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Redistribution through education and other transfer mechanisms ☆

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Abstract

Educational subsidies are frequently justified as a method of altering the income distribution. It is thus natural to compare education to other tax-transfer schemes designed to achieve distributional objectives. While equity-efficiency trade-offs are frequently discussed, they are rarely explicitly treated. This paper creates a general equilibrium model of school attendance, labor supply, wage determination, and aggregate production, which is used to compare alternative redistribution devices in terms of both deadweight loss and distributional outcomes. A wage subsidy generally dominates tuition subsidies across a wide range of fundamental parameters for the economy. Both are generally superior to a negative income tax. With externalities in production, however, there is an unambiguous role for governmental subsidy of education, because it both raises GDP and creates a more equal income distribution.

JEL classification: D6; H2; I2

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1. Introduction

Education occupies a central position in the policies of governments around the world and is almost always heavily subsidized. The underlying justification for governmental involvement takes a variety of forms, but increasingly it is suggested that expanded educational investments both strengthen the national economy and improve the societal distribution of income and welfare. Education, for example, had a prominent role in the United State's "War on Poverty," begun in the 1960s and the programs begun then continue through today. And the expansion of public colleges and universities over the past three decades has rested on distributional underpinnings. This paper takes seriously the potential for education to play a role in redistribution, and in that vein considers how well education compares to alternative approaches to redistribution. The ultimate objective is to compare alternative programs in terms of both aggregate output effects and redistributive effects.

By pointing to the high economic returns to additional education, many people readily accept a significant governmental role in the production and financing of education. But of course the appropriateness, or even beneficial influence, of governmental involvement requires more than merely finding high private and social returns to schooling. As a general rule, an active role for government is justified either by some market imperfection or by an alternative objective of government, such as redistributional motives, that extends past simple maximization of aggregate output.

Appeals to externalities such as improving the functioning of democratic government or reducing crime have provided traditional support for government's ensuring free and universal elementary and secondary schools. But such arguments are less convincing when considering governmental investments in higher education. It is difficult to imagine that marginal externalities of this sort are large, or anywhere near the 40 percent of higher education revenues that come from governmental appropriations (National Center for Education Statistics, 2000).[1]

Instead of relying on externality arguments, providing subsidies to higher education, especially through free or reduced tuition programs at public colleges and universities, is more frequently justified either on distributional grounds or on capital market imperfections and the inability to borrow against human capital (e.g., Becker, 1993[1964]; Garratt and Marshall, 1994; Hanushek et al., 2003). Access to higher education is seen as a way of improving the distribution of income—particularly as related to parental income, race, or socioeconomic status. Once put into a distributional context, however, it is natural to compare educational subsidies with alternative ways of distributing income.[2] Education may have unique features, since human capital investments have productive value, but the

[1] An alternative externality argument could also follow from growth effects as highlighted by endogenous growth models. To address these issues, our analysis below considers such production externalities—although this situation clearly stacks the case in favor of educational subsidies because of the potential efficiency gains.

[2] An earlier formulation of this problem can be found in Layard (1979, 1981).

governmental interventions involving taxes to support governmental provision of higher education and price modifications through tuition reductions are still distortionary. Therefore, it is plausible that other redistributional tools could have lower efficiency costs.

Since the act of redistributing resources and income typically will introduce distortions into the economy, no consideration of the redistributive impact of a governmental program is complete without understanding any efficiency costs related to the program. For the most part, analyses of governmental transfer programs are partial equilibrium analyses that assume little aggregate distortion and thus concentrate largely on the impact to the recipients.[3] Throughout the world, however, educational subsidies and other transfer programs are large (Smeeding et al., 1993) and could have a noticeable impact on output and wages in the economy.[4] This paper focuses on just the interaction of aggregate output and distributional outcomes.

The simple general equilibrium model of the economy developed here combines both tax and transfer programs and permits a full comparison of alternative transfer mechanisms. In the basic model, the only role of government is the redistribution of income. It accomplishes this task by raising funds with a (distortionary) linear income tax. It then redistributes income through three canonical transfer programs: lump-sum redistribution, a wage subsidy, or a tuition subsidy to schooling. (When lump-sum spending is combined with the income tax, this transfer device becomes a negative income tax program.) Individuals make both schooling and labor supply decisions. Schooling has productive value, but no externalities are initially considered. In many ways, the education subsidies considered here look like the provision of higher education in the United States—where tuition is heavily subsidized and where there are few supply constraints.

A central methodological consideration is treatment of the trade-off between equity and efficiency. While policy discussions frequently suggest considerations of such a trade-off, it is difficult to find examples of analyses that deal explicitly with both equity and efficiency. Most analyses of public transfer programs discuss only redistribution without mention of any efficiency losses, while other analyses of public programs with explicit outcome objectives discuss efficiency, or cost–benefit

[3] There are a few exceptions, although each focuses on different aspects of the economy than we do. Fair (1971) considers a model of the economy which incorporates the optimal distribution of income into the analysis. Thurow (1971) also highlights individual preferences over the distribution of income. Bishop (1979) compares alternative transfer programs in an aggregate, general equilibrium model. Gramlich and Wolkoff (1979) provide a methodology for assessing the utility gains from transfers but do not consider any general equilibrium impacts. And, Browning (1993) investigates how efficiency losses enter into the calculation of the costs of governmental redistribution.

[4] A number of interesting recent papers have begun to delve into general equilibrium models from different vantage points: school finance arrangements and income distribution—Glomm and Ravikumar (1992), Fernandez and Rogerson (1998), and Benabou (2002); taxes and inequality—Heckman et al. (1998a, b) and Benabou (2002); college finance and distribution—Sheshadri and Yuki (2000) and Caucutt and Kumar (2003); growth and inequality—Leung (1995a), Galor and Moav (2000). They tend, however, to provide assessments of alternative school finance mechanisms without comparisons to other income redistribution devices.

considerations, without any integrated treatment of distributional consequences. The one exception to this dichotomy is abstract analyses of maximizing social welfare functions that can include distributional arguments. But it is generally true that different social welfare functions—that meet standard preference axioms but that allow very different weights for efficiency and equity interests—provide minimal guidance, since they can suggest very different optimal policies depending on the specific functional form.

This analysis focuses directly on the equity-efficiency trade-off in a general equilibrium framework that makes efficiency issues central. Our approach describes the locus of feasible results for each redistributional device in output-distribution space. If any device dominates the others in the sense of permitting greater equity for any given level of output, we know that it will be chosen with any social welfare function (that positively values both output and more equality). Of course, if such universal dominance is not found, choice of the optimal policy and redistributional device will revert to a dependence on the precise social welfare function that is applied.

In our analysis, the exact definition of distributional aspects of the economy deserves consideration in identifying the optimal policy. Specifically, there are two distinct ways of calculating the distributional outcomes of policies: in an ex ante or in an ex post sense. The former, which is calculated before the outcomes of decisions are known, corresponds most closely to an "opportunity" standard, while the latter, which is calculated on outcomes observed after the results of decisions are realized, corresponds more closely to conventional distributional discussions based on current empirical information. In many ways, a criterion based on the ex ante distribution of utility seems to match most distributional discussions best, but it does not permit the empirical verification that considerations of the ex post distribution does. Nonetheless, as we demonstrate below, this distinction does not substantially change the analytical results.

A second dimension of the assessment is the objective of consideration itself. Our analysis quite naturally generates loci of aggregate income and its distribution under different policies. Yet, when economic behavior affect labor-leisure choices directly—as it does in our analysis—ignoring the utility gains that come with more leisure potentially leaves out a substantial portion of the economic behavior. We concentrate on utility comparisons for our analysis.

In our base case, a wage subsidy can obtain any feasible level of aggregate utility along with more equality in the ex ante distribution of utility than is possible with the alternative subsidy schemes. This result does not prove to be sensitive to the underlying distribution of abilities in the economy or to reasonably wide variation in the fundamental parameters of the economy. On the other hand, depending on the underlying distribution of abilities in the economy, education subsidies can dominate when distributional calculations are based on ex post outcomes. Further, with the introduction of production externalities, the use of education subsidies becomes an efficient approach over most levels of governmental intervention, but this result is not particularly surprising because of the efficiency value of counteracting the externality.

2. The basic model

The model focuses on the role of schooling and transfers in an economy where society cares about both aggregate consumption and the distribution of individual welfare. The basic structure revolves around a one-period general equilibrium model of a competitive economy. The government provides schools and operates transfer programs, all of which must be paid for by either tuition or proportional taxes on income that are sufficient to balance the budget. Individuals make optimizing choices about school attendance and the labor-leisure trade-off based upon school costs and expected wages. The schooling decision involves uncertainty because individuals with different ability have different chances of successfully completing schooling. Because taxes can be raised only through distortionary taxes, the effects of alternative transfer policies on either the performance of the economy or the distribution of welfare are not obvious.

2.1. Agent behavior

The model considers an economy with an uncountably infinite number of types of agents with differing ability, a. Ability has no direct labor market payoff but instead indicates 'educational ability', the chance of succeeding in schooling; completing school, however, does have a direct labor market payoff.[5] For simplicity, the population of agents is normalized to unity and the index of ability, a, is distributed on the interval $[0, 1]$ according to the density function $f(a)$, $\int_0^1 f(a)\,\mathrm{d}a = 1$. (More details on this will appear in later sections). An agent of type a faces the fully known probability $P_a = 1 - a$ of being successful in school. (Note that higher a means a lower probability of success). Ex post there are only two skill levels of workers in the economy—educated workers who successfully completed school and uneducated workers who either did not attend school or did not successfully complete school. Each agent chooses at the beginning of his or her life whether to go to school or not, based on school tuition, t, and the expected wages from school attendance. In this one-period model, schooling is instantaneous, and there is no opportunity cost of attempting schooling, although there is the uncertainty of school completion. Agents also have perfect knowledge of the equilibrium wage structure: successfully completing school earns a wage of w^{e} and not successfully completing school earns a wage of w^{u}. Given a proportional income tax rate, $\tau \in [0, 1]$, and possible direct government transfers, m (described below), all agents maximize a utility function:

$$U(c, l) = c - \varepsilon \frac{(L^i)^{1+v}}{1+v}$$

[5] Partial completion of schooling has been shown to have labor market returns, e.g., Kane and Rouse (1995). Cognitive skills are also rewarded independent of the quantity of schooling; see Hanushek (2002). We employ this simplification for computational reasons, although as discussed below it can be relaxed within the spirit of the model.

subject to a budget constraint:

$$c \leqslant w^i L^i (1-\tau) + m - tI,$$

where c is consumption, L^i is labor supply, v and ε $(v, \varepsilon > 0)$ are parameters related to the disutility of labor, $i = \mathrm{e}$ (educated) or u (uneducated), m is any lump-sum cash transfer from government, τ is the tax rate, t is the tuition fee, and I is an indicator function that takes on the value 1 if the agent attends school and 0 otherwise.[6] Since the utility function is semi-linear, it allows us to focus on the effects of redistribution without the presence of any insurance incentives on the part of the agent.[7]

The optimal labor supply choice of the individual, L^i, is simply a function of the wage rate as:

$$L^i = \left(\frac{(1-\tau)w^i}{\varepsilon}\right)^{1/v}.$$

Labor supply is increasing in wages, and backward bending behavior of the supply function is ruled out. With $v < 1$, the labor supply function is convex; with $v > 1$, the labor supply function is concave. The marginal utility of leisure is independent of the lump-sum transfer m; that is, direct transfers do not affect the supply of labor.

The schooling decision can be understood by comparing the expected utility obtained from enrolling in school with the utility from not attending school but instead entering the labor market. Individuals attending school either successfully finish and become educated labor (e) or fail and are relegated to being uneducated labor (u), the same status as not attending school at all. The utility of an agent who is successful in school (U^{e}) is,

$$U^{\mathrm{e}} = [w^{\mathrm{e}}(1-\tau)]^{(1+v)/v} \varepsilon^{-1/v} \left(\frac{v}{1+v}\right) + m - t$$

while the utility of an agent who goes to school but fails (U^{f}) is,

$$U^{\mathrm{f}} = [w^{\mathrm{u}}(1-\tau)]^{(1+v)/v} \varepsilon^{-1/v} \left(\frac{v}{1+v}\right) + m - t.$$

The indirect utility of agents will be convex in (after-tax) wages as long as $(1+v)/v > 1$, but it is linear in transfers. This implies that agents will not have any incentive to buy insurance against school failure. The expected utility of an agent of ability type a who attends school ($\mathrm{E}U^{\mathrm{s}}$) is just the appropriately weighted average of these utilities:

$$\mathrm{E}U^{\mathrm{s}} = P_a U^{\mathrm{e}} + (1 - P_a) U^{\mathrm{f}}$$

which gives

$$\mathrm{E}U^{\mathrm{s}} = m - t + \varepsilon^{-1/v} \left(\frac{v}{1+v}\right) [(1-a)(w^{\mathrm{e}})^{(1+v)/v} + a(w^{\mathrm{u}})^{(1+v)/v}](1-\tau)^{(1+v)/v}.$$

[6] Among others, Greenwood et al. (1988), Rebelo and Carlos (1995), and Gomes et al. (1997) use this utility function in real business cycle applications. In an international context, it can generate realistic cross country correlations in consumption; see Devereaux et al. (1992) and Leung (1995b).

[7] The model can be easily extended to the case with a concave utility function.

The expected utility of uneducated agent who never attend school is

$$\mathrm{E}U^{\mathrm{n}} = [w^{\mathrm{u}}(1-\tau)]^{(1+v)/v}\varepsilon^{-1/v}\left(\frac{v}{1+v}\right) + m.$$

Note that the lowest realized utility in the economy is obtained by failures, since failure leaves an agent with the skills of an uneducated person but with having paid tuition in order to attempt schooling. Thus, those choosing not to attend school have certain utility of $U^n = U^{\mathrm{f}} + t$. (Agents attending school are not allowed to default on tuition.)

The agent goes to school if $\mathrm{E}U^{\mathrm{s}} \geqslant \mathrm{E}U^{\mathrm{u}}$. Thus, from the previous comparisons,

$$\begin{aligned}\mathrm{E}U^{\mathrm{s}} \geqslant \mathrm{E}U^{\mathrm{u}} &\Leftrightarrow P_a U^{\mathrm{e}} + (1-P_a)U^{\mathrm{f}} \geqslant U^{\mathrm{f}} + t \\ &\Leftrightarrow (1-a) \geqslant \frac{t}{U^{\mathrm{e}} - U^{\mathrm{f}}}\end{aligned}$$

which yields a unique ability cutoff, which is also equivalent to the enrollment ratio,

$$a^* = 1 - \frac{t}{\varepsilon^{-1/v}\left(\frac{v}{1+v}\right)(1-\tau)^{(1+v)/v}[(w^{\mathrm{e}})^{(1+v)/v} - (w^{\mathrm{u}})^{(1+v)/v}]}. \tag{1}$$

Since there is a continuum of agents, the measure of the population who choose not to go to school will be $1 - \int_0^{a^*} f(a)\,\mathrm{d}a$. The measure who go to school and succeed is $N^{\mathrm{e}} = \int_0^{a^*}(1-a)f(a)\,\mathrm{d}a$ where $(1-a)$ is again the probability of success. The uneducated population, N^{u}, is the sum of the measure who go to school and fail, N^{f}, and those who do not go to school at all, N^{n}, $N^{\mathrm{u}} = 1 - N^{\mathrm{e}}$.

Given this basic structure, a first-best approach would be to tax ability, a. Because ability is exogenously set for each individual, taxing it would not distort education or labor supply decisions. Thus, any redistribution could be accomplished without the efficiency loss that accompanies the income tax considered here. At the same time, it is reasonable to presume that the social planner cannot observe an individual's true ability and therefore cannot use ability taxes.

2.2. Wage determination

The economy has only two types of workers in the economy: those who have successfully completed school and those who have not.[8] In order to determine wages, it is assumed that all agents have access to an aggregate CES production function:

$$Y = A[\xi(E^{\mathrm{e}})^\rho + (1-\xi)(E^{\mathrm{u}})^\rho]^{1/\rho}$$

where $E^{\mathrm{e}} = L^{\mathrm{e}}N^{\mathrm{ew}}$ is the effective units of educated labor, N^{ew} is the amount of successfully educated agents who also participate in goods production, and $E^{\mathrm{u}} = L^{\mathrm{u}}N^{\mathrm{u}}$ is the effective units of uneducated labor taking into account labor supply of each type of worker.[9] With an underlying competitive economy, wages are simply

[8] This structure of wages is convenient, because it allows for direct calculation of the wages facing individuals. We consider the restrictiveness of this below.

[9] As discussed below, N^{ew} recognizes that educated workers are also needed to teach.

the marginal product for each type of worker:

$$w^{e} = A\xi\left[\xi + (1-\xi)\left(\frac{E^{u}}{E^{e}}\right)^{\rho}\right]^{(1-\rho)/\rho}$$

$$w^{u} = A(1-\xi)\left[\xi\left(\frac{E^{e}}{E^{u}}\right)^{\rho} + (1-\xi)\right]^{(1-\rho)/\rho}.$$

The degree of substitution between factors is defined by the parameter ρ. When $\rho = 0$, this becomes the Cobb–Douglas case. When $\rho = 1$, E^{e} and E^{u} are perfect substitutes, and when $\rho \to -\infty$ factors are perfect complements and the production function is Leontief. The elasticity of substitution is $\sigma = 1/(1-\rho)$.

2.3. Government transfers and budget

This model abstracts from how the composition of government expenditures is determined and ignores any role of government other than the redistribution of income and welfare. The government must maintain a balanced budget and is restricted to the use of a proportional income tax to raise revenues. The level and form of this budget is determined by the type of redistribution. Three redistribution schemes are considered: tuition subsidies for education, a negative income tax, and a wage subsidy.

2.3.1. Education subsidies

A significant portion of the discussion of higher education finance has concentrated on intergenerational equity and access. For example, Hansen and Weisbrod (1969) suggested that the implicit subsidies in the California public higher education system were skewed toward the wealthy; McPherson and Schapiro (1991), in their broad evaluation of higher education finance, focus on how public tuition subsidies interact with parental incomes. We on the other hand do not consider any intergenerational effects but instead ask the more fundamental question, 'What are the redistributive effects of education subsidies compared to no governmental intervention or to alternative redistributional programs?'

With education subsidies, the government taxes income at rate τ and offers education at a subsidized tuition t, which is set by policy to be less than the cost of education per student, g (determined below). Since the population in the economy is normalized to 1, the budget constraint facing the government simply equates total expenditure on schools to tuition and tax payments:

$$N^{r}g = N^{r}t + \tau[w^{e}N^{e}L^{e} + w^{u}N^{u}L^{u}], \tag{2}$$

where $N^{r} = \int_{0}^{a^{*}} f(a)\,\mathrm{d}a$ is the equilibrium enrollment. For individual agents in this economy, the government provides no cash transfers, so $m = 0$, but the tuition faced by anybody attending school is less than its production costs.

2.3.2. Negative income tax (NIT)

Reacting in part to the then-existent high marginal tax rates on welfare and transfers, Friedman (1962) and others have proposed transfers to the low income population through a negative income tax. With redistribution through a negative income tax (NIT), all individuals in society receive a lump-sum transfer m which acts as the guaranteed income of an agent with no other income. Labor income is then taxed (or the transfer is reduced by some portion of labor income), but at a rate below 100 percent. This vision of a fundamentally different transfer mechanism than existing welfare programs led, among other things, to a series of random-assignment experiments designed to evaluate programmatic effects, although the clear focus was on changes in labor supply behavior (see Munnell, 1986).

The combination of a linear income tax and lump-sum transfers m assumed here is a special case of the NIT. Again, with the normalization of the population to 1, the government budget constraint is

$$m = \tau[w^{\mathrm{e}}N^{\mathrm{e}}L^{\mathrm{e}} + w^{\mathrm{u}}N^{\mathrm{u}}L^{\mathrm{u}}]. \tag{3}$$

While some NIT schemes propose different tax rates above and below break-even level for receiving positive net subsidies, our analysis considers a single marginal tax rate, τ. Since all workers pay a proportional income tax, individual income is subsidized when $m > \tau w^i L^i$ and taxed otherwise. Because of the special nature of this economy with just two different wage rates, the more educated cannot receive a net subsidy. In this case, education is not subsidized (i.e., $g = t$), which is equivalent to schools being provided privately.

2.3.3. Wage subsidy

A final alternative is direct subsidization of the wages of the uneducated. Wage subsidies have been advocated by economists because of the ability to target them on identified populations. Various temporary and permanent forms of wage subsidies have been employed in the United States and in OECD countries, but their effectiveness is not fully understood (see Katz, 1998). Much of the attention and discussion of currently available subsidies focuses on the employment effects, but here we focus entirely on the income redistributions aspects.

In our implementation, a tax τ^{e} is levied on educated agents who earn w^{e}, while the uneducated receive a proportional wage subsidy of τ^{u} on their wages of w^{u}. In other words transfers in terms of wage supplements go directly to those who fail and those who do not go to school. The government budget constraint is thus:

$$\tau^{\mathrm{e}}w^{\mathrm{e}}N^{\mathrm{e}}L^{\mathrm{e}} = \tau^{\mathrm{u}}w^{\mathrm{u}}N^{\mathrm{u}}L^{\mathrm{u}}. \tag{4}$$

Note that the budget constraint facing the individual agents is also altered to reflect the different tax (subsidy) rates on income for the educated and uneducated workers. The labor supply of the educated and uneducated agents become:

$$L^{\mathrm{e}} = \left(\frac{(1-\tau^{\mathrm{e}})w^{\mathrm{e}}}{\varepsilon}\right)^{1/v}$$

$$L^{\mathrm{u}} = \left(\frac{(1+\tau^{\mathrm{u}})w^{\mathrm{u}}}{\varepsilon}\right)^{1/v}.$$

The modified school selection constraint is

$$a^{*} = 1 - \frac{t}{\varepsilon^{-1/v}\left(\frac{v}{1+v}\right)[(1-\tau^{\mathrm{e}})^{(1+v)/v}(w^{\mathrm{e}})^{(1+v)/v} - (1+\tau^{\mathrm{u}})^{(1+v)/v}(w^{\mathrm{u}})^{(1+v)/v}]}. \tag{5}$$

In addition, it must be true in equilibrium that educated agents earn more than uneducated agents, i.e.,

$$w^{\mathrm{e}}L^{\mathrm{e}}(1-\tau^{\mathrm{e}}) > w^{\mathrm{u}}L^{\mathrm{u}}(1+\tau^{\mathrm{u}}). \tag{6}$$

Government expenditures, thus, consist entirely of work subsidies.

The alternative transfer schemes considered here operate in very different ways. The wage subsidy is in some sense the most targeted of the three, because only those succeeding in school pay taxes and only those failing in school or never attending receive the transfer. For the other two subsidies, taxes are proportionate to the realized wages and the chosen labor supply, but the transfers are more diffuse. With the education subsidy, all people attending school (regardless of success) receive the transfer. For the NIT, transfers benefit everyone equally.

2.4. School costs (g)

The social cost of education has been treated as a fixed material cost with no direct consideration of the opportunity cost of human capital employed by the education sector and unavailable for direct production. Clearly, however, the largest element of the production cost of schools is skilled labor, making it appropriate to consider how school costs vary with the wage rates and demands for schooling that are central to this analysis.

The simplest approach for defining school costs assumes that it takes b teaching hours to educate a student, whether he or she will graduate or not. Further, it is assumed that a teacher can only teach n_b students simultaneously (i.e., schooling is produced by a simple fixed coefficient technology). Underlying this development is an implicit perspective that there is no choice over quality of schooling and that all educated workers are equally productive in teaching or in goods production. In equilibrium, all skilled workers must receive the same utility from teaching or from goods production. Thus, the teacher is only willing to work the same amount of time as any skilled worker is willing to work L^{e}, and they also face the same tax rate as other educated workers.

For the model economy with a population equal to unity and with an equilibrium enrollment ratio of N^{e}, the number of teachers demanded is $N^{t} \equiv (N^{\mathrm{e}}b)/(n_b L^{\mathrm{e}})$, which is the total teaching hours needed divided by the number of student classroom hours each teacher can provide.[10] Hence, the teacher–student ratio in this model is $N^t/N^e = b/(n_b \cdot L^e)$, which is endogenous because L^e is endogenous. It is also obvious that we only need to consider the ratio of the parameters b/n_b, rather than their levels separately.

Because some educated citizens are needed to teach, we have to modify the consideration of workers in the economy. Specifically, we have $N^e = N^{ew} + N^t$ rather than N^e in (2)–(4). The total " number", or measure, of educated workers for goods production N^{ew} is equal to the total number of successful students N^e, net of the number of teachers N^t, or $N^{ew} = N^e - N^t$. We consider only cases where N^{ew} is positive. Since only workers directly contribute to goods production, the social cost of education (g) is measured by the working hours of the teachers times the wage rate of educated workers.[11]

3. Measuring performance

Our criteria for performance of the economy consider both the aggregate output and resulting utility of individuals and the distribution of individual welfare. Most other analyses of transfers concentrate on one or the other dimensions of outcomes without focusing on their interaction.

Aggregate distributional issues are seldom explicitly considered, but there are several consistent ways to formulate the problem to incorporate such distribution. For example, if distributional elements enter each individual's utility function, distribution would automatically be taken care of whenever social utility is calculated as the aggregation of individual welfare. Alternatively, society's concerns about distributional issues could be introduced directly at the level of the social welfare function—by explicitly identifying weights on distributional outcomes.

We follow a different approach. For each tax rate and distributional mechanism we trace out the feasible surface for combinations of aggregate outcomes and the distribution of welfare. This equity-efficiency locus then permits a social planner to

[10] Notice this formulation implicitly assumes that the teachers themselves need to be students first. This calculation is somewhat awkward in a static model but understandable if the static model is perceived as being a steady state of a dynamic economy.

[11] The formulation with endogenous schooling costs yields some sharply different conclusions than a formulation with fixed schooling costs. For example, with general productivity improvements, wages of all types of workers will increase proportionally. If the (social) cost of education is exogenous, the school enrollment ratio (a^*) unambiguously increases, because the enrollment ratio will depend on the relative level of the exogenous cost of education to the level of productivity. However, if the social cost of education is endogenous, an increase in the skilled/educated worker's wage also increases the opportunity cost of being a teacher. In fact, under the particular formulation employed here, the level of productivity will have no effect on the equilibrium enrollment ratio. With endogenous school costs, the model also generates the prediction that, as the working hours of skilled workers decrease, the teacher–student ratio will increase. This seems consistent with the historical experience internationally, although similar results could be generated by other models of schooling demand.

Formally, $g = (\text{Total wage bill for teachers})/(\text{Total number of students}) = (N^t * L^e * w^e)/a^* = (b/n_b) * w^e$.

maximize overall welfare by selecting both a transfer mechanism and a size of government. Even within this analytical framework, however, a variety of natural alternatives exist.

Within our framework, it is most natural to describe both the aggregate performance of the economy and the distribution of welfare in terms of individual utilities. Not only does the underlying set of preferences drive individual investment and work behavior but it also provides a direct indication of the benefits that individuals derive from their labor leisure choices. Nonetheless, it is also easy to contrast these outcomes with the equilibrium income generated by the model. Here, we describe just the utility calculations. Additionally, the development focuses on the computations for education subsidies or a negative income tax. The straightforward modification for the multiple tax rates in the wage subsidy case is not explicitly described but is easy to derive.

3.1. Aggregate expected utility (AEU)

We consider a social planner who maximizes the sum of the expect utility levels of all agents, $S(\tau, t)$. This simple utilitarian welfare function, which aggregates the utility of agents who are successful in school, who fail and become uneducated, and who do not go to school at all, is simply:

$$\begin{aligned} S(\tau, t) &= \int_0^{a^*} [(1-a)U^{\mathrm{e}} + aU^{\mathrm{f}}] f(a)\,\mathrm{d}a + \int_{a^*}^1 U^{\mathrm{n}} f(a)\,\mathrm{d}a \\ &= U^{\mathrm{e}}N^{\mathrm{e}} + U^{\mathrm{f}}N^{\mathrm{f}} + U^{\mathrm{n}}N^{\mathrm{n}}, \end{aligned}$$

where a^* is the ability of the marginal student enrolled in college, U^{e} is the utility of successful agents, U^{f} is the expected utility of those who fail, and U^{n} is that for agents who do not go to school at all.[12]

In an economy with education subsidies, the planner maximizes this function subject to Eqs. (1) and (2), while in the economy with a negative income tax (lump-sum cash transfers), the planner maximizes $S(\tau, t)$ subject to (1) and (3) since agents bear all the costs of education. In the case of wage subsidy, the planner maximizes social welfare subject to (5) and (4).

3.2. Measurement of inequality

The effects of the redistribution schemes can be viewed in two separate ways—ex ante and ex post—with resulting differences in interpretation. The ex ante calculations can be directly interpreted as the degree of equality of opportunity faced by the population. The ex post calculation on the other hand indicates the degree of contemporaneous inequality and is, in a political economy sense, likely to

[12] Note that at this point there is no need to distinguish between teachers and educated workers involved in production, since they must have the same utility. The weights in S reflect the total number of agents successfully completing school.

be very relevant for policy decisions about redistribution. In our simplified economy, alternative ways of aggregating the utility distribution make little difference, and therefore the Gini coefficient is selected as the summary measure.[13]

The computation with either after-tax utility or income levels is particularly straightforward in the ex post problem. There are three income classes in the economy. The highest wage earners are those who are successful in schooling with a net income of $(1-\tau)w^{e}L^{e}-t+m$. The second highest wage earners are those who do not go to school and who have a net income of $(1-\tau)w^{u}L^{u}+m$, while the poorest are those who fail in school and have a net income lower by the amount of tuition paid, $(1-\tau)w^{u}L^{u}-t+m$. The discrete nature of the underlying incomes and utilities implies that the Lorenz curve (relating the cumulative population distribution to the cumulative income distribution) has three linear segments whose length reflects the proportions of the population in each group. The Gini coefficient is easily calculated from the area between the Lorenz curve and the 45° line representing an equal income (or utility) distribution. The larger the area, the more inequality that exists, and the larger the value of the Gini coefficient.

The nature of the ex post distribution also points out the conceptual superiority of the ex ante calculations. The people who try school but fail clearly have a higher expected utility at the time of the decision—otherwise they would not have attended school. While the realized outcome may differ, they are better off than those not attending in the sense that they have better opportunities. The ex ante calculations do vary directly with ability level. For low ability people (who do not attempt further schooling), ex ante and ex post utility are the same. People with greater ability (who attempt schooling) will always have ex ante utility at least as high as these low income people. In fact, even among those who enroll in colleges, ex ante utility rises with ability as the probability of successfully completing schooling rises with ability. In the computations, the Lorenz curve for ex ante utility is approximated through discretization.

4. Base case outcomes

The intuition behind the mechanics of the model is as follows: Wages between educated and uneducated workers are unequal due to a skill premium arising from successfully completing schooling. Wages are determined by the marginal products derived from an aggregate production function. Government's only function is redistributing income, which is accomplished by first raising revenues with a distortionary tax that directly affects labor–leisure choices. The form of subsidy employed has direct implications for the amount of schooling attempted and completed and thus for wages in the economy. The feedback through distorted decisions has implications for both aggregate outcomes and the distribution of welfare.

[13] See Lambert (1990) and Cowell (2000) for more details.

Comparisons among the alternative policy regimes requires fixing a number of key parameters and underlying distributions. Unfortunately, the key parameters have not been estimated very precisely. We begin with a base case benchmarked to prevailing estimates of the central elasticity parameters. Subsequent sections investigate the sensitivity of the results both to parameter choices and to more fundamental specification issues including the underlying ability distribution and the presence of growth externalities.

4.1. Fundamental parameter values

The decision of parameter values begins with the preference side. The key elements affecting individual choice are the underlying elasticity of labor supply ($1/v$) and the elasticity of substitution between educated and uneducated labor ($\sigma = 1/(1-\rho)$). Despite considerable empirical analysis employing both experimental and econometric approaches, a surprisingly wide range of estimates for labor supply elasticities exists (Pencavel, 1986; Killingsworth and Heckman, 1986; Blundell and MaCurdy, 1999). As a base case, we use an uncompensated wage elasticity of 1/3, which falls between the (generally lower) elasticity estimates for males and the (generally higher) estimates for married females (Blundell and MaCurdy, 1999).

The substitution between different classes of labor has received less attention. An early estimate by Johnson (1970) places the elasticity of substitution between college and high school workers at 1.3, although sensitivity analysis yields a very broad range. Katz and Murphy (1992) provide a series of alternative estimates that depend on the time series of relative demand shifts, but their point estimate in direct estimation is 1.41. Katz and Autor (1999) review and evaluate alternative estimation approaches and results and show a considerably larger range of estimates. Our base case estimates use $\sigma = 1.3$.

Finally, in terms of key assumptions, we begin with a uniform distribution of abilities (symmetric around 0.5). (The details can be found in the appendix). Even though it is common for estimates of IQ or other measures of ability to be approximately normally distributed, we know of no analysis that addresses the functional form for scholastic ability—the ability to complete schooling—as used here. As with the other key parameters, however, we subsequently investigate the sensitivity of the results to this distributional specification.[14]

[14] The rest of the base calibration is as follows. We set ξ to be 0.5 so that the wage ratio between skilled and unskilled worker with no governmental intervention is approximately 1.4, i.e., $w^e/w^u \approx 1.4$. Notice also that under the current formulation, the tuition–skilled worker wage ratio is related to the zero-tax teacher–student ratio, $t/w^e = g/w^e = b/n^b$. We set b/n^b equals to 0.05, which is close to the empirical calculation of t/w^e. Lastly, we set the productivity parameter A in the production function to be 0.4 so that the equilibrium enrollment ratio with zero tax and zero subsidy is about 60%. There does not exist a reliable estimate for the scale parameter in the labor supply function, ε, although this is not a key parameter for our analysis. In the benchmark case, ε is set to 3 so that the working hours for both educated and uneducated workers are in between 30 and 40 percent of their total time endowment.

Table 1
Distribution of school attendance and success by subsidy scheme and tax rate for baseline equilibrium (proportions of population): E, education subsidy; W, wage subsidy; N, negative income tax

Tax rate (τ)	School successes			Nonattendees			School failures		
	E	W	N	E	W	N	E	W	N
0.00	0.41	0.41	0.41	0.43	0.43	0.43	0.16	0.16	0.16
0.03	0.44	0.39	0.40	0.36	0.46	0.44	0.21	0.15	0.16
0.06	0.46	0.38	0.40	0.28	0.49	0.45	0.26	0.13	0.15
0.09	0.48	0.36	0.40	0.18	0.52	0.45	0.34	0.11	0.15
0.12	0.50	0.35	0.39	0.09	0.55	0.46	0.41	0.10	0.14

4.2. Base results

With the balanced governmental budget, the tax rate simply indexes the size of each program. Table 1 shows how the different subsidy schemes promote very different patterns of attendance in school. With no taxes or transfers (i.e., the no government case), 41 percent of the population attends school and successfully completes, another 16 percent attends school but fail, and the remaining 43 percent never attends. Given the structure of the economy, all of the people attending school have higher ability than the most able person not attending school, but the failed and successful groups will each have people of overlapping ability. As the tax rate and subsidy increase, the programs have very different attendance patterns.[15] With larger education subsidies, the net tuition to the student falls, and a greater proportion of students attends school. The largest impact of this, however, is on the failure rate. While successful completers go from 41 percent of the population in the no subsidy case to 50 percent in the case of a 12 percent tax to support education, the proportion attending but failing school rises from 16 percent to 41 percent. This response reflects the high levels of tuition subsidy. At a 6 percent tax rate, tuition to students is only 45 percent of school costs; at a 12 percent tax rate, tuition is just 10 percent of school costs.[16] The school attendance behavior is always individually optimal given the tuition costs and wage structure that results, but many more now fall into the lowest realized utility group (the failed students).

The pattern is very different for the two other subsidy schemes. For each, increasing levels of subsidy lead to lower school attendance and a smaller educated work force, with the declines being more dramatic for the direct wage subsidy. Because the earnings disadvantage of not being educated are leveled out, high wage subsidies work against investment in schooling and lead to substantial changes in attendance.

[15] Our simulations have tax rates for schooling going from 0 to 12 percent (the point where virtually everybody attends). This upper bound is obviously far beyond current expenditures on college.

[16] The cost of schooling does decline slightly with higher subsidies for tuition because the wages of educated workers and thus teachers are driven down, making schooling cheaper given the linear cost function. But the effects of the schooling cost decline are not central to the results.

Table 2
Relative wages of educated and uneducated workers by subsidy scheme and tax rate for baseline equilibrium

Tax rate (τ)	Education subsidy	Wage subsidy	Negative income tax
0.00	1.40	1.40	1.40
0.03	1.32	1.47	1.41
0.06	1.25	1.54	1.43
0.09	1.20	1.62	1.44
0.12	1.18	1.71	1.46

The distortions in the economy introduced by the taxes and subsidies have direct implications for wage distributions in the economy. Table 2 shows the relative wages of educated to uneducated workers. In the competitive economy with no government ($\tau = 0$), educated workers have gross wage rates that are 40 percent above those of uneducated workers. Education subsidies induce more people to go to school, and the increased proportion of successfully educated workers squeezes their relative wages—with the wage premium for college educated workers falling below 20 percent. The other two subsidy schemes, however, work in just the opposite direction, with the most dramatic impact coming for the wage subsidy where the relative earnings of the educated grow to 1.71 with a 12 percent tax rate.

A typical distributional analysis might well stop with these descriptive statistics, but these outcomes do not show the complete picture of the effects on the economy. First, they neglect any consideration of how the distortions influence aggregate production and welfare. Second, they must be combined with the transfer programs in order to understand the full impact on individual welfare, since the pre-tax wages and outcomes ignore the direct transfers. Third, at any tax rate, the different subsidy schemes introduce different amounts of distortion into the economy, implying that better comparisons would involve subsidy schemes at levels of equal aggregate distortion.

Fig. 1 provides a direct comparison of each of the subsidy schemes in terms of their effects on aggregate expected utility and on the ex ante distribution of welfare. This figure highlights the trade-off of efficiency—measured by losses in AEU—and of equity—measured by 1-Gini defined in terms of ex ante utility. Fig. 1 plots each of the subsidies for tax rates between zero to 12 percent (in increments of 0.5 percent). The competitive economy with a zero tax rate yields the largest aggregate utility, and increases in the tax rate decrease aggregate utility in each of the subsidy schemes. But, with higher taxes more redistribution occurs, and the distribution of utility becomes more equal (as seen by increasing values of 1-Gini). Thus, if society values both aggregate output and more equality, movement up and to the right represents improvement in overall societal welfare.

Fig. 1, providing the locus of feasible aggregate output (in utility terms) and opportunity distributions under each scheme, indicates that a wage subsidy is a superior subsidy scheme to both education tuition subsidies and a negative income tax. Under any social welfare function, the wage subsidy can provide higher welfare,

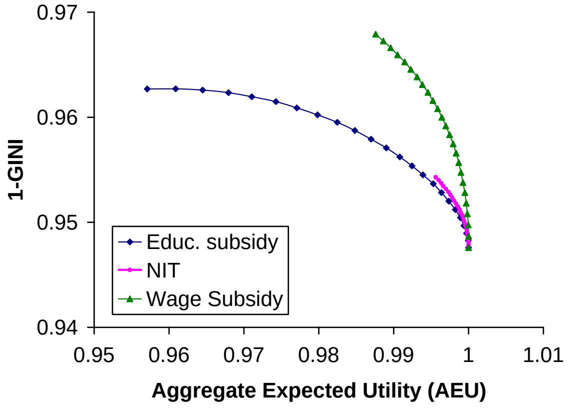

Fig. 1. Aggregate expected utility and ex ante distribution of utility (base case).

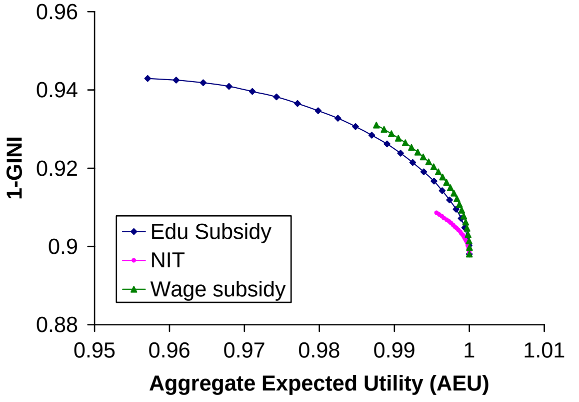

Fig. 2. Aggregate expected utility and ex post distribution of utility (base case).

because it can achieve any feasible level of aggregate expected utility with more equality than either of other two subsidy schemes. Moreover, with educational subsidies, attempting to achieve higher levels of redistribution becomes increasingly costly in terms of efficiency losses to the economy as is seen from the losses in aggregate utility.

As noted, however, other measures of equity are possible, and Fig. 2 displays the same trade-offs for the ex post calculations of the utility distribution. Wage subsidies still dominate the other two schemes, but the most obvious comparison of these distributions is that the alternative come noticeably closer together in their aggregate output and distributional effects. Further, educational subsidies move ahead of the negative income tax in the ex post calculations that focus not on opportunities but on realized outcomes. In an ex ante comparison, people of higher ability always are better off than those with lower abilities, because they have increased probabilities of successfully completing schooling and thereby obtaining higher wages. In an ex post sense, however, this is not the case because all failures begin with higher ability than the group that did not attempt schooling. Thus, not only does the amount of redistribution change but the character of the subsidies also changes.

The figures vividly illustrate one additional important feature: the tax rate is a very imperfect index of the impact of governmental interventions. Importantly, the varying distributional schemes have very different distortionary effects at any given tax rate, so the typical practice of comparing the redistribution from alternative transfer mechanisms by choosing a common tax rate will yield very misleading comparisons. At a 12 percent tax rate, the economy employing a negative income tax loses only 0.4 percent of aggregate expected utility, compared to losses of 1.2 percent for the wage subsidy, and 5.2 percent for the education subsidy. Put the other way, an education subsidy program with a 3 percent tax rate, a wage subsidy program with a 6 percent tax rate, and an NIT program with a 10 percent tax rate each has an equivalent deadweight loss (but they will have very different implications on inequality). The combined general equilibrium effects of tax and subsidy programs illustrate the importance of programmatic detail in determining the welfare implications of governmental interventions, although most conventional program analyses miss this.

5. Sensitivity analysis

The comparisons of the alternative approaches to governmental transfers build upon a stylized model of the economy, and it is important to understand how the varying aspects of this portrayal of the economy affect the overall conclusions. As mentioned, the key parameters for our simplified economy have not been estimated with much precision. Additionally, there are larger modeling perspectives, including the measurement of outcomes and the structure of labor markets, that deserve attention.

5.1. Parameter variations

We directly analyze the effects of the varying transfer programs assuming different labor elasticities, different substitution across education classes, and different distributions of individual abilities. For labor elasticities $(1/v)$, we employ values of $1/3$ and of $1/6$, values which appear to bound the bulk of existing estimates for men and women in the United States economy. For the elasticity of substitution between educated and uneducated labor, we consider $\sigma = 1.0, 1.3, 2.0$ and 4.0. An elasticity of 1.0 corresponds to the Cobb–Douglas production function case, and estimates below one do not appear consistent with the time series evidence on wage changes (Katz and Autor, 1999). Nonetheless, the amount of substitution across skill groups is not well estimated. Finally, in addition to the uniform ability distribution, we consider two linearized distributions for $a \in [0, 1]$. The first is symmetric with a peak at $a = 0.5$, while the second is skewed toward low ability people with the peak at $a = 0.75$.

Table 3
Social welfare comparisons of subsidy regimes with ex ante utility calculations under alternative model parameters: W, wage subsidy; N, negative income tax; E, education subsidy

Ability distribution	Elasticity of substitution for education			
	$\sigma = 1.0$	$\sigma = 1.3$	$\sigma = 2.0$	$\sigma = 4.0$
	Labor supply elasticity $(1/v) = 1/3$			
Uniform	$W \succ E \approx N$	$\boldsymbol{W \succ N \approx E}$	$W \succ N \succ E$	$W \succ N \succ E$
Symmetric	$W \succ E \succ N$	$W \succ E \succ N$	$W \succ E \approx N$	$W \succ N \succ E$
Skewed	$W \succ N \succ E$	$W \succ N \succ E$	$W \succ N \succ E$	$W \succ N \succ E$
	Labor supply elasticity $(1/v) = 1/6$			
Uniform	$W \succ E \succ N$	$\boldsymbol{W \succ E \succ N}$	$W \succ E \approx N$	$W \succ N \succ E$
Symmetric	$W \approx E \succ N$	$W \approx E \succ N$	$W \succ E \approx N$	$W \succ N \approx E$
Skewed	$W \succ E \succ N$	$W \succ E \succ N$	$W \succ E \approx N$	$W \succ N \succ E$

Table 4
Social welfare comparisons of subsidy regimes with ex post utility calculations under alternative model parameters: W, wage subsidy; N, negative income tax; E, education subsidy

Ability distribution	Elasticity of substitution for education			
	$\sigma = 1.0$	$\sigma = 1.3$	$\sigma = 2.0$	$\sigma = 4.0$
	Labor supply elasticity $(1/v) = 1/3$			
Uniform	$W \approx E \succ N$	$\boldsymbol{W \succ E \succ N}$	$W \succ E \succ N$	$W \succ N \approx E$
Symmetric	$E \succ W \succ N$	$E \succ W \succ N$	$W \approx E \succ N$	$W \succ N \succ E$
Skewed	$W \succ E \succ N$	$W \succ E \succ N$	$W \succ E \approx N$	$W \succ N \succ E$
	Labor supply elasticity $(1/v) = 1/6$			
Uniform	$W \approx E \succ N$	$W \approx E \succ N$	$W \approx E \approx N$	$W \succ N \approx E$
Symmetric	$E \succ W \succ N$	$E \succ W \succ N$	$E \succ W \succ N$	$E \approx W \approx N$
Skewed	$W \succ E \succ N$	$W \succ N \approx E$	$W \succ N \approx E$	$W \succ N \approx E$

Tables 3 and 4 (ex ante utility distributions) (ex post utility distributions) provide a symbolic summary of the loci of aggregate utility and 1-Gini under the different subsidy schemes (comparable to Figs. 1 and 2). For this, $X \succ Y$ signifies that the plot for subsidy scheme X at different tax rates always lies above that for subsidy scheme Y. $X \approx Y$ means that neither dominates over the entire distribution. In such a situation, the X and Y plots generally lie close to each other and intersect one or more times at different tax rates.[17] The bold elements of the tables corresponds to the base case described above.

[17] In some cases, tax rates greater than 0.12 for the wage subsidy are required to compare the different regimes. Specifically, the tuition subsidy with a 12 percent tax rate often yields very large relative inefficiency but more equality than a wage subsidy at 12 percent tax rates, even though a wage subsidy still dominates by going to a larger governmental intervention.

The most important aspect of these sensitivity analyses is that the prior results are not affected much by considering a broad range of parameters for the economy. When evaluated on an ex ante basis, the wage subsidy regime quite generally proves superior. Thus, even though education is generally lauded from an "opportunity" viewpoint, it does not provide superior outcomes to wage subsidies when evaluated on an ex ante, or opportunity, basis.

On an ex post basis, we do, however, find some ambiguity about the superiority of wage subsidies: The tuition subsidies tend to look attractive ex post when abilities follow a symmetric distribution that peaks in the middle. Since the cutoff enrollment rate in the no tax case is reasonably close to the center of the distribution (57 percent), changes in incentives for school attendance at this point have large effects on the population induced to continue schooling. In comparison, with the uniform and skewed distributions, the impact on enrollment is less, and tuition subsidies cannot have the same influence on the distribution of outcomes.

One concern, discussed elsewhere, is whether any findings of ex post superiority of tuition policies are driven by sensitivity to the parameters or by the specialized structure that does not permit ability to have a direct payoff in the labor market. The individuals failing school have the lowest realized utility, because they get the wages of an uneducated person but also have to pay tuition. This fact leads to a ranking of outcomes that differs from the ranking of ability and the ranking of better opportunities (comparing failed people to those who never choose to attend college). Thus, differences in ex ante and ex post calculations do not necessarily represent just alternative summaries of behavioral outcomes.

The negative income tax is generally ranked at the bottom except when the ability distribution is skewed toward low ability or when the substitution elasticity is high; in these cases the negative income tax tends to dominate education subsidies. Not surprisingly, tuition subsidies tend to look better than negative income taxes when there are lower elasticities of substitution and thus when the relative importance of education increases.

Nonetheless, the overall conclusions are remarkably insensitive to the specific parameters used.

5.2. *Other considerations*

The general equilibrium calculations begin with fundamental characteristics of the economy and then evaluate the outcomes of different governmental interventions. The evaluations are very general in the sense of tracing the societal results in aggregate outcome-distribution space without imposing any specific social welfare function. At the same time they are very specific in that they build upon a precise characterizations of individual utilities, and the results are evaluated within that framework. We know, however, that the utility function representation of the underlying preference of goods is *not* unique. In a deterministic world, the utility function is presumed unique only up to a monotonic transformation. However, with uncertainty and risk aversion, the expected utility function is unique up to an affine transformation.[18] In other words, if the utility functions U and U^* represent the same underlying preference of goods and service, then it must be the case that $U^* = d + bU$, where d and b are constant and $b > 0$. The central issue is whether such a transformation could affect our results. It is straightforward to show that enrollment decisions and wages in the economy are unchanged under affine transformations of the utility function—implying the ordering of different policies in terms of aggregate outcomes is unchanged (see the appendix). Similarly, even though the value of the Gini coefficient can change by utility transformations, our direct investigation within the context of our model shows the ordering of policies to be robust.[19] In other words, our analysis is built upon relative comparisons of outcomes under different policies and, while the utility values assigned to different outcomes are not unique, the relative ranking of programs is unique (given the basic structure of preferences for goods and of markets in our model).[20]

It is the case that our utility rankings of programs can differ from rankings based just on the outcomes in terms of income. These comparisons are, nonetheless, inconsistent with the underlying theoretical structure. The investment decisions of agents along with their choices on labor supply depend directly on their underlying preferences for leisure—and ignoring these would give a distorted picture of the policy outcomes.

One simplification embedded in the structure of the model deserves additional consideration. From the labor market perspective, there are only two types of workers: educated and uneducated, making calculation of equilibrium wages straightforward and allowing easy calculation of the individual investment decisions. It is, however, restrictive. Ability has no payoff in the labor market (other than influencing the probability of successfully completing schooling). Moreover, college dropouts are treated as being equivalent to individuals never attempting college. A variety of direct studies suggest that both of these aspects are untrue empirically (see Hanushek, 2002; Kane and Rouse, 1995).

The impact of this structure is largest on ex post calculations. In the ex ante decisions and assessments, higher ability individuals always have greater expected utility than lower ability individuals—just what would be assured by permitting labor market returns to ability or partial schooling. Thus, a broadened view that pursued alternative wage determination would simply reinforce the basic focus of the existing model. In ex post assessments, however, there are clear inversions of outcomes, where lower ability individuals have greater utility than failing students because they avoid any tuition payments. This implies that the outcome measurement is affected by both individual reactions to the economy fundamentals and by idiosyncracies of the precise earnings determination. Because the wage

[18] For instance, see Varian (1984, pp. 155–162).

[19] As described in the appendix, we cannot prove in general that the rankings of policies are invariant to all affine transformation. Nonetheless, solution of our model for a wide range of transformations yields policy invariance of the results.

[20] A more fundamental issue does remain: how might our results be affected by utility functions with varying forms of risk aversion, leisure preferences, and the like? While these topics are the subject of our larger continuing research agenda, they are beyond the scope of this paper.

simplification has such strong implications that differ from empirical findings, we emphasize the ex ante calculations. (Note, however, that the general conclusions do not differ much between the two perspectives.)

6. Production externalities of education

A strong motivation for educational investments by society has traditionally been the presumption that there are significant externalities associated with education. The usual arguments about externalities, however, apply best to elementary and secondary education and less well to higher education (Hanushek, 1996; Poterba, 1996). This view is also supported by Acemoglu and Angrist (1999). The one exception is consideration of how human capital might affect national growth rates—through, say, the development of ideas or the diffusion of technologies. In such a case, while competitive labor markets might exist, they will not be Pareto optimal, and government action might be called for on pure efficiency grounds. Here we consider such a case in a simple extension of the basic model similar to that of Romer (1986). This particular form is not only simple but also incorporates an externality that is compatible with perfectly competitive markets.

While all other aspects of our model of the economy remain the same, we now assume that all agents have access to an aggregate production function which of the CES form:

$$Y = A[\xi(E^{\mathrm{e}})^{\rho} + (1-\xi)(E^{\mathrm{u}})^{\rho}]^{1/\rho}(\overline{E^{\mathrm{e}}})^{\chi},$$

where $\overline{E^{\mathrm{e}}}$ is the ‘‘average effective units of educated labor’’, the externality part, and χ ($\chi > 0$) is a parameter indexing the strength of the externality. Since individuals take the $\overline{E^{\mathrm{e}}}$ part as given, this economy is compatible with perfectly competitive markets but individual schooling decisions will tend to yield less than optimal education in the economy. Wages are simply the marginal products:

$$w^{\mathrm{e}} = A\xi\left[\xi + (1-\xi)\left(\frac{E^{\mathrm{u}}}{E^{\mathrm{e}}}\right)^{\rho}\right]^{(1-\rho)/\rho}(\overline{E^{\mathrm{e}}})^{\chi},$$

$$w^{\mathrm{u}} = A(1-\xi)\left[\xi\left(\frac{E^{\mathrm{e}}}{E^{\mathrm{u}}}\right)^{\rho} + (1-\xi)\right]^{(1-\rho)/\rho}(\overline{E^{\mathrm{e}}})^{\chi}.$$

In equilibrium, $\overline{E^{\mathrm{e}}} = E^{\mathrm{e}}$.

The presence of the production externality changes the situation, because a subsidy to education now acts like a Pigouvian tax that enhances aggregate performance of the economy. At low levels of taxes and education subsidies, *both* aggregate expected utility and equality (1-Gini) improve, making education subsidies the clearly superior transfer mechanism. At higher levels of education subsidies, however, the inefficiency from tax distortions sometimes overcomes the efficiency gains from correcting the externality. The typical situation can be readily seen from considering the base case employed previously with the addition of the externality where $\chi = 0.1$. (An externality represented by $\chi = 0.1$ is small and cannot be readily

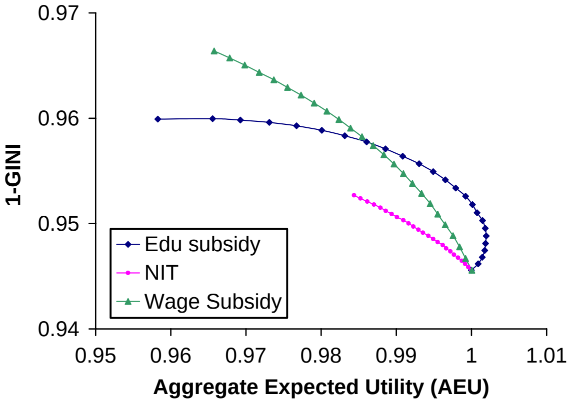

Fig. 3. Aggregate expected utility and ex ante distribution of utility with production externalities.

rejected by aggregate data; cf. Burnside et al. (1995)). Fig. 3 illustrates the output and ex ante distributional patterns from the subsidy schemes operated at differing tax rates (for the base case defined previously except for the externalities). For $\tau \leqslant 0.025$, both AEU and (1-Gini) increase under the tuition subsidy. For $0.025 \leqslant \tau \leqslant 0.045$ applied to education subsidies, aggregate utility (AEU) is decreasing, but it still remains above that obtainable without governmental intervention or with the other transfer devices. For this entire range, the advantages of correcting the externality are larger than the distortions introduced by the tax/subsidy scheme. Interestingly, however, for education subsidies with $\tau > 0.08$, the benefits of correcting the externality no longer outweigh the added distortions to the economy in pursuing redistribution through education subsidies, and redistribution would again be better accomplished with a wage subsidy.

Table 5 displays the array of sensitivity results corresponding to those provided before. The general picture is that, under the education subsidy regime, only very high tax rates (above 7.5 percent in the base case) ever yield an alternative program that dominates educational subsidies. If we think of this as a model of higher education, however, total spending on institutions of higher education in 1999 was just 2.8 percent of GDP (National Center for Education Statistics, 2000). The education and wage subsidies always dominate the negative income tax in meeting societal output and distributional goals, i.e., the locus of feasible pairs is always lowest for an NIT. For ex post utility calculations (not shown), educational subsidies *always* dominate the others across all parameter values and distributions considered. Therefore, the externalities considered here could fully justify redistribution through education subsidies, although the driving force is its ability to correct an existing distortion from the externality.

The prior analysis has also concentrated on pure strategies, i.e., choosing a single policy for governmental redistribution. With externalities, there are two objectives—correcting an externality and redistributing income. In this larger context, it may well be that combining both tuition and wage subsidies yield greater outcomes. Such a

Table 5
Education tax rate above which wage subsidies dominate education subsidies based on ex ante utility calculations (E implies education subsidies always dominate)

Ability	Elasticity of substitution for education			
Distribution	$\sigma = 1.0$	$\sigma = 1.3$	$\sigma = 2.0$	$\sigma = 4.0$
	Labor supply elasticity $(1/v) = 1/3$			
Uniform	$\tau > 0.08$	$\tau > 0.08$	$\tau > 0.09$	$\tau > 0.10$
Symmetric	E	E	E	E
Skewed	$\tau > 0.06$	$\tau > 0.06$	$\tau > 0.07$	$\tau > 0.09$
	Labor supply elasticity $(1/v) = 1/6$			
Uniform	E	E	E	$\tau > 0.10$
Symmetric	E	E	E	E
Skewed	$\tau > 0.08$	E	E	$\tau > 0.09$

perspective would transform this into a mechanism design problem, but solving for the optimal set of programs would involve imposing a specific social welfare function—something we have attempted not to do.

7. Conclusions

This paper develops a methodology for evaluating transfer mechanisms that might be expected to have both output and distributional effects. The specific focus is the potential redistributive aspects of education tuition subsidies and how they compare with those of cash transfers through either a negative income tax or a wage subsidy to low wage workers. The comparisons incorporate both deadweight losses and redistribution within a one-period general equilibrium model of the economy. Workers differ by ability, where ability indexes the probability of successfully completing schooling. Individuals decide whether or not to pursue more schooling, and, based on the outcomes of that, choose labor supply levels. The government's only role is redistributing income. It provides transfers to individuals that are financed by a (distorting) linear income tax, and it must maintain a balanced budget.

The overall results of the comparison of transfer mechanisms are very illuminating. In the simple world considered here, if there were no interest in distributional outcomes, the social optimum would be no governmental taxation or spending. With no externalities, individual schooling and labor supply choices will lead to maximum social welfare, defined by aggregate expected utility for individuals. With distributional motives which are supported by levying a distortionary income tax, however, the consideration of best governmental programs becomes more interesting.

Without externalities, wage subsidies dominate the alternative transfer mechanisms in the sense that any level of aggregate expected utility achieved by a negative income tax or an education subsidy can be achieved by a program of wage subsidies that also ensures more ex ante utility. This result is somewhat weakened, however, when utility is calculated on an ex post basis. With this metric, a few combinations of a symmetric distribution of abilities and key parameter values potentially yield superiority of tuition subsidies. When deviations in results occur, the distribution of outcomes with the wage and tuition subsidies remain quite close. Moreover, there are conceptual reasons—involving both philosophical and technical modeling issues—for weighting the ex ante results more heavily.

If there are production externalities related to the aggregate education level in the economy, the education subsidies serve a dual purpose—redistributing income while potentially moving the economy toward Pareto superior outcomes. Thus, it is not surprising that a rationalization for direct subsidies for higher education can be generally derived when externalities are involved. The beneficial effects of education subsidies on aggregate output when externalities of the growth variety are considered lead educational subsidies to dominate as a redistributional device—as long as the amount of governmental involvement is not too large. The beneficial outcomes from correcting the externality are eventually overcome by the inefficiencies of the redistribution, and wage subsidies can again become superior. The multiple objectives—addressing the externality and redistributing income—suggest nonetheless that pure strategies for government policy would not be as good as a mixed policy in this case.

In order to focus on the key comparisons among alternative governmental transfer programs, this paper does not consider a series of issues that might also be important in evaluating governmental policies toward education and redistribution. Many have argued (e.g., Becker, 1993[1964]; Garratt and Marshall, 1994) that capital market imperfections inhibit individual ability to invest in human capital. The inability to use human capital as collateral for loans is a central element of such considerations. Our continuing work finds that borrowing constraints do introduce inefficiencies, as poor but high ability people are excluded from college (Hanushek et al., 2003). In this, however, uniform tuition subsidies of the type considered here are not the optimal policy. Moving from the one period model to a dynamic model of the economy clearly captures better the investment nature of education and the role of families. A multiperiod model also permits direct investigation of the intergenerational transmission of income and its distributional implications, aspects of borrowing constraints that are highlighted in our work on the topic.[21] From a different direction, others question the potential inefficiency from governmental supply, particularly when it tends to be monopolistic (Hanushek, 1986). Thus, they tend to concentrate on the cost and quality of schooling. Here we abstract from such supply issues and assume homogeneous and efficient provision of schools (and other governmental redistribution), although potential governmental failure could influence the results. Yet another obvious extension is to incorporate political

[21] Dynamic features of educational policies are central to the analyses of Fernandez and Rogerson (1998), Heckman et al. (1998a, b), Benabou (2002), and Caucutt and Kumar (2003). These papers provide alternative perspectives on how to introduce intertemporal features into the evaluations of alternative human capital policies.

economy features of the choice of mechanisms. For example, different private interests may well lead individuals to have differing views about the appropriate transfer mechanism. These views may support collective choice for nonoptimal transfer devices.

Finally, we believe that this paper provides important methodological improvements over prior analyses of transfer programs. The magnitude of both educational programs and direct transfer programs indicate their potential for very significant general equilibrium effects. This paper provides a framework for considering both the redistributional and efficiency effects of alternative programs and for evaluating the full impacts of governmental activities.

Appendix A. Details of different distribution of ability

In this section, we will provide all the details about the different distribution of ability used in the text. To start with, the density function for uniform distribution is

$$f(a) = 1,$$

$\forall a \in [0, 1]$. The density function is continuous at every point. Recall that the formula for enrollment and total number of successful agents are $N^r = \int_0^{a^*} f(a)\,\mathrm{d}a$ and $N^e = \int_0^{a^*} (1-a) f(a)\,\mathrm{d}a$. In the case of uniform distribution, it is easy to check that

$$N^r = a^*,$$

$$N^e = a^* - \frac{(a^*)^2}{2}.$$

The other cases are analogous. The density function for symmetric distribution used in this paper is

$$f(a) = \begin{cases} 0.5 + 2a & a < 0.5, \\ 2.5 - 2a & a \geqslant 0.5 \end{cases}$$

$\forall a \in [0, 1]$. Notice that the density function is continuous at every point. Recall that the formula for enrollment and total number of successful agents are $N^r = \int_0^{a^*} f(a)\,\mathrm{d}a$ and $N^e = \int_0^{a^*} (1-a) f(a)\,\mathrm{d}a$. In the case of symmetric distribution, it is easy to check that

$$N^r = \begin{cases} 0.5a^* + (a^*)^2 & a^* < 0.5, \\ -0.5 + 2.5a^* - (a^*)^2 & a^* \geqslant 0.5, \end{cases}$$

$$N^e = \begin{cases} \frac{1}{2}a^* + \frac{4}{3}(a^*)^2 - \frac{2}{3}(a^*)^3 & a^* < 0.5, \\ -\frac{5}{12} + \frac{5}{2}a^* - \frac{9}{4}(a^*)^2 + \frac{2}{3}(a^*)^3 & a^* \geqslant 0.5. \end{cases}$$

The density function for skewed distribution used in this paper is

$$f(a) = \begin{cases} \frac{1}{2} + \frac{4}{3}a & a < 0.75, \\ \frac{9}{2} - 4a & a \geqslant 0.75 \end{cases}$$

$\forall a \in [0,1]$. Notice that the density function is continuous at every point. Recall that the formula for enrollment and total number of successful agents are $N^r = \int_0^{a^*} f(a)\,\mathrm{d}a$ and $N^{\mathrm{e}} = \int_0^{a^*} (1-a)f(a)\,\mathrm{d}a$. In the case of skewed distribution, it is easy to check that

$$N^r = \begin{cases} \frac{1}{2}a^* + \frac{2}{3}(a^*)^2 & a^* < 0.75, \\ -\frac{3}{2} + \frac{9}{2}a^* - 2(a^*)^2 & a^* \geqslant 0.75, \end{cases}$$

$$N^{\mathrm{e}} = \begin{cases} \frac{1}{2}a^* + \frac{5}{12}(a^*)^2 - \frac{4}{9}(a^*)^3 & a^* < 0.75, \\ -\frac{9}{8} + \frac{9}{2}a^* - \frac{17}{4}(a^*)^2 + \frac{4}{3}(a^*)^3 & a^* \geqslant 0.75. \end{cases}$$

Appendix B. Calculation of Gini coefficients

The measure of agents who are successful is simply $p_1 = a^* - a^{*2}/2$ while those who go to school and fail is $p_2 = a^{*2}/2$. Those who do not go to school consists of $1 - p_1 - p_2$. This gives mean (after-tax) income $\bar{y}$ as

$$[p_1((1-\tau)w^{\mathrm{e}}L^{\mathrm{e}} - t + m)] + [p_2((1-\tau)w^{\mathrm{u}}L^{\mathrm{u}} - t + m)] \\ + [(1 - p_1 - p_2)((1-\tau)w^{\mathrm{u}}L^{\mathrm{u}} + m)].$$

The area underneath the Lorenz curve is computed by summing the integral of the density of the three after-tax income classes, where the Lorenz curve is represented by the following piece-wise continuous function:

$$Z_1(p) = \frac{[(1-\tau)w^{\mathrm{u}}L^{\mathrm{u}} - t + m]}{\bar{y}}p \quad \text{for } p \in [0, p_2],$$

$$Z_2(p) = \frac{[(1-\tau)w^{\mathrm{u}}L^{\mathrm{u}} - t + m]p_2 + (p - p_2)[(1-\tau)w^{\mathrm{u}}L^{\mathrm{u}} + m]}{\bar{y}} \\ \text{for } p \in [p_2, p_1 + p_2]$$

and

$$Z_3(p) = \frac{[(1-\tau)w^{\mathrm{u}}L^{\mathrm{u}} - t + m]p_2 + [(1-\tau)w^{\mathrm{u}}L^{\mathrm{u}} + m]p_1}{\bar{y}} \\ + \frac{(p - p_1 - p_2)[(1-\tau)w^{\mathrm{e}}L^{\mathrm{e}} - t + m]}{\bar{y}} \quad \text{for } p \in [p_1 + p_2, 1].$$

The sum of the integral of the piecewise continuous function gives the area underneath the Lorenz curve. The Gini coefficient is simply $1 - (2 \times \text{area under Lorenz curve})$.[22]

[22] Again, straightforward modifications of the formulae are required for the wage subsidy case. In the case where the Gini is based on utility, the welfare of the economy measured by $S(\tau, t)$ is used as a normalization.

Appendix C. Policy orderings under affine transformation of utilities

This note concerns the ordering of different policy schemes under transformation of utility functions. We know that the utility function representation of the underlying preference of goods is *not* unique. In a deterministic world, the utility function is unique up to a monotonic transformation.[23] However, with uncertainty and risk version, the expected utility function is unique up to an affine transformation.[24] It means that if the utility functions U and U^* represent the same underlying preference of goods and service, then it must be that $U^* = d + bU,\ d, b$ are constant and $b > 0$.

Now we show how affine transformation would (or would not) change the ordering of schemes. Define $S(i)$ be the aggregated expected utility under regime i, with the original utility function

$$U(c, l) = c - \varepsilon \frac{(L^i)^{1+v}}{1+v}$$

and $S^*(i)$ be the aggregated expected utility under regime i, with the original utility function $U^* = d + bU,\ d, b$ are constant and $b > 0$.

1. First, we want to show that the N^i do not change under U or U^*. It suffices to show that the enrollment decision is not affected.

$$\begin{array}{lll} & EU^{s*} & \geqslant EU^{u*} \\ \Leftrightarrow & P_a U^{e*} + (1 - P_a) U^{f*} & \geqslant U^{f*} + bt \\ \Leftrightarrow & d + b(P_a U^{e} + (1 - P_a) U^{f}) & \geqslant d + b(U^{f}) + bt \\ \Leftrightarrow & (P_a U^{e} + (1 - P_a) U^{f}) & \geqslant U^{f} + t \\ \Leftrightarrow & (1 - a) & \geqslant \dfrac{t}{U^{e} - U^{f}}, \end{array}$$

   which is the same as the condition under the original utility function U. Since the enrollment decision is not affected, then the composition of work force will not be affected neither. Consequently, the wages will remain the same.

2. Now, we show that the ranking of two regimes will preserve with the affine transformation. By definition,

$$\begin{aligned} S(i) &= \int_0^{a^*} [(1 - a) U^{e} + a U^{f}] f(a)\, \mathrm{d}a + \int_{a^*}^{1} U^{u} f(a)\, \mathrm{d}a \\ &= U^{e} N^{e} + U^{f} N^{f} + U^{u} N^{u} \end{aligned}$$

[23] For instance, see Varian (1984).

[24] For instance, see Varian (1984, pp. 155–162).

and therefore,

$$
\begin{aligned}
S^*(i) &= U^{e*}N^{e} + U^{f*}N^{f} + U^{u*}N^{u} \\
&= \sum_{i=e,u,f} (d + bU^{i})N^{i} \\
&= d \sum_{i=e,u,f} , N^{i} + b \sum_{i=e,u,f} U^{i}N^{i} \\
&= d + bS(i),
\end{aligned}
$$

as $\sum_{i=e,u,f} N^{i} = 1$.

Hence,

$$S^*(i) - S^*(j) = b(S(i) - S(j)),$$

which means that

$$sign(S^*(i) - S^*(j)) = sign(S(i) - S(j)).$$

3. The next step is to show that how the relative ranking of inequality, measured by Gini coefficient, *could change* under the new utility function U^*. Following Lambert (1990), let $Gini(i)$ represent the Gini coefficient of the economy under regime i, with the original utility function $U(c,l) = c - \varepsilon(L^{i})^{1+v}/1+v$ and $Gini^*(i)$ be the Gini coefficient of the economy under regime i, with the original utility function $U^* = d + bU$, d, b are constant and $b > 0$.

$$Gini(i) = \frac{\sum_k \sum_j |U_k - U_j}{2N^2\mu(i)},$$

where $U_k(i)$ is the utility level of agent k under regime i, N is the total population and $\mu(i)$ is the mean under regime i. Then

$$
\begin{aligned}
Gini^*(i) &= \frac{\sum_k \sum_j |U^*_k(i) - U^*_j(i)|}{2N^2\mu^*(i)} \\
&= \frac{b\sum_k \sum_j |U_k(i) - U_j(i)|}{2N^2(d + b\mu(i))},
\end{aligned}
\tag{7}
$$

and hence

$$
\begin{aligned}
&Gini^*(i) - Gini^*(j) \\
&\quad = \frac{b\sum_k \sum_j |U_k(i) - U_j(i)|}{2N^2(d + b\mu(i))} - \frac{b\sum_k \sum_j |U_k(j) - U_j(j)|}{2N^2(d + b\mu(j))} \\
&\quad = \frac{b\{d[\mathscr{G}(i) - \mathscr{G}(j)] + b[\mathscr{G}(i)\mu(j) - \mathscr{G}(j)\mu(i)]\}}{2N^2(d + b\mu(i))(d + b\mu(j))},
\end{aligned}
$$

where

$$G(i) = \sum_k \sum_j |U_k(i) - U_j(i)|.$$

Clearly, if $\mu(j) \approx \mu(i)$, $[\mathcal{G}(i)\mu(j) - \mathcal{G}(j)\mu(i)] \approx \mu(i)[\mathcal{G}(i) - \mathcal{G}(j)]$, and hence

$$Gini^*(i) - Gini^*(j) \approx \frac{b[\mathcal{G}(i) - \mathcal{G}(j)](d + b\mu(i))}{2N^2(d + b\mu(i))(d + b\mu(j))} = \frac{b[\mathcal{G}(i) - \mathcal{G}(j)]}{2N^2(d + b\mu(j))}$$

which means that

$$sign(Gini^*(i) - Gini^*(j)) = sign(Gini(i) - Gini(j)).$$

Similarly, if $d \approx 0$, from (7) we know that

$$\begin{aligned} Gini^*(i) &= \frac{b\sum_k \sum_j |U_k(i) - U_j(i)|}{2N^2(d + b\mu(i))} \\ &\approx \frac{b\sum_k \sum_j |U_k(i) - U_j(i)|}{2N^2(b\mu(i))} \\ &= \frac{\sum_k \sum_j |U_k(i) - U_j(i)|}{2N^2\mu(i)} \\ &= Gini(i), \end{aligned}$$

hence

$$Gini^*(i) - Gini^*(j) = Gini(i) - Gini(j).$$

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