Human Capital Accumulation in a Federation

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Abstract

At least one half of the variation across U.S. school districts in real K-12 education expenditures per student is accounted for by differences between, instead of within, states. This paper studies the implications for human capital accumulation and welfare of redistribution of education expenditures by the states and the federal government. It introduces an analytically tractable model of human capital accumulation with heterogeneous agents and endogenous education policies. The equilibrium of the model features within and between-state education spending variation. Federal redistribution is shown to be welfare enhancing if the geographic mobility of labor across states is not too high.

Keywords: Human Capital, Education Expenditures, Redistribution, Federal, State and Local Governments, Geographic Mobility.

JEL codes: E24, H7, I2, J6

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1 Introduction

This paper studies the implications for human capital accumulation and welfare of Federal redistribution of education expenditures in an economy such as the U.S. where three levels of government - local, state and federal - contribute to different degrees to the financing of education.[1] The analysis is carried out using a general equilibrium overlapping generations model with heterogeneous agents, heterogeneous locations, and voting over education expenditures.

The key departure of the paper relative to existing literature (e.g. Fernandez and Rogerson, 1998) is to consider simultaneously within and between-states differences in the distribution of education resources. The existing literature has not drawn a distinction between the roles of the states and of the Federal government in redistributing education expenditures. I argue that this distinction is important because historically, and up to these days, between one half and three quarters of the variation in primary and secondary education spending per student across school districts in the U.S. is due to differences in average expenditures across U.S. states, as opposed to school districts within a state (Corcoran et al. (2003) and Section 2 below). The literature has mostly focused on the effects of state-level school finance litigation, starting with the 1970's *Serrano* lawsuits in California.[2] The importance of differences in expenditures across *states* in accounting for differences in expenditures across *students* has not received much attention in the literature. Murray et al. (1998) show that court-ordered education finance reform reduces inequality in expenditures across school districts, but they conclude their important paper with the following caveat:

> "Finally, we have shown roughly two-thirds of nationwide inequality in spending is between states and only one-third is within states, and thus school-reform litigation is able to attack only a small part of inequality. We would conclude that while education-finance reform litigation has reduced within-state inequality, it seems unlikely that further litigation will yield large reductions in national inequality in the future."[3]

[1] While I have in mind the financing of primary and secondary education, the ideas developed here are in principle applicable to tertiary education as well.

[2] See Silva and Sonstelie (1995), Evans et al. (1997), Murray et al. (1998), Fernandez and Rogerson (1999), Hoxby (2001) for analysis of the effects of court-ordered education finance reform. Interestingly, Coons et al. (1970, Appendix A, p.465) in the seminal book that provides the theoretical foundation for state-level school finance litigation, draw the reader's attention to the "state-nation analogy to the district-state picture." While they focus on education financing at the state level, they observe that "the variation among states themselves mirrors the pattern of district variation within the states. One of the implications of this is that large-scale federal aid to education is needed if we are to achieve full national equalization."

[3] The main reason why school-finance litigation is unlikely to reduce expenditures inequality in the future is that the financing of education is primarily a responsibility of the states and school districts (Fischel,

The paper has both a positive and a normative goal. The positive goal is to study the determinants of observed differences in expenditures per student within and, especially, across states. While the existing literature on sorting across jurisdictions (Epple and Sieg, 1999) tends to emphasize differences across agents in willingness to pay for better schools, as driven by income or preference heterogeneity, it is less clear that one can rationalize the observed variation in expenditures across states through sorting mechanisms. There is significantly less geographic mobility across states than across school districts in the data and a majority of adult individuals in the U.S. reside in their state of birth.[4] The normative goal is to address the question: "at what level of government should the financing of K-12 education take place?" This is a classic question in the literature on fiscal federalism (Oates, 1972) and education finance (Coons et al. 1970). It is also motivated by the recent debate in the U.S. about the role of the Federal government in the provision of pre-school in addition to primary and secondary education.[5]

This paper explicitly analyzes some of the trade-offs involved in the financing of education by local, state, and the Federal government. At a basic level the observed existence of differences in education spending across U.S. states and the correlation between the latter and measures of income per capita, suggests that redistribution of education expenditures toward poorer states might increase aggregate human capital. This argument is simply the counterpart of the one made in the literature to justify redistribution of expenditures towards poorer households within a state. That is, given diminishing returns to education spending, redistribution towards low-spending states might increase their average human capital more than it decreases the average human capital of high-spending states. As in that case, however, redistribution is likely to generate a number of equilibrium effects on the location decisions of workers, their labor supply, and ultimately the tax base from which expenditures are financed. In other words, redistribution is potentially distortionary and may lead to a loss of output and welfare. In light of this consideration and the fact that, as a matter of practice, the Federal government has historically provided only a small share (around 10 percent) of total education spending, the paper uses a general equilibrium model to study these questions.

2001). In its 1973 *San Antonio v. Rodriguez* decision, the five to four majority of U.S. Supreme Court justices declared that a system of school-financing based on local property taxes does not violate the equal protection clause of the Fourteenth Amendment to the U.S. Constitution. While declaring the inequality in expenditures across students of different school districts consistent with the U.S. Constitution, the Supreme Court also opened the door to lawsuits at the state level as most U.S. states' constitutions contain explicit references to the provision of public education.

[4] In the data, according to the 2000 Census, 61 percent of U.S. native individuals ages 23–65 who are in the workforce live in their state of birth.

[5] See, for example, the discussion in the Hoover Institution Koret Task Force on K-12 Education (2012).

The model economy features a continuum of locations (states) and agents who accumulate human capital, choose locations where to work, consume, and educate their offsprings. Locations are ex-ante different in terms of their level of productivity. Each location is characterized by a labor market and an education policy. Following Bénabou (2002), education policy is formalized as a scheme that redistributes education expenditures across agents based on their income level. A key feature of the model is the presence of two layers of redistribution, a Federal one and a state one. Federal redistribution is treated as an exogenous parameter while redistribution by the states is endogenously determined and can react to variation in the Federal policy. The structure of the model allows for closed-forms for all of the endogenous variables of interests. Consistently with the data, the model generates both within and between state dispersion in education expenditures. The within dispersion is due to heterogeneity in the distribution of human capital within each state. The between dispersion reflects differences in productivity across states.

In the model, redistribution of education expenditures has the potential to increase average human capital but also leads to lower labor supply. Analogous trade-offs between the benefits and costs of redistribution has been studied extensively in the literature by Fernandez and Rogerson (1997, 1998, 1999) and Bénabou (2002) among others. Differently from this literature, in this paper, I focus on the effects of varying the degree of redistribution of education expenditures undertaken by the Federal government. The model predicts that the states offset some of the increase in the extent of Federal redistribution so that the elasticity of education expenditures to individual income within each state is invariant to Federal policy. However, the latter is not neutral because it redistributes education expenditures from high to low productivity states. I consider the impact of Federal redistribution of education expenditures on the economy's average human capital and various welfare measures. The relevant policy trade-off is as follows. On the one hand, redistributing education resources towards households located in poorer states has the potential of increasing aggregate human capital and welfare due to diminishing returns to inputs in the production of new human capital. On the other hand, redistribution toward poorer states increases the incentives of households to locate there leading to lower average productivity of the workforce. A sufficient condition under which Federal policy has a positive impact on welfare is that the elasticity of population to wage differentials across states is not too large. In other words, Federal redistribution of education expenditures increases welfare if geographic labor mobility is not too high.

This paper is related to several literatures. The first one, which includes the contributions by Glomm and Ravikumar (1992), Boldrin (1992), Fernandez and Rogerson (1997, 1998, 1999, 2003), Bénabou (1996a, 1996b, 2002), Herrington (2013), and others, is the literature on public and private investment in human capital in economies with heterogeneous agents. Relative to this literature I emphasize the geographic dimension of the debate on education financing. Second, the paper is related to the work on the effects of education finance reform in the U.S. Historically, the role of state governments in the provision of public education has increased at the expense of the role of local governments (see Figure 1 below). In the last 40 years decisions by state Supreme Courts, starting from California's in the *Serrano v. Priest* lawsuit, have contributed to increase the role of the states in the financing of education. The effects of court-ordered reform have been studied, among others, by Evans et al. (1997), Murray et al. (1998), Fernandez and Rogerson (1999) and Hoxby (2001). Third, the paper is related to models of location choice and voting over local public goods, a literature reviewed by Epple and Nechyba (2004). A relevant paper in this literature is Calabrese et al. (2012) who compare a decentralized Tiebout-type allocation with property taxes with a centralized one. They find that the centralized allocation is often more efficient than the decentralized one. An important difference with respect to my paper is that they focus on a metropolitan area economy so they take individual income as exogenous.[6] Fourth, there is a small empirical literature on the effects of Federal Title 1 transfers to school districts with a high concentration of students under the poverty line. The main question in this literature is measuring the extent to which Federal transfers induce local and state governments to reduce their support for education. Gordon (2004) provides evidence that in the 1990s local governments offset Federal Title 1 transfers by reducing their own tax effort. Cascio et al. (2011) study the effects of the introduction of Federal aid to K-12 education in 1965 and find a large impact of Title 1 aid on education expenditures in Southern school districts. Relative to these papers I focus of the long-run implications of Federal intervention on the distribution of human capital and population both within and across states. Last, my work is related to a number of papers in the macro-development literature, such as Erosa et al. (2010), that have analyzed the implications of variation in the quantity and quality of schooling in accounting for the dispersion in per-capita income across countries. An important difference with respect to these papers is that I consider the origins and implications of variation in education expenditures across geographic regions within a Federal country with a mobile population.

The rest of the paper is organized as follows. Section 2 presents some empirical evidence to further motivate the analysis. Section 3 introduces the benchmark model. Section 4 discusses the qualitative properties of the model. Section 5 derives the decomposition of the

[6] Calabrese (2012) studies a model with two levels of government in a federation: a central government that redistributes income across households and local governments providing a public good such as education. In my paper, instead, I study the implications of shifting the same governmental function (public school provision) across different levels of government.

measure of inequality in education expenditures in a within and between-state component. Section 6 considers the effect of varying Federal redistribution on average human capital and measures of welfare. Section 7 concludes. The Appendices provide additional details on the closed-form solution and consider possible extensions of the benchmark model.[7]

2 Background

This section documents some stylized facts about education spending in the U.S. that are useful to motivate the theory and the analysis developed in the rest of the paper.

2.1 Federal, State and Local Financing

First, an important characteristics of the U.S. system of financing education is the fact that the Federal government provides a relatively small share of schools' revenue. Figure 1 shows the evolution of the percent contributions of Federal, state and local governments to total primary and secondary education revenues. While the role of the Federal government has increased starting in 1965 with the passage of the Elementary and Secondary Education Act (ESEA), in the last 50 years its share has hovered around 10 percent. The Federal government does not provide unrestricted general aid, but rather funds specialized programs through categorical grants to school districts.[8] For the U.S. as a whole, state and local governments provide the bulk of financing in almost equal amounts.[9] Education is, on average, the single most important item on state budgets (not including local governments) compared to other expenditures. For example in 2005, it accounted on average for 31 percent of general expenditures by state governments. States provide both general no-strings-attached funds to school districts through a variety of formulas (such as flat and foundation grants) as well as categorical aid for specific programs and goals (such as class-size reduction). The mix of these two types of aid varies by state.[10]

[7] An online appendix on my website provides detailed step-by-step derivation of the analytical results of the paper.

[8] Funded programs include compensatory education for low-achieving students in low-income districts (Title I of ESEA 1965), special education for students with physical and mental disabilities (Title VI, 1966 amendement to ESEA), bilingual education (Title VII, 1967 amendement to ESEA). The extent of Federal financing varies across states, with the poorer states receiving higher shares of Federal funds. In 2005, for example, New Jersey received 4 percent of its education funds from the Federal government, while Mississipi received 21 percent.

[9] The shares of funding provided by states and local governments also vary across states. At one extreme of the distribution is Hawaii with 90 percent of funds coming from the state and at the other extreme Nevada with 64 percent of funds raised at the local level (Digest of Education Statistics, 2008, table 172).

[10] See Hanushek and Lindseth (2009) for a critical discussion of the role played by state governments in the funding of public education.

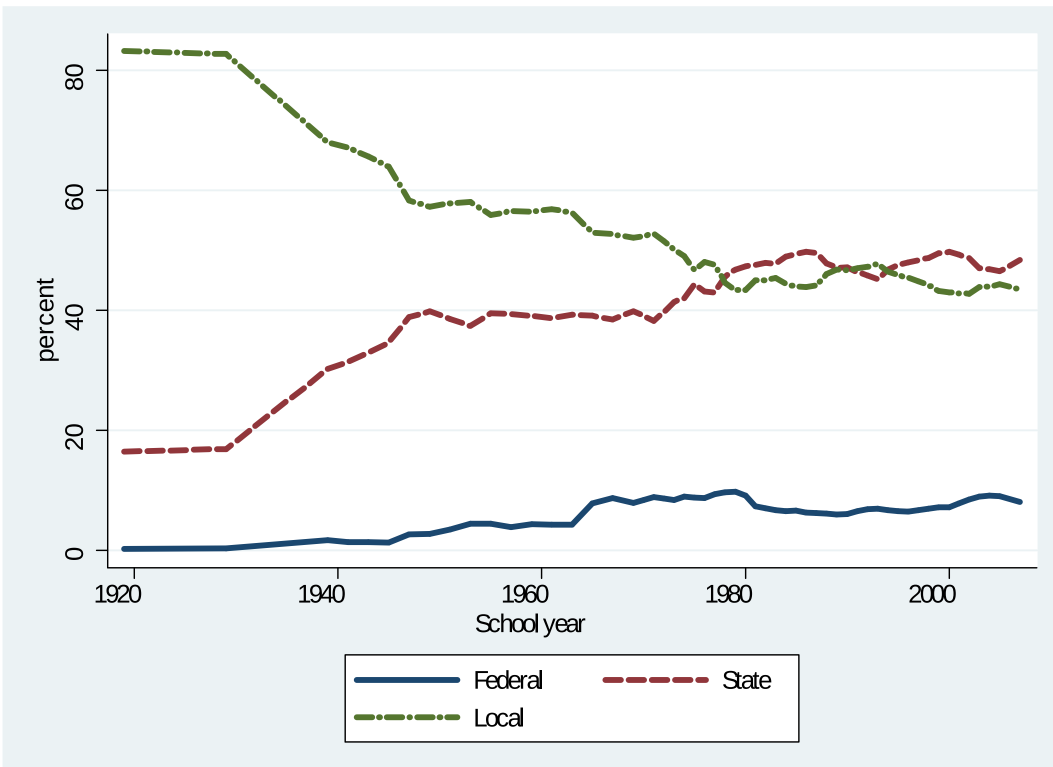

Figure 1: Shares of primary and secondary education revenue in the United States by level of government. Source: National Center for Education Statistics.

2.2 Between and Within-State Expenditure Inequality

The second stylized fact is that at least half of the variation in current expenditures per students across school districts is between-states rather than within-states. Table 1 provides information about two measures of inequality in nominal expenditures per student across school districts, the Gini coefficient and Theil index, for a selected number of years.[11]

Year	1972	1977	1982	1987	1992	1997	2002	2007	2009
Gini coefficient ($\times$100)	16.3	15.0	13.8	15.8	15.5	13.0	12.9	14.6	15.3
Theil index ($\times$1000)	43.7	37.1	31.0	40.7	40.5	30.6	29.4	39.3	43.2
Within states	13.7	14.4	14.0	12.6	13.4	9.9	8.6	10.1	10.3
Between states	30.0	22.8	17.0	28.2	27.1	20.7	20.8	29.2	32.9

Table 1: Measures of inequality in current expenditures per student across school districts. Source: Murray et al. (1998), Corcoran et al. (2003), and author's computations (see Appendix A).

The table shows a very slight reduction in inequality from 1972 to 2009 with variations over the sample period. Indicators of inequality achieve their lowest level in the late 1990s-early 2000s and then increase again. More importantly for the purpose of this paper is that the share of inequality attributable to between-states differences in expenditures across school districts is much larger than the within share. Although the decomposition of the Theil index indicates that the between-state component has fluctuated over time, it has never fallen below 55 percent (in 1982). In the last year of my data, 2009, differences across states accounted for an all-time high of 76 percent of inequality in nominal education spending per student.

Taylor (2005) has computed prices of education services across school districts and states for a selected number of years. These prices can be used to compute measures of inequality in real expenditures. The results are reported in Table 2 for some of the years in which these deflators are available.[12] Adjusting for differences in the price of education across school districts reduces the extent of the between-state variation and increases the extent of the within variation.

In any case, the between-state component accounts for at least 50 percent of the overall variation in real expenditures per student and in 2009 it approaches 66 percent.

[11] See Murray et al. (1998) for a discussion of these two indices and some of their properties. Appendix A contains detailed information about the school district data.

[12] The sample of school districts for these years is the same as in Table 1.

Year	2002		2007		2009	
	Nominal	Real	Nominal	Real	Nominal	Real
Gini coefficient ($\times 100$)	12.9	11.7	14.6	13.3	15.3	13.9
Theil index ($\times 1000$)	29.4	22.8	39.3	29.9	43.2	32.5
Within states	8.6	11.1	10.1	12.2	10.3	11.8
Between states	20.8	11.7	29.2	17.7	32.9	20.7

Table 2: Measures of inequality in real current expenditures per student across school districts. Source: author's computations using Taylor (2005)'s comparable wage index index (see Appendix A).

2.3 State-Level Expenditures and Income

The purpose of this section is to illustrate the magnitude of cross-state differences in average education spending per student and to show how these differences are strongly positively correlated with average state income.

Table 3 illustrates the quantitative magnitude of cross-state variation in average education spending per student. The latter is reduced, but not eliminated, when adjusting for differences in prices of education services (see Table 4).

Year	**Min**	**Max**	**Mean**	**Median**	**CV**
1970	7,453 (AR)	20,040 (AK)	11,672	11,989	0.25
1980	8,509 (MS)	31,177 (AK)	13,065	13,389	0.21
1990	6,842 (UT)	20,190 (NJ)	12,120	11,362	0.24
2000	6,296 (UT)	16,227 (DC)	9,941	9,412	0.20
2005	5,464 (UT)	14,954 (NJ)	9,145	8,301	0.24

Table 3: Variation in average nominal current expenditures per student across U.S. states and over time (units: 2005 dollars). The Min and Max columns include the state abbrevations. CV denotes the coefficient of variation. Data source: National Center for Education Statistics.

The ranking of states in terms of expenditures per student is also fairly stable over time. The rank correlation of nominal average state expenditures per student in 2005 with expenditures per students in 1975 is 0.64 (p-value 0.00).

Difference in average income across states are potentially an important reason behind differences in education expenditures. In the cross-section of states, average per student income is positively and significantly correlated with expenditures per student. While the elasticities vary slightly according to the particular year considered, the typical elasticity is

Year	Real	Min	Max	Mean	Median	CV	Rank Corr
2000	NO	6,296 (UT)	16,227 (DC)	9,941	9,412	0.20	0.85 (p-value 0.00)
2000	YES	6,751 (UT)	14,707 (VT)	9,941	9,333	0.15	
2005	NO	5,464 (UT)	14,954 (NJ)	9,145	8,301	0.24	0.88 (p-value 0.00)
2005	YES	5,899 (UT)	14,974 (VT)	9,145	8,658	0.19	

Table 4: Variation in current expenditures per student across U.S. states and over time (units are 2005 dollars). In the second column, NO specifies that nominal expenditures are used, while YES refers real expenditures (using Taylor (2005)'s index). Average real expenditures in each year for the whole U.S. are normalized to equal average nominal expenditures. Data source: National Center for Education Statistics and Taylor (2005).

close to one. In order to control for differences in costs of living across states I also run a state-level panel regression of expenditures per student on income per student, including state fixed effects to account for permanent differences across states in income and expenditure levels. In this case the elasticity of expenditures to income is 0.66 (standard error 0.03). The next section presents a model that allows to draw a distinction between within and between state differences in education expenditures. In the model, between-state differences in education expenditures are driven by income heterogeneity across states.

3 Model Economy

The model represents an economy where time lasts forever and individuals' lives last two periods. In the first period the agent is a child and in the second one an adult. Adult agents make labor supply decisions and invest in the human capital of their child. I follow Bénabou (2002) and model the government's education policy as a tax-transfer scheme that redistributes education expenditures towards low income agents. The novel feature of the model is the presence of three geographic/political units. The first is the *school district*, represented by a collection of households with the same human capital level within each state. This definition captures sorting of households by income level and represents an extreme version of sorting by which each school district is internally homogeneous.[13] The second is the *state* (or "location") which is characterized by a given level of productivity and a measure of residents. All agents located in the same state operate in the same labor market. The third is a *Federation* of states, defined as the collection of all states. For tractability, I focus on the model's stationary equilibrium.

[13] Fernandez and Rogerson (1997, 1999, 2003) have used this approach extensively.

3.1 Timing of Events

The timing of an agent's life is as follows. An agent is born in a state and spends his youth acquiring human capital there. An agent's state of birth has a direct influence on the agent's human capital through its policy of redistribution of education expenditures. At the beginning of his adult period, the agent chooses a state of residence in which to work and raise his child. In addition to its education policy a state is characterized by an exogenous level of productivity and a measure of resident agents. Upon choosing a location, production, labor supply, consumption, and education expenditures take place. Federal redistribution policy is exogenous and is taken as given by the residents of each state when they vote over within-state redistribution. These policies, in conjunction with parental human capital, education effort, and a random shock determine the human capital of the child, who, as an adult, will go through the same sequence of choices.

3.2 Locations, Preferences, and Technology

Formally, the economy is comprised by a continuum of measure one of states S_j, indexed by $j \in [0,1]$ and a continuum of measure one of non-altruistic agents indexed by $i \in [0,1]$ who live for two periods, as a child and as an adult. A school district is defined as a collection of agents i with the same human capital and living in the same state. Since I focus on stationary equilibria, in what follows I omit time indices and denote next period variables by a prime symbol.

Children do not have preferences of their own. An agent i living in state j cares about consumption c, time spent working, l, and his child's human capital h'. In addition, in order to generate a well-defined distribution of population across locations, an agent's utility declines with the location's resident population, denoted by n.[14] Parental preferences are represented by the following utility function:

$$U_{ij} = \rho \ln c_{ij} - \frac{l_{ij}^{\eta}}{\eta} + (1-\rho)\ln h'_{ij} - \lambda \ln n_j \tag{1}$$

where $\rho \in (0,1)$, $\lambda > 0$ and $\eta > 1$. The logarithmic specification for consumption and the the isoelastic one for labor are borrowed from Bénabou (2002) and are essential to generate closed-form solutions.

An adult agent can freely and costlessly choose where to locate. Upon choosing his

[14] In Appendix C I show how the presence of n in the utility function of an agent can be interpreted as the reduced-form version of a more general model in which each state is also characterized by a housing market. In this case the negative effect of n on utility reflects the pressure of a larger population on local housing prices.

residence an agent with human capital h who works l units of time earns income $y_{ij} = w_j l_{ij} h_{ij}$, where w_j represent the prevailing wage in the state. The budget constraint of an agent who resides in a location j is

$$y_{ij} = c_{ij} + z_{ij} \tag{2}$$

where z_{ij} is the amount spent on education by an agent in school district i and state j. In what follows, I refer to z as "education effort", to distinguish it from education expenditures received by the agent's child and denoted by e_{ij}. In an economy without government's intervention in education, we would have $z_{ij} = e_{ij}$. Policy intervention by the state and the Federal government introduce a discrepancy between these two variables. Section 3.3 below describes and discusses how these policies affect the mapping between z_{ij} and e_{ij}.

Each agent has one child who is born in the state of residence of his parent. The child's human capital is given by the following Cobb-Douglas production function:

$$h'_{ij} = \xi'_i h_{ij}^{\alpha} e_{ij}^{\beta}, \tag{3}$$

where ξ'_i is a random shock to the child's human capital.[15] The shock follows a lognormal distribution with a unit mean: $\ln \xi'_i \sim N\left(-\sigma_\xi^2/2, \sigma_\xi^2\right)$. The input h_{ij} in equation (3) reflects the direct effect that a parent's human capital has on the human capital of his child, while e_{ij} represents the effect of education expenditures on the child's human capital. The exponents α and β on these two inputs are assumed to be such that the accumulation technology exhibits decreasing returns to scale: $\alpha + \beta < 1$.

To summarize, the decision problem of an agent i involves choosing a state of residence j, labor supply l_{ij}, consumption c_{ij}, and education effort z_{ij} in order to maximize utility (1) subject to the budget constraint (2), state and Federal governments policies, and the law of motion (3) of his child's human capital.

Production of goods and services in a state j occurs through the constant returns to scale technology:[16]

$$Y_j = A_j L_j$$

where L_j denotes the total supply of efficiency units of labor located in j:

$$L_j = \int_{i \in S_j} l_{ij} h_{ij} di.$$

[15] This shock might represent the child's innate ability or simply luck. While here I am assuming that the parent observes ξ'_i at the time of making his decisions, the logarithmic form of utility implies that parental choices would be the same if the parent did not observe this shock and conditioned his choices on its expected value, instead.

[16] All results go through with decreasing returns at the cost of more complexity in the algebra. They are available from the author upon request.

Total factor productivity, A_j is lognormally distributed across states (or, equivalently, labor markets) with mean normalized to one: $\ln A_j \sim N\left(-\sigma_A^2/2, \sigma_A^2\right)$.[17] Competitive firms hire efficiency units of labor in each location in order to maximize profits.

3.3 Education Policy

Redistribution of education expenditures occurs at two levels. The Federal government introduces a first layer of redistribution. After Federal redistribution, education expenditures for a child in household i are given by:

$$e_{ij}^f = \left(\frac{\widetilde{y}^f}{y_{ij}}\right)^{\tau^f} z_{ij}, \tag{4}$$

where the federal education policy is summarized by the couple $\left(\tau^f, \widetilde{y}^f\right)$. Notice that the variable $\widetilde{y}^f$ represents the income level of an agent that receives a zero net transfers from the Federal government, or equivalently the break-even level of income such that $e_{ij}^f/z_{ij} = 1$. Higher values of the parameter τ^f are associated with larger proportional transfers e_{ij}^f/z_{ij} of education expenditures toward low income households. While τ^f is a parameter that can be varied exogenously, $\widetilde{y}^f$ is an endogenous variable determined by the budget constraint of the Federal government:

$$\int \int_{i \in S_j} e_{ij}^f didj = \int \int_{i \in S_j} z_{ij} didj, \tag{5}$$

where e_{ij}^f depends on $\widetilde{y}^f$ through equation (4).

This equation simply states that the aggregate education expenditures post-Federal redistribution have to equal the pre-redistribution aggregate education effort. In other words, the Federal policy is purely redistributive.

The second layer of redistribution occurs at the state level. A state government redistributes expenditures across the school districts located within the state. After state redistribution, education expenditures by a household (or school district) i located in state j are given by:

$$e_{ij} = \left(\frac{\widetilde{y}_j^s}{y_{ij}}\right)^{\tau_j^s} e_{ij}^f. \tag{6}$$

State j's education policy is summarized by the couple $\left(\tau_j^s, \widetilde{y}_j^s\right)$. The policy variable τ_j^s, assumed to be positive, is the state-level analog of τ^f, and determines the extent of redistri-

[17] It is straightforward to generalize the model to allow for an endogenous component of total factor productivity. Formally, the latter could be specified as $A_j \overline{h}_j^{\delta}$ ($\delta > 0$) with the endogenous component $\overline{h}_j$ being the mean of the human capital distribution in state j. This version of the model can also be solved analytically and results are available upon request.

bution of education expenditures toward low-income districts within a state. Higher value of τ_j^s are associated with more aggressive redistribution by a state. The variable $\widetilde{y}_j^s$ denotes the level of income of an agent that receives a zero net transfer from state j. As in the case of Federal policy, $\widetilde{y}_j^s$ must be consistent with the fact that state governments' policy is purely redistributive:

$$\int_{i \in S_j} e_{ij} di = \int_{i \in S_j} e_{ij}^f di, \tag{7}$$

where the integrals are taken over all agents i who reside in state S_j.

In what follows I treat the extent of Federal redistribution τ^f as a parameter while I endogenize the state-level policies τ_j^s. State level redistribution is decided after location and production decisions. Following Bénabou (1996b), the decisive agent in the determination of τ_j^s in each location j is assumed to be the agent at the p-th percentile of the distribution of income in the location, with p being independent of j. When $p = 1/2$, this reduces to the standard majority voting system in which the agent with median income is decisive, since preferences over τ_j^s are single-peaked.[18] As shown below the political process in each state selects τ_j^s as a function of τ^f.[19] The policy analysis in Section 6 consists of determining the effects of exogenous changes in τ^f on the equilibrium of the model, taking into account the endogenous reaction of state-level redistribution policies.[20]

Before moving forward, it is useful to comment on the nature of education policies in this model. First, both Federal and state policies redistribute education expenditures toward low-income agents. Hence, in equilibrium, the distribution of expenditures e_{ij} is more compressed than the distribution of effort z_{ij}. Second, since states can only redistribute among its residents, location matters for the amount of education expenditures an individual is exposed to. Two individuals with the same income level receive different education expenditures if they live in different states. By contrast, Federal policy treats two individuals with the same income but located in different states in the same way. Third, while there are no explicit separate taxes and transfers in this formulation of policy, there is an important special case in which a tax-transfer interpretation applies. The special case is that of a centralized state system with no Federal redistribution ($\tau_j^s = 1$ and $\tau^f = 0$). This situation can be interpreted as one in which each state imposes a proportional income tax to finance constant

[18] See Section 4.1 for a proof of single-peakedness.

[19] An alternative to the specification adopted here is to reverse the order of redistribution with state redistribution followed by Federal redistribution. In this alternative situation the multiplicative nature of education subsidies and the logarithmic assumption on utility would eliminate any dependence of τ_j^s on τ^f. Federal redistribution would then be more effective, relative to the economy considered here, because it would not elicit any behavioral offset on the part of state governments.

[20] It is feasible, but cumbersome, to endogenize the choice of τ^f. The problem is that the policy space becomes two-dimensional and standard median voter results do not apply. See Nechyba (1997) for an analysis of voting in such setting that borrows from Shepsle (1979)'s structure-induced equilibrium.

expenditures per pupil across income levels, where the amount may vary across states.[21] Last, a feature of the redistribution scheme adopted here is that state and Federal policies affect the tax price of education expenditures, or the resource cost for a school district of marginally increasing its purchases of education services. Whenever τ^f and τ_j^s are positive the tax price declines with an agent's income. Policies that affect the tax-price affect the incentives to spend on education at the margin and operate differently from policies, such as lump-sum transfers, that affect the infra-marginal incentives to spend on education. State education finance policies often take the form of foundation grants, which leave unaffected school districts' incentives at the margin (Fernandez and Rogerson, 2003). A number of states adopt power equalizing schemes, whose incentive properties most closely resemble the ones specified here. In a power equalizing scheme a school district chooses a tax rate that does not apply to its own tax base, but rather to a tax base specified by the state. Thus, according to such scheme, the tax price faced by a district is equal to the ratio of its tax base (income in this case) and the tax base specified by the state, with poorer districts facing tax prices less than one and richer districts tax prices larger than one.[22] Transfers from the Federal government to school districts under Title I of ESEA are independent of local effort (subject to a lower bound; see Gordon (2004)) and so, to a first approximation, are lump-sum in nature. While analyzing lump-sum transfers in this model is feasible, doing so would sacrifice its analytical tractability.

3.4 Stationary Equilibrium

Given a Federal redistribution policy that satisfies the budget constraint of the Federal government, a stationary equilibrium is represented by a wage, a measure of residents, and a redistribution policy for each state; consumption, education expenditures and labor supply choices for each agent; hiring decisions for each firm such that: i) firms optimize; ii) state-level policies are determined by the agent in the p-th percentile of the state's income distribution, taking as given the geographic distribution of population, and the labor supply and education expenditure choices of the agents; iii) agents choose consumption and education spending to maximize their utility subject to the budget constraint in their state of residence, taking as given redistribution policies; iv) adult agents are indifferent among all possible locations of residence; v) the within-state distribution of human capital and the between-state distribution of population are constant over time.

[21] The proof of this equivalence result is available upon request. Centralized systems are observed in some states, such as California.

[22] As described by Fernandez and Rogerson (2003), there are two types of power equalizing schemes. The one with recapture is described in the text. A version without recapture is such that a district can choose whether to tax the base chosen by the state or its own base, thus capping the tax price to one.

4 Characterization of the Stationary Equilibrium

In this section I characterize the stationary equilibrium of this economy. Specifically, in order to keep the model analytically tractable, I focus on a stationary equilibrium in which the distribution of human capital within each location is lognormally distributed, $\ln h \sim N(m_j, \Delta^2)$. Notice that in this equilibrium the mean of log human capital varies across locations, but its variance does not. In what follows I solve for (m_j, Δ^2) and the other equilibrium variables of interest as a function of the structural parameters of the model. Given that the timing of the model is such that mobility choices are followed by production, consumption and redistribution, in what follows I begin with the redistribution stage and work my way backward.[23]

4.1 State-Level Policy

After production, consumption and labor supply choices, agents in each state choose the level of redistribution of education expenditures. Agents choose the state-level education policy variable τ_j^s subject to the balanced budget condition (7). Notice that since labor supply and education expenditures decisions have been made at this stage, an agent's preferred τ_j^s maximizes its post-redistribution expenditures e_{ij}. In turn, the latter has a component that is determined by the Federal government, denoted by e_{ij}^f, that is taken as given by the agent, and a component determined by the state government $\left(\widetilde{y}_j^s / y_{ij}\right)^{\tau_j^s}$. Taking logs of this expression, the objective function of an agent with income y_{ij} can be written as:

$$\tau_j^s \left(\ln \widetilde{y}_j^s - \ln y_{ij}\right) = \tau_j^s \left[m_j + \Delta^2 \left(1 - \tau^f - \frac{\tau_j^s}{2}\right) - \ln h_{ij}\right], \tag{8}$$

where, in order to replace $\widetilde{y}_j^s$, I have used the balanced budget equation (7), the optimal choice of z_{ij} described in equation (12) below, and the assumption that human capital is lognormally distributed.[24] Equation (8) illustrates the trade-off faced by an agent i in determining his preferred τ_j^s. Notice that this is a purely distributional problem, as all economic decisions have been made at this point. On the one hand, a higher value of τ_j^s reduces the gap in education expenditures between the level an agent can afford based on his income and the level associated with an agent with income $\widetilde{y}_j^s$. On the other, a more progressive redistribution implied by a higher τ_j^s reduces the break-even level $\widetilde{y}_j^s$ itself through the balanced budget equation (7). Intuitively, to achieve a marginally smaller gap in education expenditures

[23] Details about the solution of the model and the derivation of the main results are contained in an online appendix available at https://sites.google.com/site/danicpiraniweb/Home/publication.

[24] Notice that equation (8) is quadratic and concave in τ_j^s as long as $\tau_j^s > 0$. Therefore, preferences over τ_j^s are single-peaked.

between income groups, the magnitude of the subsidy received by a given low-income agent has to fall.

The degree of redistribution τ_j^s preferred by an agent with human capital h_{ij} is given by:

$$\tau_{ij}^s = 1 - \tau^f + \frac{m_j - \ln h_{ij}}{\Delta^2},$$

which decreases in Federal redistribution τ^f and in the agent's (log) human capital $\ln h_{ij}$, and it increases in the average (log) human capital of the state, m_j.

I assume, as Bénabou (1996b) that the decisive voter has human capital at the p-th percentile of the human capital distribution within a state. The human capital level of the pivotal voter is h_j^p such that:

$$\ln h_j^p = m_j + \Phi^{-1}(p)\,\Delta, \tag{9}$$

where Φ denotes the cumulative distribution function of the normal distribution. It follows that the equilibrium level of redistribution in all locations is given by

$$\tau^s = 1 - \tau^f - \frac{\Phi^{-1}(p)}{\Delta}, \tag{10}$$

where Δ is endogenous and determined below (see equation 19). Notice that equilibrium redistribution at the state level declines on a one-for-one basis with Federal redistribution. As it will become evident in the next section, this result implies that the income elasticity of education expenditures within a state is independent of whether the Federal or state government undertakes the redistribution. Notice that redistribution is lower the higher the human capital rank of the decisive agent. When $p = 1/2$ a majority voting equilibrium obtains, as preferences over redistribution are single-peaked. In this case redistribution is full in the sense that the income elasticity of expenditures is zero (see equation (14) below).[25] If $p > 1/2$, as is assumed in the rest of the paper, the decisive agent has human capital weakly larger than the median and redistribution of education expenditures is less than full.[26]

4.2 Production and Consumption Choices

Before voting, but after mobility choices, agents in a location choose consumption, labor supply and education effort anticipating the policy variables τ^s and τ^f. It is straightforward

[25] This result is due to the timing of the model according to which voters take as given labor supply when deciding on redistribution. Appendix D considers the alternative timing assumption that implies that even when $p = 1/2$, redistribution is always less than full.

[26] Formally, when $p > 1/2$, $\Phi^{-1}(p) > 0$ and $\tau^s + \tau^f < 1$ in equation (10). As equation (14) in Section 4.2 shows, this implies that the elasticity of education expenditures to income is strictly positive.

to show that the consumption, education effort, and labor supply choices that maximize the utility function (1) subject to the budget constraint (2) are given by:

$$c_{ij} = \frac{\rho}{\rho + (1-\rho)\beta} y_{ij} \tag{11}$$

$$z_{ij} = \frac{(1-\rho)\beta}{\rho + (1-\rho)\beta} y_{ij} \tag{12}$$

$$l^* = \left(\rho + (1-\rho)\beta\left(1-\tau^s-\tau^f\right)\right)^{\frac{1}{\eta}} \tag{13}$$

where y_{ij} denotes and agent's income. Notice that consumption of goods and education effort are linear in income, while labor supply depends only on the overall degree of redistribution of education expenditures. Notice also that, combining equation (12) with equations (6) and (4), the post-redistribution level of education expenditures can be written as:

$$e_{ij} = \frac{(1-\rho)\beta}{\rho + (1-\rho)\beta} \left(\widetilde{y}^f\right)^{\tau^f} \left(\widetilde{y}^s_j\right)^{\tau^s} y_{ij}^{1-\tau^s-\tau^f}, \tag{14}$$

so that $1-\tau^s-\tau^f$ represents the elasticity of education expenditures to an agent's income. This expression for education expenditures makes clear how the post-redistribution education expenditures of an agent depend on his income, and conditional on income, on his state of residence. The income elasticity of education expenditures within a state j is unaffected by changes in Federal redistribution τ^f because, as this parameter increases, τ^s declines in an offsetting way (equation 10). However, equation (14) also shows that the overall level of education expenditures in a state j depends on Federal redistribution because, given an agent's income, a higher value of τ^f implies a lower dependence of expenditures on the characteristics of the state, as summarized by the policy variable $\widetilde{y}^s_j$.

From the representative firm's profit maximization in each location, the wage w_j must equal the marginal product of labor:

$$w_j = A_j.$$

4.3 Geographic Mobility

The first decision stage of an agent's life concerns geographic mobility across states. Free mobility implies that an agent with a given human capital has to obtain the same utility independently of the location in which he chooses to settle. The indirect utility function of an agent with human capital h and child with human capital shock ξ', residing in a state j takes the following form, up to an additive constant:

$$
\begin{aligned}
V_j\left(h,\xi'\right) \;=\;& \left(\rho+(1-\rho)\left(\alpha+\beta\left(1-\tau^s-\tau^f\right)\right)\right)\ln h+(1-\rho)\ln\xi' \\
&+(\rho+(1-\rho)\beta)\ln l^*-\frac{(l^*)^\eta}{\eta} \\
&+(1-\rho)\,\beta\tau^s\left(1-\tau^f-\frac{\tau^s}{2}\right)\Delta^2+(1-\rho)\,\beta\tau^f\ln\left(\widetilde{y}^f/l^*\right) \\
&+\left(\rho+(1-\rho)\,\beta\left(1-\tau^f\right)\right)\ln A_j+(1-\rho)\beta\tau^s m_j-\lambda\ln n_j.
\end{aligned} \tag{15}
$$

Notice that an agent's utility depends on location j to the extent that total factor productivity A_j, population n_j, and average log human capital m_j do. The expression for indirect utility incorporates the result derived in Section 4.1 that all locations are characterized by the same redistribution policy variable τ^s.

The assumption of free mobility then implies that the location-specific variables in the indirect utility function have to be linked as follows:

$$
\left(\rho+(1-\rho)\,\beta\left(1-\tau^f\right)\right)\ln A_j+(1-\rho)\beta\tau^s m_j-\lambda\ln n_j=v, \tag{16}
$$

where v is an endogenous variable. The latter is determined in equilibrium by the requirement that aggregate population has measure one:

$$
\int n_j dj=1. \tag{17}
$$

The first term on the left-hand side of equation (16) represents the direct effect of higher wages on an agent's utility. Locations with higher total factor productivity enjoy higher wages, but the Federal redistribution policy implies that a portion of those wages are redistributed to locations with lower total factor productivity. The second term captures the positive effect that higher average human capital in a state has on its residents' education expenditures due to within-state redistribution. Equation (16) pins down the level of population n_j as function of the exogenous productivity of the location A_j, and the (endogenous) distribution of human capital as summarized by the lognormal parameter m_j. Locations with higher total factor productivity and higher average human capital have larger populations. This equation also illustrates how the parameter λ determines the responsiveness of population to differences in states' characteristics, with higher values of λ being associated with a lower elasticity. As it will become clearer in Section 6.2, this parameter plays an important role in determining the sign and magnitude of the welfare benefits associated with Federal redistribution.

4.4 Human Capital Distribution and Population

The previous sections characterize the model's equilibrium for a given distribution of human capital within each state. In this section I determine the endogenous distribution of human capital in each state and the distribution of population across states. Given equation (3) the law of motion for log human capital in state j is:

$$\ln h'_{ij} = \ln \xi'_{ij} + \alpha \ln h_{ij} + \beta \ln e_{ij}.$$

In order to preserve normality I focus on an equilibrium in which migration, to the extent that it occurs, does not alter the density of human capital in a location. Replacing the expression for education expenditures (equation 14 and its components) in the law of motion for human capital and performing some algebra, we obtain the parameters of the equilibrium distribution of human capital in location j. Specifically, the latter is a lognormal with parameters:[27]

$$m_j = \widetilde{m} + \frac{\beta\left(1-\tau^f\right)}{1-\alpha-\beta\left(1-\tau^f\right)} \ln A_j \tag{18}$$

$$\Delta^2 = \frac{\sigma_\xi^2}{1-\left(\alpha+\beta\left(1-\tau^f-\tau^s\right)\right)^2}, \tag{19}$$

where $\widetilde{m}$ is defined as:

$$\begin{aligned} \widetilde{m} \equiv\ & \frac{1}{1-\alpha-\beta}\left(\beta \ln \frac{(1-\rho)\beta l^*}{\rho+(1-\rho)\beta} - \frac{\sigma_\xi^2}{2}\right) + \frac{\beta}{1-\alpha-\beta}\frac{\sigma_A^2}{2} Q \\ & + \frac{\beta}{1-\alpha-\beta}\frac{\Delta^2}{2}\left(1-\left(1-\tau^s-\tau^f\right)^2\right). \end{aligned}$$

The term Q, defined in Appendix B, is non-negative if $\tau^f \geq 0$, equals zero if and only if $\tau^f = 0$, and depends separately on the redistribution variables τ^f and τ^s. The Q term reflects the inter-state dimension of Federal redistribution from poor to rich states and it is the counterpart of within-state redistribution operating through the term that multiplies Δ^2.

A few comments on the equilibrium distribution of human capital in a state j are in order. First, as equation (18) illustrates, locations with higher total factor productivity are characterized by higher average human capital, as long as $\beta > 0$ and $\tau^f < 1$. However, Federal redistribution (a higher value of the parameter τ^f) reduces the sensitivity of average human

[27] Notice that this finding confirms the initial guess that the mean of the log distribution of human capital in a state is specific to that location while the variance is not.

capital to local productivity. Second, given τ^f, the overall degree of redistribution $\tau^f + \tau^s$ has an ambiguous effect on average log human capital. On the one hand, more redistribution leads to lower labor supply and lower accumulation of human capital. On the other, more redistribution leads to higher human capital because it increases the human capital of income-poor households with relatively high returns to investment more than it decreases the human capital of income-rich households. The latter effect prevails when inequality is relatively large. Redistribution also leads to smaller within-state inequality, as measured by Δ. Third and last, notice that equation (19) links the inequality index Δ to redistribution $\tau^f + \tau^s$, while equation (10) links redistribution to inequality. It is straightforward to show that as long as $p \geq 1/2$ this system of two equations in two unknowns has a unique solution.[28]

In order to solve for the equilibrium level of population in state j, replace equation (18) in equation (16) and apply the equilibrium condition (17) to obtain:

$$n_j = A_j^{\vartheta} \exp\left\{\frac{\sigma_A^2}{2}\vartheta\left(1-\vartheta\right)\right\}, \tag{20}$$

where ϑ denotes the elasticity of a state's population to its productivity and wage. This parameter is given by the following function of the model's structural parameters:

$$\vartheta \equiv \frac{\rho}{\lambda} + \frac{(1-\rho)\beta\left(1-\tau^f\right)}{\lambda}\left(1 + \frac{\beta\tau^s}{1-\alpha-\beta\left(1-\tau^f\right)}\right). \tag{21}$$

Notice that the parameter ϑ is positive. Thus, locations with higher total factor productivity have larger populations in equilibrium. Notice also that higher state redistribution (a higher level of τ^s) tends to *increase* the attractiveness of locations with relative high total factor productivity because a portion of these states' expenditures are redistributed among the resident population. For the same reason a more generous Federal redistribution (a higher level of τ^f) tends to reduce ϑ.

To close the model, one has to find v in equation (16) by imposing condition (17). The closed-form expression for this variable is reported in Appendix B.

5 Education Expenditures Within and Between States

Before turning to policy analysis, the model can be used to perform the same decomposition of education expenditures inequality into within-state and between-state components

[28] To see this, notice that according to equation (19) inequality Δ is decreasing in $\tau^f + \tau^s$ while according to equation (10), the sum $\tau^f + \tau^s$ is weakly increasing in Δ as long as $p \geq 1/2$. Hence there is at most a unique solution for $\left(\Delta, \tau^f + \tau^s\right)$. It is also straightforward to show that that solution always exists.

as performed in Section 2.2. This exercise clarifies the determinants of the distribution of expenditures across individuals and locations.

I measure inequality in expenditures per student using the Theil index, T^e. The latter can be decomposed into a within and a between state component as follows:

$$T^e = \underbrace{\int \frac{n_j E_j [e_{ij}]}{E [e_{ij}]} T_j^e dj}_{\text{within-state}} + \underbrace{\int \frac{n_j E_j [e_{ij}]}{E [e_{ij}]} \ln \frac{E_j [e_{ij}]}{E [e_{ij}]} dj}_{\text{between-state}}, \tag{22}$$

where T_j is the within-state Theil index:

$$T_j^e = \frac{1}{n_j} \int_{i \in S_j} \frac{e_{ij}}{E_j [e_{ij}]} \ln \frac{e_{ij}}{E_j [e_{ij}]} di.$$

The expression $E_j [e_{ij}]$ in the formulas above denotes average education expenditures in state j, while

$$E [e_{ij}] = \int n_j E_j [e_{ij}] dj$$

represents the economy-wide average education expenditures.

Replacing the relevant equilibrium variables and performing some algebra, the expression in (22) can be written as a function of the model's parameters:

$$T^e = \underbrace{\frac{\Delta^2}{2} \left(1 - \tau^f - \tau^s\right)^2}_{\text{within-state}} + \underbrace{\frac{\sigma_A^2}{2} \left(\frac{(1-\alpha)\left(1-\tau^f\right)}{1 - \alpha - \beta\left(1 - \tau^f\right)} \right)^2}_{\text{between-state}}, \tag{23}$$

where Δ^2 is given by equation (19) and τ^s is given by equation (10).

Several observations are in order. First, the within-state Theil index, the first term on the right-hand side of equation (23), is the same across all locations.[29] Both state and Federal redistribution contribute to lower the within-state variance, but τ^f does not have an independent effect on it because τ^s offsets it. Second, the between-state component is strictly positive as long as locations have different productivity ($\sigma_A^2 > 0$) and Federal redistribution is not perfect ($\tau^f < 1$).[30] The between-state term declines as τ^f increases and Federal redistribution becomes more pronounced. Between-state expenditures inequality increases with the parameters β and α because differences in expenditures are amplified and

[29] The within-state Theil index equals half of the variance of log education expenditures within each state. This is a property of the lognormal distribution.

[30] A similar decomposition can be performed for per capita income y_{ij} and human capital. The Theil index for both variables is similar to the one in equation (23), except that the within state component is given by $\Delta^2/2$.

perpetuated over time through their effect on states' human capital accumulation.[31]

6 Policy Analysis

In this section I use the model to perform a number of policy experiments. First, in order to connect the analysis to the existing literature, in Section 6.1 I abstract from cross-state heterogeneity in productivity and use the model to analyze the effects of redistribution on long-run human capital accumulation. Second, in Section 6.2, I consider the full model and evaluate the human capital and welfare effects of varying Federal redistribution, as indexed by the parameter τ^f. In order to assess the robustness of my results to the measure of welfare, in Section 6.3 I discuss an alternative measure and its influence on the results. Finally, in Section 6.4 I illustrate some of the model's prediction for welfare using numerical examples with calibrated parameter values.

6.1 Redistribution in the Economy with Homogeneous Locations

Let's start by considering the one-location version of the model. This is achieved by eliminating differences in productivity across states, i.e. imposing $\sigma_A^2 = 0$. In this case, the distinction between state and Federal redistribution is irrelevant, so denote $\tau^s + \tau^f$ by τ^*.[32] Equations (18) and (19) imply that average log human capital in this case is simply:[33]

$$E\left[\ln h; \sigma_A^2 = 0\right] = \frac{\beta}{1-\alpha-\beta} \ln \frac{(1-\rho)\beta l^*}{\rho + (1-\rho)\beta} + \frac{\sigma_\xi^2}{2} \frac{\beta}{1-\alpha-\beta} \left(\frac{1-(1-\tau^*)^2}{1-(\alpha+\beta(1-\tau^*))^2} - \frac{1}{\beta} \right). \tag{24}$$

Higher levels of redistribution of education expenditures, as indexed by τ^*, have opposite effects on average log human capital. On the one hand, as τ^* grows, labor supply l^* declines and so does average human capital. This effect is represented by the first term on the right-hand side of equation (24). On the other hand, redistribution can increase average human capital by shifting expenditures away from richer households and towards poorer ones. To see this, consider that the second term on the right-hand side of equation (24) is larger when $\tau^* = 1$ than when $\tau^* = 0$.[34] Thus, as long as the elasticity of labor supply is not too

[31] Notice that the Federal component of redistribution τ^f has no effect on intergenerational mobility, instead. The correlation between parent and child's log human capital in the model is $\left[\alpha + \beta\left(1 - \tau^s - \tau^f\right)\right]$.

[32] Recall from equations (10) and (19) that τ^* is implicitly determined by the condition $\tau^* = 1 - \Phi^{-1}(p)/\Delta(\tau^*)$, where I have emphasized the dependence of Δ on τ^*.

[33] I compute the expected value of log human capital instead of the expected value of human capital because the former is the relevant variable to compute expected utility and welfare.

[34] The peak of average human capital is reached at a level $\tau^* \in (0,1)$.

large (i.e., η is sufficiently large), average human capital and income can be larger in the economy with some redistribution than in the economy without any redistribution.[35] This is a point made by Bénabou (2002) and others. Differently from these authors, in what follows I focus on a different policy experiment, namely varying τ^f while leaving τ^* unchanged. This requires considering the version of the economy with heterogeneous locations.

6.2 Federal Redistribution in the Economy with Heterogeneous Locations

Consider now the economy with heterogeneous locations, i.e., $\sigma_A^2 > 0$. The policy experiment I undertake is to exogenously modify the extent of Federal redistribution τ^f and evaluate its effect on average human capital, its distribution, the distribution of population across locations, and ultimately welfare. Notice that as τ^f varies the sum of τ^f and τ^s, denoted by τ^*, stays constant (see footnote 32).

The average of log human capital is now:

$$\begin{aligned} E\left[\ln h; \tau^f\right] &= E\left[\ln h; \sigma_A^2 = 0\right] + \\ &+ \frac{\beta}{1-\alpha-\beta}\frac{\sigma_A^2}{2}Q\left(\tau^f\right) - \frac{\sigma_A^2}{2}\frac{\beta\left(1-\tau^f\right)}{1-\alpha-\beta\left(1-\tau^f\right)} \\ &+ \sigma_A^2\vartheta\left(\tau^f\right)\frac{\beta\left(1-\tau^f\right)}{1-\alpha-\beta\left(1-\tau^f\right)}, \end{aligned} \tag{25}$$

where $\ln E\left[h; \sigma_A^2 = 0\right]$ is defined in equation (24) and I have emphasized the dependence of the functions of parameters Q and ϑ on τ^f.[36] The terms on the second row of equation (25) represent the effect of heterogeneity in productivity across locations on the *simple* average of log human capital. The term on the third row, instead, represents the additional impact that heterogeneity in productivity has on average log human capital through redistribution of population. I am interested in how each of these two terms varies with the degree of Federal redistribution, τ^f. Specifically, I consider a comparison of the case $\tau^f = 0$ (no Federal redistribution) with the case $\tau^f > 0$.

Consider first the effect of Federal redistribution on the simple average of log human capital. As equation (23) shows, as τ^f increases the between-state component of inequality in education expenditures declines. This redistribution from high to low spending states tends to increase the simple average of log human capital due to diminishing returns to

[35] Notice that in this economy, aggregate income is simply $Y = l^* \times E\left[\ln h; \sigma_A^2 = 0\right]$ so income increases with τ^* under stricter conditions than the ones needed to increase average log human capital.

[36] Recall that $E\left[\ln h; \sigma_A^2 = 0\right]$ does not depend on τ^f.

education expenditures in the production function of new human capital. Formally, it is straightforward to verify that the second row of equation (25) is larger when $\tau^f > 0$ than when $\tau^f = 0$, because $Q(0) = 0$ and $Q\left(\tau^f\right) > 0$ for $\tau^f > 0$.

The second effect of Federal redistribution on average human capital is due to the redistribution of population away from high productivity locations and towards low productivity ones. This effect is unambiguously negative, as the third row of equation (25) is monotonically declining in τ^f. The intuition is that low productivity locations are characterized by lower average human capital than high productivity ones, hence a redistribution of population towards the former tends to reduce the overall average. This second effect disappears as mobility costs increase (i.e., the parameter $\lambda \to \infty$) and $\vartheta\left(\tau^f\right)$ converges towards zero.[37]

I can then conclude that a sufficient condition for average log human capital in the economy to be higher when $\tau^f > 0$ than when $\tau^f = 0$ is the presence of sufficiently high mobility costs.[38]

While average (log) human capital is an important element of the model, it is not, per se, a measure of welfare. As a welfare criterion I adopt a consumption equivalent measure. Specifically, I compute the proportional increase $T\left(\tau^f\right)$ in an agent's consumption in the economy with $\tau^f = 0$ that is needed to yield the same expected utility as in an economy with $\tau^f > 0$. Formally, $T\left(\tau^f\right)$ satisfies the following condition:

$$\begin{aligned} & \rho E\left[\ln c; \tau^f\right] + (1-\rho) E\left[\ln h; \tau^f\right] - \lambda E\left[\ln n; \tau^f\right] \\ = \; & \rho E\left[\ln c\,(1+T)\,; \tau^f = 0\right] + (1-\rho) E\left[\ln h; \tau^f = 0\right] - \lambda E\left[\ln n; \tau^f = 0\right]. \end{aligned} \tag{26}$$

Notice that all the expectations are computed using the equilibrium densities of consumption, human capital, and population and take into account both the within and the between-state distributions of the relevant variables. After appropriate substitutions one obtains that $T(\tau^f)$ is such that:

$$\begin{aligned} \ln\left(1 + T(\tau^f)\right) = & \frac{1}{\rho}\left(E\left[\ln h; \tau^f\right] - E\left[\ln h; \tau^f = 0\right]\right) + \\ & + E\left[\ln A; \tau^f\right] - E\left[\ln A; \tau^f = 0\right] - \frac{\lambda}{\rho}\left(E\left[\ln n; \tau^f\right] - E\left[\ln n; \tau^f = 0\right]\right). \end{aligned} \tag{27}$$

Equation (27) illustrates the three basic effects that determine the sign and magnitude of $T(\tau^f)$. First, Federal redistribution affects welfare by changing average log human capital

[37] As $\lambda \to \infty$ all locations are populated by a measure one of agents. Notice also that $Q\left(\tau^f\right)$ converges towards a strictly positive number as $\lambda \to \infty$ (equation 33).

[38] In order for average human capital to increase, there must be sufficiently decreasing returns to scale in the accumulation of human capital. See the discussion in Section 6.3.

in the economy, as captured by the first term on the right-hand side of equation (27). The change in average log human capital affects utility through the agent's consumption and the human capital of his offspring. Second, Federal redistribution affects the distribution of labor across locations characterized by heterogeneous productivity. This redistribution has both an indirect effect on aggregate production, as captured by the second effect on the right-hand side of (27), and a direct effect on utility, as captured by the third effect on the right-hand side of (27).[39]

Consider now each of these three effects in more detail. The first effect has already been discussed above. Specifically, Federal redistribution leads to higher average log human capital if there are sufficiently high geographic mobility costs. Second, the population-weighted log productivity term in equation (27) is given by:

$$E\left[\ln A; \tau^f\right] - E\left[\ln A; \tau^f = 0\right] = \sigma_A^2 \left(\vartheta\left(\tau^f\right) - \vartheta\left(0\right)\right) < 0, \tag{28}$$

where the negative sign can be verified using the expression for ϑ in equation (21). Federal redistribution provides incentives for agents to locate in states with lower productivity, reducing aggregate output. Thus, Federal redistribution tends to decrease welfare through this channel, by moving labor away from high productivity states.

Third and last, the difference in average log population density between the two economies can be obtained manipulating equation (20):

$$E\left[\ln n_j; \tau^f\right] - E\left[\ln n_j; \tau^f = 0\right] = \frac{\sigma_A^2}{2}\left(\vartheta\left(\tau^f\right)^2 - \vartheta\left(0\right)^2\right) < 0. \tag{29}$$

Thus, since Federal redistribution reduces population density, it tends to increase welfare, as measured by $T(\tau^f)$. Notice that this effect is simply the counterpart of the previous one. Federal redistribution reduces average log productivity in the economy but also alleviates some of the negative consequences of agglomeration of population in high productivity states. Both of these effects disappear as the disutility associated with higher density increases (i.e., λ becomes larger) because in this case a location's population becomes independent of its productivity and density is equalized across states.[40]

In summary, I have established that if mobility costs are high enough ($\lambda \to \infty$), the consumption equivalent measure $T(\tau^f)$ is positive, meaning that welfare is higher in the economy with some Federal redistribution ($\tau^f > 0$) than in the economy without ($\tau^f = 0$).

[39] Recall that, everything else equal, agents dislike higher population density.

[40] Formally, as $\lambda \to \infty$, the parameter $\vartheta \to 0$ and $\lambda\vartheta$ converges to a constant. Hence $\lambda\vartheta^2 \to 0$ as well. This can be verified using the expression for ϑ in equation (21).

6.3 An Alternative Welfare Measure

The welfare measure employed in the previous section is based on a comparison of the expected utilities of living in two different economies. As discussed in Bénabou (2002), a comparison of expected utilities places a positive welfare value on the pure redistribution of consumption across agents, even when average consumption in the economy does not change. In order to avoid this issue, I follow Bénabou (2002) and consider an alternative welfare measure. This is defined as the proportional gain in consumption in the economy with $\tau^f = 0$ that makes the utility of living in such economy, evaluated at the *average value* of its arguments, equal to its counterpart in the economy with $\tau^f > 0$:

$$\begin{aligned} & \rho \ln E\left[c;\tau^f\right] + (1-\rho)\ln E\left[h;\tau^f\right] - \lambda \ln E\left[n;\tau^f\right] \\ = \; & \rho \ln E\left[c\left(1+\widehat{T}\right);\tau^f = 0\right] + (1-\rho)\ln E\left[h;\tau^f = 0\right] - \lambda \ln E\left[n;\tau^f = 0\right] \end{aligned} \tag{30}$$

where $E\left[c;\tau^f\right]$ is the average consumption in the economy with Federal redistribution τ^f and similarly for the other variables. According to this definition, $\widehat{T}(\tau^f)$ records a welfare gain only if Federal redistribution induces an increase in average consumption, or an increase in average human capital, or a reduction in average population density. Pure redistribution of consumption from one set of agents to another does not, per se, lead to welfare gains. After appropriate substitution we obtain that the welfare measure $\widehat{T}(\tau^f)$ satisfies:

$$\begin{aligned} \ln\left(1+\widehat{T}(\tau^f)\right) = \; & \frac{1}{\rho}\left(\ln E\left[h;\tau^f\right] - \ln E\left[h;\tau^f=0\right]\right) + \\ & + \ln E\left[A;\tau^f\right] - \ln E\left[A;\tau^f=0\right] - \frac{\lambda}{\rho}\left(\ln E\left[n;\tau^f\right] - \ln E\left[n;\tau^f=0\right]\right). \end{aligned} \tag{31}$$

The economic intuitions behind the three terms on the right-hand side of equation (31) have already been discussed in the previous section. Some of these expressions are now analytically different because they measure the log of an average rather than the average of a log. In what follows, I briefly discuss how each of these three terms relates to its counterpart in Section 6.2.

First, the log change in average human capital between the two economies is equal to the difference in average log human capital plus a negative term that reflects Jensen's inequality:

$$\begin{aligned} \ln E\left[h;\tau^f\right] - \ln E\left[h;\tau^f=0\right] = \; & E\left[\ln h;\tau^f\right] - E\left[\ln h;\tau^f=0\right] + \\ & \frac{\sigma_A^2}{2}\left(\frac{\beta\left(1-\tau^f\right)}{1-\alpha-\beta\left(1-\tau^f\right)}\right)^2 - \frac{\sigma_A^2}{2}\left(\frac{\beta}{1-\alpha-\beta}\right)^2. \end{aligned}$$

Thus, since the Jensen's inequality term in the second row of this equation is negative, the conditions to guarantee that Federal redistribution increase average human capital are more stringent than the one discussed in the previous section. They include, in addition to a relatively large value of λ, also the existence of sufficiently diminishing returns to human capital accumulation:

$$\alpha + 3\beta < 1. \tag{32}$$

Second, the proportional difference in average productivity between the two economies - the second term on the right-hand side of equation (31) - has the same expression as in equation (28) and is therefore negative. Last, the proportional difference in average population density across locations - the third term on the right-hand side of equation (31) - can be shown to be twice as large as the expression in equation (29) and is also negative. As in the previous section, both effects disappear as λ becomes larger.

To summarize, sufficient conditions for $\widehat{T}(\tau^f) > 0$ are a relatively large disutility of density (a large value of λ) and sufficiently decreasing returns to human capital accumulation (condition 32).

In order to establish the welfare-maximizing degree of Federal redistribution and to further illustrate the effects discussed in this and in the previous section I now turn to some numerical examples.

6.4 Numerical Examples

I consider a numerical version of the model, keeping in mind that the purpose here is mainly to illustrate its mechanisms rather than to provide a quantitative assessment of the magnitude of the effects. In these examples, I focus on the consequences of varying τ^f for given τ^*. In order to compute the welfare effects I need to assign values to the following parameters $(\beta, \alpha, \rho, \lambda, \tau^*, \sigma_A)$.[41] Notice that the welfare effects of Federal redistribution are independent of the elasticity of labor supply η.[42]

I follow Bénabou (2002), and set the human capital production function parameters to $\alpha = 0.35$ and $\beta = 0.25$.[43] Given these two parameters, $\rho = 0.82$ is set to match the share of K-12 education in aggregate consumption in the year 2000, or 5.1 percent according to the

[41] Treating τ^* as a parameter rather than an endogenous variable requires one to select a specific value for the rank p of the decisive voter at the state-level. Given the calibration strategy outlined in the text, the implied value of p is 0.56. Thus, the decisive voter in each state has more human capital than the median.

[42] The welfare effect of overall redistribution τ^* of course depend on the elasticity of labor supply, as discussed in Section 6.1.

[43] Notice that at these parameter values, the sufficient condition in equation (32) does not hold. However, this is only a sufficient condition for the results of Section 6.3. In fact, the numerical results show a welfare gain according to the measure $\widehat{T}(\tau^f)$, even when the condition in equation (32) is not satisfied.

Economic Report of the President (2000). To pin down τ^*, impose that half of the inequality in real expenditures is within-states and overall inequality equals the Theil index for 2002 (see Table 2):[44]

$$\Delta^2 (1-\tau^*)^2 = \frac{22.8}{1,000},$$

Given an estimate of Δ this equation pins down τ^*. Since Δ is the within-state standard deviation of log income in the model, I compute its data counterpart using the 2000 Census and obtain a value of 1.03. Hence, the implied numerical value of τ^* is 0.85.[45] I set σ_A so that the between-state portion of expenditures inequality in the model is half of the total when $\tau^f = 0$, leading to $\sigma_A = 0.09$. Last, the population mobility parameter λ is set to obtain an elasticity of population to wages (ϑ in the model) equal to 0.5, as estimated by Kennan and Walker (2011). Given the other parameters, this yields a value of $\lambda = 1.78$.

Figure 2 traces out the compensating variation $T(\tau^f)$ as a function of τ^f in the range $[0, \tau^*]$. The figure also represents individually the three components of $T(\tau^f)$ discussed in the previous section.

In this case, the overall welfare effect is positive and the peak level of welfare is reached at τ^f close to 0.61. The magnitude of the welfare gain in this case is about 0.38 percent of consumption. By far, the largest of the three effects discussed in Section 6.2 is the one associated with the change in average log human capital. The welfare-maximizing level of Federal redistribution leads to large shifts in the distribution of expenditures across states. Notice how in this numerical example parameters are set so that the between-state component of expenditures inequality accounts for half of the overall Theil index. When τ^f equals its welfare maximizing value, the between component of inequality is about 8 percent of its value relative to the case $\tau^f = 0$. Thus, the welfare-maximizing Federal redistribution all but eliminates inequality in expenditures among states.

How does a welfare gain of Federal redistribution equal to 0.38 percent of consumption compare with the welfare gains of expenditures redistribution within states? To provide an answer to this question, I compute the welfare gain of within-state redistribution τ^* in the economy with no heterogeneity in productivity across states ($\sigma_A = 0$).[46] The latter can be thought of representing the "standard" model of redistribution studied in the literature (e.g. Bénabou (2002)). In order to compute a numeric value for this welfare measure, I

[44] The Theil index reported in Table 2 has been multiplied by 1,000 for convenience, so I am undoing this transformation here.

[45] Given the parameters β and α and the value of τ^*, the structural parameter σ_ξ must equal 0.95 to guarantee that $\Delta = 1.03$.

[46] The welfare measure is the proportional gain in consumption in the economy with no redistribution ($\tau^* = 0$) that makes an agent indifferent between this economy and an economy with some redistribution ($\tau^* > 0$). The analytical expression for this welfare measure is reported in Appendix E.

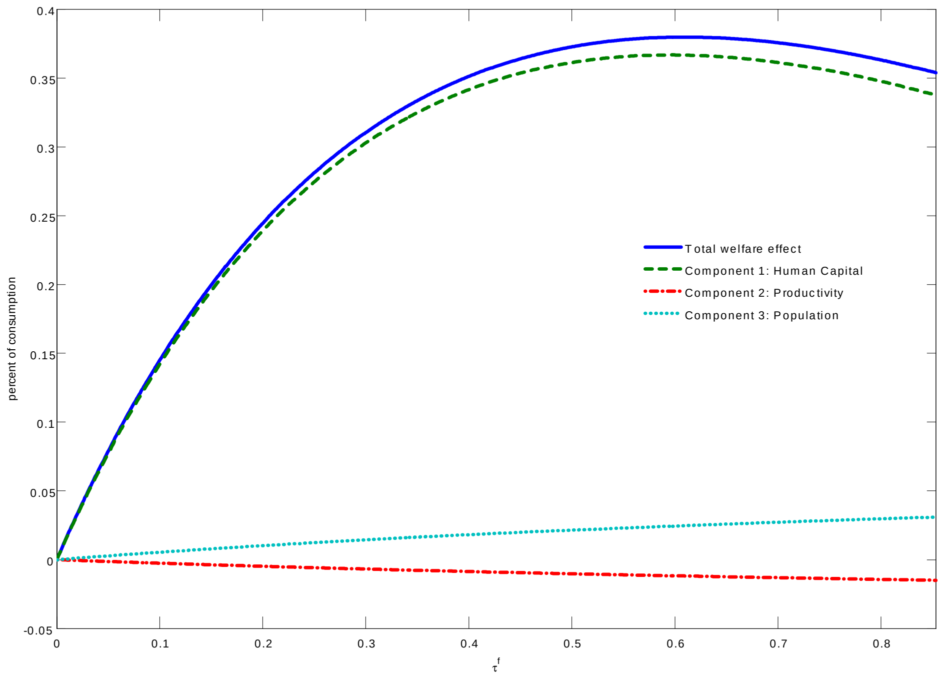

Figure 2: Welfare effects of Federal redistribution and its components.

need to assign a value to the labor supply parameter η. To make results comparable to the literature, I follow Bénabou (2002) and set $\eta = 6$. Given this number and the other calibrated parameters, welfare in the economy with homogeneous locations is maximized at $\tau^* = 0.87$. This is the same figure reported by Bénabou (2002, Table II, page 509) for his economy, providing support for the idea that the version of my model with homogeneous locations is indeed quantitatively comparable to the literature. The welfare gain of within-state redistribution associated with $\tau^* = 0.87$, as measured by the consumption equivalent variation, is equal to 38 percent of consumption, or about one hundred times larger than the number obtained for the welfare gain from optimal Federal redistribution τ^f. The reason for why the gains from Federal redistribution are much smaller than the ones associated with overall redistribution in a one-location version of the model is that, in both cases, welfare gains are proportional to the underlying inequality in education expenditures that redistribution is presumed to reduce. In the one-location version of the model the relevant inequality is represented by the variance σ_ξ^2 of the idiosyncratic human capital shock, while in the heterogeneous-location model the relevant inequality is the variance σ_A^2 of productivity across states. According to my calibration, the variance of the idiosyncratic shock $\sigma_\xi^2 = 0.95^2$ (see footnote 45) is about one hundred times larger than the variance of productivity across states, $\sigma_A^2 = 0.09^2$. This is approximately the same factor by which the welfare gains of

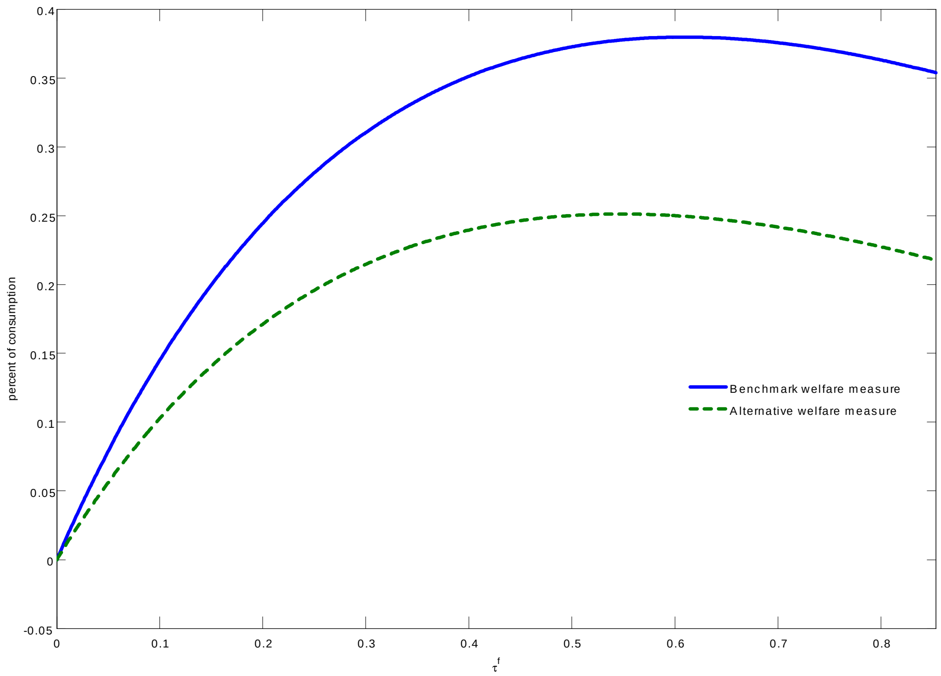

Figure 3: Benchmark and alternative welfare measures.

redistribution differ in the two economies being compared.[47]

Figure 3 compares the welfare measure $T(\tau^f)$ with the alternative $\widehat{T}(\tau^f)$ discussed in Section 6.3 for the same set of parameters. The adoption of $\widehat{T}(\tau^f)$ as a measure of welfare reduces the optimal τ^f to about 0.55 and the welfare gain to 0.25 percent of consumption. The implied between-state inequality in education expenditures is now 11 percent of the benchmark value. Thus, the quantitative results are not very sensitive to the specific welfare index in use.

In the remaining of this section, I evaluate the sensitivity of the results to changes in the degree of labor mobility, as proxied by λ, and in the differences in productivity across states, as captured by σ_A^2.

Consider first variation in the parameter λ. As λ becomes smaller states with higher productivity tend to absorb more population in equilibrium. Hence the net benefits of Federal redistribution decline. Table 5 reports the welfare maximizing value of τ^f and its impact on between-state expenditure inequality as a function of alternative values of the

[47] In this comparison, it is important to keep in mind that inequality in productivity across states is the relevant dimension of inequality for the purpose of Federal redistribution because states fully offset the portion of Federal redistribution that affects individuals within each state. If we imposed $\tau^s = 0$ in all states (no state-level redistribution), then Federal redistribution would produce welfare gains of the same order of magnitude as redistribution by the states.

parameter λ.

Parameter λ	Elasticity pop to wage	Welfare maximizing τ^f	Welfare gain $T(\tau^f)$ (%)	Expenditure inequality btw states relative to $\tau^f = 0$ (%)
∞	0	0.62	0.38	7.73
1.79	1/2	0.61	0.38	8.02
0.89	1	0.60	0.37	8.31
0.09	10	0.50	0.29	14
0.04	20	0.41	0.22	22
0.02	50	0.19	0.07	52

Table 5: Sensitivity analysis of welfare gains from Federal redistribution of education expenditures. Changes in λ.

The results show how at the benchmark value of λ the benefits of Federal redistribution are quantitatively very similar to the ones obtained if the population was completely immobile ($\lambda \to \infty$). As geographic mobility increases (i.e., the parameter λ decreases), the rationale for Federal redistribution declines. Notice, however, how the welfare-maximizing reduction in expenditures inequality between states remains sizeable even at very low values of λ.

Consider now how changes in the cross-sectional variance of log productivity σ_A^2 affect the welfare gains from Federal redistribution. The welfare gains (or losses) increase linearly with σ_A^2 while the optimal degree of Federal redistribution τ^f is independent of σ_A^2 because the latter scales up proportionately both the benefits and costs of Federal redistribution.[48] Thus, if we increase the parameter σ_A from 0.09 to 0.13, the welfare-maximizing τ^f remains the same, while the welfare gains in Table 5 approximately double.

7 Summary and Conclusions

This paper studies the process of human capital accumulation in an heterogeneous agents economy characterized by multiple locations (states) within a federation. Previous literature has mostly focused on the implications of school finance reforms - such as those that have occurred in the U.S. in the last 40 years - involving an increase in states' role at the expense of local funding. This paper takes this analysis further by drawing a distinction between state and Federal financing. This focus is motivated by the evidence that at least half, and

[48] This can be noticed by observing that all the terms on the right-hand side of the formula for the welfare gain in equation (27) are scaled up and down by σ_A^2.

possibly more, of the differences in education spending per student in the U.S. are between, rather than within, states.

On the positive side, in equilibrium, the model generates dispersion in average education spending across states. Consistent with the data, states with higher productivity and income spend more per student, despite geographic mobility of labor. The model also generates dispersion in education expenditures within each state. On the normative side, I show how the model provides support for some degree of Federal redistribution provided that the elasticity of population flows to wage differentials is not too large.

I conclude the paper offering a number of possible extensions and more general comments. In order to keep the model tractable I have abstracted from some potentially important issues. The first one is competition among states for population and human capital in the politico-economic process that determines the extent of state redistribution. The standard argument is that aggressive redistribution leads to a race to the bottom among localities, providing a further argument in favor of a Federal role. Second, while the logarithmic specification of utility keeps the model tractable, it also implies that individuals spend a constant fraction of income on education, independently of the degree of redistribution. Empirical evidence suggests that the demand for education services is relatively inelastic, suggesting that redistributive policies that affect the tax price for education should lead to an increase in effort by richer districts and a decline by poorer ones. The net effect is in principle ambiguous in this context and numerical analysis may be used to quantify it.

The third important issue from which the paper has abstracted has to do with potential benefits from delegating education financing policies to the states. Among those, are heterogeneity of preferences; the value of decentralized experimentation with education standards and curricula, that might be hard to accomplish without independent revenue sources; and potential informational advantages of state-level decision-makers over Federal ones (Oates, 1972). This paper has pointed out some inefficiencies stemming from the link between household income levels and expenditures on education. It it feasible, at least in theory, to design policies that preserve some of the benefits of Federalism mentioned above while reducing these inefficiencies.[49]

Last, an important area of future research is to complement the analysis of the effects of specific Federal policies with research on the *design* of Federal policies with desirable properties. Both this paper and papers by Gordon (2004) and Cascio et al. (2011) have emphasized that Federal financing of education might induce offsetting actions by local and state governments. For example, in my model the states neutralize any attempt by the Federal government to reduce within-state expenditures inequality, while Gordon (2004)

[49] See Feldstein (1975) for an early discussion of this challenge in the context of local and state governments.

shows how local governments in the 1990s reduced their own education tax effort in response to Federal transfers. It would be interesting and useful to study alternative mechanisms by which the Federal government might be able to affect schooling expenditures, as opposed to limiting the analysis to varying parameters within a pre-determined class of policies. An optimal mechanism would have to take into account the various systems of state-level education finance that are currently prevalent in the U.S.

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A School-District Level Data

Table 1 contains statistics and data on current education expenditures from three sources. First, the Gini and Theil coefficients for the years 1972–1992 are taken from Table 2 in Murray et al. (1998). In turn, these indices are based on a sample of about 10,000 unified regular operating school districts from 46 states (districts from Alaska, Hawaii, DC, Montana and Vermont are not in their sample). They drop from their sample districts that, in a given year, either exceed 150 percent of expenditures of the district in the 95th percentile of the expenditures distribution, or that fall short of 50 percent of expenditures of the district in the 5th percentile of the same distribution. The current education expenditures data for school districts are taken from the Census of Governments School System Finance (F-33) File. Corcoran et al. (2003) extend the Murray et al. (1998) data sample and computations of the Gini and Theil indices to the year 1997. The statistics for 1997 in my Table 1 are from Corcoran et al. (2003, Table 1). Finally, I have computed the statistics in my Table 1 for the years 2002, 2007 and 2009 using school district-level current expenditure data. I constructed the sample of school districts using exactly the same criteria as Murray et al. (1998) listed above.

Table 2 reproduces Table 1 as far as nominal expenditures are concerned. The columns titled "Real" contain Gini and Theil indices for the same sample of school districts as the "Nominal" column. In order to compute real expenditures data, I divide the nominal expenditure data on Taylor (2005)'s comparable wage index, which is available at the school district level for a selected number of years. The comparable wage index is a deflator for nominal education expenditures whose purpose is to allow researchers and policymakers to convert nominal spending into a quantity of education services purchased by school districts. Given that a large fraction of current school expenditures go into teachers' salaries, the basic idea behind this index is to use the wages of individuals who are not educators, but are comparable to educators in terms of observable characteristics, to control for differences in the cost of education services.

B Closed-Form Expressions

The expression for Q in equation (18) is:

$$Q = \frac{(1-\alpha)\,\tau^f}{1-\alpha-\beta\,(1-\tau^f)}\left[2\vartheta + \frac{\left(1-\tau^f\right)(\beta+1-\alpha)}{1-\alpha-\beta\,(1-\tau^f)}\right], \tag{33}$$

where ϑ is defined in equation (21). Thus, as claimed in the text, when $\tau^f = 0$, $Q = 0$, and when $\tau^f > 0$ we have $Q > 0$.

The closed-form expression for v is given by:

$$v = (1-\rho)\beta\tau^s\widetilde{m} - \frac{\sigma_A^2}{2}\lambda\vartheta\,(1-\vartheta)\,, \tag{34}$$

where $\widetilde{m}$ is defined after equation (18).

C Version of the Model with Housing

In the version of the model with housing (see e.g. Roback (1982)) the utility function is

$$U = \widehat{\rho}\,(\ln c + \phi \ln x) - \frac{l^\eta}{\eta} + (1-\widehat{\rho})\ln h' \tag{35}$$

where $\widehat{\rho} \in (0,1)\,, \phi > 0$, $\eta > 1$, and housing consumption is denoted by x. The budget constraint of an agent is:

$$y_{ij} = c_{ij} + p_j x_{ij} + z_{ij}$$

where p_j is the rental price of housing in state j. Housing services in state j are produced by combining land, whose supply is normalized to one in each location, and units of the homogeneous final good. Let the production function for housing services in location j be given by:

$$X_j = K_j^\psi$$

with $\psi < 1$. The optimal demand for housing services by household i is given by:

$$x_{ij} = \frac{\phi}{p_j} c_{ij}. \tag{36}$$

The representative firm supplying housing services chooses K to maximize profits:

$$\max_K \left\{ p_j K^\psi - K \right\}$$

leading to the first-order condition:

$$\psi p_j K_j^{\psi-1} = 1.$$

Taking into account the definition of X_j this leads to the following inverse supply function for housing services:

$$p_j = \frac{1}{\psi} X_j^{1/\psi - 1}. \tag{37}$$

Equilibrium in the housing market requires that the supply of housing equals the demand for it. Replacing the latter into equation (37) and solving for p_j yields the following expression for the price of housing as a function of population n_j and average income $\overline{y}_j$ in state j:

$$p_j = \frac{1}{\psi^{\psi}} \left(\frac{\phi \widehat{\rho}}{\widehat{\rho}\,(1+\phi) + (1-\widehat{\rho})\,\beta} n_j \overline{y}_j \right)^{1-\psi}, \tag{38}$$

It is then simple to show that, replacing equations (36) and (38) in the term $\ln x$ in equation (35), yields an indirect utility function that depends negatively on $\ln n_j$. Average income $\overline{y}_j = A_j l \exp\left(m_j + \Delta^2/2\right)$ and so it depends on the same variables that already appear in the indirect utility of the benchmark model (15). Hence, the indirect utility function of the model with housing would depend on the same variables and through the same functional relations (essentially logarithms and summations) as the benchmark indirect utility function.

D Alternative Timing of Voting

In this section I consider the alternative timing assumption whereby voters take into account the distortion to labor supply when choosing τ^s. The objective of a voter with human capital h in choosing τ^s is to maximize:

$$(1-\rho)\beta\tau^s \left[m_j + \Delta^2 \left(1 - \tau^f - \frac{\tau_j^s}{2} \right) - \ln h \right] + \left(\rho + (1-\rho)\beta \left(1 - \tau^f \right) \right) \ln l^* - \frac{(l^*)^{\eta}}{\eta}$$

where the first term is the same as in equation (8) and the second and third ones capture the distortions to labor supply.

The first order condition for τ^s is then:

$$(1-\rho)\beta \left[m_j + \Delta^2 \left(1 - \tau^f - \tau_j^s \right) - \ln h \right] + \frac{(1-\rho)\,\beta\tau^s}{l^*} \frac{\partial l^*}{\partial \tau_j^s} = 0$$

where $\partial l^* / \partial \tau^s < 0$. This means that the benefits of higher redistribution is smaller with this alternative timing than in the version in the main text. The decisive voter has human capital given by equation (9). The equilibrium level of redistribution in all locations is thus implicitly defined by the following equation:

$$(1-\rho)\beta\Delta^2 \left[1 - \tau^f - \tau^s - \frac{\Phi^{-1}(p)}{\Delta} \right] + \frac{(1-\rho)\,\beta\tau^s}{l^*} \frac{\partial l^*}{\partial \tau^s} = 0$$

where l^* is a function of $\left(\tau^f + \tau^s\right)$. Thus, the fact that $\partial l^*/\partial \tau^s < 0$ implies that, even when $p = 1/2$, it must be the case that in equilibrium $\tau^f + \tau^s < 1$.

E Welfare Measure for the Economy with Homogeneous Locations

The welfare for the economy with homogeneous locations ($\sigma_A^2 = 0$) concerning variation in τ^* is $\widetilde{T}$ such that:

$$\begin{aligned} & \rho E\left[\ln c; \tau^*, \sigma_A^2 = 0\right] + (1-\rho) E\left[\ln h; \tau^*, \sigma_A^2 = 0\right] \\ = \; & \rho E\left[\ln c\left(1 + \widetilde{T}\right); \tau^* = 0, \sigma_A^2 = 0\right] + (1-\rho) E\left[\ln h; \tau^* = 0, \sigma_A^2 = 0\right], \end{aligned}$$

where I have taken into account that in this economy $n = 1$ in all locations. After the appropriate substitutions I obtain:

$$\ln\left(1 + \widetilde{T}(\tau^*)\right) = \frac{1}{\rho}\frac{1-\alpha}{1-\alpha-\beta}\ln\frac{l^*(\tau^*)}{l^*(0)} + \frac{\beta}{1-\alpha-\beta}\frac{\sigma_\xi^2}{2}\frac{1-(1-\tau^*)^2}{1-(\alpha+\beta(1-\tau^*))^2},$$

where the ratio of labor supplies in the two economies is:

$$\ln\frac{l^*(\tau^*)}{l^*(0)} = \frac{1}{\eta}\ln\left(\frac{\rho + (1-\rho)\beta(1-\tau^*)}{\rho + (1-\rho)\beta}\right).$$