $v(q)$ can be approximated by the expression:

$$y_0 + B(1+q)^\delta/\delta \qquad\qquad (14)$$

and the substitution effect dominates for positive values of δ whereas the income effect dominates for negative values.[8] Fourth, the term $(1+q)$ is used rather than q as a normalization to avoid large negative numbers. Lastly, it should be noted that (13) is a specification meant to hold only over the relevant region of q, since otherwise some parameter values and values of q yield negative expected income.

3.2 Parameter Values

We choose parameter values such that the steady state of the model matches important observations for the US economy. In particular, we require that the steady state of the model match several aggregate expenditure shares, elasticities, and properties of the income distribution for the US economy.

There are three commodities in the model: consumption, housing, and education, and hence two independent expenditure shares. The ratio of annual aggregate housing expenditures to aggregate expenditures on consumption including housing (averaged over 1960-1990) was .15, and the average annual ratio of spending on public elementary and secondary education to aggregate expenditures on consumption including housing was .053.

We match four elasticities: the price elasticities for housing demand and supply, the elasticity of mean earnings with respect to the quality of education, and the cross-sectional elasticity of community public education expenditures with respect to community mean income.

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[8]The fit of this approximation depends on how closely the transformation from a continuous to a discrete distribution preserves the mean of log income.

Quigley (1979) surveys the literature on urban housing markets and quotes a price elasticity of housing demand (gross of taxes) equal to -.7 and a price elasticity of housing supply equal to .5. (A demand elasticity less than one in absolute value corresponds to a negative value of α, which is required to satisfy Assumption 1.) The functional form we have chosen for the utility function does not imply a constant demand price elasticity for housing. Since homotheticity implies that the price elasticity of demand for housing is independent of income, to compute the latter we can use the cross-sectional observations of housing prices and quantities generated in the steady state. These cross-sectional observations result from the differences in gross-of-tax housing prices across communities.

A key difference between the two communities in our model is that in equilibrium C_1 has both higher mean income and quality of education than C_2. From the steady-state equilibrium one can compute a cross-sectional elasticity of per-student educational expenditures with respect to community mean income. We calibrate the model so that this elasticity lies within the range found in reality. Many empirical studies obtain estimates of this elasiticity (see Inman (1979) and Bergstrom, Rubinfeld and Shapiro (1982) for surveys). The range of estimates obtained is .24-1.35, although the vast majority of the estimates lie in the narrower range of .4-.8. We choose parameter values so that the value of this elasticity evaluated at the model's steady state equals .62. A value less than one is significant because it implies that communities with higher mean incomes are spending more on education but taxing at a lower rate. Hence, mean income has a negative effect on tax rates.

Card and Krueger (1992) carry out an extensive study of the relationship between indicators of the quality of education and subsequent earnings. We

draw on their evidence to guide us in choosing a value for the elasticity of earnings with respect to education quality. They present two pieces of relevant information: decreasing the student to teacher ratio by ten students would increase earnings by 4.2%, and raising teachers' wages by 10% would increase earnings by .45%. Over the period 1960-1990 the average annual ratio of teacher's wages to total costs for public elementary and secondary schools was 38%, and the average annual student-teacher ratio over the same period is 21.3. The resulting estimates of the elasticity of earnings with respect to education expenditures (quality) are .1249 and .1184 respectively. In the model we compute the elasticity of earnings with respect to quality of education by using the cross-sectional variation in q across communities in the steady state. We calibrate the model to a value of .1213, but also explore the sensitivity of our results to changes in this value.

Card and Krueger's elasticity estimates combine two different effects of quality on earnings: an increase in earnings holding years of education constant, and an increase in wages due to increased years of education. While we do not model the effect of quality on years of education, we nonetheless use the combined estimate since our model should be interpreted as including both effects.

The six items of information described above (two expenditure shares and four elasticities) can be used to determine six parameter values: a_c, a_q, b, δ, α, and B.

Varying the ratio of a_1 to a_2 (the housing supply parameters) affects relative housing prices in the two communities and therefore also the steady-state distribution of the population between communities. We set the a_j equal

to each other rather than attempt to match a particular population ratio; thus their values are effectively a choice of units for housing. In our benchmark specification we set $a_1 = a_2 = 1$.

The choice of γ is somewhat arbitrary. We set $\gamma = 0$ in our benchmark specification. This lies within the range of estimates for the risk aversion coefficient found in the asset pricing literature. We consider other values for this parameter in a later section.

The final piece of information we use in calibration is data on the income distribution of families from the 1980 Census. We choose the $\tilde{y}_i$'s to match the commonly used income intervals--$\tilde{y} = (0, 5, 7.5, 10, 15, 20, 25, 35, 50)$--and set the vector of y_i's equal to $(2.5, 6.75, 8.75, 12.5, 17.5, 22.5, 30, 42.5, 60)$ (where income is measured in thousands). Two additional items of information are the 1980 Census values of mean and median family income values, equal to 21.4 and 17.9 respectively. We choose y_0 and σ^2 such that the mean and median incomes generated by the model in the steady state match the corresponding figures from the 1980 Census.[9]

3.3 Discussion

One issue concerning the calibration procedure should be noted. Whereas the model assumes that public education is entirely financed at the local level, the US data correspond to a situation where state aid accounts for a substantial protion of educational expenditures. It is possible, therefore, that the statistics that we match in the calibration procedure are not invariant to the structure of educational finances, and hence should not be

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[9]When we compute median income in the model we assume that individuals with income y_i are uniformly distributed over the interval $[\tilde{y}_i, \tilde{y}_{i+1}]$.

used to calibrate a model with only local financing. The fact that financing provisions have changed significantly over the last thirty years provides an opportunity to gauge the extent of this problem. The aggregate expenditure shares for housing and (elementary and secondary) education have been relatively constant over the last thirty years and we know of no evidence to indicate significant changes in the price elasticity of housing demand over time. Hence the concern raised by this issue for the estimates used for the calibration is minor.

Calibrating the model to match the cross-sectional elasticity of per student educational expenditures with respect to community mean income is more problematic. Much of the empirical work effectively involves a regression of (log of) community education expenditures per student on a number of variables including log of community mean income and on a variable designed to capture the effect of state aid on the marginal price of educational expenditures faced by the tax payer. The coefficient on mean income is then interpreted as the elasticity of expenditures with respect to mean income. While the empirical work attempts to take into account the rules by which state aid is provided, the elasticity estimated need not be invariant to these rules.

The empirical estimates, however, are derived from many states and while there is a range of estimates many of them are quite close to each other. In light of the concerns raised above, Section 5 provides a sensitivity analysis that allows us to address how changes in the values of the elasticities used in the calibration affect our results.

4. Results

4.1 Properties of the Benchmark Model

In this section we report the parameter values generated by the calibration described in the previous section, display some additional properties of the steady state and analyze the dynamics of the system. As noted before, the assumptions made in Section 2 are not sufficient to guarantee a unique stratified equilibrium to the two-stage game played each period. For the functional forms and parameter values that we use, however, equilibrium for the one period game is always unique, there is a unique steady state, and there is convergence to the steady state. We will not discuss the features of equilibrium allocations along the transition to a steady state, but note that in all the simulations run the convergence was quite rapid; typically the system was very close to the steady state after only one or two periods.

Table One below reports the parameter values used in the calibration and steady state values for several variables.[10]

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[10]While the calibration procedure guarantees that the mean and median income in the model's steady state are equal to their counterparts in the US data, it is also of interest to examine how closely the steady-state distribution of income in the model matches the income distribution for the US economy. The distribution of income from the 1980 US Census is given by (.07,.06,.07,.15,.15,.14,.19,.11..06). As is well-known, the log normal distribution does a good job of accounting for the observed income distribution except that it does not have enough mass in the tails. Not surprisingly, therefore, the same is true of the model's steady-state income distribution.

Table One

Parameter Values
Preference Parameters: $a_c=.936$ $a_q=.053$ $\alpha=-.6$ $\gamma=-.0001$;
Housing Supply Parameters: $a_1=a_2=1$ $b=.5$
Education-Earnings Relationship: $\delta=-4.5$ $B=7.7$ $y_0=2.95$ $\sigma^2=.63$
Steady-State Values
$\lambda=$ (.02,.06,.10,.21,.18,.13,.15,.09,.05)
mean income$=21.5$ median income$=17.8$
price elasticity of housing demand$=-.70$
earnings elasticity wrt quality$=.1213$
education expenditures/total consumption$=.054$
housing expenditures/total consumption$=.15$
elasticity of quality wrt community mean income$=.62$

Table Two provides the steady-state values of the community variables.

Table Two

	c_1	c_2
t	.284	.50
p	1.46	1.12
q	1.60	0.86
μ	37.8	14.0
ρ		.315

As required in a stratified equilibrium, both quality and the gross price
of housing are higher in community one. The net-of-tax price of housing is

also higher in community one. Note that spending per student is nearly twice as great in C_1 than in C_2. Although there are many metropolitan areas in which this range of expenditures exists, this ratio is somewhat on the extreme side of what is observed in the US data. This is not surprising, however. Our model describes how expenditures would vary across communities if all financing were done at the local level. The fact that differences are not as large in the US data as they are in our calibrated model simply indicates that state aid does (on average) decrease differences in educational expenditures across communities.

The steady-state values displayed above also determine the intergenerational pattern of income mobility. In the steady state all individuals with income greater than 22,500 live in C_1, all individuals with income less than 22,500 live in C_2, and individuals with income equal to 22,500 are split across the two communities. Since the quality of education differs across communities, the children of wealthier individuals will belong to a different income distribution when old than that of the children of poorer individuals. In the steady state computed above, these two income distributions are given by:

	Table 3	
Income	Dist. for C_1	Dist. for C_2
2.5	.02	.02
6.75	.06	.07
8.75	.09	.10
12.5	.20	.22
17.5	.18	.18
22.5	.14	.13
30.0	.16	.15
42.5	.10	.08
60.0	.06	.05

Of related interest are the average incomes when old for children educated in C_1 and C_2. These values are equal to 22.6 and 21.0 respectively, a difference of more than twenty percent.

4.2 Policy Experiment

In this section we determine the effects of switching to a public education system in which there is no local financing. Rather, all children, regardless of the community in which they live, receive the same quality of public education. This is similar to the system of financing education in some European countries, in which spending is not determined locally but rather at the national level. Formally, the stage game introduced in section 2 is modified so that in the second stage the voting over the property tax rate takes place in a single system in which all individuals participate. It

should be clear that in a subgame-perfect equilibrium of this game the price

of housing must be equated across communities: since all individuals face the

same tax rate and obtain the same quality of education independently of the

community in which they live, no one would choose to reside in the community

with the higher housing price.

We use the functional forms and parameter values from the calibration

procedure described above to determine the effects of this change in policy.

This is a classic policy analysis exercise in which the fundamentals or

primitives are held constant but individuals are allowed to adjust their

decision rules in response to the change in the policy environment.

We compute the steady-state equilibrium for this economy. It remains

true that there is a unique equilibrium in each period, a unique steady state,

and that the economy converges to the steady state. Table Four displays some

of the properties of the steady state equilibrium.

Table Four   Steady State With National Financing

$\lambda = (.02, .06, .09, .21, .18, .13, .16, .10, .05)$

t=.40   p=1.30   q=1.19

educational expenditures/total consumption = .057

housing expenditures/total consumption = .14

mean income = 22.0

median income = 18.3

All rows of the intergenerational income transition matrix are now identical

and equal to the steady-state income distribution λ.

Comparing the outcomes of the two systems indicates many results which

were qualitatively expected. For example, spending per child in the second

system lies in between the two community values in the first system. There is also more intergenerational income mobility in this case than under the local financing system; whereas under local financing a child whose parent's income was below 22.5 had a 59% chance of having income below 22.5 (and therefore remaining in C_2), a child whose parent's income was greater than 22.5 had only a 55% chance of ending up with income less than 22.5. Under national financing, on the other hand, all children have a 56% chance of ending up with income below 22.5. Two results (not necessarily expected) are that average income increased as did educational expenditures as a fraction of consumption expenditures under national financing.

4.3 Welfare Effects

It is clearly desirable to have some measure of the welfare change associated with the change in the educational financing system. We construct the following steady-state welfare measure. We compute the expected utility for an individual of each economy in the steady state assuming that the individual's income is a random draw from the steady-state income distribution. If λ_i is the fraction of the population with income y_i in the steady-state and U_i is the steady-state utility of an individual with income y_i then the expected utility is given by:

$$\Sigma \lambda_i U_i. \tag{15}$$

Under local financing this value is -.2657, whereas under national financing it is -.2594.

In order to translate the difference in utility into a measure which is not affected by monotone transformations of the utility function, we calculate the percent by which the vector of current income $(y_1, y_2, \ldots y_9)$ would have to

be reduced in the case of a single system in order for an individual to be indifferent between living in the two economies. Prices, tax rates and quality of education are held constant when this calculation is carried out. The magnitude of the required decrease in income turns out to be 2.5%. This is a very large difference in welfare; most welfare costs of alternative policies usually turn out to be a fraction of a percent of total income. Note that the above welfare calculation did not take into account the welfare of the owners of housing who receive the rental income. Including them reinforces the previous result. Total producer surplus from the housing market is easily computed in the two economies; it also increases by roughly 6% when local financing is removed.

What is the source of these large welfare gains? This is the question that we turn to next. Differences in steady-state welfare can be induced by changes in the U_i and/or changes in the λ_i. For the two financing systems studied above, it turns out that each of the U_i is greater under local financing, i.e., conditional on knowing their income, all individuals prefer the steady state of the local financing system. Since expected utility is higher in the case of national financing it is obviously the case that changes in the distribution of income (i.e. the λ_i's) must more than offset the decrease in the U_i's. Note that the income distribution under national financing stochastically dominates that under local financing; in particular, λ_1 through λ_4 are greater under local financing whereas λ_5-λ_9 are greater under national financing. The income distribution under national financing is characterized by a single parameter--the mean of the log normal distribution. (Recall that the variance of the log normal distribution is fixed at .63,

independently of spending on education.) Hence, the extent to which the

distribution of income under national financing stochastically dominates that

under local financing is determined solely by mean income under national

financing.

An explanation for the higher level of mean income in the steady-state

under national financing, may therefore provide insight into the higher

welfare achieved under national financing. The relationship between spending

per student and mean of log income (equation (13)) is relevant to this

discussion. Since the mean of log income is concave in q it follows that

holding total spending on education fixed, next period's mean income is

greatest if these funds are divided equally across all students. Whereas this

is what occurs under national financing, under local financing the students

in C_2 receive roughly half the per student expenditures of the students in C_1.

We calculate the income distribution that would result from this pattern of

educational expenditures. The mean of this distribution is 22.3, a gain of

3.7% over the mean of 21.5 that results from the pattern of educational

expenditures found in the steady state under local financing. We also

evaluate the effect of this change in income distribution on expected utility

holding the U_i's fixed at their steady-state values under local financing but

correcting for the change in q across communities. This calculation holds the

gross price of housing fixed and allocates individuals into communities using

the same value of income for the boundary individual in the steady state. The

resulting value for expected utility is -.3462. Smoothing of q across

communities apparently has a significant postive effect on both mean income

and welfare--the above welfare change is more than 70% of the total change

associated with moving from local to national financing. Translated in terms of the decrease in the income vector needed to make an individual indifferent between the national financing system and the level of utility obtained by smoothing the q across communities, the required reduction is now only 1.7% as compared to the previous figure of 6.6%.

The above calculation evaluated the impact on welfare from smoothing q across communities holding prices and income of the boundary individual constant. This change in the pattern of educational expenditues may improve welfare through two channels. First is the effect described above: smoothing q is more efficient from the perspective of producing income next period. Second is an effect due to concavity of preferences over q. Old individuals have indirect preferences over quality of education described by $v(q)$. In the calibrated model $v(q)$ is concave (as assumed), and hence parents are risk averse with respect to q. Holding total spending on education constant, therefore, the average value of $v(q)$ is maximized when q is constant across communities. A simple calculation, however, indicates that the quantitative magnitude of this effect is small. In particular, using values from the steady state under local financing, $v(\rho^* q_1^* + (1-\rho^*) q_2^*)$ exceeds $\rho^* v(q_1^*) + (1-\rho^*) v(q_2^*)$ by only .0009, which is only about 5% of the difference in steady-state expected utilities for the two financing systems. Thus, concavity in the relationship expressed in (13)--which is captured by the parameter δ--is apparently a significant factor in accounting for the welfare gain.

The steady-state allocation with local financing would appear to involve an inefficient use of housing resources--the net-of-tax housing price is much larger in the wealthier community. This effect, however, appears to be

quantitatively small. In the steady-state under local financing, total
housing consumption in C_1 and C_2 are 1.27 and 1.05 respectively. The
difference in net-of-tax housing prices across communities is .38. If this
total housing consumption were evenly distributed across communities, 1.135
units would be consumed in each of C_1 and C_2, and the housing supply functions
would require a net-of-tax price equal to 1.29 in each community. Total
spending on housing under this scenario would decrease, but the decrease
amounts to .23% of mean income, a very small amount compared to the total
welfare change.

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