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ABSTRACT

This paper defines and estimates general equilibrium treatment effects. The conventional approach in the literature on treatment effects ignores interactions among individuals induced by the policy interventions being studied. Focusing on the impact of tuition policy, and using estimates from our dynamic overlapping generations general equilibrium model of capital and human capital formation, we find that general equilibrium impacts of tuition on college enrollment are an order of magnitude smaller than those reported in the literature on microeconomic treatment effects. The assumptions used to justify the LATE parameter in a partial equilibrium setting do not hold in a general equilibrium setting. Policy changes induce two way flows. We extend the LATE concept to a general equilibrium setting. We present a more comprehensive evaluation to program evaluation by considering both the tax and benefit consequences of the program being evaluated and placing the analysis in a market setting.

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General Equilibrium Treatment Effects:

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This paper considers the effects of changes in tuition on schooling and earnings, accounting for general equilibrium effects on skill prices. The typical evaluation estimates the response of college enrollment to tuition variation using geographically dispersed cross-sections of individuals facing different tuition rates. These estimates are then used to determine how subsidies to tuition will raise enrollment. The impact of tuition policies on earnings are evaluated using a schooling-earnings relationship fit on pre-intervention data and do not account for the enrollment effects of the taxes raised to finance the tuition subsidy. Thomas Kane (1994) exemplifies this approach.

The danger in this widely used practice is that what is true for policies affecting a small number of individuals need not be true for policies that affect the economy at large. A national tuition-reduction policy that stimulates substantial college enrollment will likely reduce skill prices, as advocates of the policy claim. However, agents who account for these changes will not enroll in school at the levels calculated from conventional procedures which ignore the impact of the induced enrollment on earnings. As a result, standard policy evaluation practices are likely to be misleading about the effects of tuition policy on schooling attainment and wage inequality. The empirical question is how misleading? We show that these practices lead to estimates of enrollment responses that are more than ten times larger than the long-run general equilibrium effects. We also improve on current practice in the treatment effects literature by considering both the gross benefits of the program and the tax costs of financing the treatment as borne by different groups.

Evaluating the general equilibrium effects of a national tuition policy requires more information than the tuition-enrollment parameter that is the centerpiece of partial equilibrium policy analysis. Most policy proposals extrapolate well outside the range of known experience and ignore the effects of induced changes in skill quantities on skill prices. To improve on current practice, we have developed an empirically justified dynamic overlapping-generations general equilibrium framework for the pricing of heterogeneous skills. It is based on an empirically grounded theory of the supply of schooling and post-school human capital, where different schooling levels represent different skills. Individuals differ in learning ability and in initial endowments of human capital. Household saving behavior generates the aggregate capital stock, and output is produced by combining the stocks of different human capitals with physical capital. The framework explains the pattern of rising wage inequality experienced in the United States in the past 30 years (James Heckman, Lance Lochner and Christopher Taber, 1998). In this paper we apply this framework to evaluate tuition policies that attempt to increase college enrollment.

The statistical and econometric literature on "treatment effects" is remarkable for its inattention to the market consequences of the programs it evaluates. The widely used "Rubin" model (Donald Rubin, 1978) assumes no interactions among the agents being analyzed. The paradigm in the econometric literature on "treatment effects" is that of evaluating the effectiveness of a drug. It assumes that there are no spillovers to society at large that flow from drug use (or "treatment") by individuals.

The literature in economics recognizes these spillover effects. The classical analysis of union relative wage effects by H. Gregg Lewis (1963) explicitly accounts for the discrepancy between the effects of "treatment" (unionism) on an individual and "treatment" applied to an industry when prices adjust to industry-wide unionization levels. Our analysis extends Lewis' static general equilibrium framework to a dynamic setting with skill formation.

I. Conventional Models of Treatment Effects

The standard framework for microeconometric program evaluation is partial equilibrium in character (see James Heckman and Richard Robb, 1985). For a given individual i, $Y_{0,i}$ is defined to be the outcome the individual receives if he participates in the program, and

$Y_{1,i}$ is the outcome he receives if he does not participate. The treatment effect for person i is $\Delta_i = Y_{1,i} - Y_{0,i}$. When interventions have general equilibrium consequences, these effects depend on who else is treated and the market interaction between the treated and the untreated.

To see the problems that arise in the standard framework, consider instituting a national tuition policy. In this case, $Y_{0,i}$ is person i's wage if he does not attend college, and $Y_{1,i}$ is his wage if he does attend. The "parameter" Δ_i then represents the impact of college, and it can be used to estimate the impact of tuition policies on wages. It is a constant, or policy-invariant, parameter only if wages $(Y_{0,i}, Y_{1,i})$ are invariant to the number of college and high school graduates in the economy.

In a general equilibrium setting, an increase in tuition increases the number of individuals who attend college, which in turn decreases the relative wages of college attendees, $Y_{1,i}/Y_{0,i}$. In this case, the program not only impacts the wages of individuals who are induced to move by the program, but it also has an impact on the wages of those who do not. For two reasons, then, the "treatment effect" framework is inadequate. First, the parameters of interest depend on who in the economy is "treated" and who is not. Second, these parameters do not measure the full impact of the program. For example, increasing tuition subsidies may increase the earnings of uneducated individuals who do not take advantage of the subsidy. To pay for the subsidy, the highly educated would be taxed and this may affect their investment behavior. In addition, more competitors for educated workers enter the market as a result of the policy, and their earnings are depressed. Conventional methods ignore the effect of the policy on nonparticipants. In order to account for these effects, it is necessary to conduct a general equilibrium analysis.

II. Exploring Increases in Tuition Subsidies in A General Equilibrium Model

We first simulate the effects of a revenue-neutral \$500 increase in tuition subsidy financed by a proportional tax on enrollment in college and wage inequality starting from a baseline economy that describes the U.S. in the mid 80s and that produces wage growth profiles and schooling enrollment and capital stock data that match micro and macro statistics. The partial equilibrium increase in college attendance is 5.3 percent in the new steady state. This analysis holds skill prices, and therefore college and high school wage rates, fixed – a typical assumption in microeconomic "treatment effect" analyses.

When the policy is evaluated in a general equilibrium setting, the estimated effect falls to 0.46 percent. Because the college-high school wage ratio falls as more individuals attend college, the returns to college are less than when the wage ratio is held fixed. Rational agents understand this effect of the tuition policy on skill prices and adjust their college-going behavior accordingly. Policy analysis of the type offered in the "treatment effect" literature ignores the responses of rational agents to the policies being evaluated. There is substantial attenuation of the effects of tuition policy on capital and the stocks of the different skills in our model. In our baseline specification, we allow skill prices and interest rates to adjust in general equilibrium but hold the pre-subsidy tuition level fixed. Simulating the policy under a number of additional alternative assumptions about the parameters of the economic model, including a case where tuition costs rise with enrollment, reproduces the basic result of substantial partial equilibrium effects and much weaker general equilibrium effects.

Our steady state results are long-run effects. When we simulate the model with rational expectations, the short-run enrollment effects are also very small, as agents anticipate the effects of the policy on skill prices and calculate that there is little gain from attending college at higher rates. If we simulate using myopic expectations, the short-run enrollment effects are much closer to the estimated partial equilibrium effects. All of these results are qualitatively robust to the choice of different tax schedules. Progressive tax schedules choke off skill investment and lead to lower enrollment responses in general equilibrium.

We next consider the impact of a policy change on discounted earnings and utility. We decompose the total effects into benefits and costs, including tax costs for each group. For the sake of brevity, we report overall results and not the results by ability type. Table 1 compares outcomes in two steady states: (a) the benchmark steady state and (b) the steady state associated with the new tuition policy. Given that the estimated schooling response to a $500 subsidy is small, we instead use an extremely high $5000 subsidy for the purpose of exploring general equilibrium effects. The row High School - High School reports the change in a variety of outcome measures for those persons who would be in high school under the benchmark or new policy regime; the High School - College row reports the change in the same measures for high school students in the benchmark who are induced to attend college only by the new policy; College - High School outcomes refer to those persons in college in the benchmark economy who only attend high school after the new policy is put in place; and so forth.

By the measure of the present value of earnings, some of those induced to change are worse off. Contrary to the monotonicity assumption built into the LATE parameter of Guido Imbens and Joshua Angrist (1994), defined in this context as the effect of tuition change on the earnings of those induced to go to college, we find that the tuition policy produces a two-way flow. Some people who would have attended college in the benchmark regime no longer do so. The rest of society also is affected by the policy–again, contrary to the implicit assumption built into LATE that only those who change status are affected by the policy. People who would have gone to college without the policy and continue to do so after the policy are financially worse off for two reasons: (a) the price of their skill is depressed and (b) they must pay higher taxes to finance the policy. However, they now receive a tuition subsidy and for this reason, on net, they are slightly better off both financially and in terms of utility. Those who would abstain from attending college in both steady states are essentially indifferent between the two steady states. They pay higher taxes, but their skill becomes more scarce and their wages rise. Those induced to attend college by the policy are better off in terms of utility but are not better off in terms of income. Note that neither category of non-changers is a natural benchmark for a "difference in differences" estimator.

The movement in their wages before and after the policy is due to the policy and cannot be attributed to a benchmark "trend" that is independent of the policy.

Table 2 presents the impact of the $5000 tuition policy on the log earnings of individuals with ten years of work experience for different definitions of treatment effects. The partial equilibrium version given in the first column holds skill prices constant at initial steady state values. The general equilibrium version given in the second column allows prices to adjust when college enrollment varies. Consider four parameters initially defined in a partial equilibrium context. The *average treatment effect* is defined for a randomly selected person in the population in the benchmark economy and asks how that person would gain in wages by moving from high school to college. The parameter *treatment on the treated* is defined as the average gain over their non-college alternative of those who attend college. The parameter *treatment on the untreated* is defined as the average gain over their college wage received by individuals who did not attend college. The *marginal treatment effect* is defined for individuals who are indifferent between going to college or not. It is a limit version of the LATE parameter under conventional assumptions made in discrete choice theory (Heckman, 1997). Taber (1997) considers this parameter in his analysis of schooling choices. Column 2 presents the general equilibrium version of *treatment on the treated.* It compares the earnings of college graduates in the benchmark economy with what they would earn if no one went to college.[1] The treatment on the untreated is defined analogously by comparing what high school graduates in the benchmark economy would earn if everyone in the population were forced to go to college. The *average treatment effect* compares the average earnings in a world in which everyone attends college versus the earnings in a world in which nobody attends college. Such dramatic policy shifts produce large estimated effects. In contrast, the general equilibrium marginal treatment effect parameter considers the gain to attending college for people on the margin of indifference between attending college and attending high school. In this case, as long as the mass of people in the indifference set is negligible, partial and general equilibrium parameters are the same.

The final set of parameters we consider are versions of the LATE parameter. This parameter depends on the particular intervention being studied and its magnitude. The partial equilibrium version of LATE is defined on the outcomes of individuals induced to attend college, assuming that skill prices do not change. The general equilibrium version is defined for the individuals induced to attend college when prices adjust in response to the policy. The two LATE parameters are quite close to each other and are also close to the marginal treatment effect.[2] General equilibrium effects change the group over which the parameter is defined compared to the partial equilibrium case. For the $5000 subsidy, there are substantial price effects and the partial equilibrium parameter differs substantially from the general equilibrium parameter.

We also present partial and general equilibrium estimates for two extensions of the LATE concept: LATER *(the effect of the policy on those induced to drop out of college and go to high school)*—Reverse LATE—and TLATE *(the effect of the policy on all of those induced to change whichever direction they flow)*. LATER is larger than LATE, indicating that those induced to drop out of college have larger gains from dropping out than those induced to enter college have from entering. TLATE is a weighted average of LATE and LATER with weights given by the relative proportion of people who switch in each direction.

III. Summary

This paper defines and estimates general equilibrium treatment effects. Focusing on the impact of tuition policy, we find that general equilibrium impacts of tuition on college enrollment are an order of magnitude smaller than those reported in the literature on microeconometric treatment effects. The assumptions used to justify the LATE parameter in a microeconomic setting do not carry over to a general equilibrium framework. Policy changes, in general, induce two-way flows and violate the monotonicity—or one-way flow—assumption of LATE. We extend the LATE concept to allow for the two-way flows induced by the policies. We present a more comprehensive approach to program evaluation by considering both the tax and benefit consequences of the program being evaluated and placing the analysis in a market setting.

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Notes

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[1]In the empirical general equilibrium model of Heckman, et al. (1998a), Inada conditions for college and high school are not imposed and the marginal product of each skill group when none of it is utilized is a bounded number. If Inada conditions were imposed, this counterfactual and the counterfactual treatment on the untreated would not be defined.

[2]The latter is a consequence of the discrete choice framework we use to model schooling choices in our model. See Heckman (1997).

Table 1

Simulated Effects of $5000 Tuition Subsidy on Different Groups

Steady State Changes in Present Value of Lifetime Wealth

(Thousands of 1995 Dollars)

Group(Proportion)†	After-Tax Earnings Using Base Tax‡	After-Tax Earnings‡	After-Tax Earnings Net of Tuition‡	Utility‡
	(1)	(2)	(3)	(4)
High School-High School(0.528)	9.512	-0.024	-0.024	-0.024
High School-College(0.025)	-4.231	-13.446	1.529	1.411
College-High School(0.003)	-46.711	-57.139	-53.019	-0.879
College-College(0.444)	-7.654	-18.204	0.420	0.420

(†) The groups denote counterfactual groups. For example, the High School-High School group consists of individuals who would not attend college in either steady state, and the High School-College group would not attend college in the first steady state, but would in the second, etc.

(‡) Column (1) reports the after-tax present value of earnings in thousands of dollars discounted using the after-tax interest rate where the tax rate used for the second steady state is the base tax rate. Column (1) reports just the effect on earnings, column (2) adds the effect of taxes, column (3) adds the the effect of tuition subsidies and column (4) includes the nonpecuniary costs of college expressed in dollars.

Table 2

Treatment Effect Parameters

Partial Equilibrium and General Equilibrium

Difference in Log Earnings

College Graduates versus High School Graduates

at Ten Years of Work Experience

Parameter	Prices Fixed† (1)	Prices Vary‡ (2)	Fraction of Sample& (3)
Average Treatment Effect (ATE)	0.281	1.801	100%
Treatment on Treated (TT)	0.294	3.364	44.7%
Treatment on Untreated (TOU)	0.270	-1.225	55.3%
Marginal Treatment Effect (MTE)	0.259	0.259	-
LATE* $5000 Subsidy:			
Partial Equil.	0.255	-	23.6%
GE (HS→Col) (LATE)	0.253	0.227	2.48%
GE (Col→HS) (LATER)	0.393	0.365	0.34%
GE Net (TLATE)	-	0.244	2.82%
LATE* $500 Subsidy:			
Partial Equil.	0.254	-	2.37%
GE (HS→Col) (LATE)	0.250	0.247	0.24%
GE (Col→HS) (LATER)	0.393	0.390	0.03%
GE Net (TLATE)	-	0.264	0.27%

(†) "Prices Fixed" denotes the difference in log earnings between college and high school graduates conditional on various groups. Prices are held constant at their initial steady state levels when wage differences are calculated.

(‡) In column (2), we allow prices to adjust in response to the change in schooling proportions when calculating wage differences.

(&)For each row, column (3) presents the total fraction of the sample over which the parameter is defined.

(*) The LATE group denotes the effect on earnings for persons who would be induced to attend college by a tution change. In the case of GE, LATE measures the effect on individuals induced to attend college when skill prices adjust in response to quantity movements among skill groups. The partial equlibrium LATE measures the effect of the policy on those induced to attend college when skill prices are held constant at the benchmark level.